MACHINIST GRINDER

NSQF LEVEL - 4

2nd Year

TRADE THEORY

SECTOR: CAPITAL GOODS & MANUFACTURING

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : **Capital Goods & Manufacturing**

Duration : **2 Years**

Trade : **Machinist Grinder - Trade Theory - 2nd Year - NSQF Level - 4 (Revised 2022)**

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Machinist Grinder 2nd Year Trade Theory** in **CG & M Sector** under **Yearly Pattern.** The NSQF Level - 4 (Revised 2022) Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Director General, Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

ATUL KUMAR TIWARI, ***I.A.S***
Secretary
Ministry of Skill Development & Entrepreneurship,
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December 2023
New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of Federal Republic of Germany. The prime objective of this Institute is to develop and provide instructional materials for various trades as per the prescribed syllabus under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/ NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **Machinist Grinder 2nd Year - NSQF Level - 4 (Revised 2022)** under the **CG & M** Sector for ITIs.

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NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intented to be used in workshop . It consists of a series of practical exercises to be completed by the trainees during the two years course of the **Machinist Grinder 2nd year** in **Capital Goods & Manufacturing** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF Level - 4 (Revised 2022)

This manual is divided into Eleven modules. The Eleven modules are given below

Module 1	Tool & Cutter Grinding
Module 2	Surface Grinding
Module 3	Gauges
Module 4	Surface and Cylindrical Grinding - I
Module 5	Cylindrical Grinding - I
Module 6	Honing
Module 7	Cylindrical Grinding - II
Module 8	Internal Grinding
Module 9	Lapping
Module 10	Surface and Cylindrical Grinder - II
Module 11	CNC Machine

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

TRADE THEORY

The manual of trade theory consists of theoretical information for the two years course of the **Machinist Grinder 2nd year** in **Capital Goods & Manufacturing** Trade. The contents are sequenced according to the practical exercise contained in the manual on Trade Theory. Attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This co-relation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self learning and should be considered as supplementary to class room instruction.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No.	Learning Outcome	Exercise No.
1	Perform re-sharpening of different milling cutters [Different milling cutters:- plain, slitting saw] **(Mapped NOS: CSC/N0109)**	2.1.97 & 98
2	Make different components having straight & angular surface with close tolerance limit and check different fault. [Different components: - V' block, plain cylindrical bar, cube; tolerance limit - ±0.01mm; different faults - cracks, blow-holes, chatters] **(Mapped NOS: CSC/N0109)**	2.2.99 - 112
3	Make different gauges with close tolerance limit and check accuracy with different gauges. [Different gauges: - snap gauge, ring gauge; tolerance limit- (H7/h7); Checking gauges- ring, plug] **(Mapped NOS: CSC/N0109)**	2.3.113 - 116
4	Produce different components of non-ferrous metal within appropriate accuracy. [Different components - taper pin, rectangular bar; accuracy limit- ±0.01mm.] **(Mapped NOS: CSC/N0109)**	2.4.117 - 119
5	Produce different components involving cylindrical angular grinding operation to close limit accuracy. [Different components- lathe centre, milling machine arbor; accuracy:- h6 or H6] **(Mapped NOS: CSC/N0109)**	2.5.120 - 123
6	Prepare surface of a component by honing operation & Check accuracy. [Accuracy limit: ±0.001mm] **(NOS: CSC/N9409)**	2.6.124
7	Produce components by different taper grinding operation and check accuracy. [Different taper grinding: - compound or double taper, steep taper, morse taper; accuracy limit - ±0.008mm.] **(Mapped NOS: CSC/N0109)**	2.7.125 - 133
8	Produce male and female components by different grinding to close tolerance limit. [Different grinding: - step and slot grinding; tolerance limit- H6/h5] **(NOS: CSC/N0109)**	2.8.134 - 139
9	Prepare surface of a job by performing lapping & buffing to close limit h5. **(NOS: CSC/N9409)**	2.9.140 - 143
10	Make components by different grinding to close tolerance limit and check accuracy. [Different grinding: - cylindrical taper, surface grinding & shoulder grinding; tolerance limit- h6] **(Mapped NOS: CSC/N0109)**	2.10.144 - 146
11	Identify different components of CNC lathe to understand working and prepare part programme by using simulation software. **(NOS: CSC/NO115)**	2.11.147 - 155

SYLLABUS FOR MACHINIST GRINDER

2ND YEAR **DURATION : TWO YEARS**

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 45 Hrs; Professional Knowledge 10 Hrs	Perform re-sharpening of different milling cutters [Different milling cutters: - plain, slitting saw] **(Mapped NOS: CSC/N0109)**	97. Perform grinding of plain milling cutter. (20 hrs) 98. Perform grinding of slitting saw milling cutter. (25 hrs)	Milling cutters and its nomenclature. Grinding of bushes and cylinders steps and precautions to be taken. (10 hrs.)
Professional Skill 160 Hrs; Professional Knowledge 45 Hrs	Make different components having straight & angular surface with close tolerance limit and check different fault. [Different components: - V' block, plain cylindrical bar, cube; tolerance limit - ±0.01mm; different faults - cracks, blow-holes, chatters] **(Mapped NOS: CSC/N0109)**	99. Perform grinding on plain flat surface in surface grinding machine with close tolerances (±0.01mm.) (21 hrs)	Dial test indicators marking block, height gauge and surface plate their description. (06 hrs.)
		100. Perform grinding on angular surface like 'V' block. (21 hrs)	Principle of vernier caliper, protractors, micrometers (O/S, I/S and depth) and other instruments having vernier graduations. Combination sets-their use care and maintenance. (06 hrs.)
		101. Grind parallel block on surface grinding machine within close limits (±0.01mm.) (08 hrs) 102. Perform plain cylindrical grinding to close limit with accuracy of h7. (12 hrs).	Bonding materials their kinds description and uses. Grade and structure at grinding wheels. Brief about ISO- 9000. Importance of Quality. (07 hrs.)
		103. Perform cylindrical bore grinding within accuracy ±0.01mm. (15 hrs) 104. Set and grind jobs on chucks and face plates. (08 hrs)	Wheel marking system selection of wheels. Specification and types (shapes & size) of grinding wheels, diamond wheels and their uses. (07 hrs.)
		105. Balance grinding wheel (06 hrs) 106. Mount grinding wheel. (03 hrs) 107. Perform right angle grinding on surface grinding machine within accuracy ± 0.01mm. (16 hrs)	Mounting of grinding wheels, grinding wheels, collets and mandrels, balancing of grinding wheels by different methods. (06 hrs.)
		108. Perform wheel dressing for rough and finishing grinding. (01 hrs) 109. Grind a cube to close limit. (Tolerance within ±0.01mm.) (24 hrs)	Types of dresses-steel type, abrasive Diamond tool and rotary dresses abrasive bricks and sticks their description, use, care and maintenance. (07 hrs.)
		110. Perform shoulder grinding on cylinder-grinding machine to close limit h7. (08 hrs) 111. Perform slot grinding on surface grinding machines to close limits H7. (09 hrs)	Dressing and truing of grinding wheels advantage of balancing, inspections and care of grinding wheels. Wheel storage.

		112. Find different faults while grinding. viz., Cracks, blow holes, chatters. (08 hrs)	Heat generated in grinding dry and wet grinding, use of coolants their composition and selection, limit, fit and tolerances as per ISI: 919-1963. Basic size and its deviation position of tolerance zone with respect to zero lines. Fits different types clearance, interference and transition Interchangeable system Letter symbols for holes and shafts and fundamental deviation hole basis and shaft 9basis systems. (06 hrs.)
Professional Skill 86 Hrs; Professional Knowledge 25 Hrs	Make different gauges with close tolerance limit and check accuracy with different gauges. [Different gauges: - snap gauge, ring gauge; tolerance limit- (H7/h7); Checking gauges- ring, plug] **(Mapped NOS: CSC/ N0109)**	113. Grind Snap gauge in close limit to H6. (25 hrs)	Gauges-feeler, taper gauge radius, plug, ring snap (fixed and adjustable) and slip their description use care and maintenance. (06 hrs.)
		114. Perform grinding on cylindrical taper using standards ring gauges. (19 hrs)	Inside micrometer depth gauge, special types of micrometers, universal dial test indicator their construction and function. (06 hrs.)
		115. Perform grinding of ring gauge using plug gauge. (20 hrs)	Special type of grinding machine centreless, thread crankshaft etc. their description, use care and maintenance. (06 hrs.)
		116. Grinding long cylindrical using steady rest to close limit of h6. (22 hrs)	Essential mechanism of grinding machines, wheel is guards to IS: 1991-1962 machine guards etc. Process of cleaning and oiling at grinding machines (care and Maintenance) types of steady rests their description and use (07 hrs.)
Professional Skill 65 Hrs; Professional Knowledge 17 Hrs	Produce different components of non-ferrous metal within appropriate accuracy. [Different components - taper pin, rectangular bar; accuracy limit- ±0.01mm.] **(Mapped NOS: CSC/N0109)**	117. Grind thin plates to close limits of h6 using coolants. (25hrs)	Principle types of grinding fluids importance of uniform temperature, selection and use at grinding fluids, method of supplying grinding fluids. (06 hrs.)
		118. Perform grinding on parallel and taper pins using chuck and collets-h6. (20hrs)	Types of holding devices methods of holding work, type of centres - holding work between centres types of chucks and holding process in chucks. (05 hrs.)
		119. Select grinding wheel and perform grinding on rectangular bar of non-ferrous metals within accuracy ±0.01mm. (20hrs)	Holding work on face plate, pneumatic chuck and magnetic chuck. Precautions to taken before grinding, peripheral of surface speed of grinding wheels, importance of constant wheel speeds, calculations at S.F.P.M. (06 hrs.)
Professional Skill 85 Hrs;	Produce different components involving cylindrical	120. Perform grinding on machine centre to close limit h6 or H6. (20hrs)	Calculation at R.P.M. and S.F.P.M. of grinding wheels calculation of work speed for cylindrical grinding speed

Professional Knowledge 20 Hrs	angular grinding operation to close limit accuracy. [Different components- lathe centre, milling machine arbor; accuracy:- h6 or H6] **(Mapped NOS: CSC/N0109)**		and feeds for cylindrical grinding speed and feeds for internal grinding. (05hrs.)
		121. Perform Facing and Chamfering within accuracy ±0.01mm or ± 5 minutes. (20hrs)	Traverse and over run of traverse,width of wheel and depth of cut in different types of grinding achiness. Grinding allowance and time estimation. Rough and finish grinding process. (05 hrs.)
		122. Perform step grinding on surface grinding machine to close limit h6 or H6. (22hrs)	Surface grinding methods of surface grinding by using periphery of grinding wheel and ring edge of grinding wheel. Types of surface grinding machines. Work finish, wheel selection holding of work. (05 hrs.)
		123. Perform V-block grinding within accuracy ±0.01 mm, ± 5 minutes, surface finish N5. (23hrs)	Process of grinding angular surfaces. Grinding slots and grooves. Grinding "V" blocks. Recommended wheel speeds for surface grinding machines. (05 hrs.)
Professional Skill 18 Hrs; Professional Knowledge 06 Hrs	Prepare surface of a component by honing operation & Check accuracy. [Accuracy limit: ±0.001mm] **(NOS: CSC/N9409)**	124. Grind cylindrical steps and perform honing (18hrs)	Hones and Honing, types of honing stones there description and use. Amount and rate of stock removal. Adjustment for elementary honing conditions, honing tolerances. (06 hrs.)
Professional Skill 135 Hrs; Professional Knowledge 30 Hrs	Produce components by different taper grinding operation and check accuracy. [Different taper grinding: - compound or double taper, steep taper, morse taper; accuracy limit - ±0.008mm.] **(Mapped NOS: CSC/N0109)**	125. Finish surface of Angular form grinding within accuracy of ±0.01mm. (20hrs)	Cylindrical-types of cylindrical grinding operation traverse method, plunge cut method and form grinding method. Alignment of head stock and tail stock. (05 hrs.)
		126. Grind cylindrical steps with shoulder and chamfer within accuracy ±0.008mm. (20hrs)	Method of plain cylindrical surface grinding step-grinding and shoulder and face grinding. (05 hrs.)
		127. Perform compound or double taper grinding accuracy of ±0.008mm. and surface finish of N5 (22hrs)	Method of grinding external and angle (simple) taper and steep. Taper double compound taper. (05 hrs.)
		128. Perform steep taper grinding with in accuracy ±0.008mm. (12 hrs) 129. Grind lathe centre within accuracy ±0.008 mm. surface finish N4. (13 hrs)	Use of universal head for angular grinding. Measuring and checking of taper and angles. Use of taper plug and ring gauges. (05 hrs.)
		130. Make Morse taper within accuracy ±0.008 mm. surface finish N4. (08 hrs) 131. Perform Plug grinding within accuracy ±0.008 mm. surface finish N4. (08 hrs)	Taper and angle checking by using protractors, micrometer and rollers. (05 hrs.)

		132. Finish Metric tapers by grinding within accuracy ±0.008 mm. surface finish N4. (09 hrs)	
		133. Perform Taper grinding using sine bar, D.T.I. and gauge blocks to close limit h6. (23hrs)	Use of sine bar and gauge block-taper checking by sine bar gauge block D.T.I. micrometer and rollers. Other out of round surfaces. Holding work with fixed steady rest, in process gauges and pneumatic gauges. (05 hrs.)
Professional Skill 67 Hrs; Professional Knowledge 20 Hrs	Produce male and female components by different grinding to close tolerance limit. [Different grinding: - step and slot grinding; tolerance limit- H6/ h5] **(NOS: CSC/ N0109)**	134. Grind taper up to close limit H6. (6hrs) 135. Grind lathe centre within h7. (8hrs)	Centreless grinding process of holding job, and types of operations. Effect of setting work above and below wheel centre. Jig and fixture holding work by fixture and vice non-electric and magnetic chuck. Use of three jaw and two jaw steady rest (05 hrs.)
		136. Perform internal step grinding to close limit H6, (13 hrs) 137. Grind ring gauge to close limit-H7. (8hrs)	Internal centreless grinding methods of holding jobs and processes of grinding. Selection of wheels. Internal grinding work movement and wheel movement. Rotation and reciprocation of job and wheel spindle, Internal grinding allowance, selection of wheels for internal grinding allowance, selection of wheels for internal grinding. Thread grinding method of holding jobs methods of grinding threads and thread calculation. (095hrs.)
		138. Perform slot grinding to close limit h5. (16hrs)	Thread grinding method of holding jobs method of grinding threads and thread calculation. (05 hrs.)
		139. Perform cylindrical step grinding (16hrs)	Various types of thread grinding wheels and their selection. Types of dressers and process of process of dressing selection of coolants and their use. (05 hrs.)
Professional Skill 19 Hrs; Professional Knowledge 06 Hrs	Prepare surface of a job by performing lapping & buffing to close limit h5. **(NOS: CSC/N9409)**	140. Perform Lapping on flat surface. (05hrs) 141. Perform Lapping on cylindrical surface (06hrs) 142. Perform Buffing to close limits . (8hrs)	Laps and lapping material, types of laps lapping abrasives rotary diamond lap lapping lubricants lapping pressures wet and dry lapping. Hand lapping and machine lapping. Lapping flat surface lapping cylindrical surface polishing wheels polishing operations abrasive buffing wheels (06 hrs.)
Professional Skill 70 Hrs; Professional Knowledge 20 Hrs	Make components by different grinding to close tolerance limit and check	143. Perform cylindrical Taper grinding. (10hrs)	-Do- (05 hrs.)

	accuracy. [Different grinding: - cylindrical taper, surface grinding & shoulder grinding; tolerance limit- h6] **(Mapped NOS: CSC/ N0109)**	144. Perform surface grinding within accuracy ±0.01mm. (20hrs)	Grinding defects and their corrections, inaccurate work out of round, out of parallel taper on and irregular marks spiral scratches, discoloured burnt surface etc. (05 hrs.)
		145. Perform Multi-step cylindrical grinding. (20hrs)	Grinding defects and their correction. Waviness marks of surface, chatters-short close evenly spaced long and regularly spaced, marks in phase with vibration of floor, random marks, random waves etc. Glazing of wheel and loading of wheel. (05 hrs.)
		146. Perform shoulder grinding on cylinder-grinding machine to close limit h7. (20hrs)	Dressing and truing of grinding wheels advantage of balancing, inspections and care of grinding wheels. Wheel storage. (05 hrs.)
Professional Skill 90 Hrs; Professional Knowledge 23 Hrs	Identify different components of CNC lathe to understand working and prepare part programme by using simulation software. **(NOS: CSC/NO115)**	147. Prepare different types of documentation as per industrial need by different methods of recording information. (12 hrs)	Importance of Technical English terms used in industry -(in simple definition only)Technical forms, process charts, activity logs, in required formats of industry, estimation, cycle time, productivity reports, job cards. (05 hrs.)
		148. Identify CNC machine (04 hrs) 149. CNC machine operation like Jog, Reference Edit, MDI, Auto Mode Program. Call & Entry, Simulation, Tool off-set Tool changing /Orientation. (12 hrs)	Introduction to CNC Technology CNC M/c. principle advantages classification, drives, controls. Basic information on CNC machine & maintenance of CNC M/c. computer aided CNC Language. Introduction to CNC grinding. (05 hrs.)
		150. Know rules of personal and CNC machine safety, safe handling of tools, safety switches and material handling equipment using CNC didactic/ simulation software and equipment. (10 hrs) 151. Identify CNC lathe machine elements and their functions, on the machine. (10 hrs) 152. Understand the working of parts of CNC lathe, explained using CNC didactic/ simulation software. (15 hrs) 153. Identify machine over travel limits and emergency stop, on the machine. (05 hrs) 154. Decide tool path for turning, facing, grooving, threading, drilling. (15 hrs) 155. Identify safety switches and interlocking of DIH modes. (05 hrs)	Personal safety, safe material handling, and safe machine operation on CNC turning centers. CNC technology basics, Comparison between CNC and conventional lathes. Concepts of positioning accuracy, repeatability. (06 hrs.) CNC lathe machine elements and their functions - bed, chuck, tailstock, turret, ball screws, guide ways, LM guides, coolant system, hydraulic system, chip conveyor, steady rest, console, spindle motor and drive, axes motors, tail stock, encoders, control switches. Feedback, CNC interpolation, open and close loop control systems. Machining operations and the tool paths in them – stock removal in turning and facing, grooving, face grooving, threading, drilling. (07 hrs.)

Milling cutters - Elements

Objectives: At the end of this lesson you shall be able to
- **state the elements of a milling cutter**
- **explain the parts of milling cutter.**

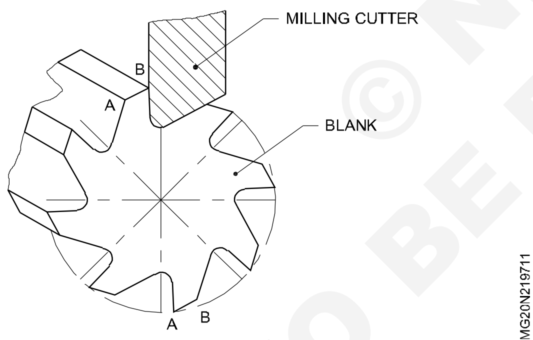
Milling cutters are multiple point cutting tools. They are made from cylindrical blanks with the teeth formed by milling the chip space. (Fig 1) The number of teeth so milled depends on the diameter of the cutter as well as on the type of operation, namely roughing and finishing. A roughing cutter will have less number of teeth as compared to a finishing cutter of the same diameter.

The types of milling cutters are solid cutter tipped solid cutter inserted teeth cutter.

Solid cutters made of one piece material generally high speed steel is used.

> **Most of the high speed steels cutters are dry ground as the sharpening operation. In dry grinding heat produced main body of the cutter. If the water is applied to the heated cutter small hair line cracks may develop at the cutting edge of the cutter.**

Fig 1



The principal parts of a milling cutter shown in Fig 2.

Body of the cutter: The part of the cutter left after exclusion of the teeth.

Cutting edge: The edge formed by the intersection of the face and the provision of primary clearance for relief angle.

Face: The portion of the gash adjacent to the cutting edge.

Fillet: The curved surface at the bottom of the gash.

Gash: The chip space between the back of teeth and face of the another teeth.

Land: The part of the back of tooth adjacent to the cutting edge.

Land is depending up on the type and size of cutter width of the land is about 0.8mm to 1.6mm.

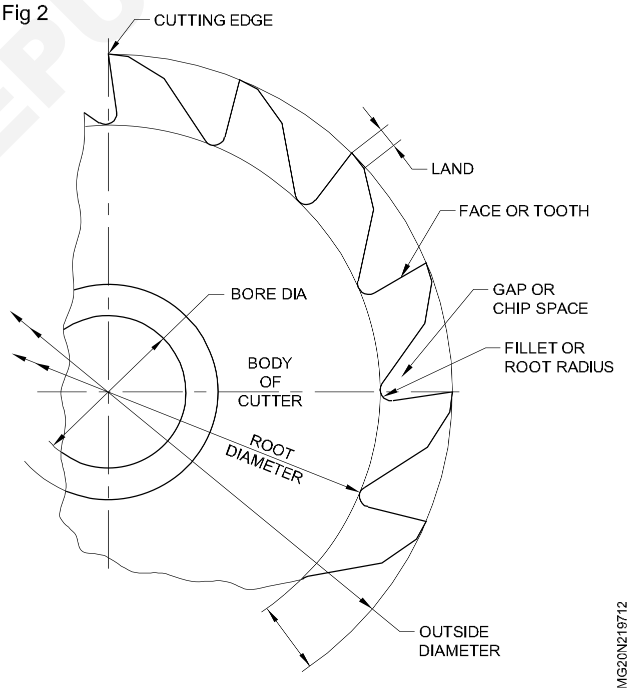
Outside diameter: The diameter of the circle passing through the peripheral cutting edge.

Bore diameter: It is provide for insert the mandrel / Arbor.

The standard bore sizes of the cutter is 22, 27, 32mm and 1" most commonly use of bore 27 and 32mm.

Root diameter: The diameter of the circle passing through the bottom of the filled.

Fig 2



Elements of milling cutter - 2

Objectives: At the end of this lesson you shall be able to
- **state the angle of milling cutters**
- **explain the influence of angle in machining.**

Angles of milling cutter (Fig 1): Similar to a single point cutting tool. The milling cutter teeths are also provided with rake angle.

Clearance angle and other cutting angles in order to removed of metal efficiently. The following angles are

Primary clearance (Fig 1): It is a clearance ground on the land adjacent to the tooth face. The primary clearance angle are 6^o to 8^o as a standard.

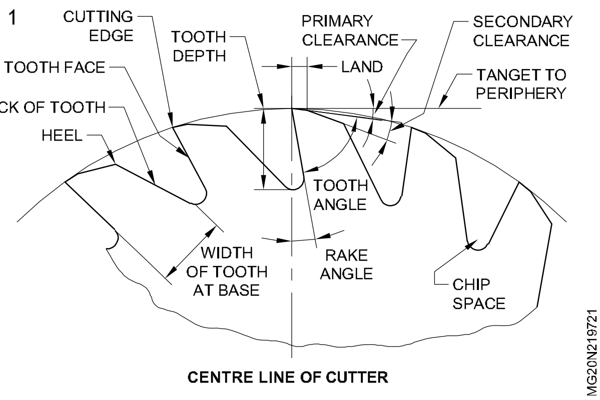


Fig 1

Secondary clearance (Fig 2): It is a clearance ground behind the primary clearance. It provide to additional clearance to the cutter behind the teeth space usually secondary clearance angle are 15^o.

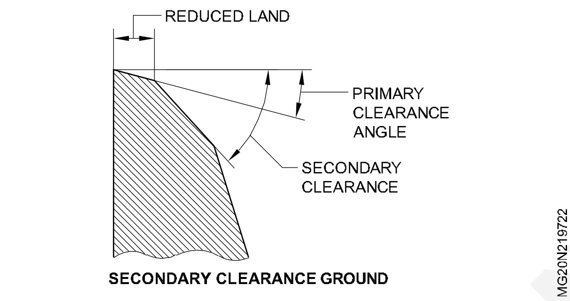


Fig 2

Clearance angle: The proper clearance angle mainly depends up on the type of the cutter, its diameter and hardness of the material to be machined. To give clearance angle in the cutting edge to avoid the rubbing the work piece while machining.

Generally the clearance angle for cutters upto 75mm dia is 6^o to 7^o and larger than 75mm dia it is 4^o to 5^o.

Recommended clearance angle for the material to be machined is given in Table 1.

Table 1

Material to be machined	**Clearance angle in degree**
Low carbon steels	5 - 7
High carbon and alloy steels	3 - 5
Steel castings	5 - 7
Cast Iron	4 - 7
Brass and soft bronze	10 - 12
Medium and hard bronze	4 - 7
Aluminium	10 - 12

Rake angle (Radial): The angle measured in the diameter plane between the face of the tooth and a radial line passing through the teeth cutting edge.

Positive zero and negative rake

The rake angle may be positive zero or negative as shown in Fig 3.

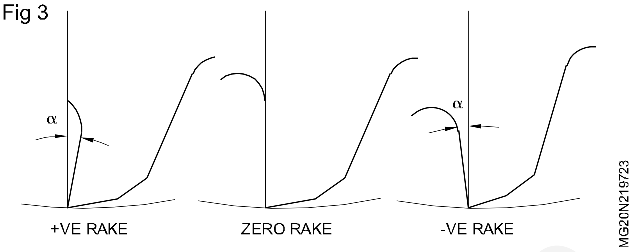


Fig 3

The positive rake is used for general purpose, and is used specially for milling materials which produce continuous chips. In the positive rake, the weakest point is presented to cut first. (Fig 4a) the reaction forces tend to pull the cutter into the work (Fig 4b) and the cutter forces tend to lift the work piece. (Fig 4c) The positive rake cutting edges peal the chip away from the work, and hence there is a likelihood of breakage of cast iron parts, especially those having thin and fragile sections.

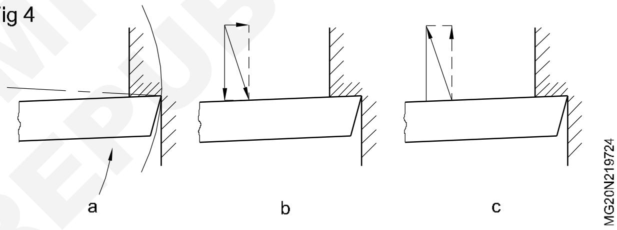


Fig 4

A negative rake makes the tooth stronger and is suitable for roughing cuts. In the negative rake, the strong area is presented to cut first. (Fig 5a) The reaction forces tend to push the cutter away from the work (Fig 5b) and the cutter forces tend to push the work against the fixture. (Fig 5c)

The zero rake is ideal for milling material like cast iron, brass etc. which produce broken chips.

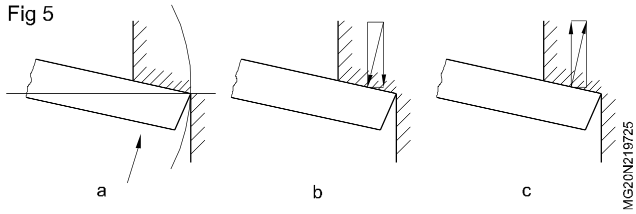


Fig 5

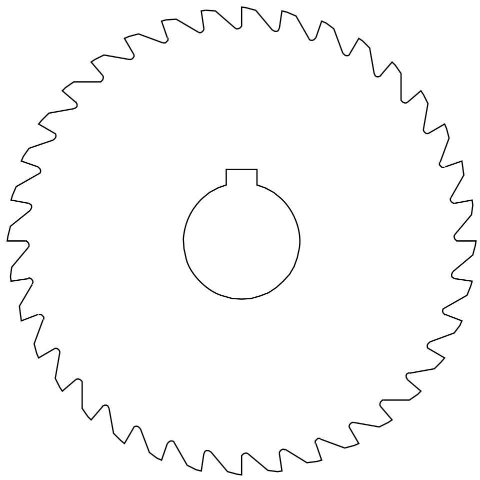
Sharpening methods of milling cutters

Objectives: At the end of this lesson you shall be able to
- **explain the sharpening of slitting saw cutter**
- **describe the sharpening of side and face milling cutter.**

1 Sharpening a slitting saw (Fig 1)

Slitting saw can be sharpened successfully on a universal tool and cutter grinder. Slitting saws are ground in the same way as milling cutters (Fig 1).

Fig 1



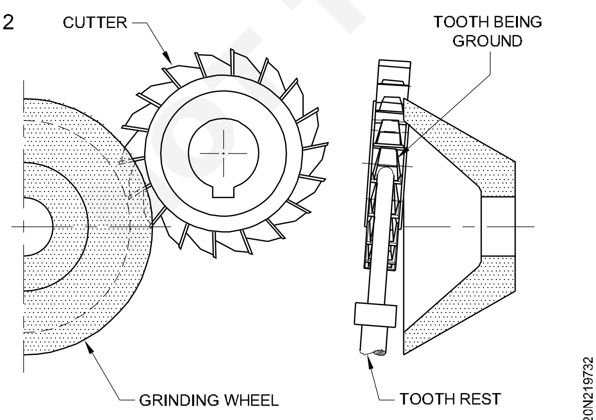
SLITTING SAW

- The saw may be held on mandrel or stub arbour which fits into the cutter head or it may be mounted on mandrel fixed between centres of tailstocks.
- A flaring cup wheel or taper cup wheel can be used to produce the required clearance angles.

> **To minimize the effect of wheel wear, the last cut should be very light a rule applying to all class of cutter grinding.**
>
> **Clearance angles only ground for slitting saw.**

2 Sharpening of side and face cutter (Figs 2&3)

Fig 2



GRINDING THE SIDE TEETH WITH A CUP WHEEL

The peripheral teeth edges of a side milling cutter are ground as in the case of an end mill.

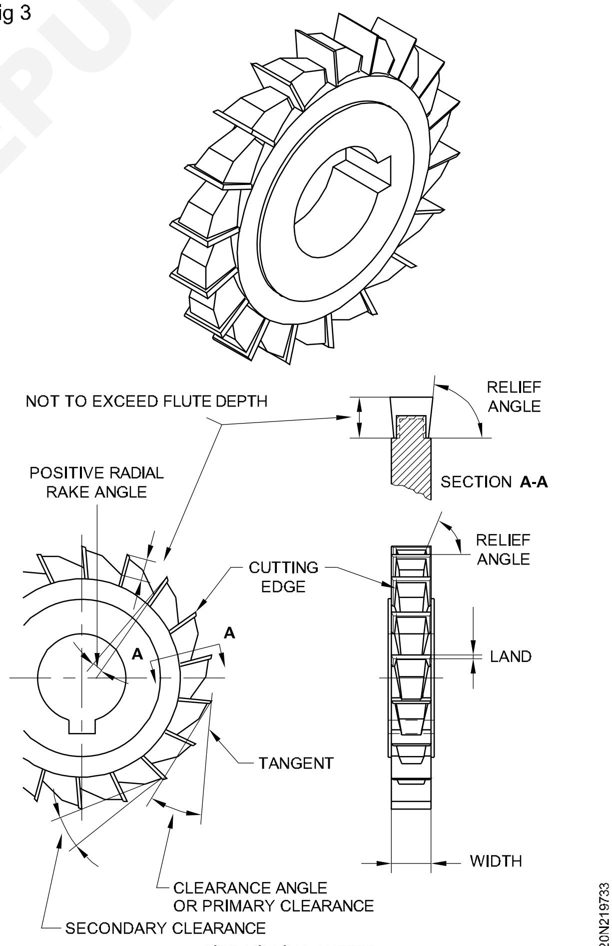
The edge on each side of each tooth must also be ground. These edges taper from the peripheral edge.

A cup wheel is used with the headstock tilted to provide the clearance angle. This also keeps the trailing face of the wheel away from the cutter.

Use a flexible tooth rest mounted on the headstock. When an edge has been ground, the side mill is simply rotated against the spring action of the tooth rest to position the next tooth for grinding.

> **The length of the primary clearance on the side teeth should not exceed the depth of the flute.**
>
> **That part of the side teeth that extends below the flute depth is relieved by grinding back at a 3° angle from the flute depth to the bottom of the side tooth.**

Fig 3



SIDE MILLING CUTTER

Sharpening primary and secondary clearance on milling cutters

Objectives: At the end of this lesson you shall be able to
- **explain important of clearance angle and methods of resharpening the milling cutter.**

To increase the life of a milling cutter, it is to be re-sharpened as soon as it becomes blunt or dull.

Clearance angles: The most important point in cutter grinding is producing the correct relief or clearance behind the cutting edge. This varies slightly according to;

- The material of the job to be milled.
- The diameter of the cutter.
- The material of the cutter.

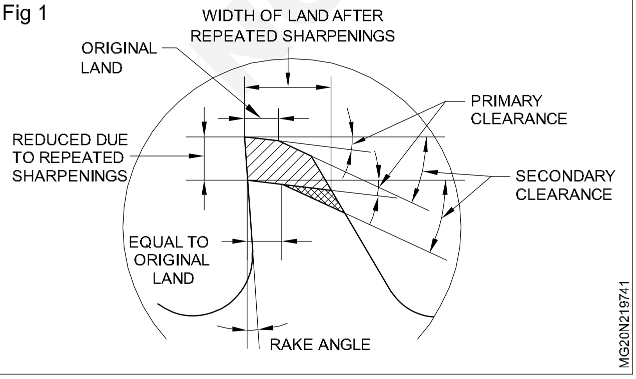
There are no hard and fast rules for determining the clearance but out of vast experience, the following angles may be taken as a guidance. Too little clearance causes bad surface finish, while too much clearance for chattering, causes chip off cutting edges.

Materials to be cut	Clearance angle for H.S.S. cutters
Low carbon steels	5^o-7^o
High carbon & alloy steels	4^o - 7^o
Cast iron	4^o-7^o
Soft brass, bronze & copper	10^o-12^o
Medium & hard bronze	4^o-7^o
Aluminium, magnesium, plastics etc.	10^o-12^o

These angles are average for cutters between 50 to 150mm diameter. Minimum angles may be taken for larger dia. cutters and maximum angles for small cutter and end mills etc.

Secondary clearance: Sometimes where a heavy roughing cut is employed or where a cutter has been ground frequently until a wide land has resulted a secondary clearance, is ground to reduce the land to a nominal width. i.e. approximately 1mm to 1.5mm (Fig 1) the recommend secondary clearance angles vary from 15^o to 25^o, depending upon the type, size and number of teeth of the milling cutter.

Fig 1



Centre setting: The basic principle of all set up is for the operator to first set the tooth to be ground at the same height as the centre of the cutter and then lower the tooth at an angle equal to the clearance required. This principle applied to all cutters for grinding both the peripheral and side teeth.

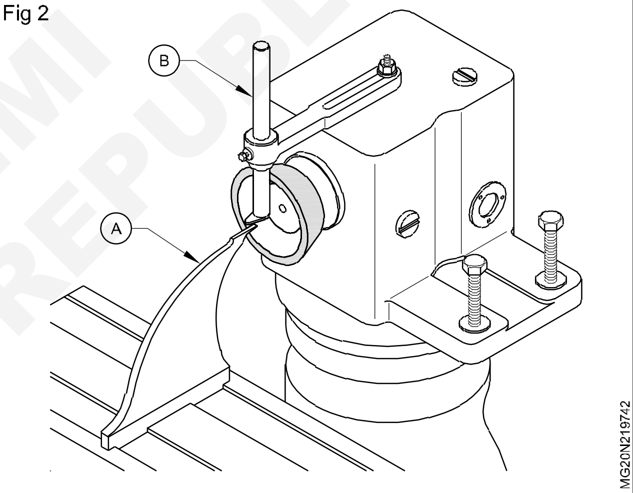
Fig 2 shows two types of centre setting gauge provided. The gauge 'A' which is common to the 10mm height of the centre and the gauge 'B; which is clamped to the top of the wheel head and carries a stop collar which is set of the wheel head and carries a stop collar which is set to correspond with the centre line of the wheel spindle.

Setting for grinding clearance angles : The clearance angles can be obtained by means of three methods.

Linear setting

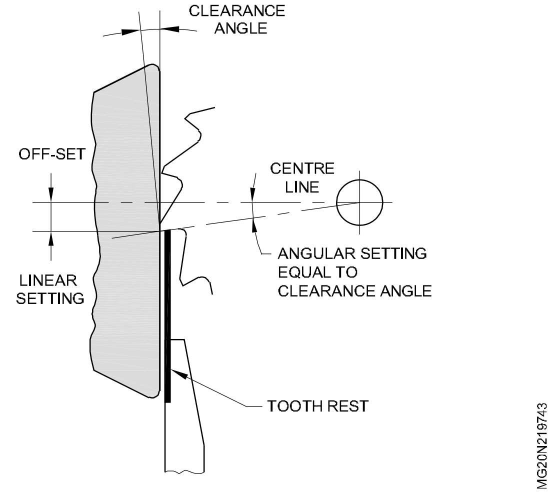
- Adjust the height of wheel head until the tips of the height gauges in line with each other. (Fig 2)

Fig 2



Lower the wheel head by the amount calculated as below. (Fig 3)

Fig 3

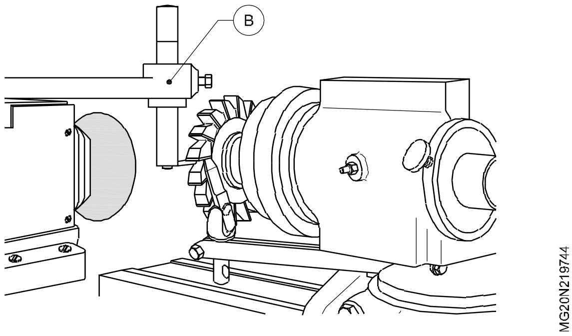


OFFSET=clearance angle x 0.0087 x dia. of cutter E.g. 7° x 0.0087 x 100mm (of cutter)

OFFSET = 6.09mm.

- Place the tooth on the centre gauge 'B'. (Fig 4)

Fig 4

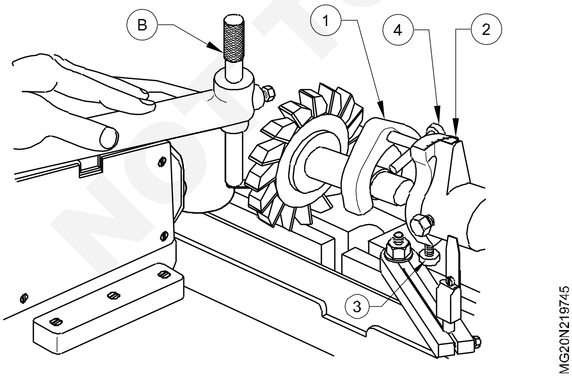


- Set the tooth rest under the tooth to be ground.
- Remove centre gauge 'B' and grind with the front face of the cup wheel, indexing from tooth to tooth until the whole cutter has been sharpened.
- Wheel head swivelling above 7° primary secondary 25°

2 Clearance setting gauge

- The clearance angle setting gauge is a graduated carrier bracket, which fits to the left hand tailstock and can be adjusted radially through 15°. (Fig 5)
- Set the wheel centre by the centre setting gauge.
- Mount the cutter on the mandrel and fix the mandrel between the tailstock centres.
- Repeat the above steps for remaining teeth.
- Unlock the screw 'D' and index to next teeth. Lock the screw D and grind.
- Set the teeth to rest on the tip of the centre setting gauge.
- Set angle setting gauge (2) at (0o) and clamp the carrier (1) to the mandrel using the screw (4). (Fig 5)

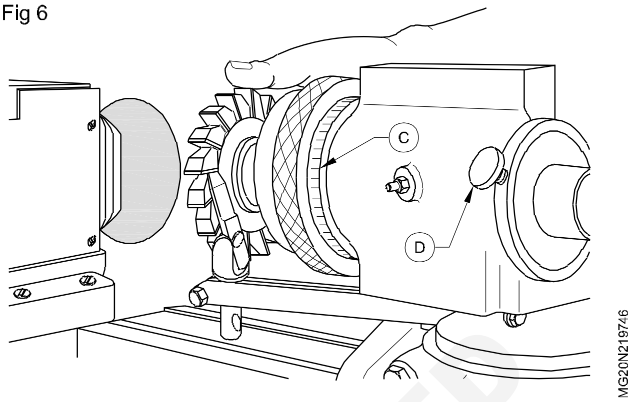
Fig 5



- Remove the centre setting gauge and rotate the angle setting gauge (2) to the required clearance angle and lock firmly by the screw (3).
- Set the tooth rest under the tooth to be ground and remove the carrier (1).
- Start grinding by indexing from tooth to tooth.

3 Direct setting from cutter head: When the cutter is mounted on a stub arbour in the cutter head, the clearance angle can be obtained direct from the graduated dial (C) on the work head spindle. (Fig 6)

Fig 6



- Set one of the cutting edges at the centre by centre setting gauge.
- Note the reading on the graduated dial and rotate the spindle to the required number of degrees and lock the spindle in position by screw (D).
- Set the tooth rest under the tooth to be ground and commence grinding.

Clearance angle setting while using indexing drum for dividing. (Fig 7)

Fig 7

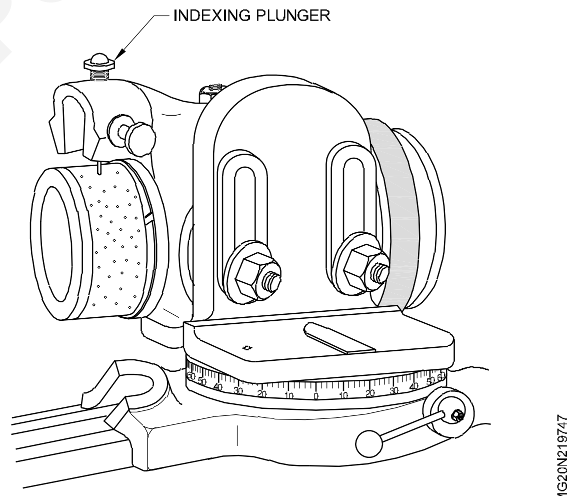


Fig 8 show the details of the tooth setting to obtain clearance angle. The table 1 & table 2 provide the guide lines of setting at different angles corresponding to the wheel diameter.

"A" above centre for "FORWARD" grinding.

"A" below centre for "FRONT TO BACK" grinding.

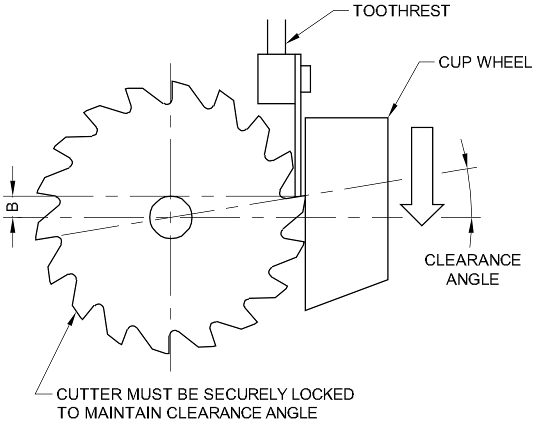
This distance can also be calculated using the formula

"A"=Radius of wheel x sine of clearance angle.

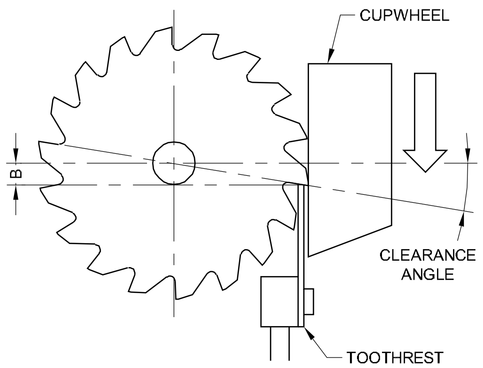
'B' as for 'A' in table 1

'B'=Radius of cutter x sine of clearance angle.

Fig 8



TOOTHREST 'B' ABOVE CUTTER CENTRE TO OBTAIN CLEARANCE ANGLE (FRONT TO BACK GRINDING)



LOWERING 'B' OF TOOTHREST TO PROVIDE CLEARANCE (FORWARD GRINDING)

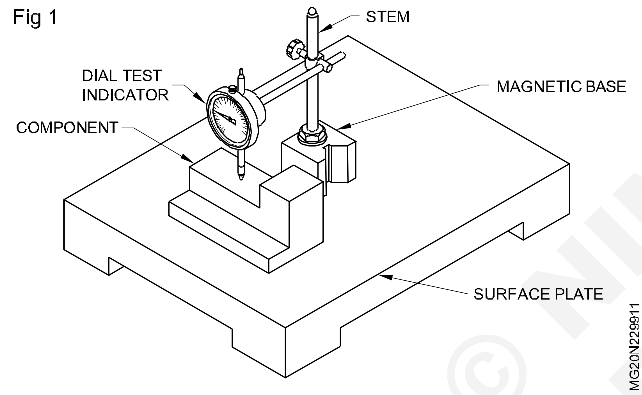
MG20N219748

Dial Test Indicators

Objectives: At the end of this lesson you shall be able to
- **state the principle of a dial test indicator**
- **identify the parts of a dial test indicator**
- **state the important features of a dial test indicator**
- **state the functions of a dial test indicator**
- **identify the different types of stands.**

Dial test indicators are instruments of high prescision, used for comparing and determining the variation in the sizes of a component. (Fig 1) These instruments cannot give the direct reading of the sizes like micrometers and vernier calipers. A dial test indicator magnifies small variations in sizes by means of a pointer on a graduated dial. This direct reading of the deviations gives an accurate picture of the conditions of the parts being tested.

Fig 1



Principle of working

The magnification of the small movement of the plunger or stylus is converted into a rotary motion of the pointer on a circular scale (Fig 2)

Types

Two types of dial test indicators are in use according to the method of magnification. They are

- plunger type (Fig 3)
- lever type (Fig 4)

The plunger type dial test indicator

The external parts and features of a dial test indicator are as shown in figure 3

1 Pointer

2 Rotatable bezel

3 bezel clamp

4 Back lug

5 Transparent dial cover

6 Stem

7 Plunger

8 Anvil

9 Revolution counter

For converting the linear motion of the plunger, a rack and pinion mechanism is used. (Fig 2, 3, 4))

Fig 3

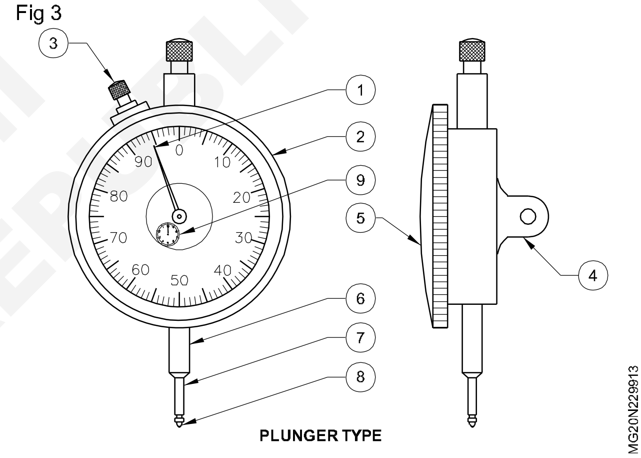
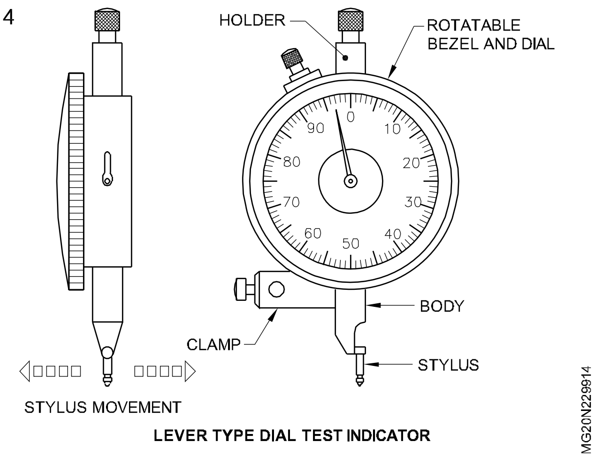


Fig 4



The lever type dial test indicator

In the case of this type of dial test indicators, the magnification of the movement is obtained by the mechanism of the lever and scroll. (Fig 5)

Fig 2

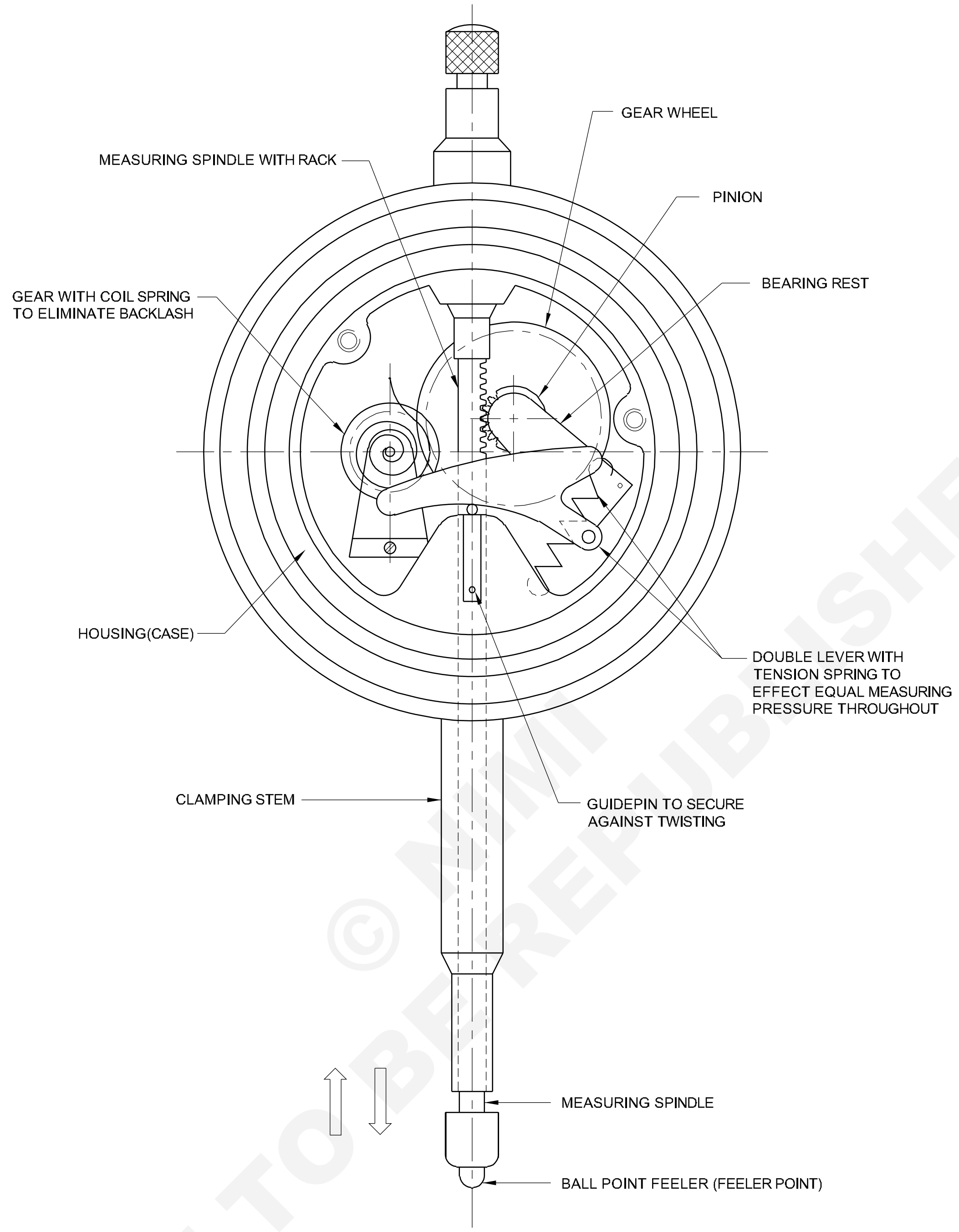
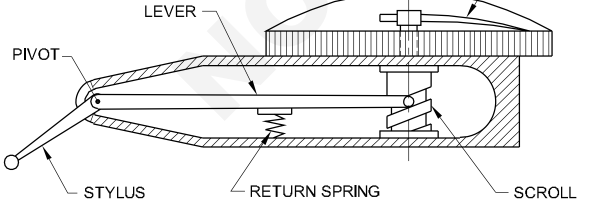


Fig 5

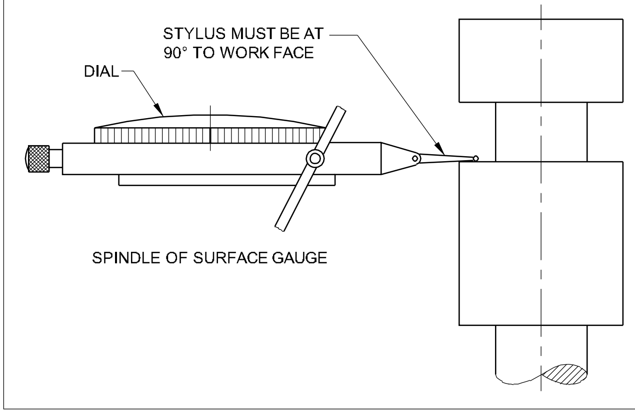


MECHANISM OF THE LEVER TYPE DIAL TEST INDICATOR

It has a stylus with a ball-type contact, operating in the horizontal plane.

This can be conveniently mounted on a surface gauge stand, and can be used in places where the plunger type dial test indicator application is difficult. (Fig 6)

Fig 6



Important features of dial test indicators

An important feature of the dial test indicator is that the scale can be rotated by a ring bezel, enabling it to be set readily to zero

Many dial test indicators read plus in a clockwise direction from zero, and minus in the anticlockwise directions so as to give plus and minus indications.

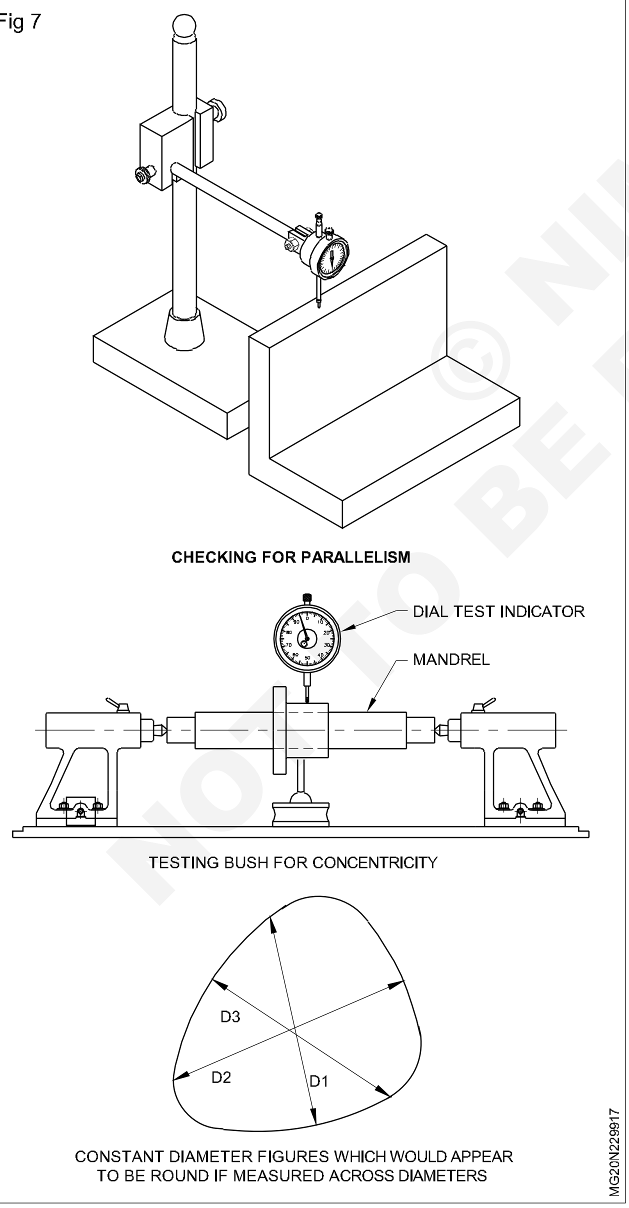
Uses (Fig 7 shows a few applications.)

- To compare the dimensions of a work piece against a known standard, Eg slip gauges
- To check plane surfaces for parallelism and flatness
- To check parallelism of shafts and bars.
- To check concentricity of holes and shafts

Indicator stands

Dial fest indicators are used in conjunction with stands for holding them so that the stand itself may be placed on datum surface or machine tools

Fig 7



The different types of stands are (Fig 8)

- magnetic stand with universal clamp
- magnetic stand with flexible post (Fig 9)
- general purpose holder with cast iron base.

NOTE

The arrows indicate the provisions in the clamps for insertion of the dial test indicator.

Fig 8

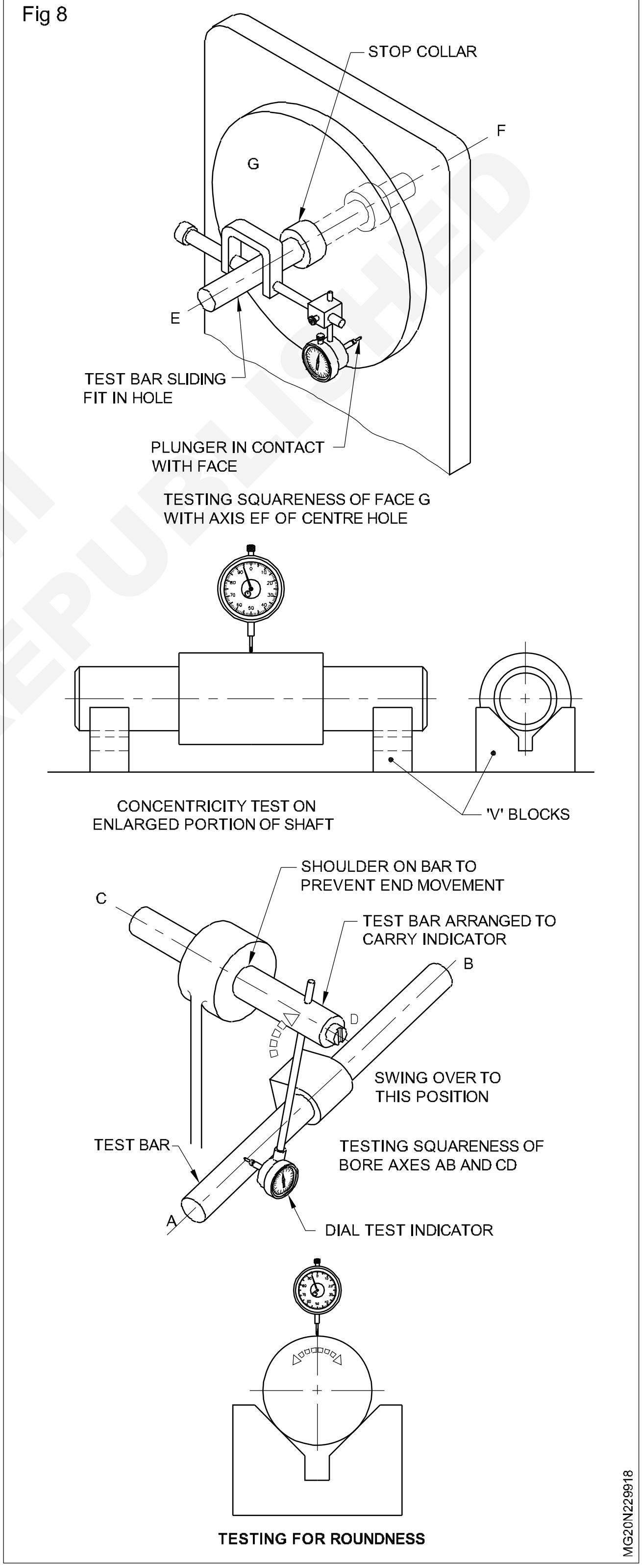
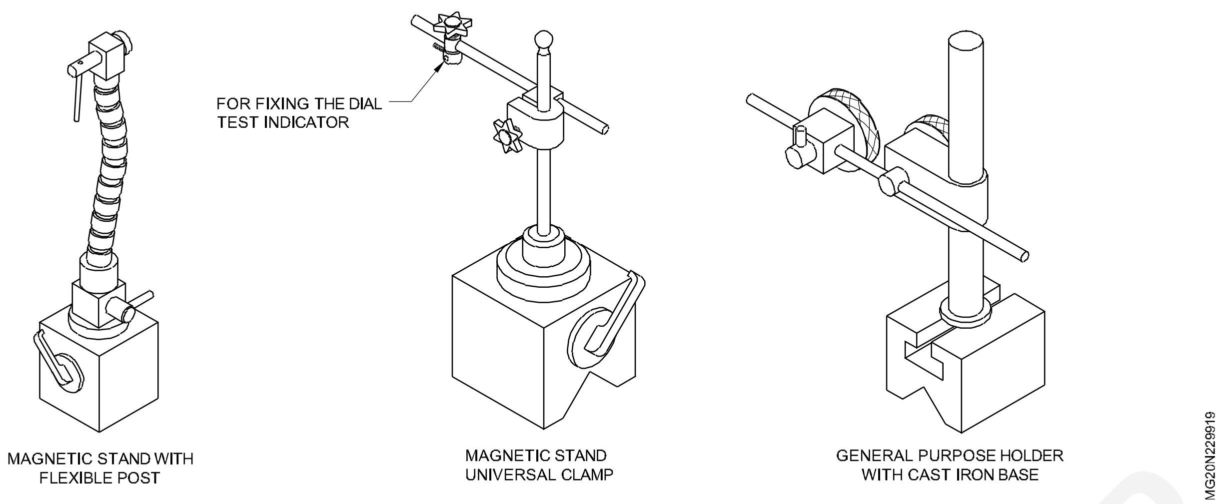


Fig 9



Vernier height gauge

Objectives: At the end of this lesson you shall be able to
- **name the parts of a vernier height gauge**
- **state the functions of each part**
- **list out the specific uses of a vernier height gauge.**

Specific uses of vernier height gauge: Accurate measurements are important in layout (marking off) and inspection work. (Figs 1 & 2)

Vernier height gauges are particularly suitable for marking off accurate distances, and centre locations.

Fig 1

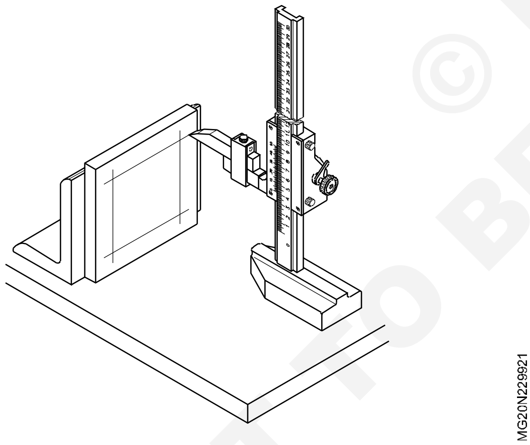
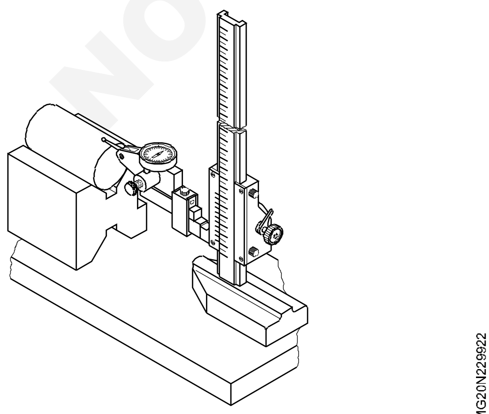


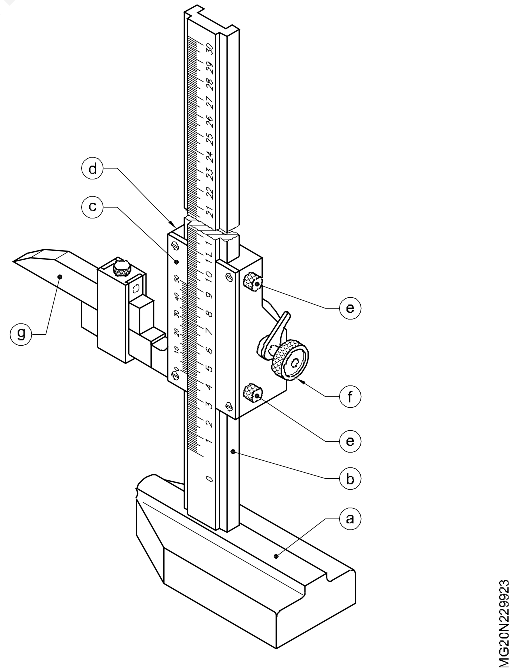
Fig 2



The graduations and readings are the same as those of a vernier caliper.

Parts of a vernier height gauge and their functions: The main parts of a vernier height gauge and their functions are given here. (Fig 3)

Fig 3



Base (a): This is the datum from which measurements and settings are made. The underside of the base is hardened, ground and lapped.

Beam (b): This is similar to the beam scale of a vernier caliper and is attached to the base.

Vernier slide (c): This unit slides on the beam and carries the vernier plate (d), locking screws (e). fine setting device (f) and scriber (g). Some vernier height gauges are provided with a rack and pinion arrangement for moving the slide along the beam.

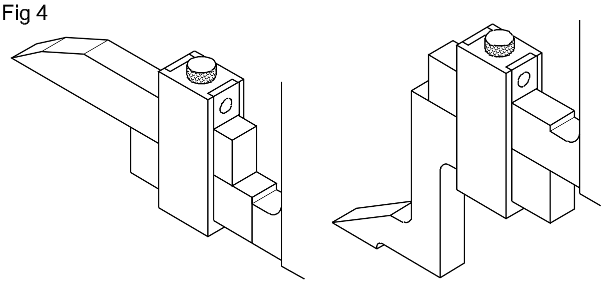
Vernier height gauges are provided with both straight and offset scribers. (Fig 4a & 4b)

Zero setting of the vernier height gauge: The offset scriber permits zero setting of the instrument from the datum surface.

While using a straight scriber, the zero setting of the instrument is at a level above the datum surface. In this case the zero setting is to be checked using the precision round block, supplied along with the instrument.

Vernier height gauges with which we can measure from the datum surface without the special offset scribers are also available.

Fig 4



The size of the vernier height gauge is stated by the height of the beam. The most commonly used size has a beam of 300 mm height.

Vernier height gauges are used with surface plates or other accurate flat surfaces.

Surface plate

Objectives: At the end of this lesson you shall be able to
- **state the different types of surface plate & their description**
- **state the care and maintenance of surface plates.**

Tool maker's flat and high precision surface plates

For the measurement work of the highest precision, small circular surface plates (commonly known as tool maker's flats) are used. The flats are usually made from an alloy steel, hardened, ground and lapped.

The selection of material for these is done from steel, cast iron or alloy cast iron on the basis of the following requirements.

- The requisite hardness with proper heat treatments.
- A suitable surface for gauges to be wrung on to it.
- Sufficient stability to maintain the final limits of accuracy.

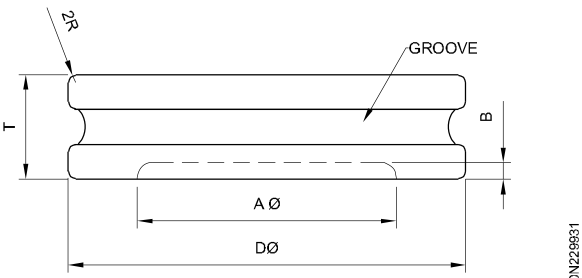
The composition of cast iron should be such that after art appropriate heat treatment operation, the sorbo-pearlitic structure having a high hardness and wear resistance is formed.

The tool maker's flats are generally circular and made of solid steel free from inclusions (preferably from hammered and upset blanks) which after proper heat treatment gives a hardness of about 93 HRC or 850 HV. The sketch of the tool maker's flat is given in Fig 1. and it shows various important dimensions also.

It is however, recommended that a shallow groove should be provided all around the periphery of larger flats (From 100 - 200 mm) to facilitate handling and also minimize the possibility of uneven hardening. The flats of size 50 to 75 mm generally have both faces finished as working surface whereas those above it have only one face finished as working surface.

D (Nominal size)	T (min)	Recess	
		Dia A	Depth B
50	12	-	-
75	15	-	-
100	18	80	3
125	25	100	4
150	30	120	6
200	35	160	6

Fig 1



TOOL MAKER'S FLAT

High precision surface plates: These are generally circular with adequate framing and ribbing underneath so that they are robust and the distortion is reduced to the minimum while in use.

The plate is supported by three feet which are smoothly machined and ground. The top of the plate generally projects about 12 mm beyond the framing and is machined around the sides. The minimum thickness of top and minimum total depth are given below.

Dia (Nominal size) mm	Min. thickness of top mm	Min. total depth mm
250	20	70
300	25	80
350	30	90

Glass surface plates: Surface plates made of glass are now available in six sizes ranging from 150x150 mm to 600x900 mm. A range of circular glass surface plates are also available. These are supplied in a velvet lined box with lid. The accuracy of the glass surface plates is of the order of 0.004 to 0.008 mm from a mean true plane. The glass surface places have the following advantages:

- These are light.
- These have immunity from burring and atmosphere corrosion.
- These maintain their accuracy for a longer period.
- Their manufacture to a higher degree of accuracy is easier. However, these require careful handling.

Granite surface plates: Granite is widely used for surface plates for all types of shop, inspection and laboratory work. Table below shows a comparison of cast iron and granite surface plates.

Characteristic	Cast iron	Granite
Wear quality	Good	Good
Stability	Excellent	Excellent
Rigidity	Excellent	Excellent.
Strength for given weight	High	Less
Strengthening by provision of ribbing	Yes	No
Effect of moisture	Rusts, but does not distort	Won't rust, but may distort
Fabrication, reconditioning	Lapped or Scraped	Must be lapped
Whether it will give up a bearing	Yes (advantage)	Not early (disadvantage)
Effect of burrs	Raises up (disadvantage)	Makes a hole (advantage)
Available shapes and sizes	Limited	Almost unlimited. (can be sawed or shaped)
Versatility in use	Excellent can be machined, drilled and tapped.	Good, but needs inserts and fasteners.

Care and use of surface plates

- The surface plate is a datum and needs to be protected against damage. When not in use, it should always be kept covered. During use, top should be frequently wiped clean from dust and other particles. When measurements are being made, a wiping cloth should be spread on the surface place to receive small tools and gauge blocks.
- Surface plate should be located in a stirred atmosphere under constant temperature control. Direct sunlight or sudden draughts should not be allowed to reach surface plate. Vertical gradient of temperature subjecting the top and underside of surface plate to different temperatures should be avoided.
- The surface plate should be supported firmly and levelled. Stands should be located on a stable foundation.

- The load on the surface plate should be distributed over the working surface, as far as possible.
- Point engagement should not be made with scraped or machined surface plates. To avoid direct point engagement with the surface plate, contact should be made through an intermediate precision gauge block or a distance piece, preferable, not more than 10 mm tall.
- Use should be made of the full available area of the working surface and not concentrated on any one area.

  The variation in local flatness of the surface should be checked occasionally by using a variation gauge.
- The excess metal due to burrs on the working surface of cast iron surface plate should be stoned away by confining attention to the burr. This operation should be followed by thorough cleaning from abrasive dust. If the surface plate is not required for some days, the surface should be coated with a corrosion preventive such as petroleum jelly.
- Rusting can be reduced by frequently wiping the top when in use and by occasionally gently rubbing with another surface plate using a paste of paraffin and a little jeweller's rouge as a lubricant.
- The wear on surface plate can be detected by rubbing it with a superior grade of surface plate and studying the rubbed appearance, by testing for deviation from straightness along lines on the surface plate, and/or using a variation gauge.

Vernier calipers

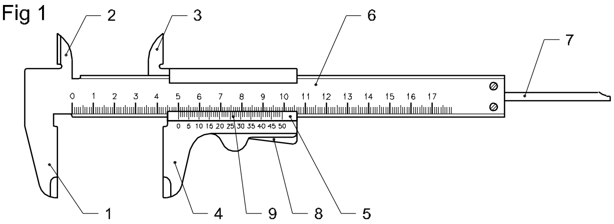
Objectives: At the end of this lesson you shall be able to
- **identify the parts of a vernier caliper**
- **state the constructional features of a vernier caliper**
- **state the uses of a vernier caliper.**

A vernier caliper is a precision measuring instrument. It is used to measure up to an accuracy of 0.02 mm (Fig 1).

Parts of a vernier caliper: (Numbers as per Fig 1)

Fixed jaws (1): Fixed jaws are part of the beam scale. One jaw is used for taking external measurements, and the other for taking internal measurements.

Fig 1



Movable jaws (2 and 3)

Fig 2

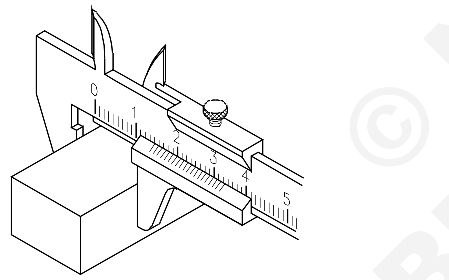
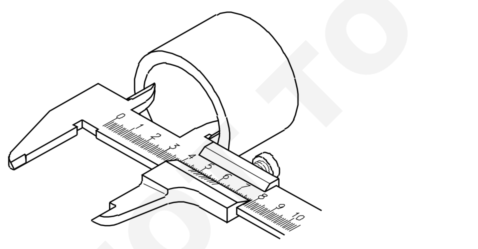


Fig 3



Movable jaws are part of the vernier slide. One jaw is used for external measurements, and the other for internal measurements. (Figs 2 and 3)

Vernier slide (5): A vernier slide moves over the beam and can be set in any position by means of a spring-loaded thumb lever.

Beam (6): The vernier slide and the depth bar attached to it, slide over the beam. The graduations on the beam are called the main scale divisions.

Depth bar (7): The depth bar is attached to the vernier slide and is used for measurement of depth.

Thumb lever (8): The thumb lever is spring-loaded which helps to set the vernier slide in any position on the beam scale.

Vernier scale (9): The vernier scale is the graduation marked on the vernier slide. The divisions of this scale are called vernier divisions.

Main scale: The main scale graduations or divisions are marked on the beam.

Sizes: Vernier calipers are available in sizes of 150 mm, 200, 250, 300 and 600 mm. The selection of the size depends on the measurements to be taken, Vernier calipers are precision instruments, and therefore, extreme care should be taken while handling them.

Never use a vernier caliper for any purpose other than measuring.

They should be used only to measure machined or filed surfaces.

> **Vernier calipers should never be mixed with any other tools.**
>
> **Clean the instrument after use, and store it in a box.**

Graduations and reading of vernier calipers

Objectives: At the end of this lesson you shall be able to
- **determine the least count of a vernier caliper**
- **state how graduations are made on a vernier caliper with 0.02mm least count**
- **read vernier caliper measurements.**

Vernier calipers: Vernier calipers are available with different accuracies. The selection of the vernier caliper depends on the accuracy needed and the size of the job to be measured.

This accuracy/least count is determined by the graduations of the main scale and the vernier scale divisions.

Vernier Principle: The vernier principle states that two different scales are constructed on a single known length of line and the difference between them is taken for fine measurements.

Determining the least count of vernier calipers

In the vernier caliper the main scale divisions (9 mm) are divided into 10 equal parts in the vernier scale.

i.e. One main scale division (MSD) = 1 mm

One vernier scale division (VSD) = 9/10 mm

Least count = 1 MSD - 1 VSD

= 1 mm-9/10 mm = 0.1 mm.

The difference between one

MSD and one VSD = 0.1 mm.

Reading vernier measurements: Vernier calipers are available with different graduations and least counts. For reading measurements with a vernier caliper, the least count should be determined first. (The least count of calipers is sometimes marked on the vernier slide.)

Fig 1

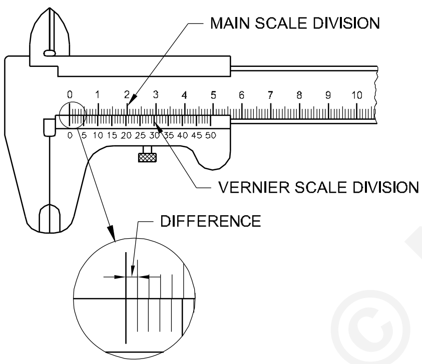
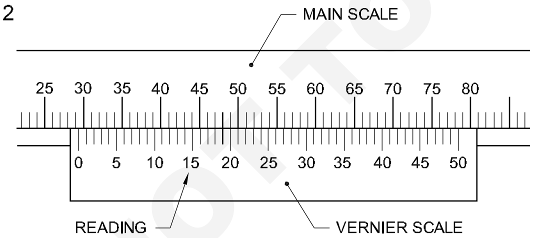


Fig 2 shows the graduations of a common type of vernier caliper with a least count of 0.02 mm. In this, 50 divisions of the vernier scale occupy 49 divisions (49 mm) on the main scale.

Fig 2



Example

Calculate the least count of the vernier given in Fig 3.

Least count = 1 mm - 49/50 mm

= 1/50 mm

=0.02mm.

Example for reading vernier caliper (Fig 4)

Main scale reading = 60mm

The vernier division coinciding with the main scale is the 28th division, value = 28 x 0.02

= 0.56 mm

Reading = 60 + 0.56 = 60.56 mm.

Fig 3

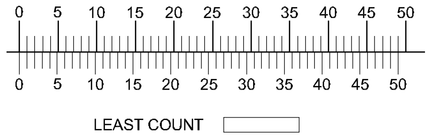
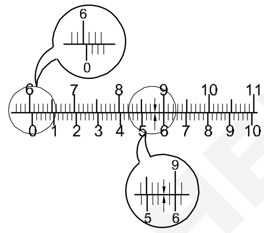


Fig 4



Classroom exercise

In Figs (5,6,7 and 8) 49 main scale divisions are divided into 50 equal parts on the vernier scale. Value of one MSD is 1 mm.

1 Calculate the least count.

2 Record the reading of each figure in the space provided.

Fig 5

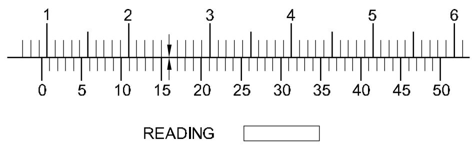


Fig 6

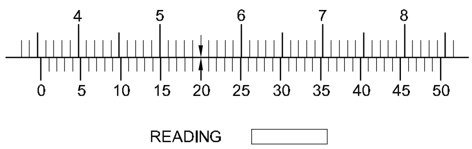


Fig 7

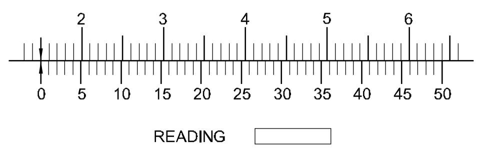
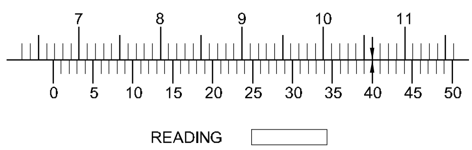


Fig 8



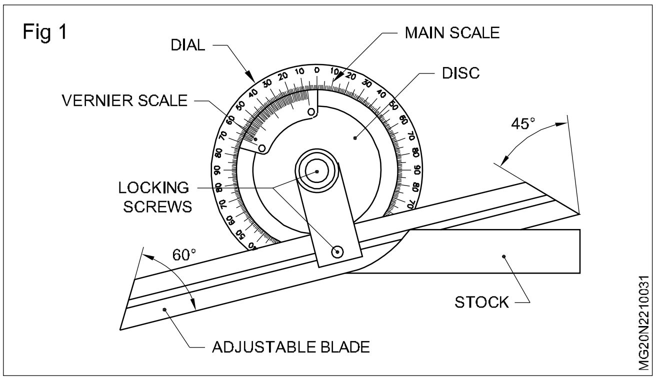
Vernier bevel protractor

Objectives: At the end of this lesson you shall be able to
- **identify the parts of a universal bevel protractor**
- **state the functions of each part**
- **list out the uses of a vernier bevel protractor.**

The vernier bevel protractor is a precission instrument meant for measuring angles to an accuracy of 5 minutes. (5')

Parts: The following are the parts of a vernier bevel protractor. (Fig 1)

Fig 1



Stock: This is one of the contacting surfaces during the measurement of an angle. Preferably it should be kept in contact with the datum surface from which the angle is measured.

Dial: The dial is an integrated part of the stock. It is circular in shape, and the edge is graduated in degrees.

Disc: It is pivoted to the dial and can be rotated through 360°. The vernier scale of the instrument is attached to the disc. The disc is locked to the dial when reading the measurement.

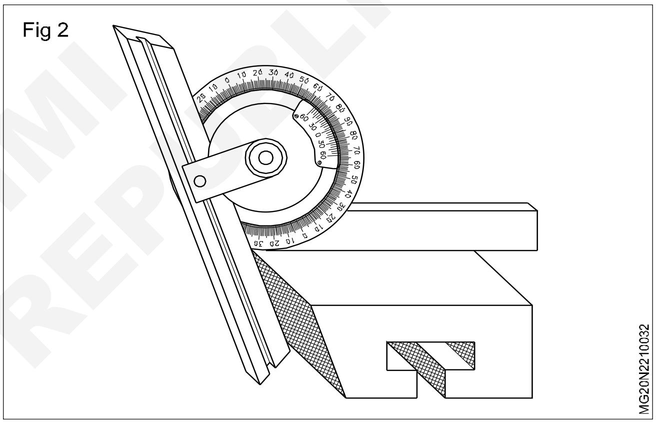
Blade: This is the other surface of the instrument that contacts the work during measurement. It is fixed to the dial with the help of the clamping lever. A parallel groove is provided in the centre of the blade to enable it to be longitudinally positioned whenever necessary.

Locking screws: Two knurled locking screws are provided, one to lock the dial to the disc, and the other to lock the blade to the dial.

All parts are made of good quality alloy steel, properly heat-treated and highly finished. A magnifying glass is sometimes fitted for clear reading of the graduations.

Uses of a vernier bevel protractor: Apart from being used for measuring angles (Fig 2) a vernier bevel protractor is also used for setting work-holding devices on machine tools, work-tables etc.

Fig 2

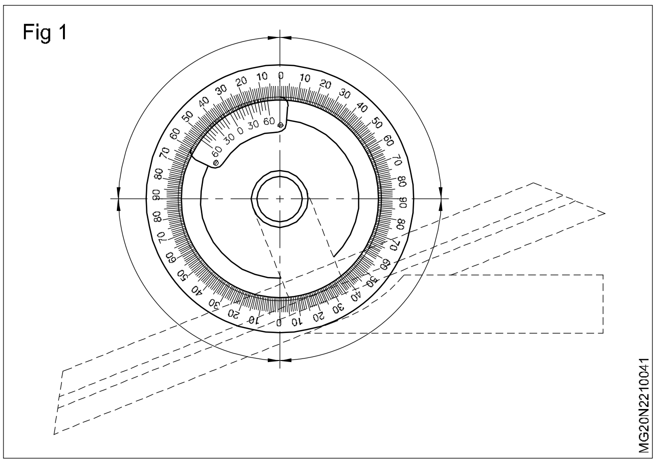


Graduations on universal bevel protractor

Objectives: At the end of this lesson you shall be able to
- **state the main scale graduations on the dial**
- **state the vernier scale graduations on the disc**
- **determine the least count of the vernier bevel protractor.**

The main scale graduations: For purposes of taking angular measurements, the full circumference of the dial is graduated in degrees. The 360° are equally divided and marked in four quadrants, from 0 degree to 90 degrees, 90 degrees to 0 degree, 0 to 90 degrees and 90 degrees to 0 degrees. Every tenth division is marked longer and numbered. Each division represents 1 degree. The graduations on the dial are known as the main scale divisions. On the disc, 23 divisions spacing of the main scale is equally divided into 12 equal parts on the vernier. Each 3rd line is marked longer and numbered as 0, 15, 30, 45, 60. This constitutes the vernier scale. Similar graduations are marked to the left of 0 also. (Fig 1)

Fig 1



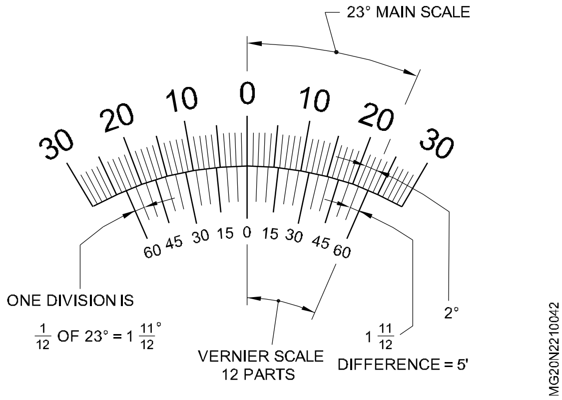
One vernier scale division (VSD) (Fig 2)

= 1 = $1^0 55'$

The least count of the vernier bevel protractor: When the zero of the vernier scale coincides with the zero of the main scale, the first division of the vernier scale will be very close to the 2^{nd} main scale division. (Fig 2)

Hence, the least count is

Fig 2

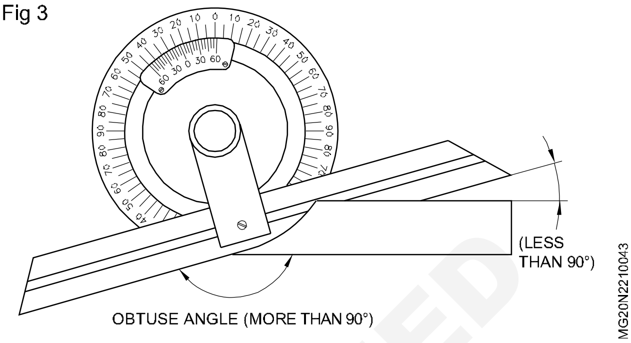


2 MSD - 1 VSD

i.e. the least count = 2^0-$1^0$55’ =5'.

For any setting of the blade and stock, the reading of the acute angle and the supplementary obtuse angle is possible, and the two sets of the vernier scale graduations on the disc assist to achieve this. (Fig 3)

Fig 3

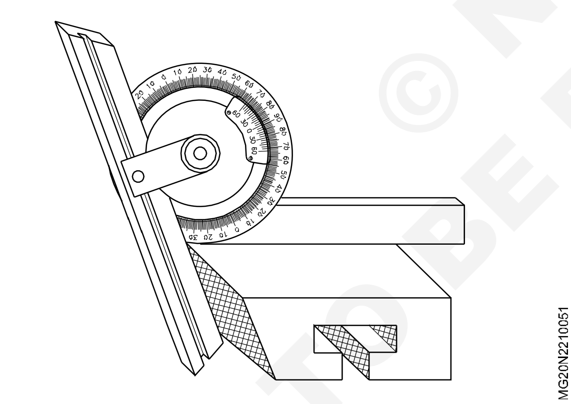


Reading of universal bevel protractor

Objectives: At the end of this lesson you shall be able to
- **read a vernier bevel protractor for acute angle setting**
- **read a vernier bevel protractor for obtuse angle setting.**

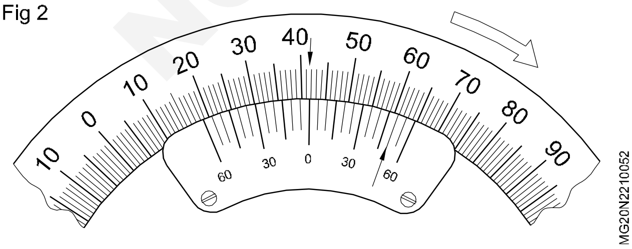
For reading acute angle set up (Fig 1): First read the number of whole degrees between zero of the main scale and zero of the vernier scale.

Fig 1



Note the line on the vernier scale that exactly coincides with any one of the main scale divisions and determine its value in minutes. (Fig 2)

Fig 2



To take the vernier scale reading, multiply the coinciding divisions with the least count.

Example: 10 x 5' = 50'

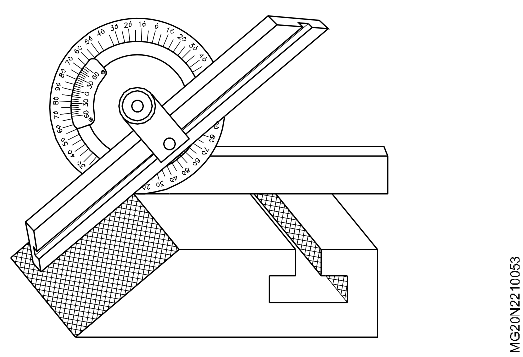
Total up both the readings to get the measurements = 41° 50'.

If you read the main scale in an anticlockwise direction, read the vernier scale also in an anticlockwise direction from zero.

If you read the main scale in a clockwise direction, read the vernier scale also in a clockwise direction from zero.

For obtuse angle set up (Fig 3)

Fig 3

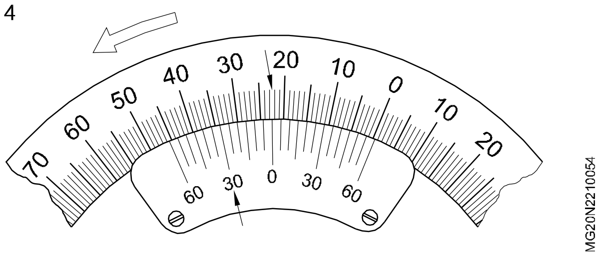


The vernier scale reading is taken on the left side as indicated by the arrow. (Fig 4) The reading value is subtracted from 180° to get the obtuse angle value.

Reading 22°30'

Measurement 180° - 22°30' = 157°30'.

Fig 4

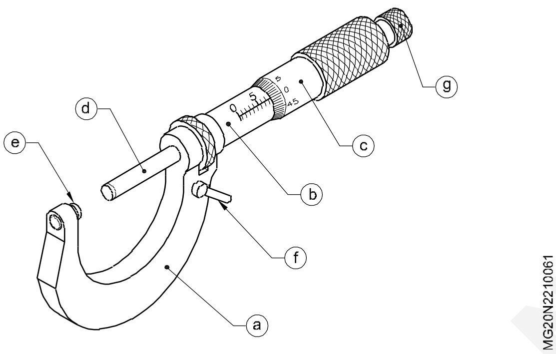


Outside micrometer

Objectives: At the end of this lesson you shall be able to
- **identify the parts of an outside micrometer**
- **state the functions of the main parts of an outside micrometer.**

A micrometer is a precision instrument used to measure a job, generally within an accuracy of ± 0.01mm Micrometers used to take the outside measurements are Known as outside micrometers. (Fig 1)

Fig 1



The parts of a micrometer are listed here.

Frame (a): The frame is made of drop-forged steel or malleable cast iron. All other parts of the micrometer are attached to this.

Barrel/sleeve (b): The barrel or sleeve is fixed to the frame. The datum line and graduations are marked on this. Thimble (c)

On the bevelled surface of the thimble also, the graduation is marked. The spindle is attached to this.

Spindle (d): One end of the spindle is the measuring face. The other end is threaded and passes through a nut. The threaded mechanism allows for the forward and backward movement of the spindle.

Anvil (e): The anvil is one of the measuring faces which is fitted on the micrometer frame. It is made of alloy steel and finished to a perfectly flat surface.

Spindle lock-nut (f): The spindle lock nut is used to lock the spindle at a desired position.

Ratchet stop (g): The ratchet stop ensures a uniform pressure between the measuring surfaces.

Graduations of metric outside micrometer

Objectives: At the end of this lesson you shall be able to
- **state the principle of a micrometer**
- **determine the least count of an outside micrometer.**

Working principle: The micrometer works on the principle of screw and nut. The longitudinal movement of the spindle during one rotation is equal to the pitch of the screw. The movement of the spindle to the distance of the pitch or its fractions can be accurately measured on the barrel and thimble. (Fig 1)

Graduations: In metric micrometers, the pitch of the spindle thread is 0.5mm.

Thereby, in one rotation of the thimble, the spindle advances by 0.5 mm.

On the barrel a 25 mm long datum line is marked. This line is further graduated to millimetres and half millimeters (i.e:-1mm and 0.5 mm). The graduations are numbered as 0,5,10,15,20 and 25 mm.

The circumference of the bevel edge of the thimble is graduated into 50 divisions and marked 0-5-10-15 ...... 45-50 in a-clockwise direction.

The distance moved by the spindle during one rotation of the thimble is 0.5mm.

$$\text{Least count} = \frac{\text{Distance moved by the spindle per revolution of the thimble}}{\text{Number of divisions on thimble graduations}}$$

$$= \frac{0.5}{50} = 0.01\text{mm}$$

The accuracy or least count of a metric outside micrometer is 0.01 mm.

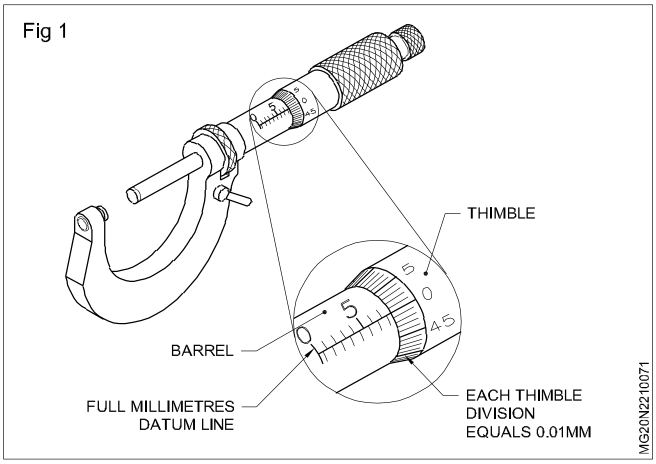


Fig 1

Reading dimensions with outside micrometers

Objectives: At the end of this lesson you shall be able to
- **select the required range of a micrometer**
- **read micrometer measurements.**

Outside micrometers are available in ranges of 0 to 25 mm, 25 to 50 mm, 50 to 75 mm, 75 to 100 mm, 100 to 125 mm and 125 to 150 mm.

For all ranges of micrometers, the graduations marked on the barrel are only 0-25 mm. (Fig 1)

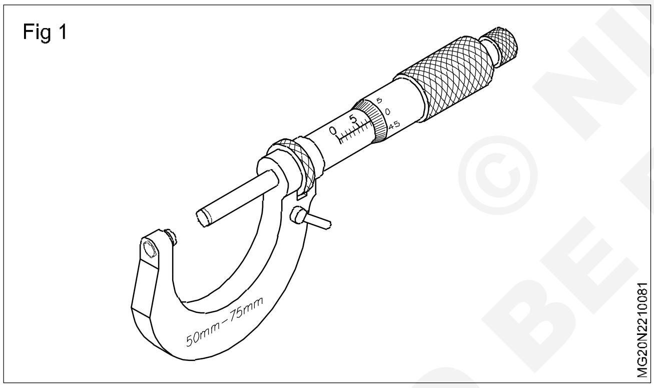


Fig 1

Reading micrometer measurements

How to read a measurement with an outside micrometer? (Fig 2)

First note the minimum range of the outside micrometer. While measuring with a 50 to 75 mm micrometer, note it as 50mm.

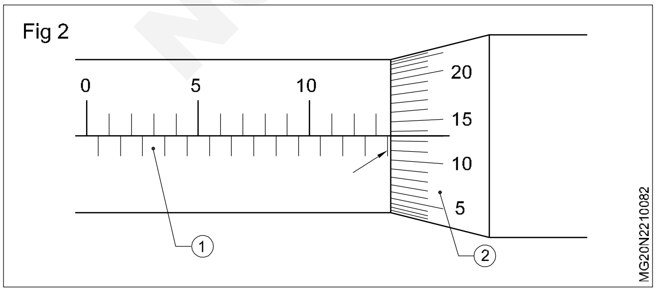


Fig 2

Then read the barrel graduations. Read the value of the visible lines on the left of the thimble edge.

13.00 mm
+ 00.50 mm

13.50 mm

Next read the thimble graduations.

Read the thimble graduations in line with the barrel datum line, 13th div. (Fig 3)

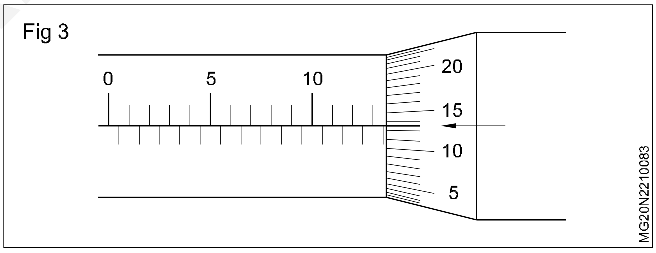


Fig 3

Multiply this value with 0.01 mm (least count).

13xO.01 mm = 0.13 mm

Add

Minimum range = 50.00 mm

Barrel reading = 13.50 mm

Thimble reading = 00.13 mm

Total **63.63mm**

The micrometer reading is 63.63 mm.

Inside micrometer - metric - construction

Objectives: At the end of this lesson you shall be able to
- **name the parts of an inside micrometer**
- **determine the reading of the bore or hole**
- **determine the reading with a spacing collar & extension rods**
- **determine the distance between internal parallel surfaces.**

Construction

The inside micrometer is similar to an ordinary outside micrometer but without the 'U' frame. (Fig 1) The measurement is taken over the contact points. As the thimble opens or closes, the contact points get opened or closed. The inside micrometer consists of a sleeve, thimble, anvils, a spacing collar and extension rods. It is also equipped with a handle to measure deep bores. The least count of the instrument is also 0.01 mm. The inside micrometer is equipped with a 12 mm spacing collar and 4 extension rods for measuring holes of ranges 50-75mm, 75-100 mm, 100-125 mm and 125-150 mm. The sleeve is marked with the main scale and the thimble with the thimble scale. The barrel has a limited adjustment of 13 mm. When the inside micrometer is closed (when zero of thimble coincides with the zero of the barrel), it is capable of reading the minimum dimension of 25 mm. In addition to this, it is possible to read up to 38 mm with the thimble opening to the extreme right. In order to read further higher ranges, a standard spacing collar of 12 mm width is to be added. This facilitates the micrometer to read a maximum range of 50 mm. (Fig 2)

Similarly, each extension rod has to be used without the collar for measuring a minimum range up to 13 mm variation and with the collar for a maximum range of measurements. A clamping screw is also provided to clamp the extension rod firmly.

Fig 1

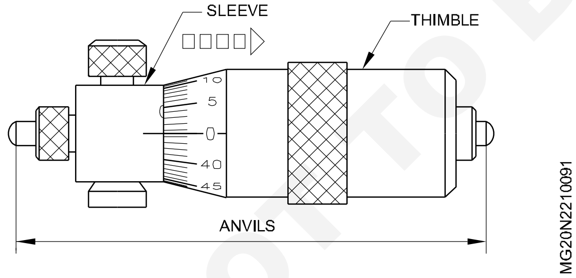
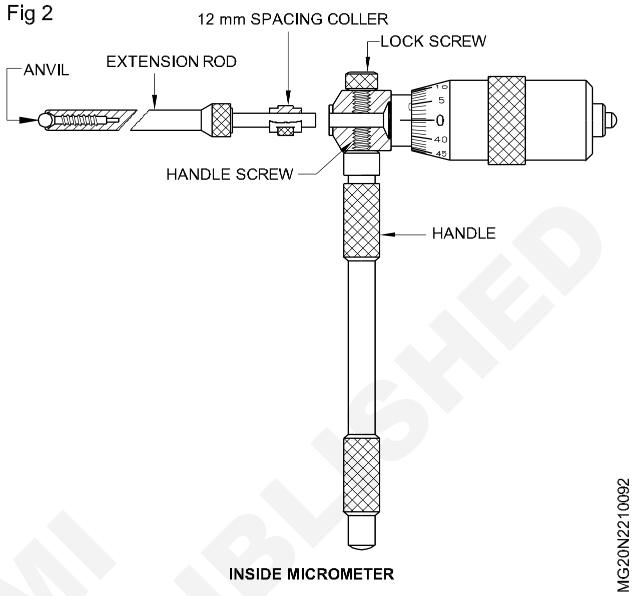


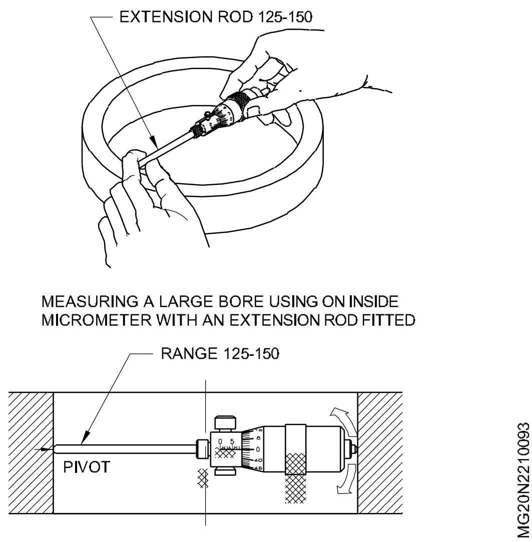
Fig 2



Determining the size of a bore or hole

Reading of inside micrometer Fig 3 shows an inside micrometer with a spacing collar and extension rod of 125-150 mm range. The size of the bore is 125 mm + 12 mm + barrel reading + thimble reading which is equal to 125 + 12 + 1.5 + 0.00 = 138.50 mm.

Fig 3



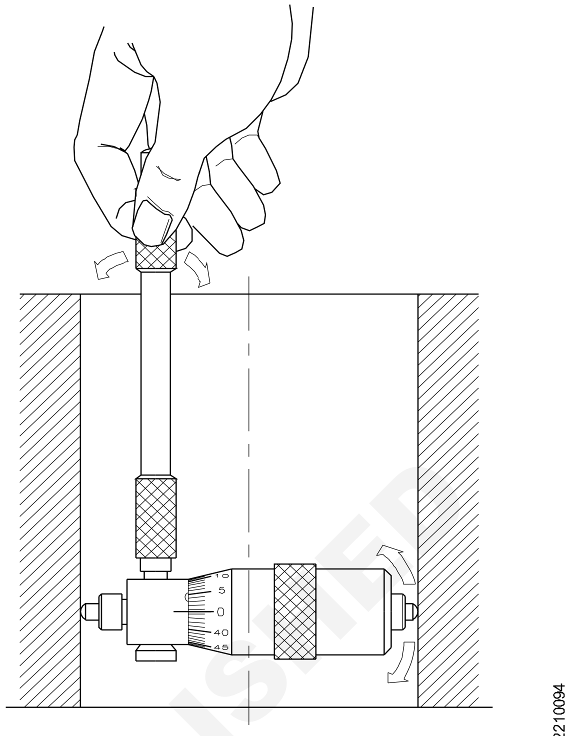
Determining the distance between internal parallel surfaces

While checking parallelism between two surfaces of a deep bore, a handle must be used along with the inside micrometer. The figure shows the inside micrometer with a handle. In order to ascertain the parallelism, a minimum of two readings has to be taken, i.e. one at the top surface of the deep bore and the other at the bottom surface of the bore. If there is no difference in the two readings, we may take it for granted that the surfaces are perfectly parallel. Any variation in the reading shows the bore has an error between the two surfaces. (Fig 4)

Uses:

This instrument is generally used to measure accurately the bored components, specifically it is used for checking cylinder bores. It is also used for measuring internal shoulders, checking ring gauges.

Fig 4



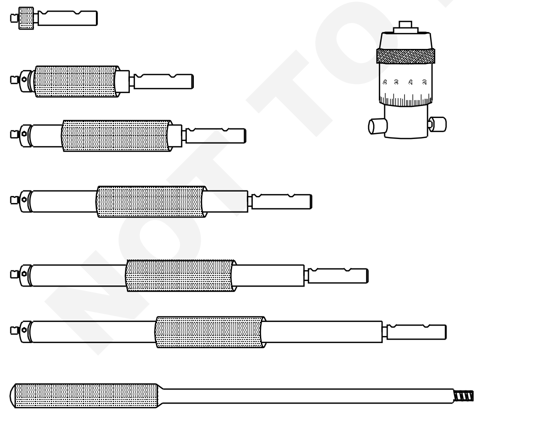
USING AN EXTENDED HANDLE WHEN MEASURING THE BORE OF A SLEEVE BEARING

Inside micrometer - Inch

Objectives: At the end of this lesson you shall be able to
- **determine the reading of inside micrometer inch**
- **calculate the least count of inside micrometer inch**
- **state the construction of inside micrometer inch.**

The inside micrometer inch is similar to inside micrometer metric. This consists of a sleeve, thimble, avoids a stitching coller and extension rods. It is also equiped with a handle to measure deep bores. The lease count of the instrument is 0.001”.

Fig 1



The inside micrometer inch is equiped with a 1/2” spacing coller an 4 extension rods for measuring holes of ranges 2” - 3”, 4” - 5” and 5” - 6” (Fig 1). The sleeve is marked with the main scale and the thimble with the thimble scale. The barrel has a limited adjustment 1/2”. When the inside micrometer is closed (zero of thimble coincides with the zero of the barrel) it is capable of reading the minimum dimension of 1”.

In addition to this, it is possible to read upto 1 1/2” with the thimble opening to the extreme right. In order to rad further higher ranges, a standard spacing coller of 1/2” width is to be added. This facilitates the micrometer to read a maximum range of 2”.

Reading of inside micrometer (Fig 2)

Graduation of inside micrometer inch.

Value of one main scale division MSD = 0.100”

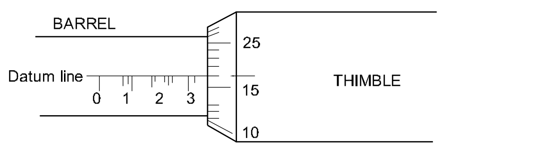
Vale of one sub division SD = 0.025”

Value of one thimble division TD = 0.001”

Reading

Main scale reading	=	3 x 0.00	= 0.300”
Sub division reading	=	1 x 0.025	= 0.025”
Thumble division coincide	=	15 x 0.001	= 0.015”
Total	=		0.340”

Fig 2



Depth Micrometers

Objectives: At the end of the lesson you shall be able to
- **name the parts of a depth micrometer**
- **slate the constructional features of depth micrometer**
- **read depth micrometer.**

Constructional features

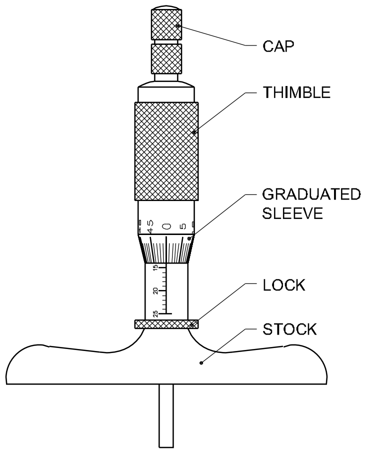
The depth micrometer consists of stock on which a graduated sleeve a fitted.

The other end of the sleeve is threaded with a 0.5mm pitch 'V' thread

A thimble which is internally threaded to the same pitch and form, mates with the threaded sleeve and slides over it.

The other end of the thimble has an external step machined and threaded to accommodate a thimble cap (Fig 1)

Fig 1



DEPTH MICROMETER

A set of extension rods is generally supplied. On each of them the range of sizes that can be measured with that rod is engraved as 0.25 25-50 50-75 75-100 100-125 and 125-150

These extension rods can be inserted inside the thimble and the sleeve

The extension rods have a collar-head which helps the rod to be held firmly (Fig 2)

It is hardened, tempered and ground. The measuring face of the stock is perfectly machined flat.

The extesion rods may be removed and replaced according to the size of depth to be measured.

Graduation and least count

On the sleeve a datum is marked for a length of 25 mm. This is divided into 25 equal parts and graduated, each fifth line is drawn a little longer and numbered. Each line representing 1 mm is further subdivided into two equal parts. Hence each subdivision represents 0.5 mm (Fig 3)

The graduations are numbered in the reverse direction, to those marked on an outside micrometer.

The zero graduation of the sleeve is on the top and the 25 mm graduation near the stock

Fig 2

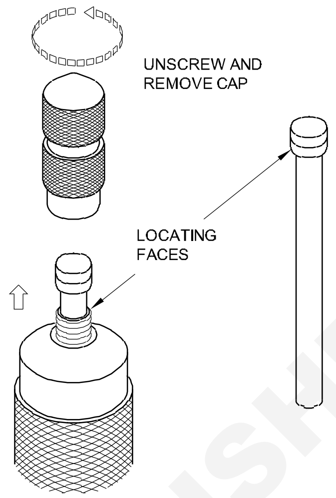
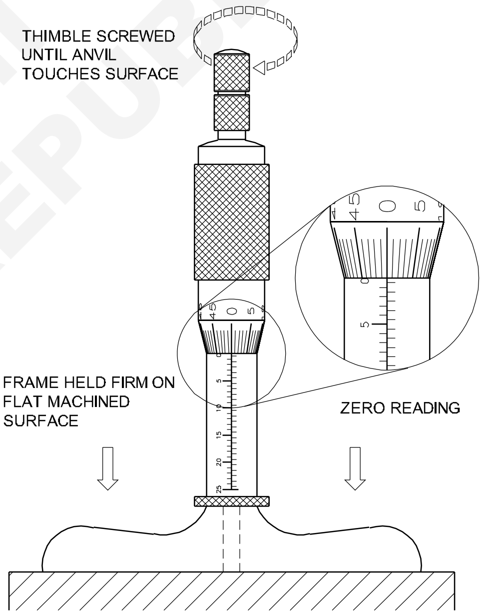


Fig 3



CHECKING THE ZERO SETTING

The bevel edge of the thimble is also graduated. The circumference is equally divided into 50 equal parts and every 5th division line is drawn a little longer and numbered. The numbering is in the reverse direction and increases from 0,5,10,15, 25, 30, 35, 40,45 and 50 (0) (Fig 4)

The advancement of the extension rod for one full turn of the thimble is one pitch which is 0.5 mm.

Therefore, the advancement of the extension rod for one division movement of the thimble will be equal to 0.5/50 0.01 mm.

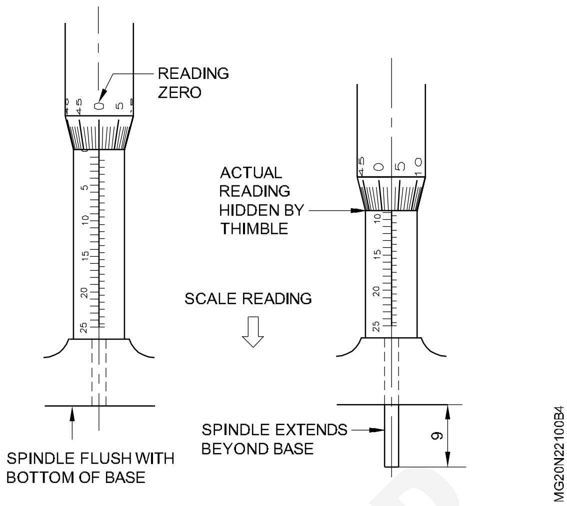
This will be the smallest measurement that can be taken with this instrument, and so, this is the accuracy of this instrument.

Uses of depth micrometers

Depth micrometers are special micrometers used to measure

- the depth of holes
- the depth of grooves and recesses
- the heights of shoulders or projections.

Fig 4



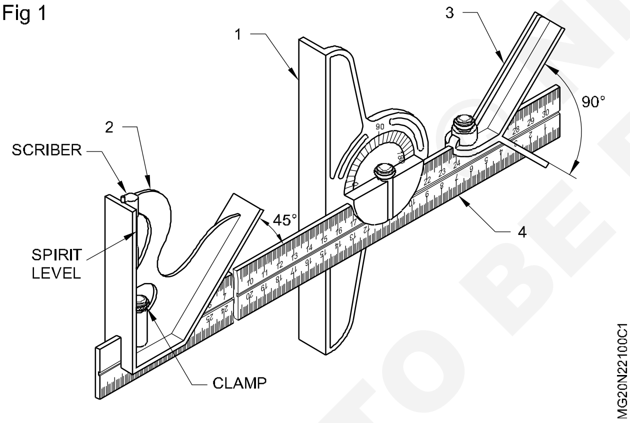
Combination set

Objectives : At the end of this lesson you shall be able to
- **identify the parts of a combination set**
- **state the uses of each attachment in a combination set.**

Combination sets can be used for different types of work, like layout work, measurement and checking of angles.

The combination set (Fig 1) has a Protractor head (1), Square head (2), Center head (3), and a rule (4).

Fig 1



Square head: The square head has one measuring face at 90° and another at 45° to the rule.

It is used to mark and check 90° & 45° angles. It can also be used to set workpieces on the machines and measure the depth of slots. (Figs 2,3, and 4)

Fig 2

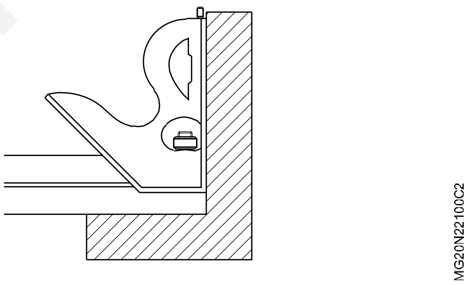


Fig 3

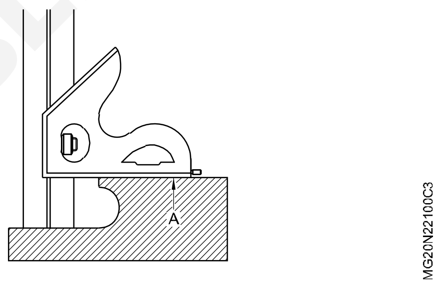


Fig 4

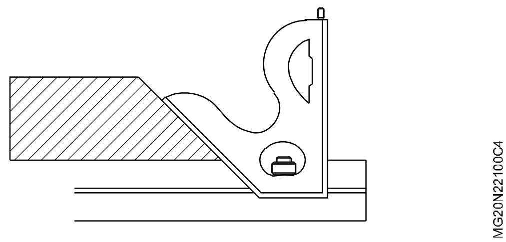
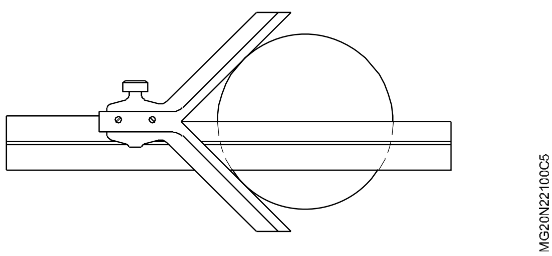


Fig 5



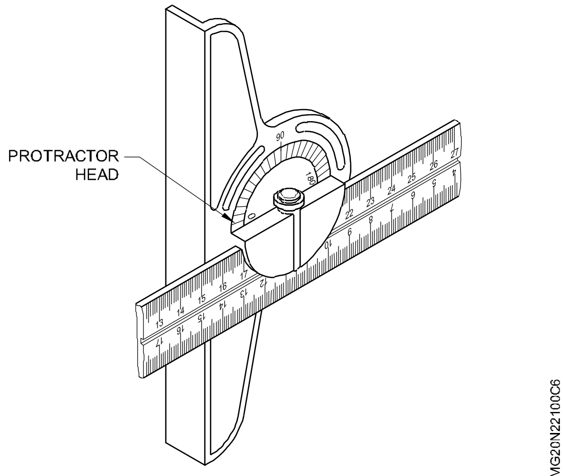
Center head: This along with the rule is used for locating the center of cylindrical jobs. (Fig 5)

For ensuring accurate results, the combination set should be cleaned well after use and should not be mixed with cutting tools, either while using or storing.

Protractor head : The protractor head can be rotated and set to any required angle.

The protractor head is used for marking and measuring angles within an accuracy of 1°. The spirit level attached to this is useful for setting jobs in a horizontal plane. (Fig 6)

Fig 6



Bonding materials, brief about ISO - 9000

Objectives: At the end of this lesson you shall be able to
- **name the different types of bonding material and their uses and drawbacks**
- **state the advantages and disadvantages of bonding materials**
- **state what is the quality control**
- **state the advantages of ISO 9000**
- **state the different series of ISO 9000.**

Bonding material: The bond chosen to act as the matrix for the abrasive particles depends upon;

- the proposed shape of the wheel
- the grain size
- the reaction of the bonding material when in contact with the coolant and
- the service requirements

Vitrified bond: Wheels containing either aluminium oxide or silicon carbide abrasive are made with the vitrified bond. The maximum safe linear speed for this class of bond is around 6,500 f.p.m. But, in the interests of safety, a speed of 5,000 f.p.m, is the general recommendation.

Wheels having the vitrified bond are suitable for both rough and finish grinding and, under suitable conditions, they will produce a finish having a low micro inch value. The precise properties of the vitrified bond are adjusted to suit the service needs and this may be traced in Table 1.

But the strength also varies with different grain sizes. (Table 2)

Manufacturing problems associated with high kiln temperatures restrict the size of a wheel having the vitrified bond to around 30 in diameter maximum, and an analysis of the advantages and drawbacks of this class of bonding material is listed in Table 3.

Table 1

Strength of the vitrified bonds

Grade	H	I	J	K	L	M	N
Strength p.s.i	600	800	1,200	1,350	1,500	1,750	2,000

Table 2

Grade M having	60	46	36 grain	Bond Q having	8	12	14	20	24 grain
strength p.s.i. :	1750	1550	1450	strength p.s.i. :	1150	1400	1450	1750	2000

Table 3

Advantages and drawbacks of the vitrified bond

Advantages	Drawbacks
It is porous and free cutting.	The process is slow.
The bond is unaffected by water, oil, acids, temperature, or climatic conditions.	Large wheels are likely to crack whilst being fused in the kiln.
The bond is hard and itself is practically an abrasive.	The maximum wheel diameter is say 30 in.
Wet mixing tends to ensure uniformity of the wheel structure.	The burning or fusing process is difficult to control, hence production troubles can arise.
The high kiln temperature tends to burn out any impurities leaving behind only the abrasive and the bond.	The high kiln temperature tends to weaken the abrasive particles.

Silicate bond: The softer and weaker silicate bond is used as the matrix for both the aluminium oxide and the silicon carbide abrasives. One advantage of this bond is that large wheels, as are used in the cutlery, also the stove and grate trades can readily be produced. Practical considerations connected with hardening the bond control the size of any wheel, the grey silicate bond lends itself to the production of larger wheels than is feasible with the vitreous bond. The combined effects of the weaker bonding material, drying at a lower temperature, are such that the abrasive particles are more readily dislodged. The net result is that the silicate bonded wheels have a free and cooler cutting action than the vitreous type. By judicious adjustment of the wheel and workpiece speeds, excessive wear can be avoided. Due to their cool cutting action, silicate bonded wheels are normally preferred when grinding fully heat-treated steel components. The advantages and drawbacks of the silicate bond are listed in Table 4.

Table 4

Advantages and drawbacks of the silicate bond

Advantages	Drawbacks
The process is rapid; special wheels can be produced within a few days.	The harder grades do not cut freely.
The bond is dependable; baking is more readily controlled.	The bond is unsuitable for extra hard and durable wheels.
With a moderate kiln or furnace temperature there is no tendency to soften the abrasive.	
With wet grinding the soda in the bond acts as a lubricant.	
The wheels cut smoothly.	
Wheels upto 60 in. dia. are made.	
Silicate bonded wheels cut cool.	
Silicate bonded wheels can be moulded on to iron backs or centres. This is impossible with the vitreous bond owing to the high firing temperature of say 1250° C.	

Shellac bond: When thin wheels are needed for cutting-off operations of bar or tube, the more flexible bonding material, shellac, is chosen as neither the vitreous nor silicate bonds will safely resist the applied bending stresses. As the shellac bond has a greater strength and retentivity than the vitrified or silicate bonds, it follows that 1). Abrasive particles are not so readily dislodged. 2) the wheels may be operated at a much higher, safe linear speed.

Its characteristics are such that the bond is only used for wheels that do not remove much metal; typical operations are grinding slots, sharpening knives and saws, thread grinding and finish grinding hardened steel rolls.

Rubber bond: Rubber bonded wheels are chiefly used when a first-class surface is demanded with close dimensional accuracy. This class of bond is also chosen, (1) When making thin cutting off wheels, (2) for regulating wheels such as those used on centreless grinding machines.

Resinoid bonds: Resinoid bonds are used for much the same purposes as the shellac and rubber types, that is, for cutting off operations, thread grinding, and for cylindrical grinding if a low micro inch value is desired.

Metallic bond: The metallic bond, as produced by the powder metal technique, is only used at the present time for the diamond wheels.

Quality control: The process of delegating responsibility and authority for a management activity, thus freeing management of unnecessary detail while retaining for it the means of assuring that results will be satisfactory, is labelled as control. The procedure for meeting the industrial quality goal is, therefore, termed quality control. The quality control, is in the nature of a feedback loop and involves:

Setting standards- determining the cost-quality, performance quality, and reliability quality standards for the product/service.

Appraising conformance - Comparing the conformance of the manufactured product/service to these standards.

Acting when necessary - taking corrective action when the standards are exceeded, and

Planning for improvements - developing a continuing effort to improve the cost, performance and reliability standards.

Quality control function is actually a collection of activities within the production system. Sales, purchasing product design, process development, manufacturing, inspection and so forth, are all different functions within the production function. Yet each of these activities includes a sub-activity devoted to quality. Each production function includes quality as one of its considerations.

The advantages of the ISO 9000 quality system for the company, its customers and its employees.

For the company

- Its products will be of a more consistent quality, and it will produce fewer rejects.
- The company will make greater savings in costs, because production will be more efficient. It will achieve economies in production (because company systems will be controlled from start to finish) and economics in time (because less effort will need to be expanded on re-doing work).
- The company can improve the quality of its raw materials and components be, requiring its suppliers to install an ISO 9000 system.
- Export marketing will be easier, because some foreign buyers place a premium on the ISO 9000 system.
- The company can expect preferential treatment from potential customers who have ISO 9000 certification system. This will mean an increase in new business.
- the company will secure greater customer loyalty, because it will continuously satisfy its customers needs and give them no cause to seek another supplier. This means that the company will suffer fewer customer losses.
- The company can use ISO 9000 in its publicity to win more sales.

For the company's customers

- The company's customers will receive products or services of a known level of quality that is independently audited.
- Customers are presented with a means of choosing between competing suppliers.
- Customers will have more confidence in the company's goods.

For the company's employees

- Staff will obtain a better understanding of their role and objectives from the documented management system.
- They will benefit from reduced stress levels, because they will be using an efficient management system, and because they know what is expected of them.
- Their morale and sense of pride will rise when they achieve the goals of registration and customer satisfaction.
- New staff can immediately learn their jobs, because the details are in writing.

The ISO 9000 family of standards : A brief description

The international standards belonging to the ISO 9000 series are briefly described in Table 5. Other standards are in the process of development. The first set of ISO 9000 series was published by ISO in 1987. It went a major revision in 1994.

Table 5

Description of ISO 9000 series of standards

Standard	Title	Contents in brief
Quality assurance models for assessment under contractual situation		
ISO 9001 : 1994	Quality systems - Model for quality assurance in design, development, production, installation and servicing.	Specifies quality system requirements for use when conformance to specified requirements is to be assured during design,development,production,delivery and servicing. It provides a quality assurance model for demonstration by a supplier of its capability and for assessment by external parties.
ISO 9002 : 1994	Quality systems - Model for quality assurance in production, installation & servicing.	Specifies quality system requirements for use when installation conformance to specified requirements is to be assured by the supplier during production, installation and servicing. It provides a quality assurance model for demonstration by a supplier of its capability and for assessment by external parties.
ISO 9003 : 1994	Quality systems - Model for quality assurance in final inspection and test.	Specifies quality system requirements and provides a quality assurance model for use where a supplier's capability to detect and control the disposition of any product non-conformity during final inspection and test needs to be demonstrated.

Quality management and quality assurance guidelines		
ISO 9000 - 1:1994	Quality management and quality assurance standards - Part 1 : Guidelines for selection and use.	Provides guidance for the selection and use of the ISO 9000 family of international standards on quality management and quality assurance. Clarifies the principal quality-related concepts needed for effective understanding and application of the standards, and the distinctions and interrelationships between them.
ISO 9000 - 2:1993	Quality management and quality assurance standards - Part 2 : Generic guidelines for the application of ISO 9001, ISO 9002 and ISO 9003.	Provides guidelines to enable users to have improved consistency, precision, clarify and understanding when applying the requirements of the ISO 9000 series of standards.
ISO 9000 - 3:1991	Quality management and quality assurance standards - Part 3 : Guidelines for the application of ISO 9001 to the development supply and maintenance of software.	Provides guidelines for software developers, suppliers, maintainers and purchasers in the specification and implementation of ISO 9001 quality system requirements as applied to software.
ISO 9000 - 4:1993	Quality management and quality assurance standards - Part 4 : Guide to dependability programme management.	
ISO 10005 : 1995	Quality management - Guidelines for quality plans.	Provides guidelines to relate generic requirements on quality system elements to the specific requirements of a particular product, project or contract. It also includes simplified examples of formats for the presentation of quality plans.
ISO 10007 : 1995	Quality management - Guidelines for configuration management.	

Quality management and quality system elements		
ISO 9004 - 1:1994	Quality management and quality system elements - part 1 : Guidelines	Provides guidelines on quality management for use within an organization in the development and implementation of a comprehensive and effective system designed to satisfy the customers needs and expectations. While serving to protect the organizations interests.
ISO 9004 - 2:1991 elements - part 2 :	Quality management and quality system Guidelines for services	Provides guidelines for the establishment of a quality system for services with the primary objective of preventing unsatisfactory services.
ISO 9004 - 3:1993	Quality management and quality system elements - part 3 : Guidelines for processed materials.	Provides a guide to quality system elements applicable to processed materials, such as bulk products, and discusses means of ensuring effective quality management.
ISO 9004 - 4:1993	Quality management and quality system elements - part 4 : Guidelines for quality improvement	Provides management guidelines for continuous quality improvement within an organization. Describe tools and techniques for a quality improvement methodology based on data collection and analysis.

Guidelines for auditing quality systems		
ISO 10011 - 1:1990 part 1 : Auditing	Guidelines for auditing quality systems -	Provides guidelines for establishing, planning, carrying out and documenting audits of quality systems as well as providing basic audit principles, criteria and practices. It allows users to adjust the guidelines to their needs.
ISO 10011 - 2:1991	Guidelines for auditing quality systems - part 2 : Qualification criteria for quality systems auditors	Sets out qualification criteria for the selection of auditors to perform quality systems audits in accordance with ISO 10011-1.
ISO 10011 - 3:1991	Guidelines for auditing quality systems - part 3 : Management of audit programmes	Provides basic guidelines for managing quality systems audit programmes. These guidelines can be used to establish and maintain an audit programme function when performing quality systems audits in accordance with ISO 10011-1 and ISO 10011-2.

Quality assurance requirements for measuring instruments		
ISO 10012 - 1:1992	Quality assurance requirements for measuring equipment - part 1 : Metrological confirmation system for measuring equipment.	Specifies quality assurance requirements for a supplier to ensure that measurements are made with the intended accuracy, & provides guidance on implementation; also specifies the main features of the confirmation system for measuring equipment.

Guidelines for developing quality manuals		
ISO 10013 : 1995	Guidelines for developing quality manuals.	This standard provides guidelines for the development.

Quality vocabulary		
ISO 8402 : 1994	Quality management and quality assurance vocabulary.	This standard defines basic terms under the following headings: general terms - terms related to quality; terms related to quality systems; & terms related to tools & techniques.

Grinding wheels - standard shapes and applications

Objectives: At the end of this lesson you shall be able to
- **state the standard shapes of grinding wheels**
- **identify the type and names of different shapes of grinding wheels**
- **state the application of each type of grinding wheel**
- **specify a grinding wheel.**

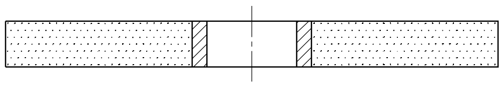
Grinding wheels are made in different shapes and sizes for grinding different jobs and for use in different machines. The size may differ in diameter, face width and bore dia.

The following are the standard shapes of grinding wheels.

Straight wheel: Type 1 (Fig 1)

This type of wheels is used on cylindrical, surface and centreless grinders for grinding cylindrical and flat surfaces. Sometimes this type of wheel is used on rough grinders for offhand grinding.

Fig 1



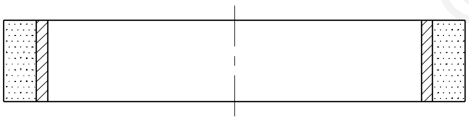
STRAIGHT

MG20N2210311

Cylinder: Type 2 (Fig 2)

This type of wheel is used on both horizontal and vertical spindle surface grinders for the surface grinding operations.

Fig 2



CYLINDER

MG20N2210312

Tapered (both sides) type 4 (Fig 3)

It is mainly used for rough grinding. The tapered sides reduce the chance of breaking.

Fig 3

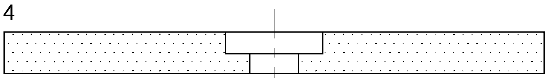
TAPERED TWO SIDES

MG20N2210313

Recessed one side: Type 5 (Fig 4)

It is used for cylindrical, surface and centreless grinding. The recess provides clearance for the flange.

Fig 4



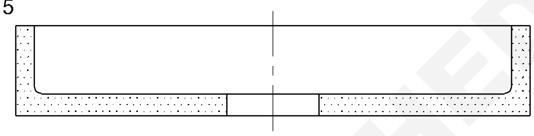
RECESSED ONE SIDE

MG20N2210314

Straight cup: Type 6 (Fig 5)

It is used on surface grinders and on tool and cutter grinders to grind flat surfaces.

Fig 5



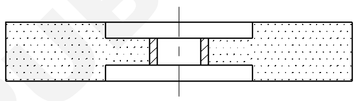
STRAIGHT CUP

MG20N2210315

Recessed both sides: Type 7 (Fig 6)

Used on cylindrical, surface and centreless grinders. The recesses provide clearance for both flanges.

Fig 6



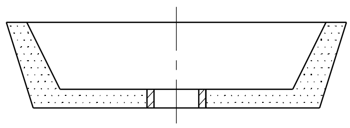
RECESSED TWO SIDES

MG20N2210316

Flaring cup: Type 11 (Fig 7)

It is used on tool and cutter grinders mainly to sharpen milling cutters and reamers.

Fig 7



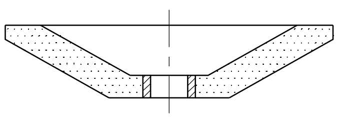
FLARING CUP

MG20N2210317

Dish: Type 12 (Fig 8)

Used on tool and cutter grinders to sharpen milling cutters with narrow slots like formed relieved cutters, hobs etc.

Fig 8



DISC WHEEL

MG20N2210318

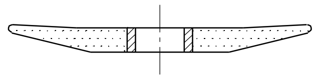
Saucer: Type 13 (Fig 9)

It is used for sharpening circular and handsaws. It is also used for gashing milling cutter teeth.

Segmented wheels (Fig 10)

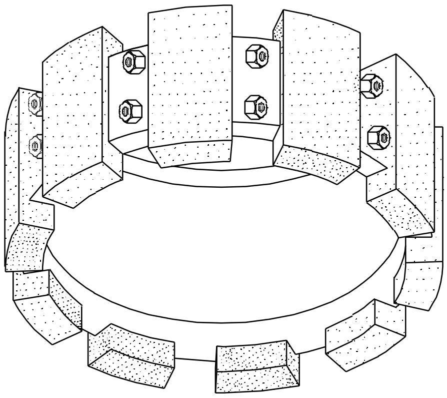
This type of wheels is formed by holding segments of abrasives using a metal holder. This is mainly used on a vertical spindle surface grinder.

Fig 9



SAUCER WHEEL

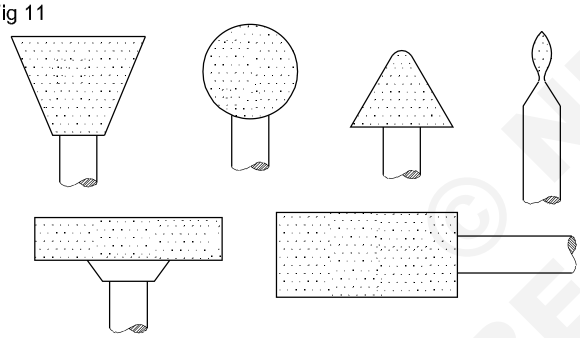
Fig 10



SEGMENTED WHEEL

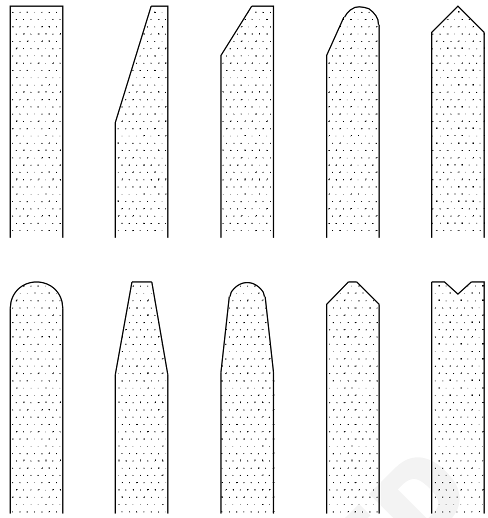
Mounted wheels (Fig 11) : These are wheels with less than 50mm dia. formed on a steel shank to various shapes. Mounted wheels are mainly used for die grinding, deburring and for finishing operations. Used on pneumatic or electric grinders.

Fig 11



Types of wheel faces : The different operations different types of wheel faces are produced by manufacturers. (Fig 12)

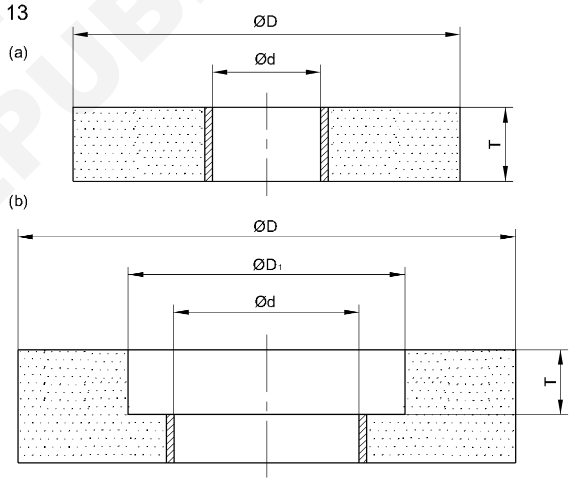
Fig 12



Grinding wheel specification : A grinding wheel is specified by its marking, shape, outside dia. bore dia. thickness etc. (Fig 13a)

A recessed wheel is specified with all the above given particulars plus the dia. of the recess and the depth of the recess. (Fig 13b)

Fig 13



Standard marking system for grinding wheels

Objectives: At the end of this lesson you shall be able to
- **interpret the marking on a grinding wheel**
- **specify a grinding wheel.**

Introduction: Standard wheel markings specify all the important wheel characteristics. The marking system comprises of seven symbols which are arranged in the following order.

Position 0 - Manufactures code

Position 1 - Type of abrasive

Position 2 - Grain size or grit number

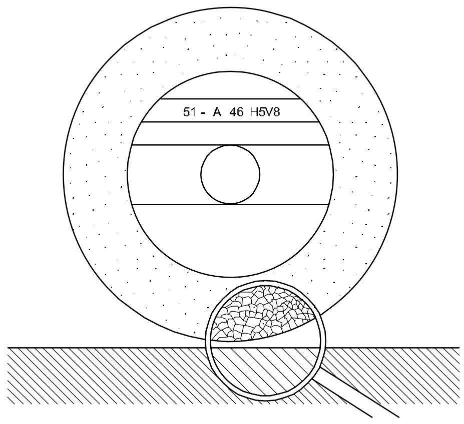
Position 3 - Grade of the wheel

Position 4 - Structure

Position 5 - Type of bond

Position 6 - Manufacture code

The figure 1 is shows the standard marking system for grinding wheel.

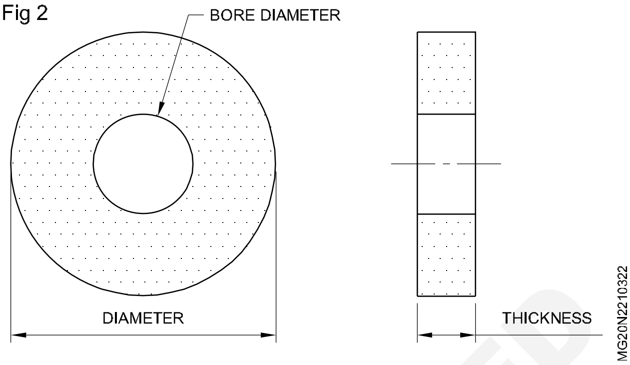


Specification of grinding wheels: A grinding wheel is specified by the; (Fig 2)

- Standard wheel markings
- Diameter of the wheel
- Bore diameter of the wheel
- Thickness of the wheel
- Type (shape) of the wheel

Example

32 A46 H8V 250 x 20 x 32 straight wheel



Example 1

Marking system - 51- A46H5V8

Table 1

Position 0	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Manufacturers symbol for abrasive (optional)	Type of abrasive grit	Grain size	Grade	Structure (optional)	Type of bond (optional)	Manufacturers own mark
51	A Aluminium oxide	46 Medium	H Soft	5 Dense	V Vitrified	8

Example 2

Marking system - PA36J6V15

Table 2

Position 0	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Manufacturers symbol for abrasive (optional)	Type of abrasive grit	Grain size	Grade	Structure (optional)	Type of bond (optional)	Manufacturers own mark
P	A Aluminium oxide	36 Medium	J Medium	6 Dense	V Vitrified	15

Diamond wheels

Objectives: At the end of this lesson you shall be able to
- **state the necessity for diamond wheels**
- **state the three types of common bonds and their specific applications**
- **state the standard grit sizes of diamond wheels**
- **select the correct diamond concentration for a given grinding situation.**

Now a days diamond wheels have become the accepted type of abrasive wheel for off-hand finish grinding of carbide single point tools. And for all precision grinding operations on cemented carbide multi-tooth cutters and chip-breaker grinding, these wheels are found to be more advantageous due to their exceptionally fast and cool cutting action and extremely low rate of wear, as compared with silicon carbide grinding wheels.

These properties of diamond wheels ultimately result in low grinding cost.

They are available with either natural or man-made diamonds. Resinoid and vitrified bonded wheels containing the man-made diamond, in the 100 grit and finer range, have proved to be very satisfactory for the grinding of cemented tungsten carbides.

Bond types: Three types of bonds are used in the manufacture of diamond wheels to suit the various fields of applications.

Resinoid bond: Resinoid bonded diamond wheels have exceptionally fast and cool cutting action and are more suitable for sharpening of multi-tooth cutters, reamers etc. for grinding chip breaker, and precision grinding operations on carbide dies, gauges, rolls etc.

Vitrified bond: Vitrified bonded diamond wheel has;

- Rigidity that gives dimensional accuracy to the work being ground
- A porus structure to promote faster and cooler cutting, and
- Positive adhesion between the bond and the diamond particles, which ensures a long, useful wheel life.

Vitrified bonded diamond wheels are particularly suitable for reconditioning excessively dull single point tools and for ordinary re-sharpening or finish grinding operations.

Vitrified bonded diamond wheels are available in straight wheels, flaring cup, dish and mounted wheels for various precision and tool and cutter grinding operations.

Metal bond: Metal-bonded diamond wheels are also used for off-hand grinding of single point tools, particularly where durability, long life and resistance to grooving are of primary considerations. When compared with other bonds, these wheels are slower in cutting.

Standard grit sizes as per IS 3264-1985: Diamond wheels (of any bond type) are supplied in the following standard grit sizes for grinding carbide tools & cutters.

Selection of Grit Size - The selection of grit size is based on the surface finish requirements and rate of material removal.

Diamond concentration: It represents the quantity of diamond with one unit of mass of wheel. Basically in grinding wheels, diamond concentration of 100 is equivalent to 4.4 carats per cubic centimetre (0.88g/cm^3). This figure corresponds to 25 percent by volume, taking the density of diamond as 3.52 g/cm^3. Standard concentration will be 125, 100, 75 and 50.

When to use "125" concentration

Used for machine grinding operations on cemented carbides, such as chip breaker grinding, cutter grinding, cylindrical, surface and internal grinding. This is also best suited for thin cutting-off wheels, mounted wheels and hand hones.

When to use "100" concentration

Wheels of “100” concentration are recommended for the same class of precision grinding operations as “125” concentration wheels. These wheels are generally more economical to use.

Surface finish	IS grit designation	
	Diamond	**CBN***
Very coarse	D 181	B 181
Medium - coarse	D 151	B 151
Medium	D 126	B 126
Medium fine	D107	B 107
Fine	D 91	B 91
Very fine	D 76	B 76
Extra fine	D 54	B 54
Superfine	D 46	B 46

When to use "75" concentration: Wheels of "75" concentration are recommended for both vitrified and metal bonded cup wheels, which are used for off-hand grinding.

When to use "50" concentration: Diamond wheels of "50" concentration and metal -bonded are used primarily in the cutting of soft stone. They are not considered economical for grinding carbides.

Depth of diamond: It depends upon the type of bond and wheel size.

Plain disc wheels - 1.6 or 3.2 or 6.3 mm depth of diamond measured radially. Cup or recessed wheels (for grinding on the side or mm) - 1.6 or 3.2 mm in the case of resinoid or vitrified bonded wheels, for metal-bonded wheels the thickness is 0.8 mm. With specific reference to cost per tool ground, wheels with a relatively large depth of diamond are more economical.

Marking - All diamond grinding wheels shall be marked legibly on the core, with the following formation.

Designation

Diamond concentration

Diamond grit size with a suffix as D for diamond and B for cubic boron nitride

Depth of diamond impregnation

Manufacturer’s serial number, and

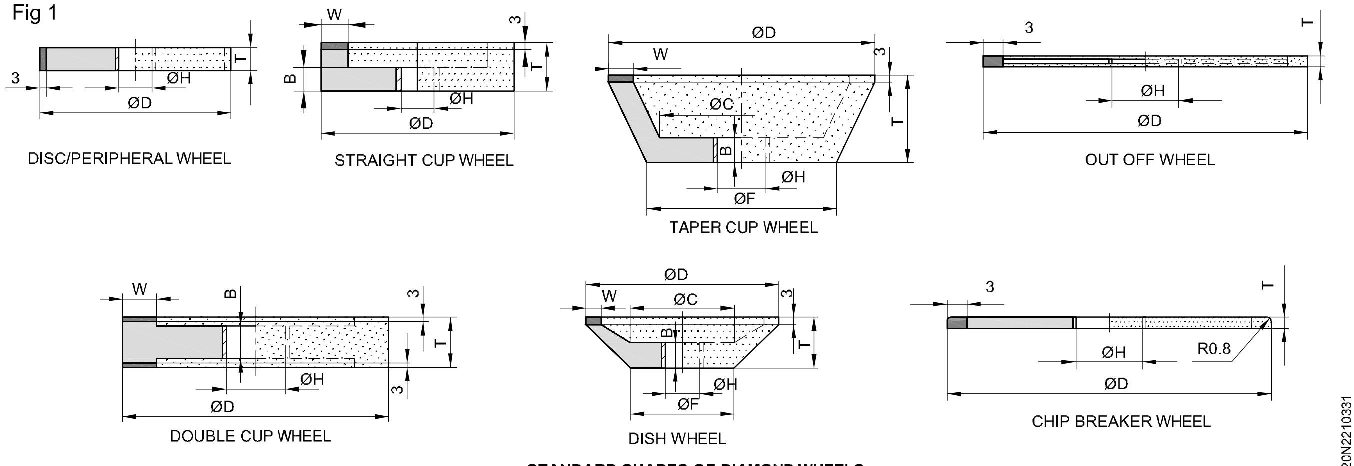
Manufacturer’s name or Trade Mark.

Method of ordering - For ordering diamond grinding wheels, quote the following information in addition to the bore diameter. (Fig 1)

Type of grinding wheel

Designation

Fig 1



STANDARD SHAPES OF DIAMOND WHEELS

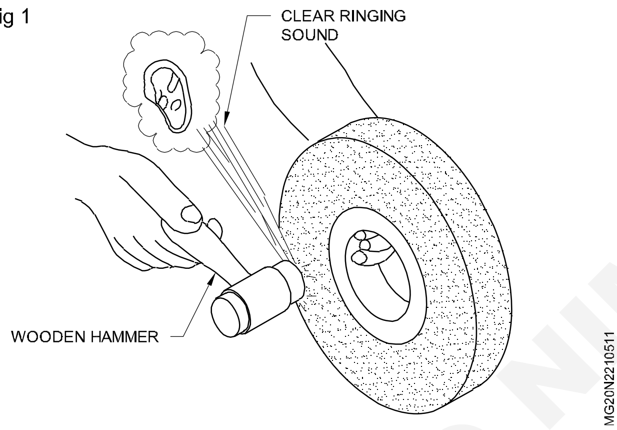
Mounting and balancing of grinding wheel

Objectives: At the end of this lesson you shall be able to
- **explain the method of mounting of grinding wheel**
- **brief the method of balancing of grinding wheel**
- **state the difference between static and dynamic balancing**
- **list the safety precaution to be taken for mounting and balancing of grinding wheel.**

Mounting the grinding wheel: Grinding wheels should be properly mounted upon suitably proportioned spindles and between properly designed flanges. This is one of the very important considerations in the use of grinding wheels.

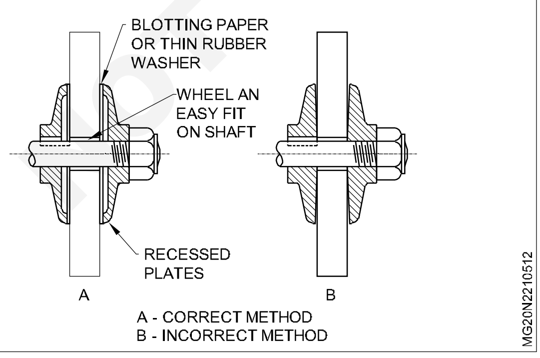
- Before mounting, the wheels are checked for cracks by light tapping. (Fig 1)

Fig 1



- Wheel flanges are also checked to see that they are free from foreign particles.
- Two thin washers of blotting paper or rubber is placed on either side of the hole. The wheel and washers are then gripped between two steel washers or flanges on the spindle. (Fig 2) The function of the paper washers is to distribute the pressure evenly when the flanges are tightened. The size of the steel flanges should be atleast one third the wheel diameter in order to provide sufficient support and grip.

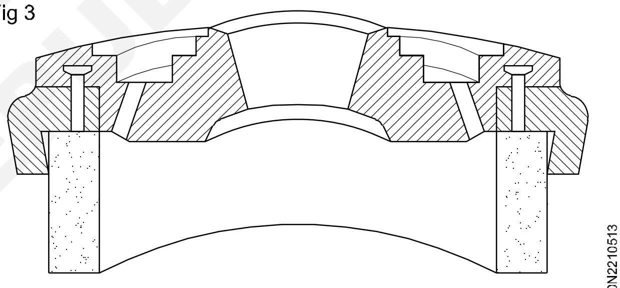
Fig 2



- The flanges are recessed so as to provide an annular bearing at their circumference. The hole in the bushing should be large enough so that the spindle may slide without cramping.
- Fitting of the grinding wheel on the wheel spindle is made a free fit, but without any slackness.
- Nuts should be tightened only sufficiently to hold firmly.
- Excessive tightening will damage the wheel.
- The ends of the spindles wheels are threaded in such a way (left-handed or right-handed) that nuts on both ends tend to tighten as the spindle revolves.

Fig 3 shows a method of mounting wheels for surface grinding purposes. The wheel is cemented into a metal ring which in turn is secured to the main grinding spindle flanged member by means of screws.

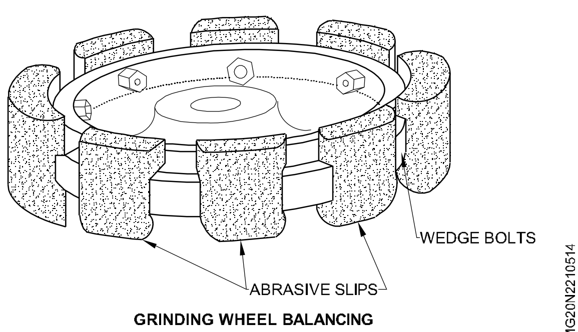
Fig 3



METHOD OF MOUNTING SURFACE GRINDING WHEEL

Fig 4 shows how wheel discs are cemented to specially designed holders and segmental wheels.

Fig 4



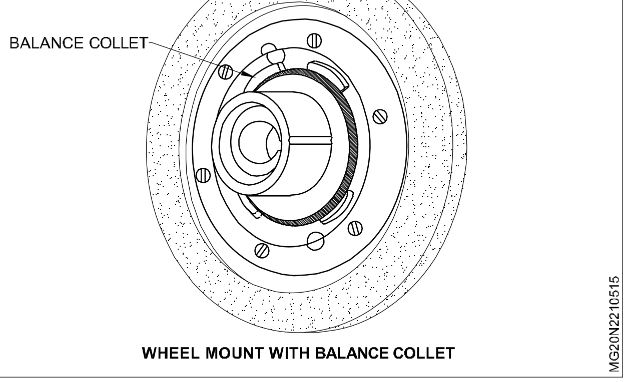
GRINDING WHEEL BALANCING

It is not possible to manufacture grinding wheels having absolutely uniform density throughout. Moreover they change in size and weight while in use. Minor variations in density doesn't in general, affect the grinding action noticeably. But in some cases it affects the balance.

Ordinary commercial wheels provided with snug fit on the wheel collet run without imbulance and without any difficulty.

But in cases like cylindrical grinding and internal grinding where grinding wheel is carried on the end of a long spindle, balancing is generally necessary owing to the over hang of the spindle. Otherwise also wheels should be carefully balanced to maintain a uniform embodying a dovetail shaped groove (Fig 5) are provided in which adjustable and moveable weights are fitted.

Fig 5



WHEEL MOUNT WITH BALANCE COLLET

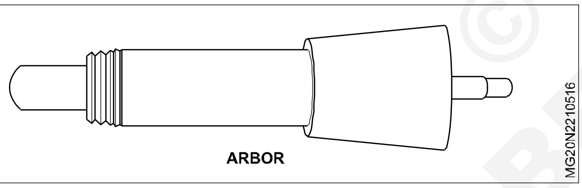
Truing before balancing is necessary because in truing considerable material may be removed from one side only which will again throw the wheel out of balance.

The steps involved in balancing the wheels are as follows:

Assemble the wheel on the collet and mount this unit on the balancing arbor. (Fig 6)

Balancing weights are either removed or set directly against each other so that the correct balancing position of the wheel many be determined.

Fig 6



ARBOR

Arbor with the wheel mounted on it is placed on the balancing ways.

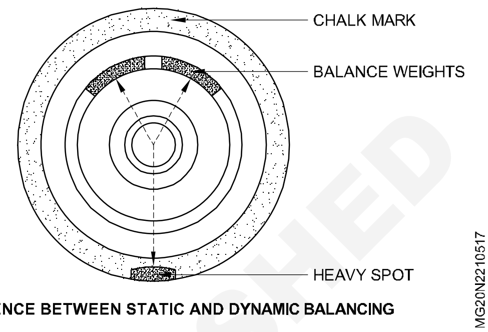
Wheel is turned and allowed to come to rest of its own with the heavy spot down.

A chalk mark is made to indicate the heavy side.

Balancing weights are shifted so that the ends meet under the chalk mark.

Balancing weights are then moved apart until perfect balancing is obtained. (Fig 7)

Fig 7



DIFFERENCE BETWEEN STATIC AND DYNAMIC BALANCING

Set screws are tightened to fit the weights in position.

The whole assembled unit is removed from the balancing ways for mounting on the machine.

Difference between static and dynamic balancing

Static balancing means that when the wheel is centred on a horizontal arbor (Frictionless) it remains at rest in any position. It is in dynamic balance if upon rotating there is no vibration nor "whip" action due to unequal distribution of its weight throughout its length.

Adverse effects of wheels which are out of balance

Consumption of more power by the machine.

Excessive wear on bearing.

Grinding wheel balancing

Objectives: At the end of this lesson you shall be able to
- **state what is a wheel balancing**
- **name the method of balancing**
- **state the procedure of balancing**
- **state the causes of breakage of the grinding wheel**
- **state the method of storage of grinding wheels.**

Wheel balancing: Wheel balancing is an action of bringing the grinding wheel to rotate concentric to its axis and the weight and density of wheel are uniform throughout its circumference. Before testing the balance of the wheel it is true.

Necessary of wheel balancing

- A good surface finish is possible to the work surface.
- Prevents wheel vibration and breakage.
- Prevents chatter marks on the work surface.
- Improves the dimensional accuracy of the work.
- Considerably increases the life of grinding wheel.
- Prevents the damage of the spindle /bearings.

Small wheel normally do not require any balancing, but larger diameters of the wheel important is the balancing. Similar equipment used to balance the wheels of motor cars.

Method of balancing

1 Static balancing 2 Dynamic balancing

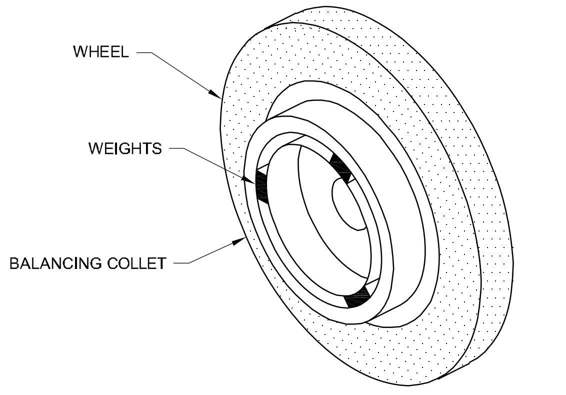
Static balancing means that when the wheel is cantered in balancing mandrel and placed on a balancing stand.

Dynamic balancing means that when the wheel can be balanced while it is running on the machine, for getting still better result.

Wheel mounted on a balancing collet (Figs 1&2)

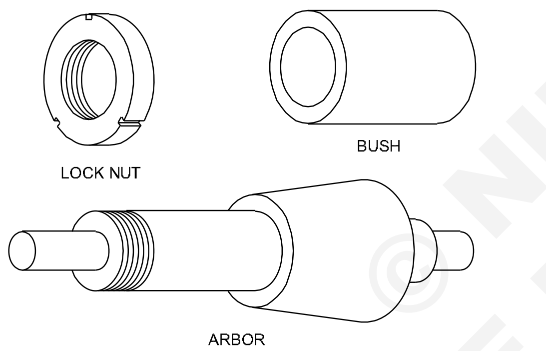
Large grinding wheels must be mounted on a balancing collet and balanced before being fitted to the grinding machine. The collect remains fitted to the wheel during use.

Fig 1



GRINDING WHEEL MOUNTED ON A BALANCING COLLET

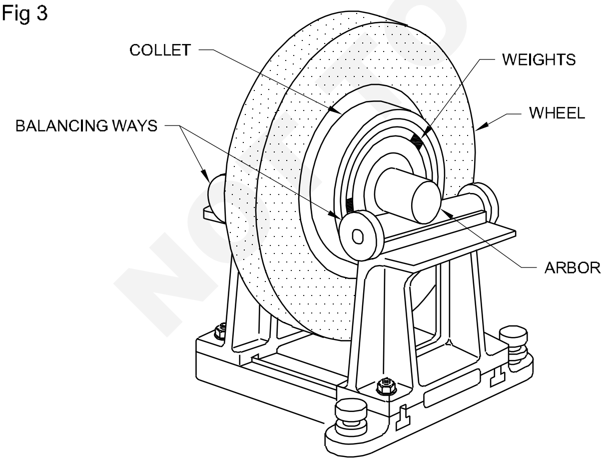
Fig 2



BALANCING ARBOR COMPONENTS

To balance a wheel proceed as follows (Fig 3)

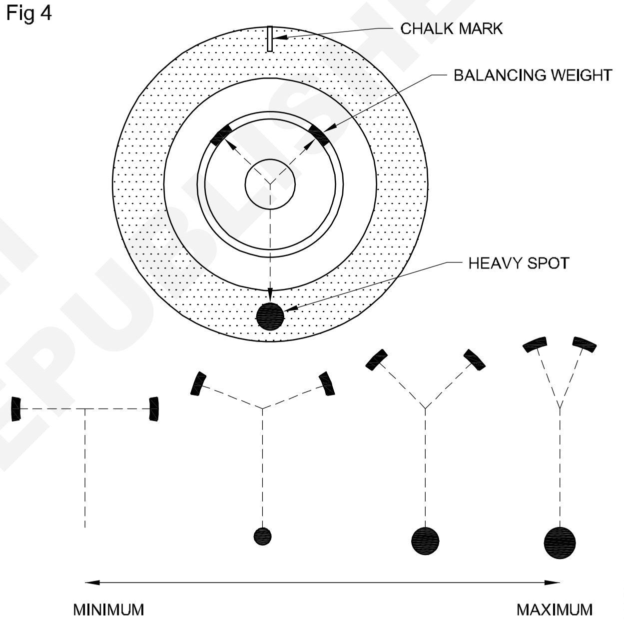
Fig 3



GRINDING WHEEL MOUNTED ON BALANCING COLLET AND ARBOR PLACED ON BALANCING WAYS

- Mount the wheel on a balancing collect.
- Fit a balancing arbour to the collet.
- Remove the adjustable weight from the collet.
- Place the arbour collet and wheel assembly on a pair of balancing ways in a position near the centre of the ways.
- Ensure that the ways are perfectly horizontal.
  - Use are accurate spirit level for this if none is mounted on the ways.
- Allow the wheel to roll slowly on the ways by a very gentle push until it comes to rest. In this rest position the heavy spot of the wheel will be on the lower part of the wheel.
  - Do not push so hard that the wheel rolls off the ways.
- Make a chalk mark on the wheel at the point opposite to the heavy spot. This will be the uppermost position of the wheel when it is at rest. (Fig 4)

Fig 4



ADJUSTING BALANCING WEIGHTS TO OBTAIN MAXIMUM AND MINIMUM COUNTERBALANCE

- Mount the balancing weights on either side of the chalk mark.
- Test as before by allowing the wheel to rotate slowly on the balancing ways, each time moving the weights a little further back from the chalk mark after the wheel comes to rest until a perfect balance is obtained.
  - The wheel is balanced when it gently comes to a stop with no tendency to roll back regardless of which portion of the wheel was the lowest at the start of the roll.
- Fix the weights in the balance position by tightening the weight set screws.
- Remove the arbor from the collect.
  - The balanced wheel with its collet assembly is now ready for mounting on the grinding machine spindle.

Wheels in use should be re-balanced at intervals since the balance may change with wear of the wheel.

Caution: If a wheel is re-dressed during service, it must be re-balanced after the dressing operation.

Reasons for wheel breakage

- Increased wheel speed.
- In correct size of bolts, nut.
- More depth of cut.
- Insufficient coolant.
- Wheel getting jammed on work.
- Wheel force fitted on spindle.
- Wheels are not checked for crack by light tapping before fitting.
- Workpiece is not hold properly (rigidly).

9 Unbalanced grinding wheel is used for grinding.

Wheel storage: Grinding wheel is properly stored on edge or piled flat as per recommendations of the manufacture.

- They should be kept in dry place.
- Racks in which wheels are stored have no tendency to roll off.

Types of dresser

Objectives: At the end of this lesson you shall be able to
- **state what is dressing and truing**
- **brief the crush truing & form truing**
- **explain the method of dressing wheel at an angle.**

Dressing and truing: The term "dressing" and truing are frequently confused although they are distinctly different.

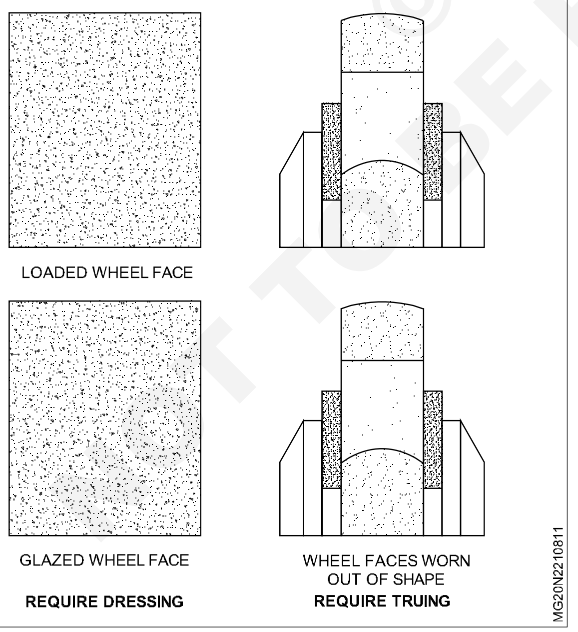
Dressing is the operation of cleaning or restoring the sharpness of the wheel face that has become dull or has lost some of its cutting ability because of loading and glazing. Dressing may be described as a sharpening operation. But it doesn't necessarily true the wheel, it may still be out of parallel, although it may do cutting well and rapidly.

Truing is the operation of removing the material from the cutting surface of a wheel so that the resultant surface runs absolutely true. It is also the operation of restoring the grinding surface to its correct geometrical shape say conical, cylindrical, plane or formed.

The frequency at which it becomes necessary to dress or true the wheels depends upon (Fig 1);

- the type of work
- the fitness of the wheel
- the skill of the operator

Fig 1



Dressing and truing tools: There are three principle types of dressing and truing tools;

- Steel dressers
- Abrasive wheels dressers
- Diamond dressers

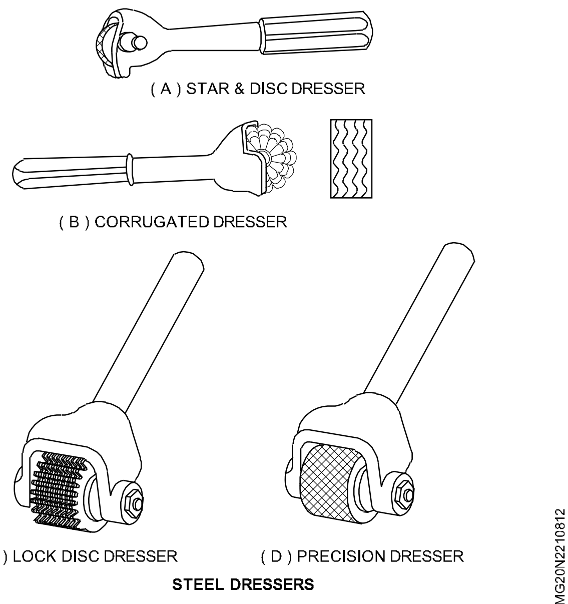
Steel dressers (Fig 2): For dressing purposes, the tool must be held rigidly in a tool post, on a work rest or it should have some other form of rigid support. The main types of steel dressers in use are:

Star and disc dresser (Fig 2A): It has pointed discs mounted loosely on a pin and separately by solid discs. It is very useful for dressing coarse-grained snagging and segmented wheels.

Corrugated disc dressers (Fig 2B): This type of dresser does not penetrate the wheel deeply and, therefore, it is possible to obtain smoother finish than what is possible with star and disc dressers. The cutters in this case are of special alloy steel. The discs being of different corrugation do not "nest".

Lock disc dressers (Fig 2C): It has a pin well supported in bearings. Steel or cast discs are mounted on the pin. The discs are locked in sets and rigidly mounted without spacers. Although this type of dressers are mainly used for medium roughing wheels, but they also find application in dressing of cam and crankshaft grinding wheels etc.

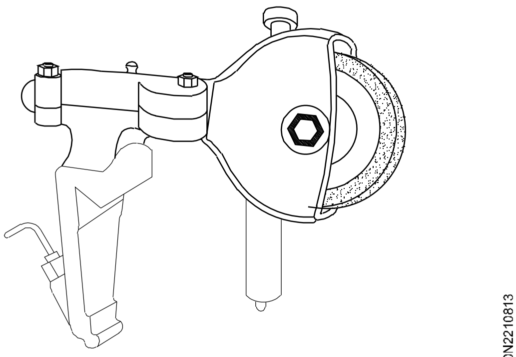
Fig 2



Precision type of dressers (Fig 2D): This tool is a substitute for diamond in commercial grinding. It has a solid steel shell or cylinder mounted on accurate bearing. It may be single or double grooved. Single-grooved type is used for wheel faces required for fine grinding of cast iron. Double-grooved type is used for grinding fine commercial purposes.

Abrasive wheel dressers : A type of abrasive wheel dresser is shown in Fig 3 Which can impart smooth clean cutting face which will not leave any dressing marks on the work. There are silicon carbide wheels in this case mounted in a holder with bearings. They are used in place of diamond for grinding operations as on pistons, camshafts, crankshafts, etc.

Fig 3

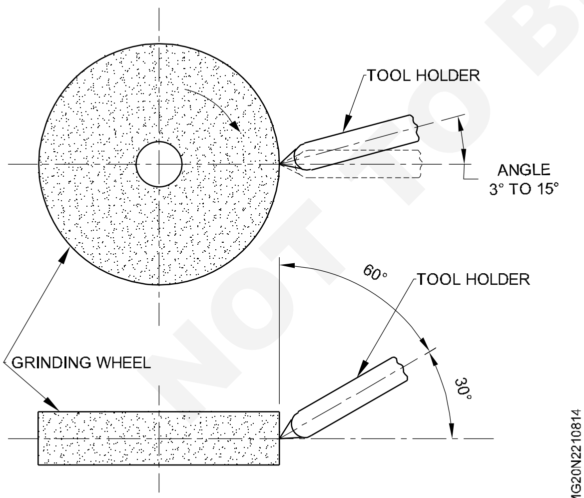


ABRASIVE WHEEL DRESSER

Diamond dressers : Diamonds which are unsuited for gems are mostly used for truing wheels for precision grinding. A single large stone is set in a matrix in a holder. Re-setting is done when it is worn. For efficient utilization, small diamonds are set in groups.

The diamond tool is set at an angle (Fig 4) to the wheel face, with the angle pointing in the same direction as the grinding travel to prevent gouging the wheel face.The tool holder is also canted 30^0 sometimes. The tool is turned in the holder as the diamond wears so as to ensure a sharp cutting point at all times. Dull diamonds have a tendency to crush and glaze the wheel face. The diamond is traversed to across the wheel face and the rapidity with which it is done depends upon the grain and grade of the wheel and the desired finish.

Fig 4



Diamond dresser is a precision tool and must be handled with care. It is brittle and is likely to break if it is pressed quickly against the grinding wheel or if a deep cut is attempted. It must be rigidly held otherwise vibrations will cause chatter, diamond marks, gouging and breaking.

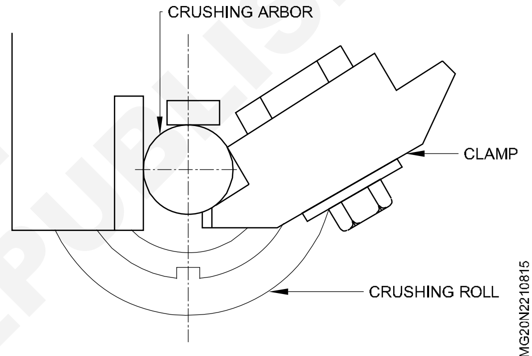
Wheels may be dressed either wet or dry, but it is done under the same conditions as when grinding. If grinding is done wet, wheel is also dressed wet.

For obtaining uniform grinding results, wheels are trued and dressed regularly after performing a specified number of pieces and uniform rates of feed and traverse is used when dressing.

Crush truing : It is also referred to as crush forming and crush dressing. It is the method of forming the face of a grinding wheel by means of a hand roller pressed against the slowly revolving grinding wheel. The roller is given a shape which is reverse of that desired on the wheel. The roller crushes the surface grains and imprints the form on the wheel.

Crush truing has been applied to centreless, cylindrical and surface grinding machines in the manufacture of form tools, for thread grinding and also for internal grinding. For intricate forms, crush truing is more economical than diamond truing. (Fig 5)

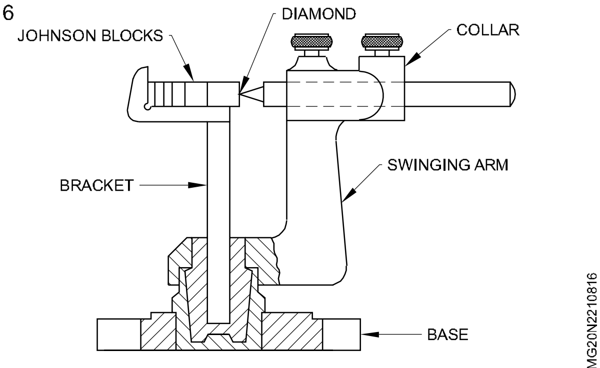
Fig 5



Form truing : Sometimes it is necessary to true a wheel face to a complicate profile for certain classes of work. Devices used for this purpose are of two types - those used for making only concave or convex surfaces and those used for forming irregular shapes.

A typical truing device of the first type is shown in Fig 6. It operates by swinging about a fixed point which forms a pivot.

Fig 6



By varying the distance of the cutting point of the truing device, variations in the corresponding radius can be obtained.

A few examples of formed wheels are shown in Fig 7. Many more other types are also commonly used.

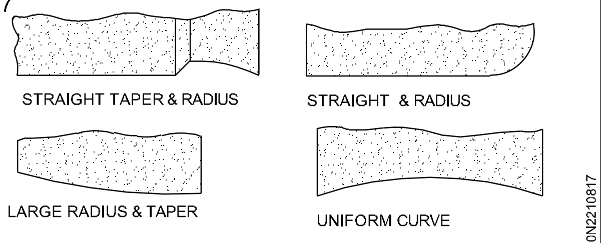


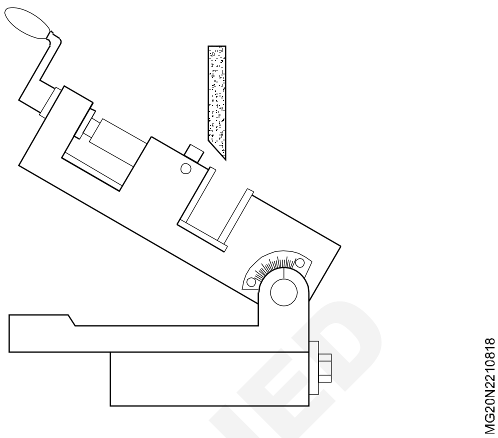
Fig 7

FORMED GRINDING WHEELS

Dressing wheel at an angle: For dressing the abrasive wheel of a surface grinder at an angle, an adjustable machine vice (Fig 8) which is graduated at the pivot is used. For inserting the diamond holder, a hole is drilled in the top of the movable jaw. For locking the diamond in position with a set screw, a hole is drilled and tapped endwise of the jaw.

The vice is placed on a magnetic chuck on the grinder table and adjusted against a stop. It is set at an angle as required. The diamond is passed back and forth across the surface of the wheel by movement of the movable jaw with the vice crank.

Fig 8



Grinding wheel dressing

Objective: At the end of this lesson you shall be able to
- **list types of wheel dressers and their uses.**

Truing and dressing wheels: For precision cylindrical grinding the cutting face of an abrasive wheel must be brought concentric with the axis of rotation and must retain its shape. If good work is to be consistently produced, an abrasive wheel needs regular attention, as the portion making contact with the workpiece must bear uniformly, with the many abrasive particles expose, in such a manner as to ensure effective cutting.

On continuous production, therefore, it is standard practice to dress the wheel after a predetermined number of articles have been ground. By adopting this procedure the wheel face is maintained in good condition, wheel wear is held to a minimum, the specified surface finish obtained and dimensional accuracy economically achieved.

Types of dressers: In general practice there are five means by which an abrasive wheel may be dressed:

- Using a suitably mounted set of steel discs or wheels.
- With an abrasive stick.
- With a small abrasive wheel, suitably mounted.
- With a diamond.
- Using a crush dressing fixture.

Wheel Dressers: The wheel dressers are of four types, as roughly described below.

The star dresser : The star wheel dresser has a number of pointed discs loosely mounted upon a pin, and plain discs are used as separators. It use is practically confined to dressing of coarse grit wheels by hand, or segmental surface-grinding wheels. That is, on wheels as chosen for rough grinding articles in the forge, foundry and welding shops.

Corrugated disc-type : A dresser having cast corrugated discs, mounted without spacers, is chosen when the operating conditions do not require the extreme open wheel structure produced by the star dresser. As the corrugated discs have the tendency to shear through the grains, instead of dislodging them from the bond, this class of dresser is used to smooth wheels chosen for rough-grinding operations.

Locked wheel dresser : The locked disc wheel dresser consists of a number of cut steel discs with elongated teeth, or cast discs with serrated or zig-zag edges. Either type of wheel is locked in sets and rigidly mounted, without spacers, upon a pin; the latter is supported in suitable bearings. The function of the locked disc dresser is to bring the abrasive particles down to the common level and slightly open the bond. Its range of usefulness is restricted to dressing wheels used for rough cylindrical grinding of such articles as crankshafts and camshafts, and rough grinding on the centreless type of machine.

Cylinder dresser : A precision cylinder type of wheel dresser is, on occasions, chosen in place of the diamond. It consists of a cylinder or solid steel shell mounted on accurate bearings. The cylinders have helical grooves running in one or both directions, or a series of evenly spaced holes or openings. The single handed grooved dresser is chosen to dress wheels when grinding cast-iron components. The dressing cylinders having both right and left-hand helical grooves, or with holes, are used when engaged in many forms of cylindrical grinding.

Abrasive sticks: Abrasive dressing sticks are of two shapes; one is square, for hand dressing, and the other has a circular cross-section for magazine mounting. The hand-dressing stick is chiefly used in the toolroom and, in action, it shears the abrasive grain rather than penetrates the bond. The stick may be used when dressing thin wheels, as when engaged in cutter grinding, and for taking the rough-dressing cuts prior to using the diamond.

The round magazine mounted stick is useful for producing various shapes on the cutting portion of a wheel, also for truing or dressing thin wheels. The stick may, on be used for rough dressing prior to final dressing with a diamond.

Abrasive wheels: An abrasive wheel dresser consists of silicon carbide abrasive particles in a vitrified bond mounted in a suitable holder. They are, generally, of two designs (1) hand- operated; (2) clamped to the machine. When in use, the axis of the dresser makes an angle with the grinding wheel so as to create a combination of crushing, wiping and shearing.

A wheel dresser of this type will leave a smooth clean free-cutting face, clear of any dressing or diamond marks. When dressing with an abrasive wheel, the grinding wheel may need slowing down but, because of the wheel surface obtained, it is a favourite means of dressing wheels, when pistons, crankshafts, camshafts, and kindred items are being ground on cylindrical and centreless grinding machine.

Diamonds: Diamonds are the chief means of dressing truing the abrasive wheels, as are used for precision grinding.

Types - There are two types of diamond used for truing abrasive wheels, the black diamond proper, and bort. The black diamond is harder and more expensive than bort, and because of its all-round efficiency, it is the best stone for general purposes. Yet, due to its high cost it should be used only by skilled and careful operators; the brown or grey bort may be used by the less skilled and, sometimes, more careless operators. It has been suggested that the grey bort is more firmly held in the solder, will do more work between each resetting and will last longer.

Sharpness - When dressing a wheel for cylindrical grinding, the diamond should be sharp and free from flats. The harder the wheel grade the greater the need for sharpness, so that the passage of the diamond across the wheel will produce a surface that will retain its cutting properties for a long period. A dull or worn diamond should be restricted to dressing the soft wheels which are chosen for surface grinding.

Advantage of balancing, inspection, care and storage of grinding wheel

Objectives: At the end of this lesson you shall be able to
- **state the advantages of balancing**
- **brief the method of wheel inspection, storage and care of grinding wheel**
- **state the safety point while handling the grinding wheel.**

Advantages of balancing

- Power consumption of the machine is not excessive.
- Wear on bearing is minimum.
- Tendency to produce defective work is reduced.
- Chances of wheel breaking is reduced.
- Better accuracy & surface finish of workpiece is obtained.
- Sources of danger to the operator is minimized.
- Vibration of machine spindle is reduced.

Wheel breakage

- Before putting to use, wheel should be examined by tapping to make sure that it is sound. Following main points should be considered to prevent breakage of wheels.
- Use correct wheel speed. Do not overspeed it.
- While mounting, make sure that correct blotters are used and flanges provide even pressure.
- Use appropriate coolant in sufficient quantity to prevent overheating.
- Do not use excessive pressure on work.
- Avoid wheel getting jammed on work.
- Prevent blows on wheel.
- Do not force wheel on arbor.
- Take necessary safety precautions governing use of grinding wheels.

Wheel storage: Grinding wheels should be properly stored on edge or piled flat as per recommendations of the manufacturers, they should be kept in a dry place and should not be subjected to extreme temperature. Racks in which wheels are stored should be such that once the wheels are placed there, they have no tendency to roll off say as a result of a sudden shock.

Saucer and cup wheels which are less than 150 mm in diameter may be stored on edge or flatwise cup wheels more than 150 mm in diameter and all cylindrical wheels are stacked flatwise. Tapered cup wheels are stacked with the backside up. All rubber and elastic wheels more than 6 mm thick are stacked on their edges. Rubber and elastic wheels which are 6 mm or less in thickness are stacked flat and on a plane surface that will not warp. The best way to store wheels 50 mm or less in diameter is in properly labelled boxes or drawers.

Safety: The operation of all high speed machinery is hazardous. It applies to grinding machine as the grinding wheel rotates at a high peripheral speed (upto 50 metres/sec and even higher).

Causes of accidents in the operation of grinding machines can be traced to one of the following four sources:

- the wheel
- the machine
- the mounting
- the method of protection.

The chief hazard is the breakage of grinding wheels. In addition to what has been stated earlier regarding prevention of wheel breakage, following measures are important for safety:

- Balance the wheel properly and also test it for its strength.
- Adjust the bearings of the spindle properly.
- Use the proper wheel guards of the required strength.
- Wear safety goggles even if wheel has a glass shield.
- See that clothing doesn't come in contact with the moving wheel or work.
- Run the new wheel at full operating speed at least for one minute before applying work.
- Do not force the work against a cold wheel, but apply gradually.
- True the wheels properly which have become out of round.

Guidelines to avoid heat generated in grinding

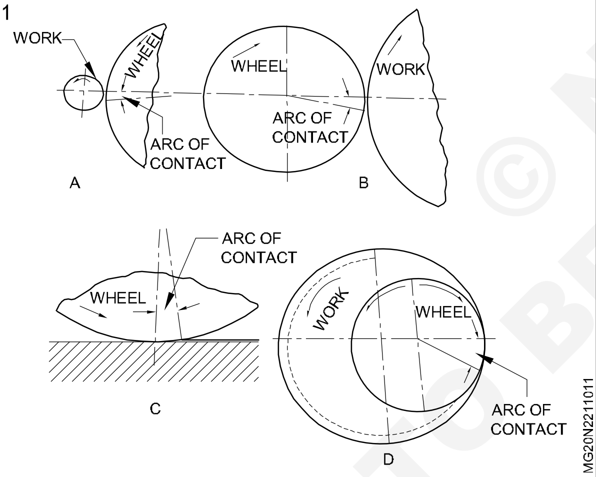
Objectives: At the end of this lesson you shall be able to
- **select the grinding wheels depending upon the arc of contact**
- **state what is wet and dry grinding**
- **list the use of grinding coolant/grinding fluids**
- **state types of grinding fluids.**

In grinding operation the heat is generated due to rubbing action between grinding wheel and the work material. This can be avoided considering the following point.

- Arc of contact
- Wet grinding
- Dry grinding
- Volume of grinding fluid use
- Method of applying grinding fluid
- Types of grinding fluid used.

Arc of contact (Fig 1): If the arc of contact is small (like in most cylindrical grinding) a few grits carry the entire penetration pressure between the wheel and the work. Increase in stress renders a wheel softer than what it would have been with a larger arc of contact. It is, therefore, better to use harder wheels if the arc of contact is small and softer wheels if the arc of contact is large.

Fig 1



This consideration is, however, modified by the structure of the wheel. If the packing of grains is closer, more number of grits share the load and, therefore wheel appears harder than one with a more open spacing.

As with the larger arcs of contact, more number of grains support the pressure between the wheel and the work, a more open structure and coarser grits can be used without concentrating too much pressure on individual grits.

Wet and dry grinding: A considerable amount of grinding eg. tool grinding is done dry mainly to avoid the additional expense of providing a pump and other accessories required for supplying adequate quantity of coolant. But wet grinding has the advantage that it provides better finish and avoids the chances of overheating. A small water tank provided for periodic quenching of tool during dry grinding is not satisfactory as it is likely to cause small cracks in the tool material. It is better to do dry grinding by applying the tool with very little pressure so that the end is not "blued".

The grinding machines which are equipped for wet grinding should be able to supply coolant in adequate quantity without undue pressure, splash or spray and be adequately drained so that the wheels are not left standing in the coolant, as this is likely to result in the wheel absorbing some liquid and atleast being out of balance.

Use of grinding fluids

Reasons for using grinding fluids(lubricants or coolants)

- To carry off the heat generated by the friction of the wheel on the work.
- To maintain uniform temperature of work as far as possible.
- To wash away dust, dirt, chips, abrasives, etc. and thus protect the finished surface of the workpiece.
- To prevent loading of wheels.
- To help obtain the desired finish of the work.
- To increase the cutting efficiency of the abrasive wheel.

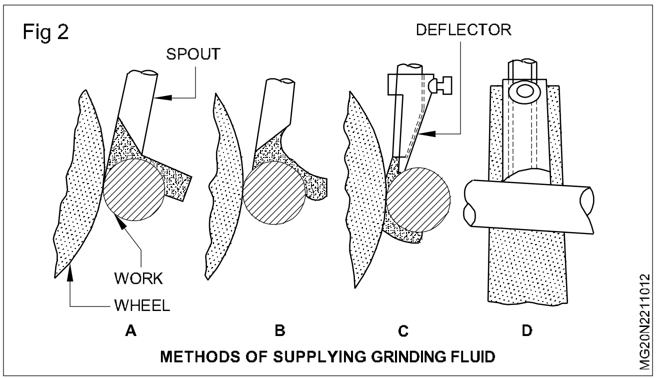
Amount of grinding fluid used: Following factors govern the amount of grinding fluid used :

- The larger the work, the greater the wheel surface in contact, which means more coolant should be supplied.
- The wider the wheel face the more the surface contact which means extra coolant should be supplied.
- The higher the work speed the more the coolant required.

In any case the supply of grinding fluid should be sufficient to keep the work as cool as possible. It must cover the full face of the grinding wheel.

Methods of supplying grinding fluids: The arrangements for supplying of grinding fluid is made by the use of a pump and the piping for carrying it to the grinding wheel. The delivery of the grinding fluid to the wheel should be in such a way that no part of the wheel is allowed to cut dry. Fig 2 shows four different arrangements.

In 'A' there is a tendency to splash the operator. 'B' is a better arrangement but with this also there is considerable splashing. This is overcome by the use of deflectors as shown in 'C' and 'D'. The deflectors can be moved up and down and also in and out so that the stream can be directed where it is most needed.



METHODS OF SUPPLYING GRINDING FLUID

Types of grinding fluids

Soluble oil and water : It forms a milky solution and has very good cooling, lubricating and rust-resistant qualities. It is applied by flooding the surface of the workpiece.

Soluble chemical grinding fluids and water : It contains rust inhibitors and bactericides so as to minimize odours and skin irritations. It may be used with flood cooling or "through-the-wheel" cooling system.

Straight oil grinding fluids : This is mainly used where high finish, accuracy and long life of the wheel are desired. As compared to water-soluble fluids, this type of fluid has better lubricating qualities, but not as high heat dissipating capacity.

Indian standard system of limits and fits - terminology

Objectives: At the end of this lesson you shall be able to
- **state the terms used under the BIS system of limits and fits**
- **define each term under the BIS system of limits and fits.**

Size: It is a number expressed in a particular unit in the measurement of length.

Basic size: It is the size based on which the dimensional deviations are given. (Fig 1)

Actual size: It is the size of the component by actual measurement after it is manufactured. It should lie between the two limits of size if the component is to be accepted.

Limits of size: These are the extreme permissible sizes within which the operator is expected to make the component. (Maximum and minimum limits) (Fig 2)

Maximum limit of size: It is the greater of the two limits of sizes. (Fig 2) (Table 1)

Minimum limit of size: It is the smaller of the two limits of size. (Fig 2) (Table 1)

Hole: In the BIS system of limits and fits, all internal features of a component including those which are not cylindrical are designated as hole. (Fig 3)

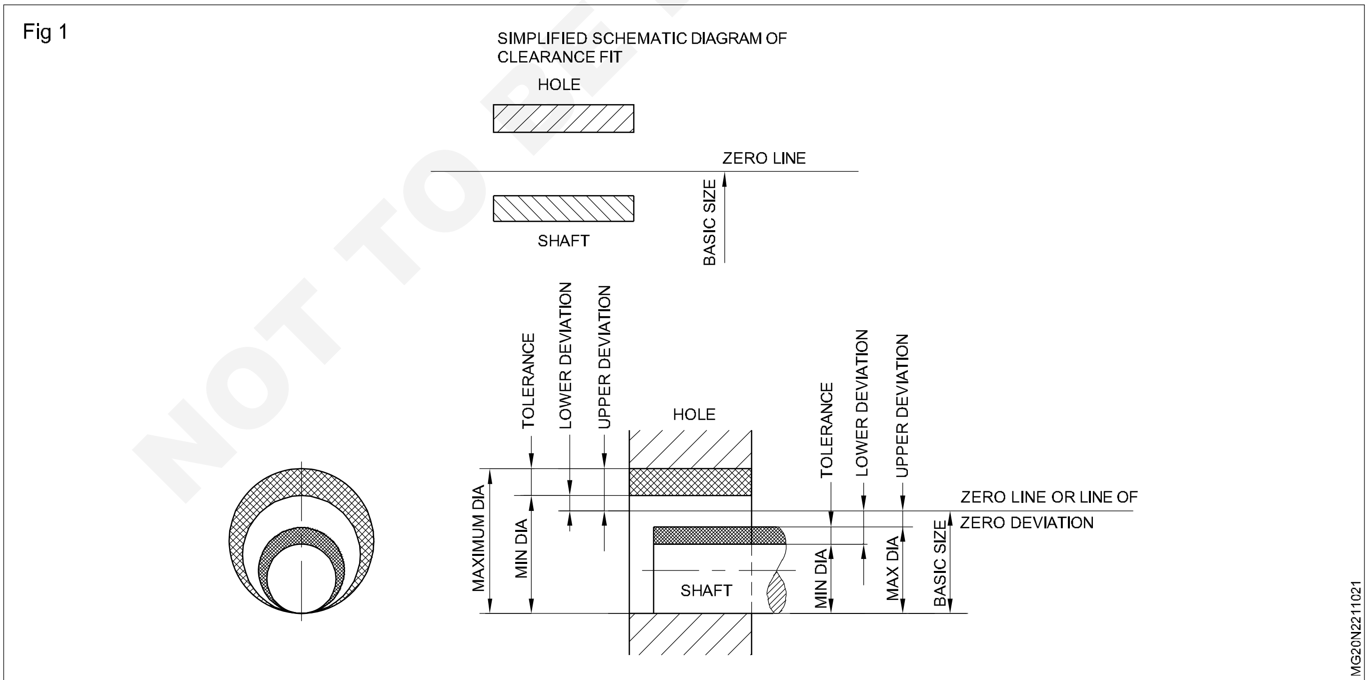


Table 1

(Examples)

S.I No.	Size of Compo -nent	Upper devia -tion	Lower devia -tion	Max.limit of size	Min limit of size
1	$20^{+.008}_{-.005}$	+ 0.008	- 0.005	20.008	19.995
2	$20^{+.028}_{+.007}$	+ 0.028	+ 0.007	20.028	20.007
3	$20^{-.012}_{-.021}$	- 0.012	- 0.021	19.988	19.979

Shaft: In the BIS system of limits and fits, all external features of a component including those which are not cylindrical are designated as shaft. (Fig 3)

Deviation: It is the algebraic difference between a size and its corresponding basic size. It may be positive, negative or zero. (Fig 2)

Upper deviation: It is the algebraic difference between the maximum limit of size and its corresponding basic size. (Fig 2) (Table1)

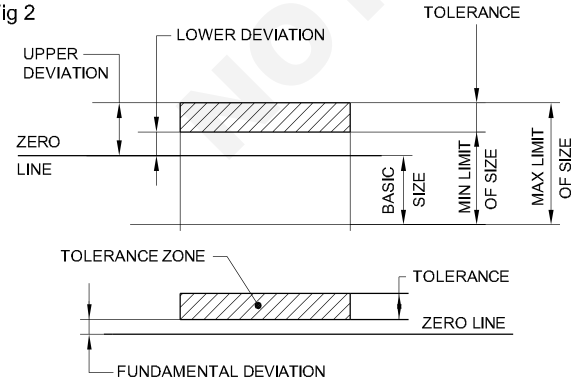
Lower deviation: It is the algebraic difference between the minimum limit of size and its corresponding basic size. (Fig 2) (Table 1)

Upper deviation is the deviation which gives the maximum limit of size. Lower deviation is the deviation which gives the minimum limit of size.

Actual deviation: It is the algebraic difference between the actual size and its corresponding basic size. (Fig 2)

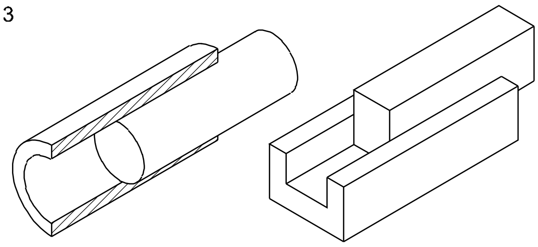
Tolerance: It is the difference between the maximum limit of size and the minimum limit of size. It is always positive and is expressed only as a number without a sign. (Fig 2)

Fig 2



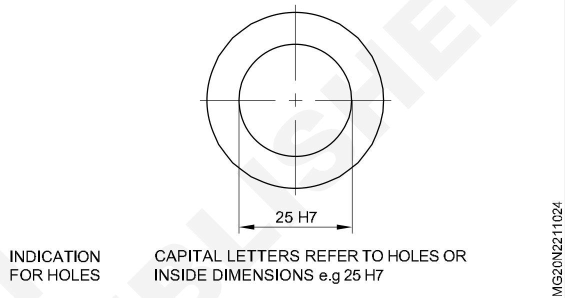
Zero line: In the graphical representation of the above terms, the zero line represents the basic size. This line is also called the line of zero deviation. (Fig 1 and 2)

Fig 3



Fundamental deviation: There are 25 fundamental deviations in the BIS system represented by letter symbols (capital letters for holes and small letters for shafts), i.e. for holes-ABCD....Z excluding I,L,O,Q and W. (Fig 4)

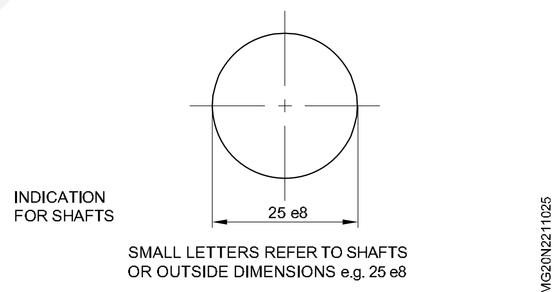
Fig 4



In addition to the above, four sets of letters JS,ZA,ZB and ZC are included.

For shafts, the same 25 letter symbols but in small letters are used. (Fig 5)

Fig 5



The position of tolerance zone with respect to the zero line is shown in Fig 6 and 7.

Fig 6

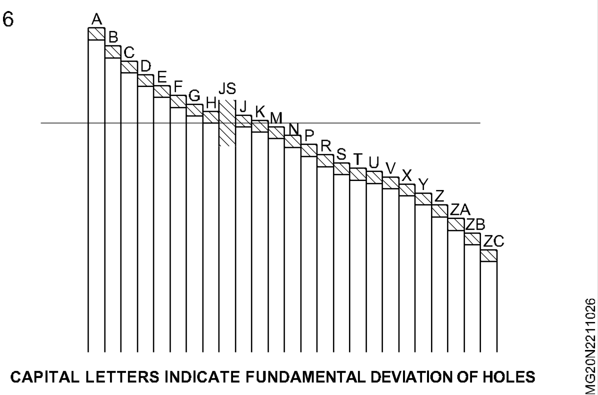
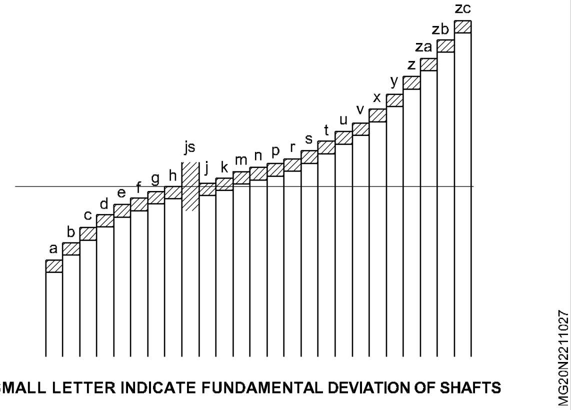


Fig 7



The fundamental deviations are for achieving the different classes of fits. (Fig 8 and 9)

Fig 8

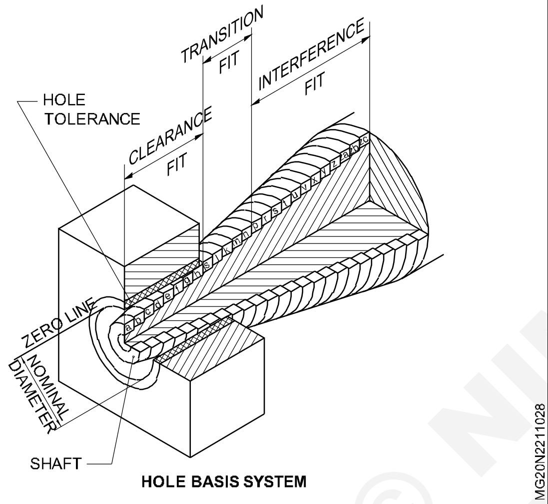
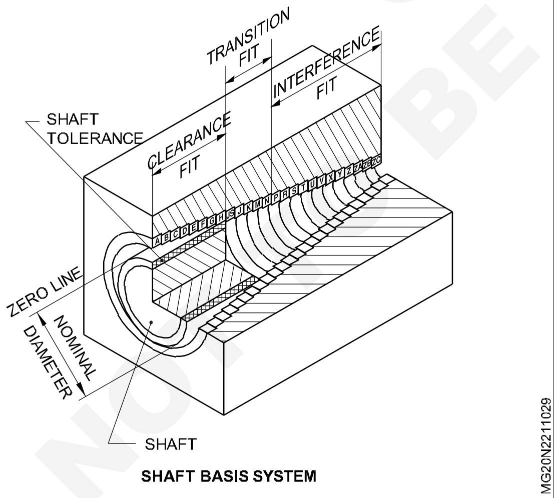


Fig 9

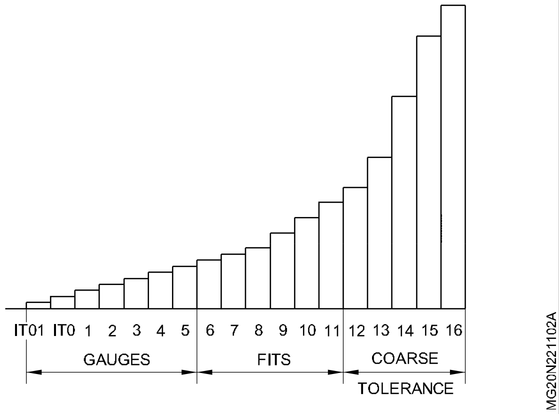


Fundamental tolerance: This is also called 'grade of tolerance'. In the B.I.S. system, there are 18 grades of tolerances represented by number symbols both for hole and shaft, denoted as IT01, IT0, IT1, IT2 .... IT16 (Fig 10)

A higher number gives a larger tolerance.

> **Grade of tolerance refers to the accuracy of manufacture.**

Fig 10

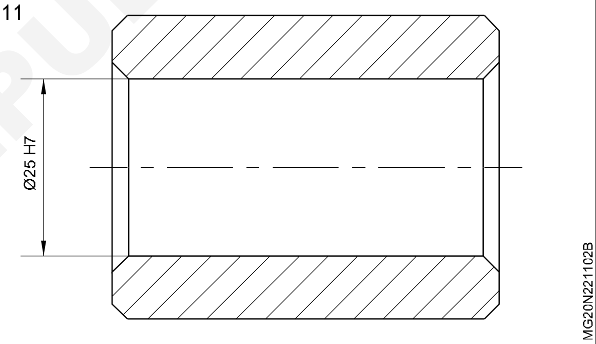


In a standard chart, the upper and lower deviations for each combination of fundamental deviation and fundamental tolerance are indicated for sizes ranging up to 500 mm. (Refer to IS 919.) An extract upto 120mm is given in Table.

Tolerance size: This includes the basic size, the fundamental deviation and the grade of tolerance.

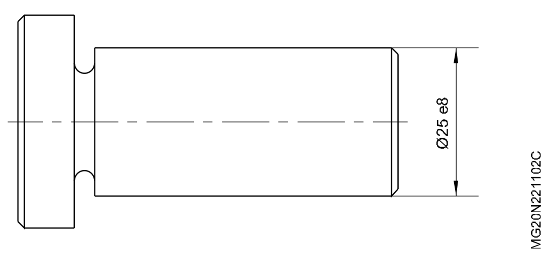
Examples: 25 H7 - is the tolerance size of a hole whose basic size is 25. The fundamental deviation is represented by the letter symbol H and the grade of tolerance is represented by the number symbol 7. (Fig 11)

Fig 11



25 e8 - is the tolerance size of a shaft whose basic size is 25. The fundamental deviation is represented by the letter symbol and the grade of tolerance is represented by the number 8. (Fig 12)

Fig 12



A very wide range of selection can be made by the combination of the 25 fundamental deviations and 18 grades of tolerances.

Example

In figure 13, a hole is shown as 25 ± 0.2 which means that 25 mm is the basic dimension and ± 0.2 is the deviation.

As pointed out earlier, the permissible variation from the basic dimension is called 'DEVIATION'.

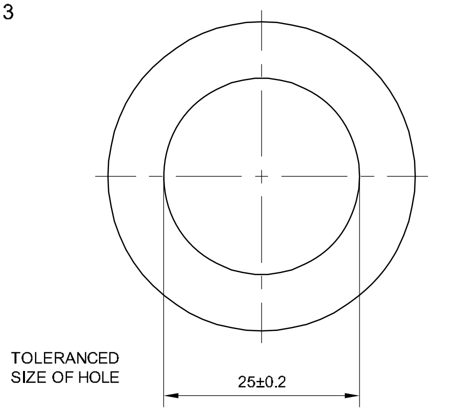
The deviation is mostly given on the drawing with dimensions.

In the example, 25 ± 0.2, ± 0.2 is the deviation of the hole of 25 mm diameter. (Fig 13) This means that the hole is of acceptable size if its dimension is between

$$25 + 0.2 = 25.2 \text{ mm}$$

$$\text{or } 25 - 0.2 = 24.8 \text{ mm.}$$

Fig 13



25.2 mm is the maximum limit. (Fig 14a)

24.8 mm is the minimum limit. (Fig 14b)

The difference between the maximum and minimum limits is the TOLERANCE. Tolerance here is 0.4 mm. (Fig 15)

All dimensions of the hole within the tolerance zone are of an acceptable size as shown in Fig 16.

As per IS 696, while dimensioning the components as a drawing convention, the deviations are expressed as tolerances.

Fig 14

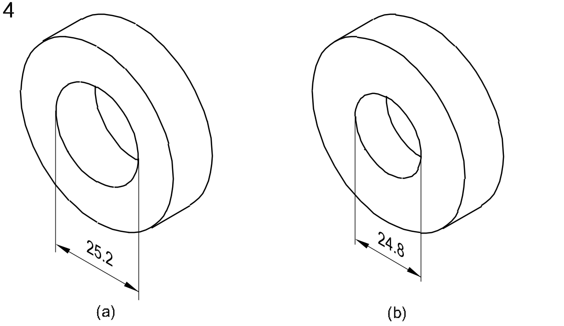


Fig 15

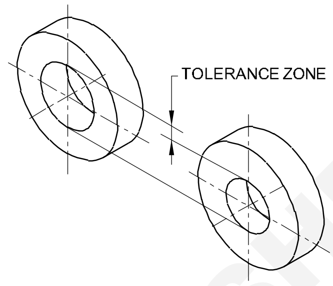
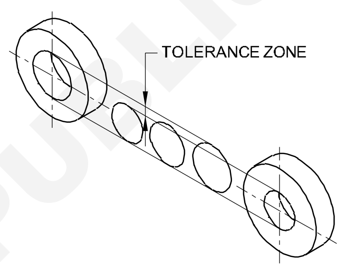


Fig 16



Fits and their classification as per the Indian standard

Objectives: At the end of this lesson you shall be able to
- **define 'fit' as per the Indian standard**
- **list out the terms used in limits and fits as per the Indian Standard**
- **state examples for each class of fit**
- **interpret the graphical representation of different classes of fits.**

Fit: It is the relationship that exists between two mating parts, a hole and a shaft, with respect to their dimensional differences before assembly.

Expression of a fit: A fit is expressed by writing the basic size of the fit first, (the basic size which is common to both the hole and the shaft) followed by the symbol for the hole, and the symbol for the shaft.

Example

30 H7/g6 or 30H7 - g6 or 30 $\frac{H7}{g6}$

Clearance: In a fit the clearance is the difference between the size of the hole and the size of the shaft, when the hole is bigger than the shaft.

Clearance fit: It is a fit which always provides clearance. Here the tolerance zone of the hole will be above the tolerance zone of the shaft. (Fig 1)

Example

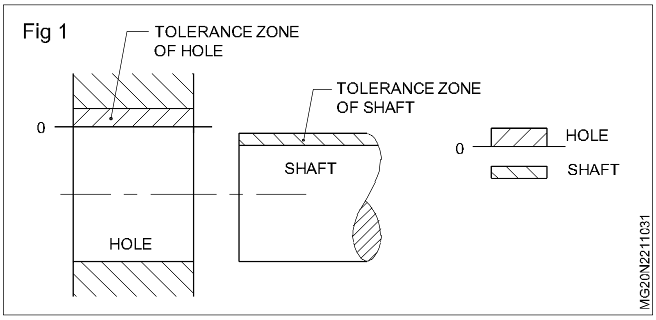
20 H7/g6

With the fit given, we can find the deviations from the chart.

For a hole 20 H7 we find in Table II, +21.

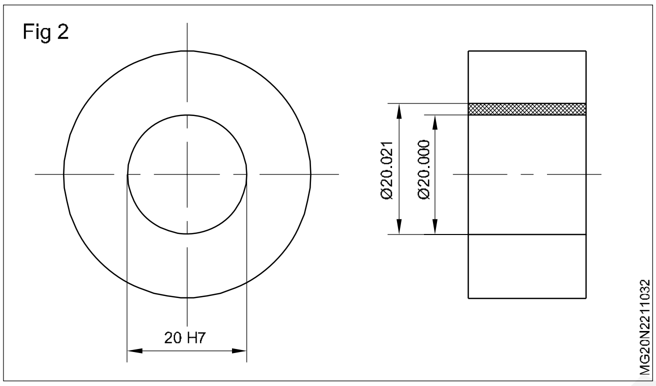
These numbers indicate the deviations in microns. (1 micrometre = 0.001 mm)

Fig 1



The limits of the hole are 20 + 0.021 = 20.021 mm and 20 + 0 = 20.000 mm. (Fig 2)

Fig 2



For a shaft 20 g6 we find in the Table – 7

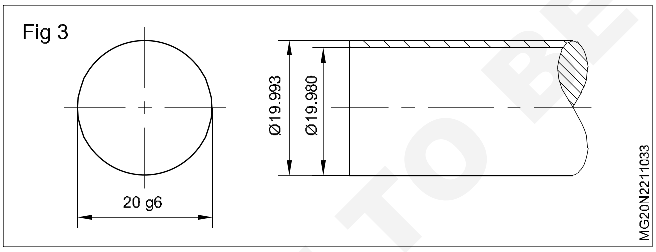
– 20.

So the limits of the shaft are

20 – 0.007 = 19.993 mm and

20 – 0.020 = 19.980 mm. (Fig 3)

Fig 3



Maximum clearance: In a clearance fit or transition fit, the maximum clearance is the difference between the maximum size hole and the minimum size shaft. (Fig 4)

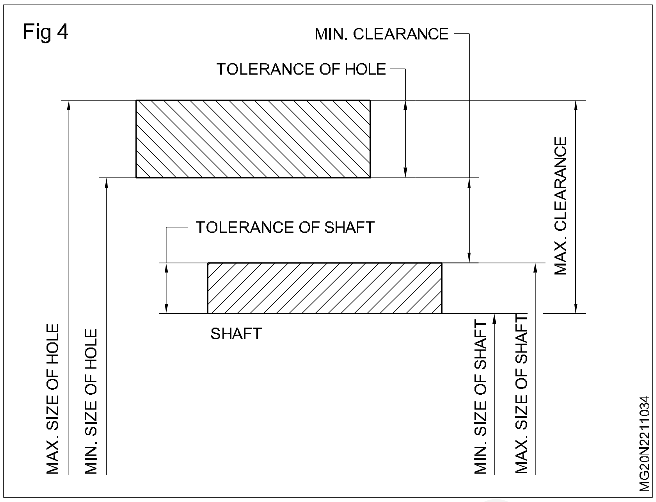
Minimum clearance: In a clearance fit, the minimum clearance is the difference between the minimum hole and the maximum shaft.(Fig 4)

The minimum clearance is 20.000 – 19.993 = 0.007 mm. (Fig 4)

The maximum clearance is 20.021 – 19.980 = 0.041 mm. (Fig 4)

There is always a clearance between the hole and the shaft. This is the clearance fit.

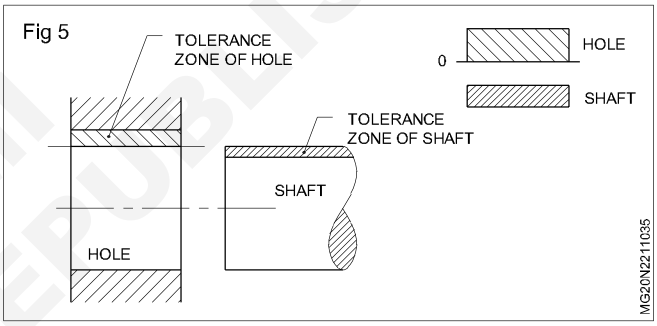
Fig 4



Interference: It is the difference between the size of the hole and the shaft before assembly, and this is negative. In this case, the shaft is always larger than the hole size.

Interference fit: It is a fit which always provides interference. Here the tolerance zone of the hole will be below the tolerance zone of the shaft. (Fig 5)

Fig 5

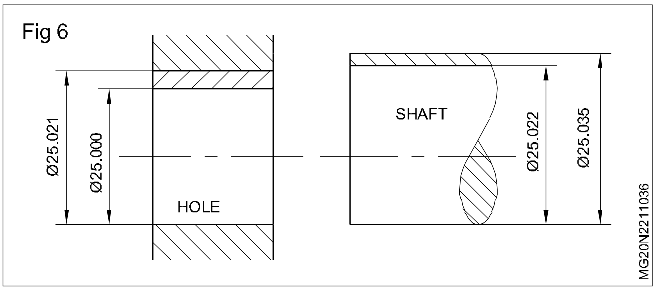


Example

Fit 25 H7/p6 (Fig 6)

The limits of the hole are 25.000 and 25.035 mm. and the limits of the shaft are 25.022 and 25.035. The shaft is always bigger than the hole. This is an interference fit.

Fig 6



Maximum interference: In an interference fit, it is the algebraic difference between the minimum hole and the maximum shaft. (Fig 7)

Minimum interference: In an interference fit, it is the algebraic difference between the maximum hole and minimum shaft. (Figs 7 & 8)

In the example shown in figure 6,

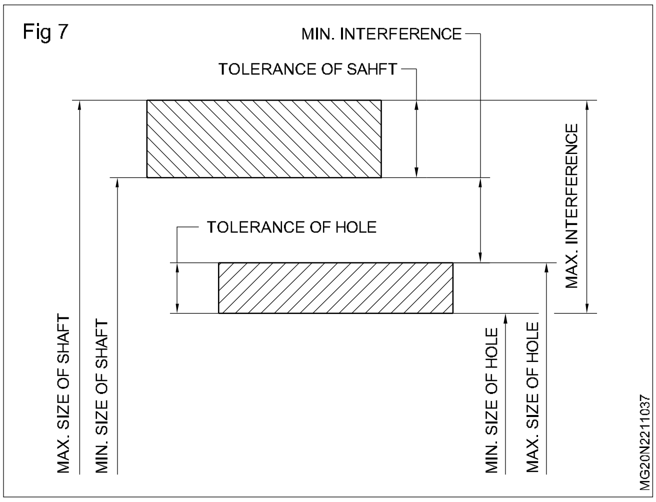
the maximum interference is = 25.035 – 25.000

= 0.035.

the minimum interference is = 25.022 - 25.021

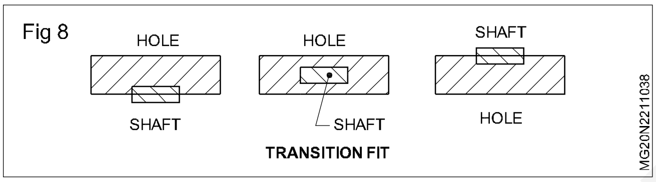
= 0.001.

Fig 7



Transition fit: It is a fit which may sometimes provide clearance, and sometimes interference. When this class of fit is represented graphically, the tolerance zones of the hole and shaft will overlap each other. (Fig 8)

Fig 8



Example

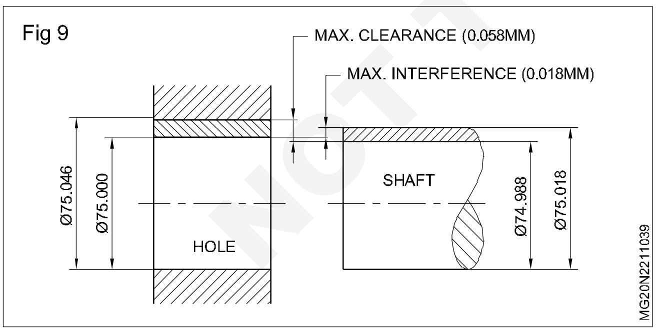
Fit 75 H8/j7 (Fig 9): The limits of the hole are 75.000 and 75.046 mm and those of the shaft are 75.018 and 74.988 mm.

Maximum clearance = 75.046 - 74.988

= 0.058 mm.

If the hole is 75.000 and the shaft 75.018 mm, the shaft is 0.018 mm bigger than the hole. This results in interference. This is a transition fit because it can result in a clearance fit or an interference fit.

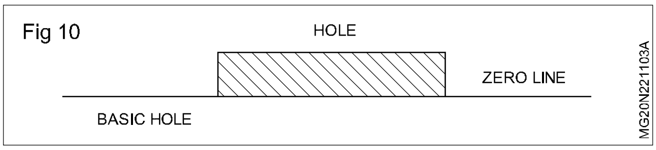
Fig 9



Hole basis system: In a standard system of limits and fits, where the size of the hole is kept constant and the size of the shaft is varied to get the different classes of fits, it is known as the hole basis system.

The fundamental deviation symbol 'H' is chosen for the holes, when the hole basis system is followed. This is because the lower deviation of the 'H' hole is zero. It is known as the 'basic hole'. (Fig 10)

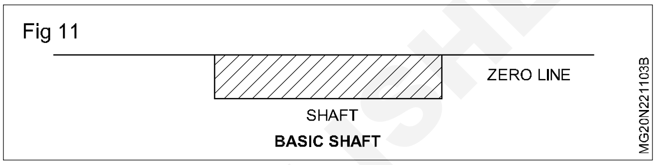
Fig 10



Shaft basis system

In a standard system of limits and fits, where the size of the shaft is kept constant and the variations are given to the hole for obtaining different classes of fits, then it is known as shaft basis system. The fundamental deviation symbol 'h' is chosen for the shaft when the shaft basis is followed. This is because the upper deviation of the 'h' shaft is zero. It is known as the 'basic shaft'. (Fig 11)

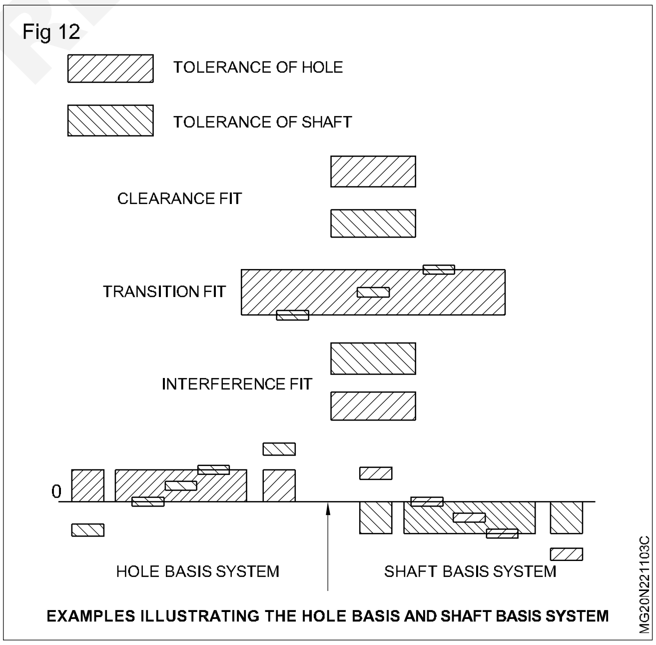
Fig 11



The hole basis system is followed mostly. This is because, depending upon the class of fit, it will be always easier to alter the size of the shaft as it is external, but it is difficult to do minor alterations to a hole. Moreover the hole can be produced by using standard toolings.

The three classes of fits, both under the hole basis and the shaft basis, are illustrated in figure 12.

Fig 12



The B.I.S system of limits and fits - reading the standard chart

Objective: At the end of this lesson you shall be able to
- **refer to the standard limit system chart and determine the limits of sizes.**

The standard chart covers sizes up to 500 mm (I.S.919 of 1963) for both holes and shafts. It specifies the upper and lower deviations for a certain range of sizes for all combinations of the 25 fundamental deviations, and 18 fundamental tolerances.

The upper deviation of the hole is denoted as ES and the lower deviation of the hole is denoted as EI. The upper deviation of the shaft is denoted as `es' and the lower deviation of shaft is denoted as `ei'.

es is expanded as ECART SUPERIOR and ei as ECART INFERIOR.

Determining the limits from the chart: Note whether it is an internal measurement or an external measurement.

Note the basic size.

Note the combination of the fundamental deviation and the grade of tolerance.

Then refer to the chart and note the upper and lower deviations which are given in microns, with the sign. Accordingly add or subtract from the basic size and determine the limits of size of the components.

Example

30H7 (Fig 1)

It is an internal measurement. So we must refer to the chart for 'holes'.

The basic size is 30 mm. So see the range 30 to 40.

Look for es, and ei values in microns for H7 combination for 30 mm basic size.

It is given as +25

+ 0.

Therefore, the maximum limit of the hole is 30 + 0.025 = 30.025 mm.

The minimum limit of the hole is 30 + 0.000 = 30.000 mm.

Refer to the chart and note the values of 40 g6.

The table for tolerance zones and limits as per IS2709 is attached.

Fig 1

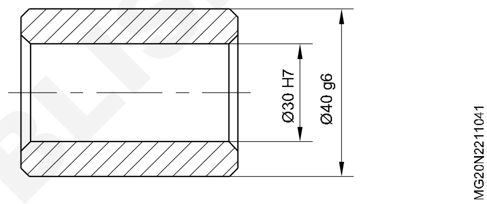


TABLE FOR TOLERANCE ZONES & LIMITS (DIMENSIONS IN μ m)

NOMINAL SIZE RANGE mm		s6	r6	p6	n6	k6	js6	h6	h7	h9	h11	g6	f7	e8	d9	c11	b11	a11	S7	R7	P7	N7	K7	JS7	H7	H8	H9	H11	G7	F8	E9	D10	C11	B11	A11
From upto	1 3	+20 +14	+16 +10	+12 +6	+10 +4	+6 0	+3 -3	0 -6	0 -10	0 -25	0 -60	-2 -8	-6 -16	-14 -28	-20 -45	- 60 -120	-140 -200	-270 -330	-14 -24	-10 -20	-6 -16	-4 -14	0 -10	+5 -5	+10 0	+14 0	+25 0	+60 0	+12 +2	+20 +6	+39 +14	+60 +20	+120 +60	+200 +140	+330 + 270
Over upto	3 6	+27 +19	+23 +15	+20 +12	+16 +8	+9 +1	+4 -4	0 -8	0 -12	0 -30	0 -75	-4 -12	-10 -22	-20 -28	-30 -60	-70 -145	-140 -215	-270 -345	-15 -27	-11 -23	-8 -20	-4 -16	+3 -9	+6 -6	+12 0	+18 0	+30 0	+75 0	+16 +4	+28 +10	+50 +20	+78 +30	+145 +70	+215 +140	+345 +270
Over upto	6 10	+32 +23	+28 +19	+24 +15	+19 +10	+10 +1	+4.5 -4.5	0 -9	0 -15	0 -36	0 -90	-5 -14	-13 -28	-25 -47	-40 -76	-80 -170	-150 -240	-280 -370	-17 -32	-13 -28	-9 -24	-4 -19	+5 -10	+7.5 -7.5	+15 0	+22 0	+36 0	+90 0	+20 +5	+35 +13	+61 +25	+98 +40	+170 +80	+240 +150	+370 +280
Over upto	10 14	+39	+34	+29	+23	+12	+5.5	0	0	0	0	-6	-16	-32	-50	-95	-150	-290	-21	-16	-11	-5	+6	+9	+18	+27	+43	+110	+24	+43	+75	+120	+205	+260	+400
Over upto	14 18	+28	+23	+18	+12	+1	-5.5	-11	-18	-43	-110	-17	-34	-59	-93	-205	-260	-400	-39	-34	-29	-23	-12	-9	0	0	0	0	+7	+16	+32	+50	+95	+150	+290
Over upto	18 24	+48	+41	+35	+28	+15	+6.5	0	0	0	0	-7	-20	-40	-65	-110	-160	-300	-27	-20	-14	-7	+6	+10.5	+21	+33	+52	+130	+28	+53	+92	+149	+240	+290	+430
Over upto	24 30	+35	+28	+22	+15	+2	-6.5	-13	-21	-52	-130	-20	-41	-73	-117	-240	-290	-430	-48	-41	-35	-28	-15	-10.5	0	0	0	0	+7	+20	+40	+65	+110	+160	+300
Over upto	30 40	+59	+50	+42	+33	+18	+8	0	0	0	0	-9	-25	-50	-80	-120 -280	-170 -330	-310 -470	-34	-25	-17	-8	+7	+12.5	+25	+39	+62	+160	+34	+64	+112	+180	+280 +120	+330 +170	+470 +310
Over upto	40 50	+43	+34	+26	+17	+2	-8	-16	-25	-62	-160	-25	-50	-89	-142	-130 -290	-180 -340	-320 -480	-59	-50	-42	-33	-18	-12.5	0	0	0	0	+9	+25	+50	+80	+290 +130	+340 +180	+480 +320
Over upto	50 65	+72 +53	+60 +41	+51	+39	+21	+9.5	0	0	0	0	-10	-30	-60	-100	-140 -330	-190 -380	-340 -530	-42 -72	-30 -60	-21	-9	+9	+15	+30	+46	+74	+190	+40	+76	+134	+220	+330 +140	+380 +190	+530 +340
Over upto	65 80	+78 +59	+62 +43	+32	+20	+2	-9.5	-19	-30	-74	-190	-29	-60	-106	-174	-150 -340	-200 -390	-360 -550	-48 -78	-32 -62	-51	-39	-21	-15	0	0	0	0	+10	+30	+60	+100	+340 +150	+390 +200	+550 +360
Over upto	80 100	+93 +71	+73 +51	+59	+45	+25	+11	0	0	0	0	-12	-36	-72	-120	-170 -390	-220 -440	-380 -600	-58 -93	-38 -73	-24	-10	+10	+17.5	+35	+54	+87	+220	+47	+90	+159	+260	+390 +170	+440 +220	+600 +380
Over upto	100 120	+101 +79	+76 +54	+37	+23	+3	-11	-22	-35	-87	-220	-34	-71	-126	-207	-180 -400	-240 -460	-410 -630	-66 -101	-41 -76	-59	-45	-25	-17.5	0	0	0	0	+12	+36	+72	+120	+400 +180	+460 +240	+630 +410
Over upto	120 140	+117 +92	+88 +63													-200 -450	-260 -510	-460 -710	-77 -117	-48 -88													+450 +200	+510 +260	+710 +460
Over upto	140 160	+125 +100	+90 +65	+68 +43	+52 +27	+28 +3	+12.5 -12.5	0 -25	0 -40	0 -100	0 -250	-14 -39	-43 -83	-85 -148	-145 -245	-210 -460	-280 -530	-520 -770	-85 -125	-50 -90	-28 -68	-12 -52	+12 -28	+20 -20	+40 0	+63 0	+100 0	+250 0	+54 +14	+106 +43	+185 +85	+305 +145	+460 +210	+530 +280	+770 +520
Over upto	160 180	+133 +108	+93 +68													-230 -480	-310 -560	-580 -830	-93 -133	-53 -93													+480 +230	+560 +310	+830 +580
Over upto	180 200	+151 +122	+106 +77													-240 -530	-340 -630	-660 -950	-105 -151	-60 -106													+530 +240	+630 +340	+950 +660
Over upto	200 225	+159 +130	+109 +80	+79 +50	+60 +31	+33 +4	+14.5 -14.5	0 -29	0 -46	0 -115	0 -290	-15 -44	-50 -96	-100 -172	-170 -285	-260 -550	-380 -670	-740 -1030	-113 -159	-63 -109	-33 -79	-14 -60	+13 -33	+23 -23	+46 0	+72 0	+115 0	+290 0	+61 +15	+122 +50	+215 +100	+355 +170	+550 +260	+670 +380	+1030 +740
Over upto	225 250	+169 +140	+113 +84													-280 -570	-420 -710	-820 -1110	-123 -169	-67 -113													+570 +280	+710 +420	+1110 +820
Over upto	250 280	+190 +158	+126 +94	+88	+66	+36	+16	0	0	0	0	-17	-56	-110	-190	-300 -620	-480 -800	-920 -1240	-138 -190	-74 -126	-36	-14	+16	+26	+52	+81	+130	+320	+69	+137	+240	+400	+620 +300	+800 +480	+1240 +920
Over upto	280 315	+202 +170	+130 +98	+56	+34	+4	-16	-32	-52	-130	-320	-49	-108	-191	-320	-330 -650	-540 -860	-1050 -1370	-150 -202	-78 -130	-88	-66	-36	-26	0	0	0	0	+17	+56	+110	+190	+650 +330	+860 +540	+1370 +1050
Over upto	315 355	+226 +190	+144 +108	+98	+73	+40	+18	0	0	0	0	-18	-62	-125	-210	-360 -720	-600 -960	-1200 -1560	-169 -226	-87 -144	-41	-16	+17	+28.5	+57	+89	+140	+360	+75	+151	+265	+440	+720 +360	+960 +600	+1500 +1200
Over upto	355 400	+244 +208	+150 +114	+62	+37	+4	-18	-36	-57	-140	-360	-54	-119	-214	-350	-400 -760	-680 -1040	-1350 -1710	-187 -244	-93 -150	-98	-73	-40	-28.5	0	0	0	0	+18	+69	+125	+210	+760 +400	+1040 +680	+1710 +1350
Over upto	400 450	+272 +232	+166 +126	+108	+80	+45	+20	0	0	0	0	-20	-68	-135	-230	-440 -840	-760 -1160	-1500 -1900	-209 -272	-103 -166	-45	-17	+18	31.5	+63	+97	+155	+400	+83	+165	+290	+480	+840 +440	+1160 +760	+1900 +1500
Over upto	450 500	+292 +252	+172 +132	+68	+40	+5	-20	-40	-63	-155	-400	-60	-131	-232	-385	-480 -880	-840 -1240	-1650 -2050	-229 -292	-109 -172	-108	-80	-45	-31.5	0	0	0	0	+20	+68	+135	+230	+880 +480	+1240 +840	+2050 +1650

Types of gauges

Objectives: At the end of this lesson you shall be able to
- **state the uses of radius gauges**
- **list the features of radius gauges.**

Radius gauge: Radius gauges are used to check the internal and external radius of workpieces.

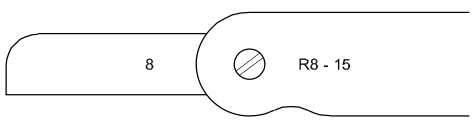
These gauges are made of high quality steel sheets, and are finished to accurate radius.

The radius of parts are checked by comparing the radius of the gauges.

Radius gauges are available in sets of several blades held in a holder. Each blade can be separately pulled out of the holder when in use.

The size of the radius is marked on the individual blades of the gauges. (Fig 1)

Fig 1



These gauges are available in different combinations with internal and external radius. (Figs 2 & 3)

Individual gauges are also available for different radius (Fig 4).

Before using the radius gauges ensure the gauges are perfectly clean, remove burrs, if any, from the workpieces, check and make sure there is no damage to the profile of the gauge.

Fig 2

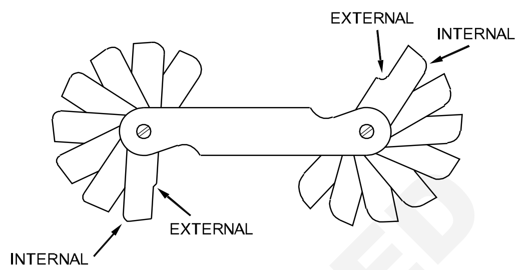


Fig 3

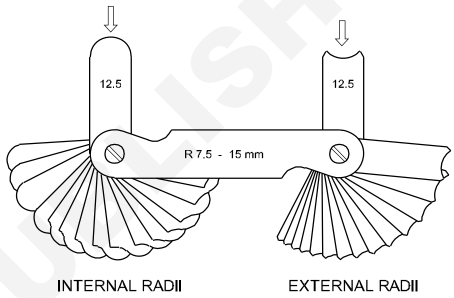
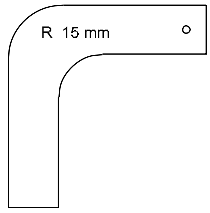


Fig 4



Limit gauges

Objectives: At the end of this lesson you shall be able to
- **state the principle of the Go and No-Go gauges and their features**
- **identify the common types of limit gauges**
- **state the uses of each type of limit gauges.**

When a number of components have to be checked it is not necessary to measure their sizes exactly but only check that the component's sizes lie within the limits of tolerance. The most economical method of checking a component is with a limit gauge.

These gauges are used in inspection because they provide a quick means of checking a specific dimension.

'Go' and 'No-Go' end principle

The dimensions of the 'Go' and `No-Go' ends of gauges are determined from the limits stated on the dimension to be gauged.

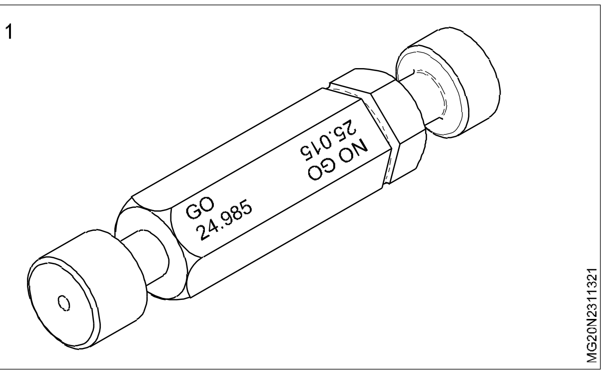
The 'Go' and 'No-Go' principle of gauging is that the'Go' end of the gauge must go into the feature being checked and the 'No-Go' end must not go into the same feature.

The dimension of the 'Go' end is equal to the maximum permissible dimension and that of the 'No-Go' end is equal to the minimum permissible dimension of the component being checked. (Fig 1)

Essential features

These gauges must be easy to handle and accurately finished. They are generally finished to one tenth the tolerance they are designed to control.

Fig 1



For example, if the tolerance is to be maintained at 0.02 mm, then the gauge must be finished to within one-tenth of tolerance designed to control.

For example if the tolerance is to be maintained to 0.02 mm, then the gauge must be finished to within 0.002 mm of the required size.

Gauges must be resistant to wear, corrosion, and expansion due to temperature.

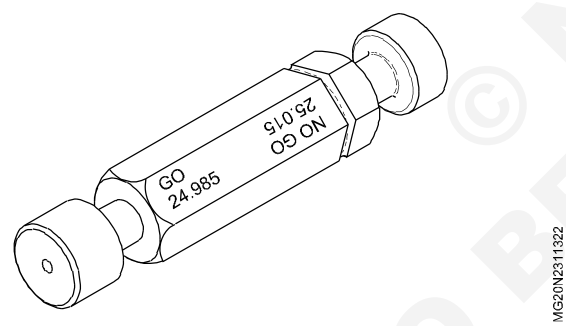
Their production cost must be lower.

The ‘Go’ end is made longer than the ‘No-Go’ end for easy identification. Sometimes a groove is cut on the handle near the ‘No- Go’ end to distinguish it from the ‘Go’ end.

Types of cylindrical plug gauges

Double-ended plug gauge (Fig 2)

Fig 2



Progressive plug gauge (Fig 3): Plain cylindrical gauges are used for checking the inside diameter of a straight hole. The ‘Go’ gauge checks the lower limit of the hole and the ‘No- Go’ gauge checks the upper limit. The plugs are ground and lapped (Fig 4)

Fig 3

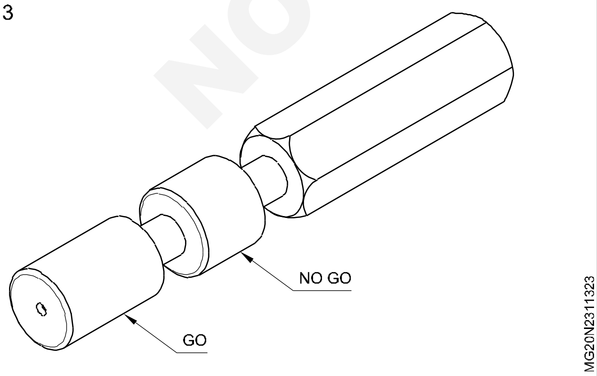
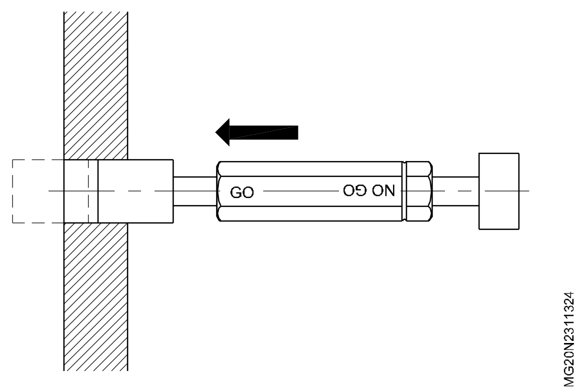
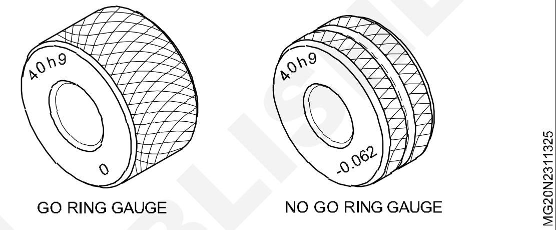


Fig 4



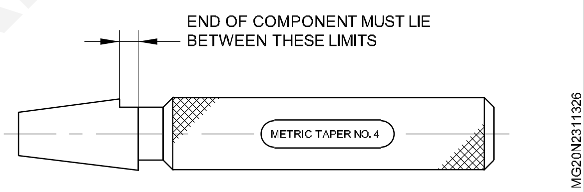
Plain ring gauges (Fig 5): Plain ring gauges are used to check the outside diameter of pieces. Separate gauges are used for checking ‘Go’ and ‘No- Go’ sizes. The `No-Go’ gauge is identified by an annular groove on the knurled surface.

Fig 5



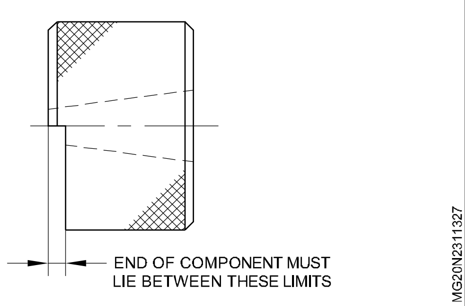
Taper plug gauges (Fig 6): These gauges made with standard or special tapers are used to check the size of the hole and the accuracy of the taper. The gauge must slide into the hole for a prescribed depth and fit perfectly. An incorrect taper is evidenced by a wobble between the plug gauge and the hole.

Fig 6



Taper ring gauges (Fig 7): They are used to check both the accuracy and the outside diameter of a taper. Ring gauges often have scribed lines or a step ground on the small end to indicate the ‘Go’ and ‘No-Go’ dimensions.

Fig 7



Thread plug gauges (Figs 8 and 9): Internal threads are checked with thread plug gauges of ‘Go’ and `No-Go’ variety which employ the same principle as cylindrical plug gauges.

Fig 8

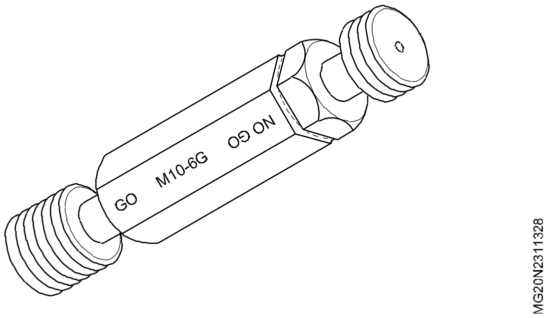
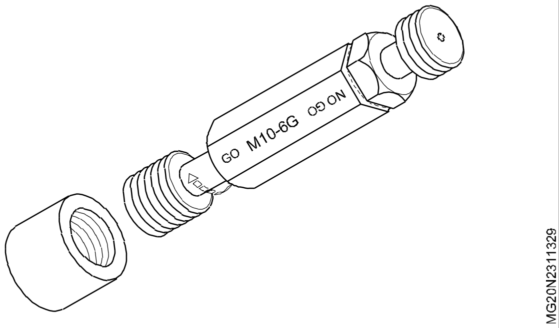
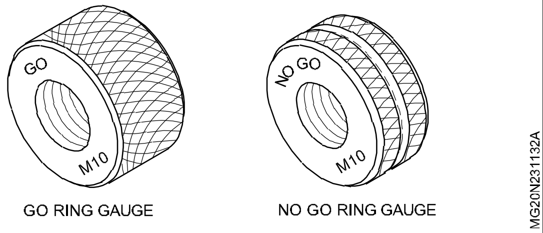


Fig 9



Thread ring gauges (Fig 10): These gauges are used to check the accuracy of an external thread and have a threaded hole in the centre.

Fig 10

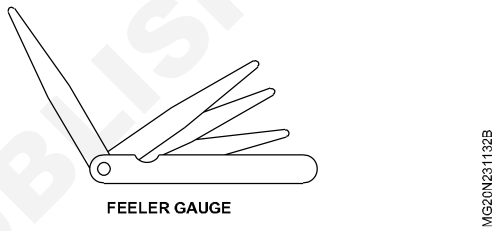


Feeler gauge (Fig 11): It consists of a series of leaves varying in thickness from ½ thousands of an inch upwards. They are made in different lengths and thickness which makes it possible to use them in varying combinations. This gauge is very useful in gauging narrow slots or clearances.

Feeler gauges are also available in metric sizes from 5/100 to 1 mm thickness.

They should not be used with undue pressure for they will not only give an incorrect reading, but will become worn. Avoid bending or wrinkling the thin blades.

Fig 11



Snap gauge

Objectives: At the end of this lesson you shall be able to
- **state the uses of a snap gauge**
- **state the features of snap gauge.**

Snap gauges are a quick means of checking diameters and thickness within certain limits by comparing the part size, to the dimension of the snap gauge.

Snap gauges are generally C-shaped and are adjustable to the maximum and minimum limits of the part being checked. When in use, the work should slide into the 'GO' gauge but not into the 'NO-GO' gauge.

Snap gauges (Figs 1&2)

Fig 1

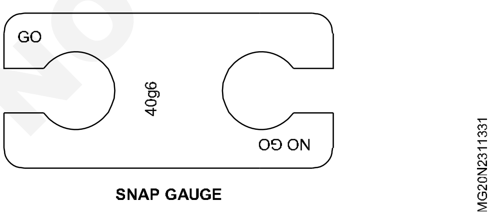
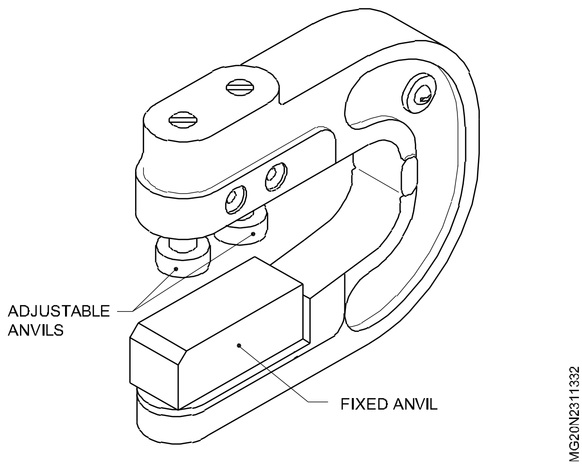


Fig 2

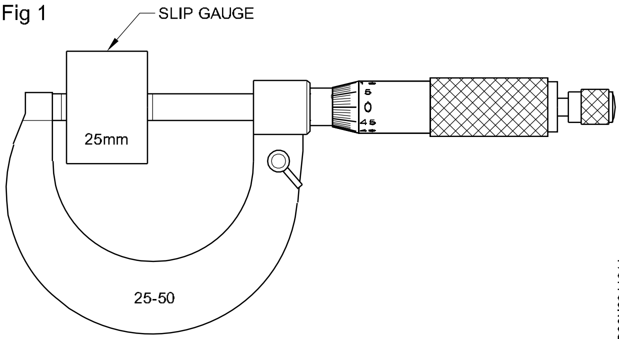


Slip gauge

Objectives: At the end of this lesson you shall be able to
- **state the features of slip gauges**
- **state the different grades of slip gauges and their uses**
- **state the number of slips in standard sets**
- **state the precautions to be followed while using slip gauges.**

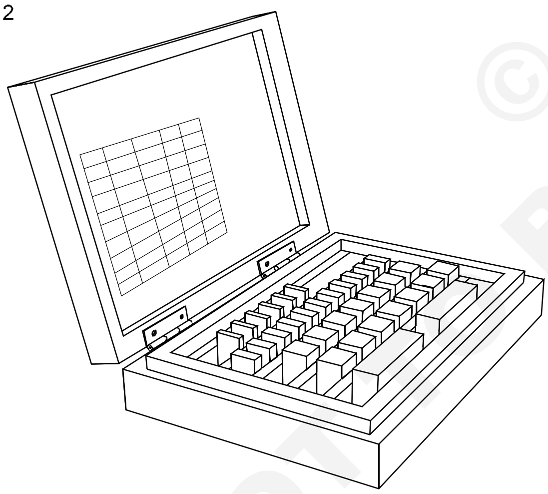
Slip gauges or gauge blocks are used as standards for precision length measurement (Fig 1) These are made in sets and consist of a number of hardened blocks made of high grade steel with very low thermal expansion They are hardened toughout, and heat treated further for stabilization. The two opposite measuring faces of each block are lapped flat and parallel definite size within extremely close tolerances.

Fig 1



These slip gauges are available in various sets with different numbers (Fig 2) (Ref Table 1)

Fig 2



A particular size can be built up by wringing individual slip gauges together. (Figs 3 & 4)

Wringing is the act of joining the slip gauges together while building up to sizes.

Some sets of slip gauges also contain protector slips made to standard thickness from higher wear-resistant steel or tungsten carbide. These are used for protecting the exposed faces of the slip gauge pack from damage while in use.

Fig 3

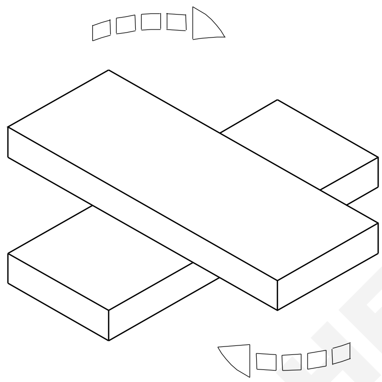
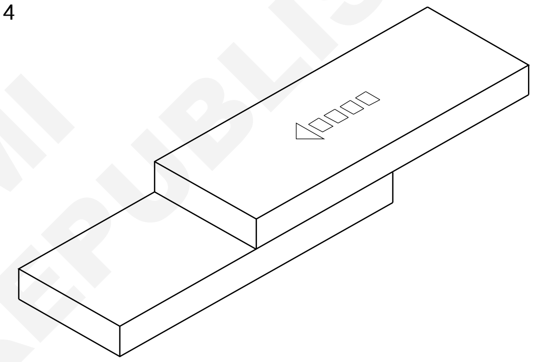


Fig 4



GRADES

The following four grades of slip gauges are recommended as per IS 2984-1981.

Grade '00', Grade '0', Grade '1' & Grade '2'.

Grade '00' shall normally be used for calibration purposes. It shall not be used in combination.

Grades 0,1 and 2 are intended for general use.

Grade '0' is used only for calibration of Inspection Grade '1'. Grade '1' is used in tool room and standards room. It is also used for calibration of Grade '2'.

Grade '2' is used on machines for setting purposes and on surface plate for inspection purposes in shop floor. It is also used for zero setting of precision measuring instruments in shop floor. **For further details refer IS 2984-1981.**

B.I.S recommendations

Three grades of slip gauges are recommended as per IS-2984.They are:

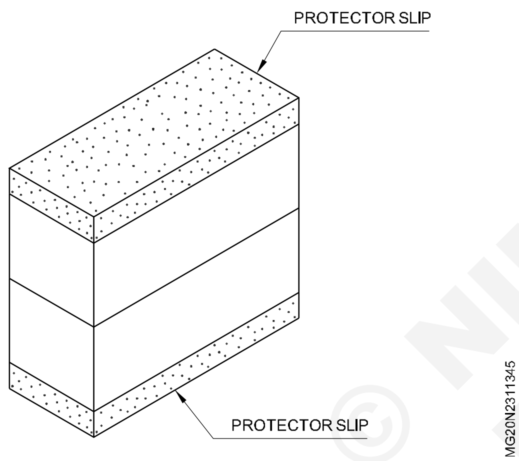
Care and maintenance points to be remembered while using slip gauges

- Avoid handling the slip gauges with bare hands, since this affects the size of them due to heating.
- Use a minimum number of blocks as far as possible while building up a particular dimension.
- While building the slip gauges, start wringing with the largest slip gauges and finish with the smallest.

While holding the slip gauges do not touch the lapped surfaces.

If available use protector slips on exposed faces. (Fig 5)After use, clean the slips with carbon tetrachloride and apply petroleum jelly for protection against rust.

Fig 5



Before use, remove the petroleum jelly with carbon tetrachloride. Use chamois leather to wipe the lapped surfaces.

TABLE 1

Different sets of slip gauges

Set of 112 pieces (M112)

Range mm	Steps (mm)	No. of pieces
Special piece 1.0005		1
1st series 1.001 to 1.009	0.001	9
2nd series 1.01 to 1.49	0.01	49
3rd series 0.5 to 24.5	0.5	49
4th series 25.0 to 1.00.0	25.0	4
Total pieces		112

Set of 103 pieces (M 103)

Range mm	Steps (mm)	No. of pieces
Special piece 1.0005	-	1
1st series 1.001 to 1.009	0.01	49
2nd series 0.5 to 24.5	0.5	49
3rd series 25 to 100	25.0	4
Total pieces		103

Set of 78 pieces (M 78)

Range mm	Steps (mm)	No. of pieces
1.0025	-	1
1.005	-	1
1.0075	-	1
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10.0 to 50.0	10.0	5
75.0 to 100.0	-	2
Total pieces		78

Set of 47 pieces (M 47)

Range mm	Steps (mm)	No. of pieces
1st series 1.005	-	1
2nd series 1.01 to 1.09	0.01	9
3rd series 1.1 to 1.5	0.1	9
4th series 25.0 to 1.00.0	1.0	24
5th series 25.0 to 1.00.0	25.0	4
Total pieces		47

Set of 87 pieces (M 87)

Range mm	Steps (mm)	No.of pieces
1st series 1.001 to 1.009	0.001	9
2nd series 1.01 to 1.49	0.01	49
3rd series 0.5 to 9.5	0.5	19
4th series 10.0 to 100.0	10.0	10
Total pieces		87

Set of 46 pieces (M 46)

Range mm	Steps (mm)	No.of pieces
1st series 1.001 to 1.009	0.001	9
2nd series 1.01 to 1.09	0.01	9
3rd series 1.1 to 1.9	0.1	9
4th series 1.0 to 9.0	1.0	9
5th series 10.0 to 100	10.0	10
Total pieces		46

Even though there are a number of sets of slip gauges available, the popularly recommended are :M112,M 87,M 46, M 38 and M9.

Set of 38 pieces (M 38)

Range mm	Steps (mm)	No.of pieces
1.005	-	1
1st series 1.01 to 1.09	0.01	9
2nd series 1.1 to 1.9	0.1	9
3rd series 0.5 to 9.5	0.5	19
4th series 10.0 to 100	10.0	10
Total pieces		87

Set of 86 pieces (M 86)

Range mm	Steps (mm)	No.of pieces
1st series 1.001 to 1.009	0.001	9
2nd series 1.01 to 1.49	0.01	49
3rd series 0.5 to 9.5	0.5	19
4th series 10.0 to 100.0	10.0	9
Total pieces		86

Set of 9 pieces (M 9)

Range mm	Steps (mm)	No.of pieces
1.001 to 1.009	0.001	49

Selection and determination of slip gauges for different sizes

Objectives: At the end of this lesson you shall be able to
- **determine slip gauges for different sizes.**

For determining a particular size, in most cases a number of slip gauges are to be selected and stacked one over the other by wringing the slip gauges.

While selecting slip gauges for a particular size using the available set of slip gauges, first consider the last or the last two digits of the subsequent value and continue to select the pieces until the required size is available.

Example (Without using protector slips)

Building up a size of 44.8725 mm with the help of 112 piece set.(Table 1)

Set of 112 pieces

Range mm	Steps (mm)	No.of pieces
1.0005	-	1
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 25.5	0.5	49
25.0 to 100.0	25.0	4
Total pieces		112

Types of special micrometers

Objectives: At the end of this lesson you shall be able to
- **identify and name the different types of micrometers other than regular micrometers**
- **state the specific use of each micrometer.**

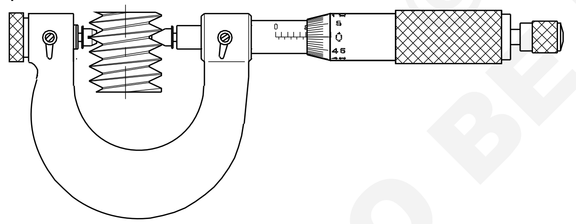
In addition to regular micrometers, there are several other types of micrometers, with the same fundamental principle, but specifically designed to meet the various special applications, such as external, internal, depth measurement etc.

Types of micrometers other than regular

- Screw thread micrometer
- Tube micrometer
- Depth micrometer
- Ball micrometer
- Digital micrometer
- Flange micrometer
- Stick micrometer
- External micrometer with interchangeable anvils
- Keyway depth micrometer

Screw thread micrometer (Fig 1): A screw thread micrometer is similar to an outside micrometer except that the spindle is pointed to fit between 60° V threads, and the anvil is shaped to fit over 60° V thread. It is used to measure the pitch diameter of the thread. Screw thread micrometers are available in many sizes depending on the pitch of the thread to be measured.

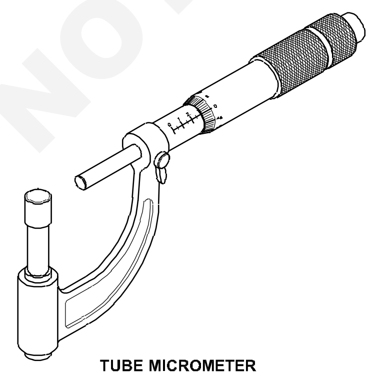
Fig 1



MG20N2311411

Tube micrometer (Fig 2): A tube micrometer is specially designed to measure the thickness of the material of piping, tubing and and other parts of similar shapes.

Fig 2



TUBE MICROMETER

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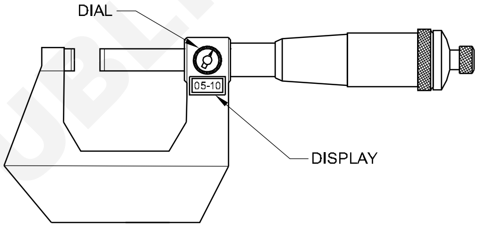
Digital micrometer (Fig 3): This type of micrometer has got a dial on the frame of the micrometer and an illuminated display below it. The dial pointer has an internal connection with the micrometer screw for measuring. The graduations on the sleeve and thimble are the same as on a regular micrometer. This micrometer is used to measure the dimensions similar to those measured by the outside micrometers, and the reading can be noted.

The advantage of this micrometer is, the readings are seen on the screen or the dial directly, without any difficulty. We need not look on the sleeve or the thimble scale coincidence. This avoids errors in reading and saves time. A layman can also read the measurement directly.

Fig 3



DIGITAL MICROMETER

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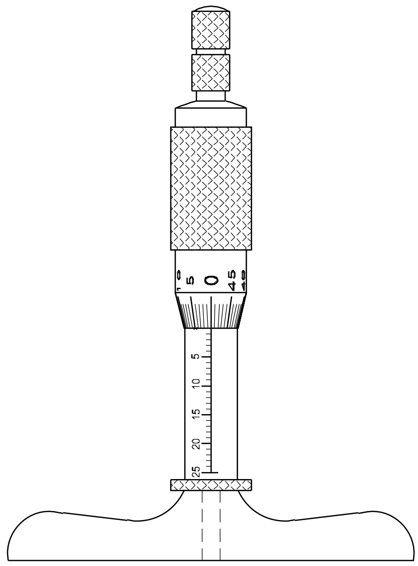
Depth micrometer (Fig 4)

Fig 4



DEPTH MICROMETER

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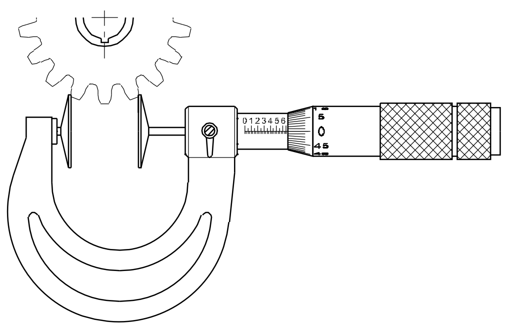
A depth micrometer is designed to measure accurately the depth of grooves, bores, counter bores, recesses and holes. The graduations are read in the same manner as is done in the case of regular micrometers. Larger ranges of depth can be measured by inserting an extension rod through the top of the micrometer. The graduations are in the reversed direction to those of an O/S micrometer.

Flange micrometer (Fig 5): A flange micrometer is similar to a regular micrometer and is equipped with two flanges in the place of the anvil and spindle. This is used to measure chordal thickness of the gear teeth and the thickness of the fins of an engine and the collar thickness of the job.

Fig 5

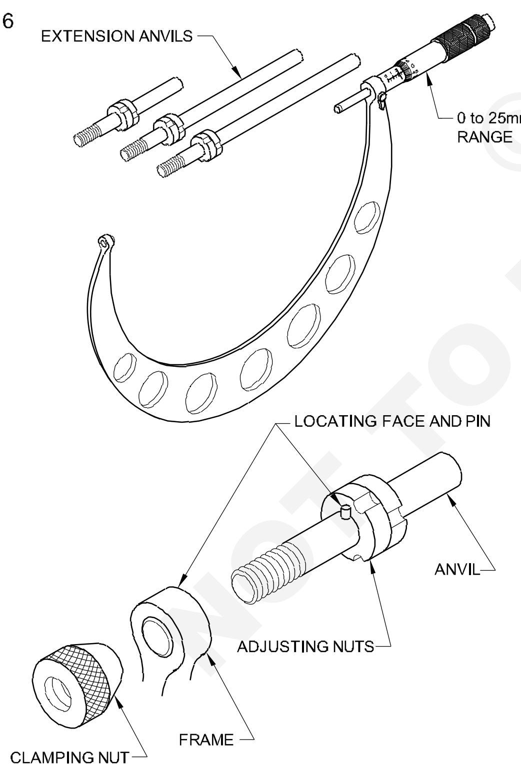


FLANGE MICROMETER

Ball micrometer: In this form of micrometer, hemispherical balls are fitted at the anvil and spindle. Measurement is similar to that in a regular micrometer. It is used to measure a sphere where the point of contact comes in between.

External micrometer with interchangeable anvils (Fig 6): It is nothing but an external micrometer. The advantage in this micrometer is the range of the micrometer can be increased by merely changing the different anvils.

Fig 6



A set of replaceable anvils is supplied in a box and the size of the anvil is marked on each anvil. Depending upon the size of the job, the anvil size can be changed, and reading can be taken. Thus it is an economy micrometer, i.e. in one micrometer itself, long ranges can be accommodated. To fix the anvils to the frame, a guide is provided and locked by a nut.

Keyway depth micrometer: It is similar to a depth micrometer except that the frame has 120° inclined butting surfaces to rest on the circumference on a cylindrical job. It is used for measuring depth of keyways on a cylindrical shaft. While measuring the depth of the keyway, first take the measurement on a cylindrical job opposite to the keyway; then take the measurement of the keyway depth, subtract the initial measurement from the final measurement to know the exact depth of the keyway.

Stick micrometers (Fig 7): Stick micrometers are designed for the measurement of longer internal lengths. These comprise of the following parts:

- A 150 mm or 300 mm micrometer unit fitted with a micrometer of 25 mm range and having rounded terminal faces.
- A series of extension rods which together with the micrometer unit, permit of a continuous range of measurements upto the maximum length required.

Secured joints are used for joining the end piece, extension rod and the measuring unit. The screw unit generally has threads of 0.5 mm pitch. The extension rod is generally hollow and has a minimum external diameter of 14 mm.

In this type of micrometer, there should be sufficient play between the external and internal threads of the joint to permit the abutment forces of the various parts of the micrometer to butt together solidly.

How the stick micrometer will look like is shown in Fig 7. Its accuracy is of the order of ±0.005 mm throughout the range. It is essential that the radius of curvature of the terminal faces of the micrometer unit be slightly less than one-half the smallest measuring range of the micrometer unit, and abutment faces should have minimum raidal width of 2 mm and properly lapped; these should be parallel to each other and normal to the axis of the micrometer unit to within 0.005 mm across their diameters.

It may be noted that screwed joints are used for joining the end piece, extension rod and the measuring unit. The screw units generally have threads of 0.5 mm pitch. The extension rod is generally.

V-Anvil micrometer caliper (Fig 8)

Special features: Any out-of-roundness condition can be quickly checked in centreless grinding and machining operations.

Direct reading eliminates use of special fixtures. It can be used for measuring odd-fluted taps, milling cutters, reamers, etc.

In this micrometer, angle of vee equals 60 degrees and the apex of the vee coincides with axis of spindle. The zero reading of micrometer starts from a point where the two sides of vee meet. It may now be seen that as the angle of vee is 60°, the micrometer will measure a distance of 3d/2 for a round piece of diameter d. It is thus simple matter to obtain the diameter from reading.

Fig 7

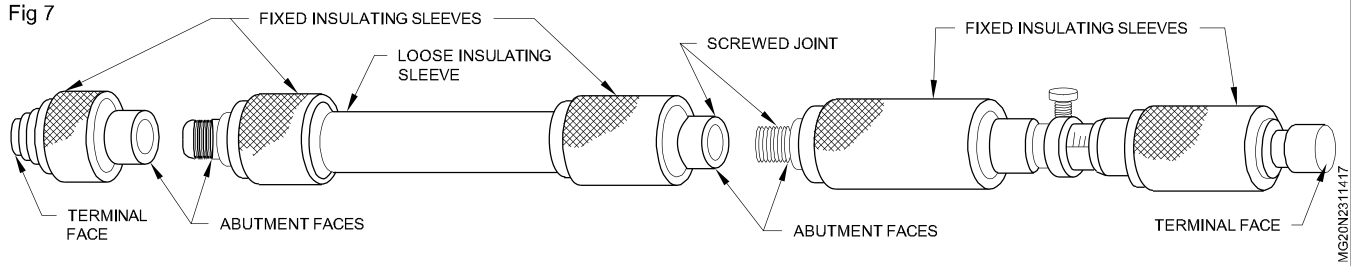
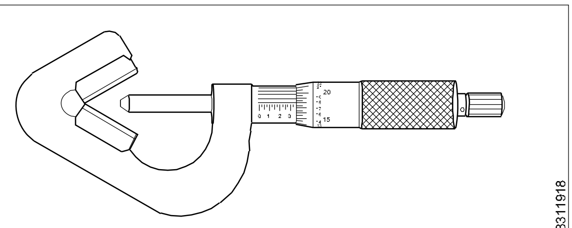


Fig 8



V-ANVIL MICROMETER CALIPER

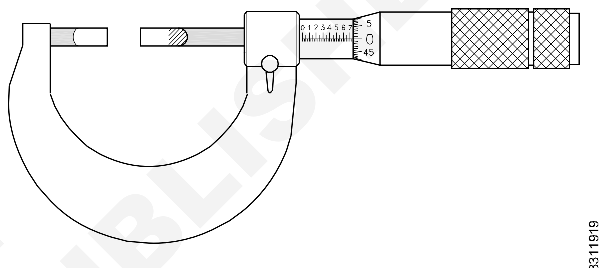
Blade type micrometer (Fig 9): It is ideally suited for fast and accurate measurement of circular formed tools, diameter and depth of all types of narrow grooves, slots, keyways, recesses, etc. It has non-rotating spindle which advances to contact the work without rotation.

Groove micrometers: These micrometers are designed for measuring grooves, recesses and shoulders located inside a bore. They have standard (12.7 mm) dia discs. 6.35 mm dia. discs are used to reach hard to get at locations inside a small bore.

All discs thicknesses are 0.75 mm and are hardened and lapped to minimize parallax and to achieve a higher degree of accuracy.

These groove micrometers measure not only thickness and spacing of grooves, but also measure from an edge to a land, or from shoulder to groove. Micrometers are satin-chrome finished throughout.

Fig 9



BLADE TYPE MICROMETER

Vernier depth gauge

Objectives: At the end of this lesson you shall be able to
- **identify the parts of a vernier depth gauge**
- **state the constructional features of a vernier depth gauge.**

Applications of vernier depth gauge (Fig 1)

A vernier depth gauge is a very commonly used precision instrument for the measuring of holes, recesses, slots and steps.

Its construction and method of reading are similar to those of a vernier caliper.

Parts of a vernier depth gauge (Fig 2)

Base (1), Graduated beam (2), Clamping screw (3). Fine adjustment mechanism (4) andVernier scale (5).

The base (anvil) is the fixed unit and serves as a datum for measurement. It also carries the vernier scale and the fine adjustment mechanism.

The beam with the main scale graduations is the sliding member or part.

Fine adjustments for measurement are made after tightening the clamping screw and the fine adjustment mechanism.

While taking measurements the base should be firmly held against the reference surface. (Fig 3)

The relief given at the end of the beam of some vernier height gauges is to avoid the seating in the corners of slots and to ensure correct reading. (Fig 4)

Remove burrs, if any, before taking measurements. Excessive pressure on the beam, while taking measurements will lift the base from the reference surface and will show wrong measurements.

Fig 1

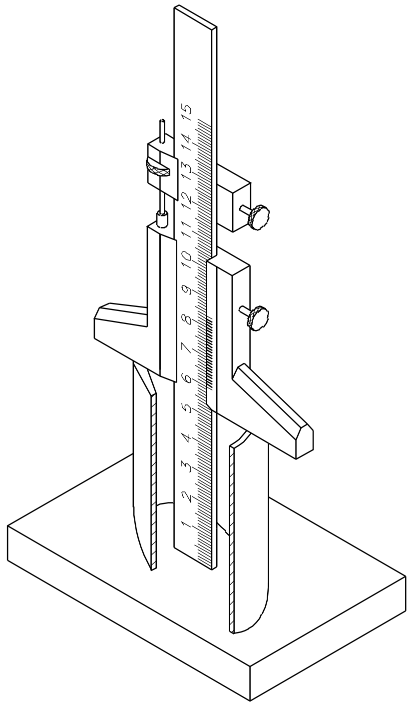


Fig 2

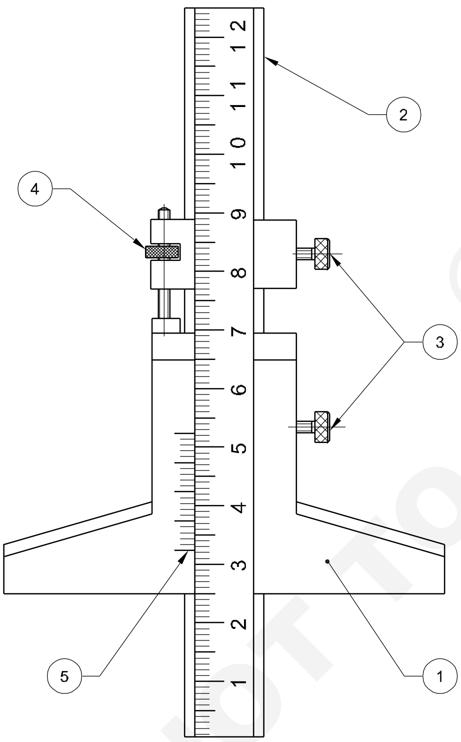


Fig 3

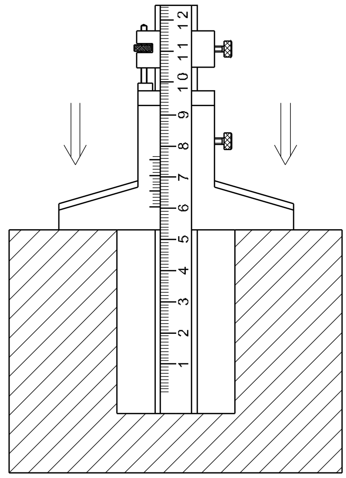
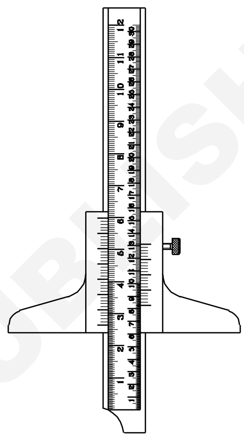


Fig 4



Special types of grinding machines

Objectives: At the end of this lesson you shall be able to
- **list the various type of special grinding machines.**

Special grinding machines

Thread grinding machines: Threads are ground on special grinding machines for accuracy and finishes no obtainable in other ways. Grinding machines both of centre and centreless type are used for this purpose.

A centre type machine looks very much similar to ordinary cylindrical grinder except that it is provided with a special wheel having grooves corresponding to the threads cut into the face. For grinding corresponding threads into the work, the table must move at the same rate as the pitch of the thread.

This is done as in the case of screw cutting on a lathe, by using a train of gears or by fitting a special shaft which has a thread cut on it to suit the lead of the thread being ground. After setting the correct speed of the table, the work is fed upto the wheel and automatic movement of the table is started. On reaching the end of the thread, the wheel automatically moves away from the work and the table returns to the starting position in readiness for another grinding cut.

Truing of the grooved wheel is done in two ways:

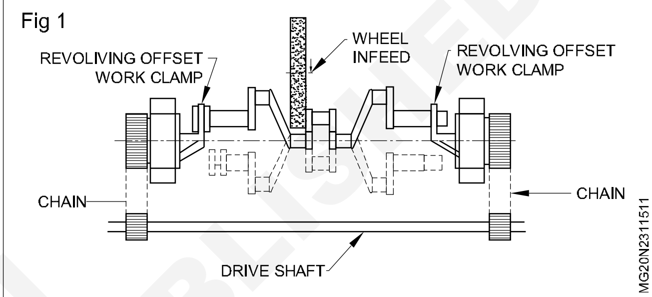
- With a diamond which is moved over the wheel at the correct pitch.
- With a hard steel wheel grooved exactly as the grinding wheel which is pressed into the latter, thus reforming the servations.

A centreless thread grinder resembles a conventional centreless grinder. However it has provision for truing circular grooves in the grinding wheel and an inclinable work rest to align the threads on the work with the grooves on the wheel. Thread grinding on this type of machine can be done very rapidly.

Cam and camshaft grinders: These are essentially cylindrical centre type grinders. The workpiece is mounted as usual between centres. The headstock and tailstock are mounted on a base on the machine ways so that they can oscillate about a centre below the work. A shortened, hardened replace of the finished camshaft is contained in the headstock. This template rotates with the work and runs against a fixed roller which makes the whole assembly to oscillate. The workpiece revolves at slow speed and keeps oscillating moving towards or away from the wheel thus generating the cam shape. The working of the machine is automatic.

Crankshaft grinders: They resemble centre type cylindrical grinders but are implemented to grind the offset pins in the throws of the crankshaft. The crankshaft is held at each end in offset clamps. (Fig 1) which are rotated from the same drive shaft by sprockets and chains. The crankshaft rotates around the axis of the pin which is being ground. In some cases grinding wheel slightly narrower than the pin is used. The wheel spindle is reciprocated for grinding full width of the pin. If the wheel as wide as the pin is used, it is fed slowly without traverse motion.

Fig 1



Way grinders: Many machine tools have hardened ways that must be ground. For this purpose single-purpose heavy grinding machines are used. Cup, ring or segmented wheels are employed. The wheel is mounted on a vertical spindle which can be tilted at an angle. In certain machines (which resemble open side planers) work table reciprocates past the vertical spindle wheel. It is possible to grind all sorts of angles on this machine. An attachment to true the grinding wheel to the desired angle is mounted on the wheel head.

Spline-shaft grinding machine: The special purpose machine is used for grinding spline shafts which are used for the sliding gears in gear boxes. The shaft is mounted between centres. An automatic dividing head which the machine is provided with, is adjusted to index any number of equally spaced divisions from two to sixteen. There are two dogs which are set to let the table move the correct stroke depending upon the length of the work.

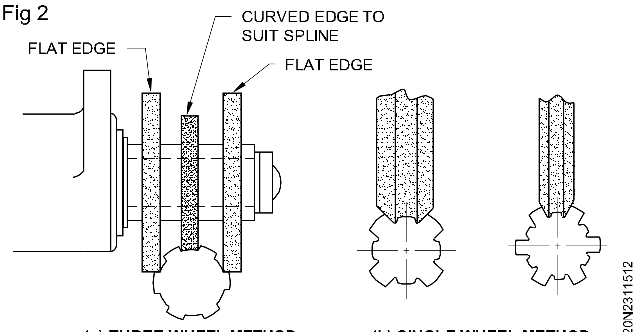
The direction of the movement is reversed when a dog comes in contact with the plunger. At the end of every stroke, the wheel gets clear of the work and the dividing head lever catches the dog causing the head to index to the next position.

Fig 2(a) and 2(b) show two different methods of grinding. In Fig 2(a) three wheels are used for grinding the splines, Machining shown in Fig 2(b) makes use of one wheel only which is true the shape of the spline with a diamond.

Rough or non-precision grinding machines

Snagging : This is the operation of removing sprues, gates, risers, fins, etc. from castings, forgings or welded structures. In this removal of excess material is of primary importance and the finish is secondary. Work is not located but only presented to the wheel or the wheel is presented to the work. Various types of machines which are used include portable, swing frame, bench, floor stand, flexible shaft grinders etc.

Fig 2



(a) THREE WHEEL METHOD (b) SINGLE WHEEL METHOD

Portable grinders: They resemble portable drills having a guard and the grinding wheel mounted on the spindle. Heavy portable grinders are used for snugging. Smaller high speed models are used in tool making and manufacturing for removing burrs and other irregularities.

Swing frame grinders - It has a horizontal frame which is suspended at its centre of gravity so that it may be moved freely within an area of operation. The motor drives the grinding wheel through a belt.

Flexible shaft grinder: It has a motor driven flexible shaft having a chuck or a collet affixed to it. It is usually mounted on a base with castors and is, therefore, portable. The chuck is capable of holding variety of tools like rotary files, drills, wheels, flat grinding discs, etc. With this equipment, grinding tools are employed or removing weld spatter or for preparing surfaces for welding. Removal of metal is the main function and finish limitation are of consideration.

Floor stand and bench grinders: They consists of a horizontal spindle carrying grinding wheels at both the ends. They are used for snagging and for off-hand grinding of cutting tools. Bigger models of the machine are fixed on the floor and hence called floor-stand. Similar forms of grinders of smaller size are mounted on a bench and, therefore, called bench grinders.

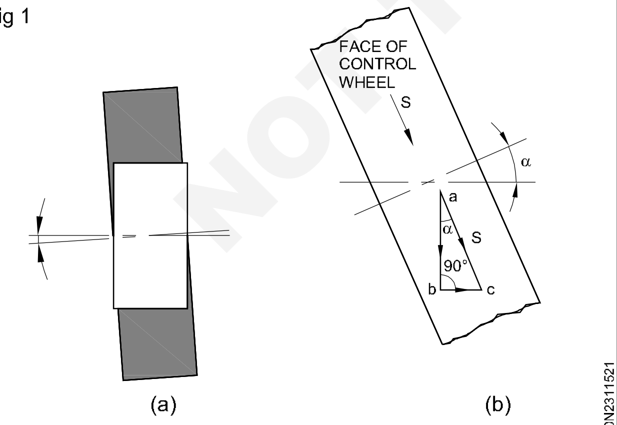
Belt grinders: These machines consists of continuous belts of coated abrasives and are used for grinding and polishing. Work is usually applied by hand against the open belt, sanding pulleys, platen, shaped forms or rolls in succession to obtain various curves and flat surfaces.

Centreless grinding

Objectives: At the end of this lesson you shall be able to
- **calculate the feed rate per revolution of workpiece in through-feed**
- **state the angle of work blade and various metals from which it is made of**
- **reason out the causes for 'taper' on workpiece due to faulty setting**
- **describe what is meant by the 'lobbing' effect and the method of eliminating it**
- **state the advantages of the centreless method over the ordinary cylindrical grinding method.**

Longitudinal feed: The feed of the workpiece across the face of the grinding wheel is obtained by inclining the axis of the control wheel as shown in Fig 1(a). This inclination results in a longitudinal movement being imparted to the revolving work. The feed rate depends on the angle of inclination (Fig 1b).

Fig 1



INCLINING CONTROL WHEEL TO IMPART FEED TO WORK

a = Angle of inclination

S = Peripheral speed of wheel

Angular velocity of triangle abc.

Angle a = a and b = 90°, speed is represented by bc, where bc = ac Sin a.

$$\text{Feed per rev} = \frac{S \times 1000 \times \sin \alpha}{\text{r.p.m of workpiece}}$$

Eg. = S = 15 m/min = 1°, rpm = 190. Determine the feed per revolution of the workpiece.

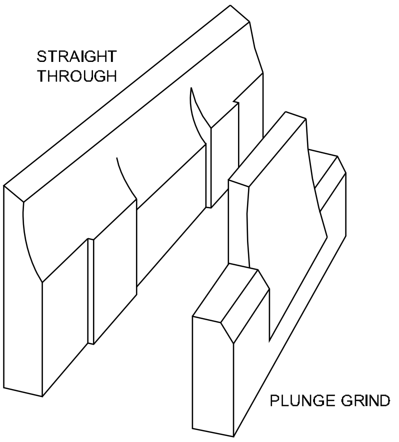
$$= \frac{15 \times 1000 \times \sin 1°}{190} = \frac{15 \times 1000 \times 0.0175}{190} = 1.38$$

1.38 mm per rev. of work.

Normally the range of adjustment provided for inclination of the control wheel is from 0° to 7°. A small inclination of 1/2° approximately is put on the control wheel when using the end-feed grinding method, for keeping enough end pressure on the work against the stop.

The work rest (or plate) and guides: The work supporting blade plays an important part in the result obtained from the machine. Its design will depend on the type of work and character of the operation. For through-feed work the blade may be longer than the width of wheels, having a projection on each side. For plunge cut grinding, the blade should be equal in length to the wheel width. (Fig 2)

Fig 2



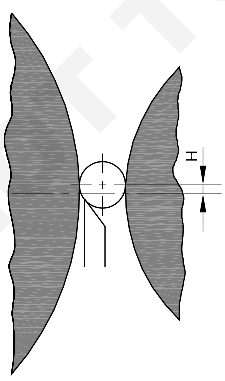
TYPICAL WORK-PLATES

The thickness of the blade must be obviously less than the work diameter, but for large work, it is not advisable to have the blade more than 12 mm thick. The inclination of the top of the blade provides, with the control wheel, work during grinding. The angle of inclination is about 30°; however, for small dia. works it is less than 30°.

The abrasion and wear on the blade surface are considerable and to provide for a reasonable life, various materials are used. They are alloy cast iron, high speed steel, bronze, stellite, tungsten-carbide.

The height of the blade must be such as to support the work above the centre line of the two wheels by about ¼th to ½th of work diameter, but with a maximum 12.7 mm of work diameter for larger work. This setting is important to prevent lobbing effect. The two wheels must not contact the work at two diametrically opposite points. (Fig 3)

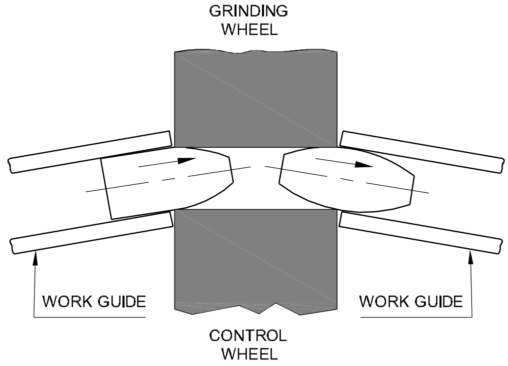
Fig 3



WORKPLATE ADJUSTMENT

Guide plates: The function of the guide plates is to ensure that the work is lined up with the wheel faces. The effect of mal-adjusted guide plates is shown (exagerated) on Fig 4.

Fig 4



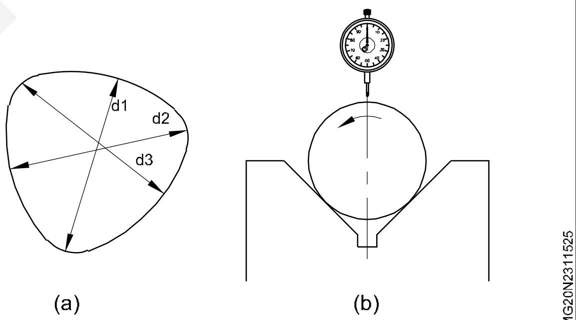
EFFECT OF MAL - ADJUSTED GUIDE PLATES

Wheel truing: Almost all the centreless grinding machines have truing and dressing fixtures incorporated for straight forward wheel truing operation. Also, machine makers supply special attachments for wheel truing to unusual shapes.

Lobbing: One characteristic of the centreless grinding process is its tendency to produce a lobbed contour (Fig 5a) instead of a true circle. This lobbing effect can be detected by Vee-block and D.T.I. checking method (Fig 5b). It is found that the greatest danger of this fault occurs when the two wheels contact the work on opposite extremities of a diameter.

For this reason only, the work blade is adjusted to lift the work above the centre line joining the centres of both the wheels.

Fig 5

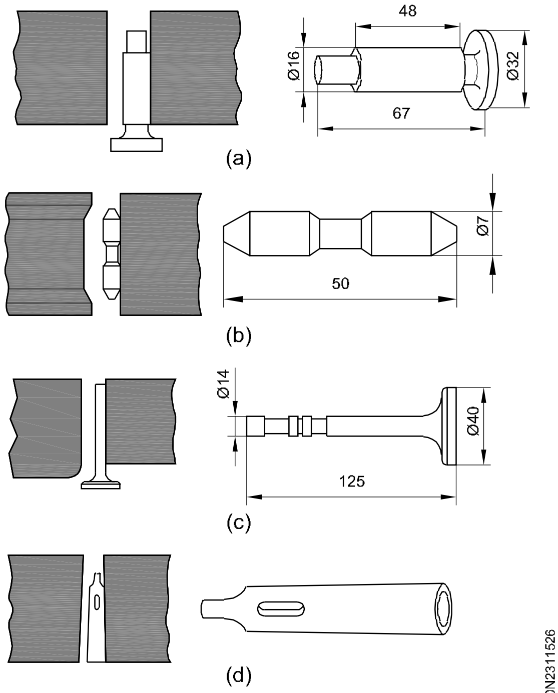


Scope of the process: Centreless grinding may be applied to works up to 150 mm diameter and length from washers to bars of 6 metres long. With the in-feed and end-feed methods, headed, tapered, stepped and formed work may be undertaken.

The limits of size and form attainable are very fine (0.0025 mm) and with suitably selected wheels the finish satisfies the most exacting requirements. The entire operation is divided into roughing and finish grinding, leaving about 0.025 to 0.050 mm as finish grinding allowance.

Naturally the applications of centreless grinding are unlimited and four representative applications are shown in Fig 6.

Fig 6



EXAMPLES OF CENTRELESS GRINDING

Advantages of centreless grinding

In through-feed grinding method, grinding is nearly continuous loading is done while the previous piece is still being ground.

The work is rigidly supported along its whole length including grinding cut, which favours heavy reductions.

There is no danger of springing long slender pieces as there is no axial thrust.

The errors due to faulty centre holes are eliminated. Hence less stock is needed to be left for grinding.

Errors in setting up and in adjusting for wheel wear are halved, since stock removal is measured in the diameter rather than on the radius.

Errors due to wheel wear are reduced.

There are few wearing surfaces in a centreless grinder and its upkeep is low.

Care and maintenance of grinding machine

Objective: At the end of this lesson you shall be able to
- **state the care and maintenance of grinding machine.**

Machine and maintenance: In the design and manufacture of a grinding machine great care is taken to ensure that the alignment of the machine frame, its bed, work head, and wheel head parts, will be retained over a long period of time.

When lifting with slings, care should be taken to follow the manufacturer's recommendations. Moreover, one should take full advantage of any assistance the makers may render during the period the machine is being brought into service.

Usually the base of the machine is provided with three feet and the machine should rest only upon these, in order that the three-point support may be maintained. When the machine has been correctly designed it is highly advisable, after the final inspectional check, to grout, it using cement. It is however, important that no wedges or packing (apart from the grounding) should be placed between the feet.

The object of grouting is to absorb any vibration that may arise from outside sources, and to carry it to the foundation the grouting is not to ensure alignment.

Foundations: A grinding machine, being a precision tool, requires a sound foundation. For this purpose a concrete bed of adequate size is the best medium. A small machine requires a minimum depth of say 2 ft. more if the soil is loose and of the made-up type.

The area dimensions should be equal to the machine base plus about 2 ft. each way. With the larger machines the depth of the concrete base should be a 3 ft. minimum more when the safe bearing load of the soil is very low.

In order to carry the load effectively it may be essential to use a grillage and spread the loading over a wide area. When choosing a site for a grinding machine a careful study should be made of the possibility of vibration from machines in the neighbourhood, or from heavy traffic passing along roads in the vicinity of the factory.

If vibrations are found to exist, and arise from the use of heavy forging presses, or drop stamps in the vicinity, or from the passage of heavy motor traffic in the adjacent roads, the wisdom of using that particular site for a precision grinding machine is open to doubt.

Tests: With the machine in position an alignment test should be made using a precision level or optical instruments to ensure that the bed is truly level in both the longitudinal and traverse directions. Adjustments should be made as and when necessary.

When using the level or the optical instrument, the checking positions should be well place and numerous; it is insufficient to take only one or two readings, particularly when the machine has a long bed.

Belts: All the belts used on a grinding machine should be of the endless type, and be such that it does not favour the creation of vibration on any portion of the machine, otherwise there is a risk that chatter marks may be found on the workpiece. A belt drive must be smooth and free from any impact loading upon the pulleys over which it must pass.

As the belt is required to be endless, then a leather, rubber, or canvas belt with a cemented lap joint may be chosen;

alternatively, and according to circumstances, one may use the endless cotton woven or rubber vee-belts. The use of metal belt fasteners on grinding machines is to be avoided.

Lubrication: No grinding machine can operated successfully if due attention is not given to its cleanliness and lubrication. Each operator should acquaint himself or herself with the lubricating points on the machine he or she operates, and ensure that all sliding and rotating parts are thoroughly lubricated several times each shift. In this manner, a few minutes a day are well spent and amply repay the trouble taken.

Daily attention should also be given to the pumps, so that the oil levels are maintained. In attention in this direction soon leads to machine troubles, poor work, and the inability to achieve the output in a reasonable time.

Cleanliness: When received from the makers, each machine should be thoroughly cleaned and the slushing grease removed; oil ways should be checked to ensure that they are free from obstruction.

With the machine working, the greatest care should be taken to keep the working surfaces clean and well lubricated. Moreover, it is necessary to keep the grinding grit out of the lubricating system, and all the oil cans used in the grinding section should be of the dust-proof variety.

The nature of the metal cutting performed on a grinding machine carries with it special hazards as regards the maintenance of accuracy.

The extremely small metal chips, tiny particles of abrasive, and the dust from the bonding material, all have a destructive influence when in contact with any machine slide or bearing, whilst the dressing of the wheel and the grinding operation itself tend to spread the particles over a wide area.

Then again the grinding fluid forms a film over the machine table and other parts and thus carries the small metal and other particles in all directions. The need for wiping down the machine at frequent intervals during the day, and at the end of the shift is imperative. Once a week at least, the machine should be given a thorough cleaning.

In order to avoid undue wear at one position on the machine table it is desirable to move the headstock, as operating conditions permit, from one position to another. It is unwise to clamp the headstock at, say, the end of the table, and never move it into a new position such practice only leads to excessive localised table wear.

Coolant bosh: Every two or three days the coolant bosh should be cleaned out and the mud removed. Good work cannot be done when the liquid is carrying, in suspension, a large amount of the grinding grit.

What is required is an adequate stream of the coolant or lubricant free from any suspended matter; hence the need for a clarifier. When conditions permit, it is wise to consider one large coolant tank and clarifier for all machines in the grinding section. Then the clean liquid is supplied to each machine at a standard temperature.

Machine centres: The machine centres should always be maintained in first class order, by regrinding as circumstances require.

Wheel slide: The wheel slide must be maintained in a clean well-oiled condition so that it will work smoothly. If allowed to become dry, stiff, and dirty, it loses that responsiveness which is essential to accurate sizing, for the slide on finishing cuts may be called to move only 0.0001 in. per pass of the wheel. 'Slide-stick' cannot be tolerated.

Wheel head: The wheel head is usually fitted with a forced lubrication system and card should be taken to ensure that this is always working satisfactorily. The following remarks apply to the successful operating of the machine.

No running adjustment should be made to the bearings until the machine has reached the normal operating temperature, which is around 120°F.

With the passing of time all lubricating oils lose some of their properties, and the bearing oil sump on a grinding machine should be drained at frequent intervals, well swilled with paraffin or petrol, and then refilled with new oil.

When the machine has been standing idle for a long period, the lubricators should be well primed with oil before setting the machine in motion, and oiling should continue until the pump commences to operate.

Machine overhaul: At times it becomes essential to have each grinding machine thoroughly overhauled. Perhaps the best conditions are when the machine is given a periodic examination once a year. If, as is very unlikely, the machine is sent back to the makers, little can be said, as normally they will do the job effectively.

When, however, the work has to be done by the machine tool fitters attached to the establishment, it is vital to see that the work is done and inspected to the same high standards as those of the makers.

In this direction it may be that the final alignment charts for the machine, taken during its erection, are available. Then they should form the basis of the work performed in the repair section, and be used by the inspection department.

When this important information is not available, then one should use the alignment charts produced by, and obtainable from, the institution of mechanical engineers or the institution of production engineers.

Steady rest

Objectives: At the end of this lesson you shall be able to
- **state what is a steady rest**
- **identify and name the types of steady rests**
- **distinguish between fixed steady rest and follower steady rest**
- **state the uses of a steady rest.**

A steady rest is a lathe accessory used to give extra support for a long slender workpiece in addition to the centre support during turning.
The most commonly used steady rests are the:

fixed steady rest

follower steady rest (travelling steady).

Fixed steady rest (Fig 1)

The figure shows the parts of a fixed steady rest.

A fixed steady rest is fixed to the lathe bed and it is stationary. It gives support at one fixed place only.

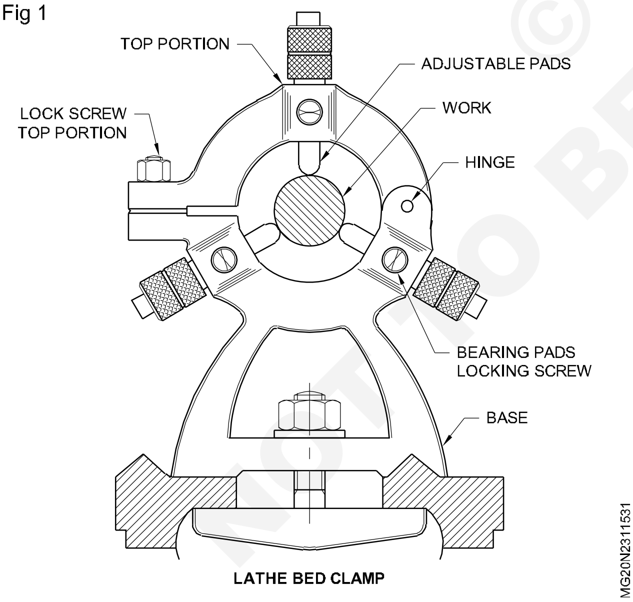
It consists of a frame containing three adjustable pads.

The base of the frame is machined to suit the inside ways of the lathe bed. The top portion is hinged at the back to permit the top to be lifted or assembled to the bottom half for allowing the work to be mounted or removed.

The fixed steady can be clamped at any desired position on the lathe bed by the base clamping screw.

The three adjustable pads can be moved radially in or out by means of adjusting screws. The three pads are adjusted on a trued cylindrical face of the workpiece.

Fig 1



Follower steady rest (Fig 2)

A follower steady is fixed to the saddle of the lathe. As it follows the tool it gives support just behind the cutting point. In the case of the follower steady the support is continuous to the entire length of cutting.

It has usually two pads. One pad is located opposite to the cutting tool and the other pad bears the top of the workpiece to prevent it from springing up.

Fig 2

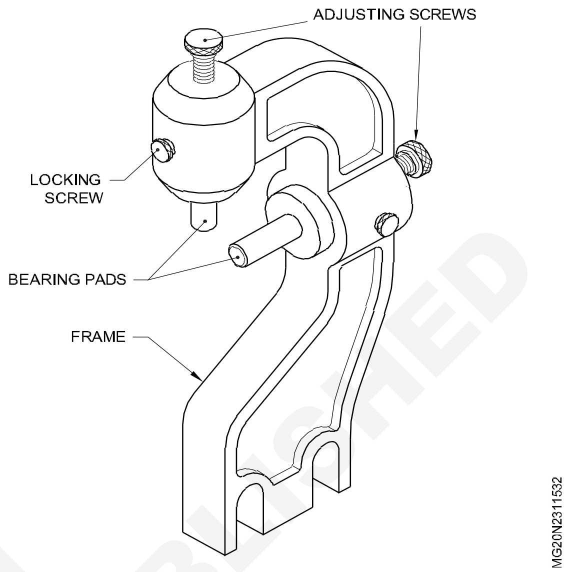
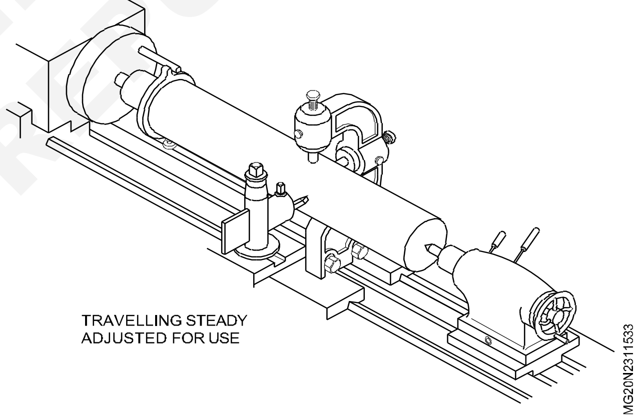


Fig 3 shows the travelling steady rest in position.

Fig 3



Desired properties of hydraulic oil

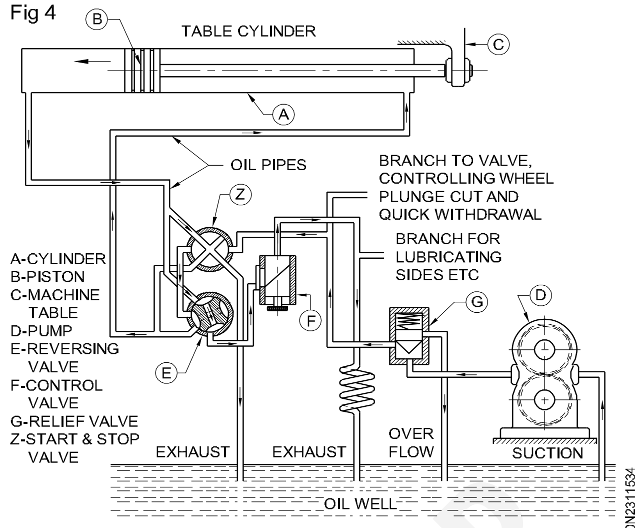
- It should not vapourize at the operating temperature.
- It must not contain or absorb air.
- It must not foam or become gummy.
- It must not cause corrosion of the moving parts.
- It must lubricate very well.
- It should have adequate viscosity even at a slightly elevated temperature.

Care and maintenance of hydraulically operated machines

- The trouble-free function of the hydraulic mechanism lies with the quality and quantity of oil in the sump just like blood in the human body. Therefore give careful attention to it. (Fig 4)

- Some of the hints given below will help you in maintaining the hydraulic drive system.
- Select the correct grade oil and maintain the correct quantity of oil in the sump as per the recommendation of the machine manufacturers.
- Do not allow the coolant to mix with the hydraulic oil through leakage.
- Do not plug the breathing holes in the oil tank.
- Periodically clean the oil fitters and strainers.
- Check the oil level through the sight glass and the oil pressure through the pressure gauge if provided.
- Report to your instructor whenever you notice any leakage of oil from the pipe connections.

Fig 4



HYDRAULIC CIRCUIT FOR OPERATING GRINDING MACHINE TABLE

Types of grinding fluid

Objectives: At the end of this lesson you shall be able to
- **state the reason for using the grinding fluid**
- **state various group of grinding fluid**
- **state the cleanliness and volume of grinding fluid required**
- **state the operational requirements for coolant**
- **state the quality need of grinding fluid**
- **state what is grinding stresses, coolant and chip formation.**

Coolants or grinding fluids

When grinding, the question arises as to the use of a coolant or lubricant, and the governing factor is the design of the machine. Assuming that due provision has been made for a tank, pump, and pipe fittings, the use of a grinding fluid is desirable for the following reasons:

- Dust hazards and their repercussions upon the health of the operators are practically eliminated.
- The wheel and workpiece are kept cool and extreme localisation of heat is eliminated.
- The coolant stream acts as a carrier of the dust and metallic particles and, in doing so, facilitates the production of a good surface finish.
- The coolant may have lubricating properties which reduce the friction due to the abrasive cutting the metal, and the non-cutting contact between the wheel and workpiece.
- Assuming that both the wheel and workpiece are flooded with a grinding fluid, the tendency of a wheel to 'load' is greatly diminished.
- The combination of the factors outlined above tends to produce an improved surface finish.

Need: The need for a grinding fluid arises from the necessity to keep the workpiece cool. With the wheel and workpiece in continuous contact, the abrasive particles remove a large number of small metal chips and much heat is generated. This must be quickly removed, as dimensional accuracy cannot be achieved unless the temperatures of the coolant and workpiece are controlled. Moreover, on fully heat-treated components, having a R_c value of 59 or over, a coolant is essential to avoid localised heating and surface cracking.

Grinding fluids: The coolants or lubricants for grinding may be roughly grouped in the following manner:

Water: Water has two important characteristics that are necessary in a grinding fluid, an excellent heat-absorption and surface wetting capacity. However the drawbacks are:

- It causes corrosion.
- Whilst the surface tension is low, water tends to hold the minute particles in suspension and these are carried back on to the surface being ground; water lacks any antiseptic powers and in time may become unhealthy.

Soda water: When half a pound of soda (Sodium carbonate) is added to one gallon of water the corrosive tendency is somewhat reduced. The liquid has a lower surface tension than plain water, hence the particles are not retained so long in suspension and are more readily precipitated. Associated with soda water are the following drawbacks:

- Being an alkaline, strong soda solutions give rise to eye and skin irritation, therefore operators do not favour working with such corrosive liquids.
- Alkaline solutions will react with the bonding material of the silicate, resinoid and shellac wheels and cause premature loosening of the abrasive.
- Soda solutions strip the paint off the machines.

Plain soap solutions

Ordinary soap solutions absorb less heat than either plain or soda water. The foam holds a large portion of the dust, dirt and abrasive particles in suspension, and the liquid will become slimy and septic; moreover, when this grease is deposited upon the hands it makes it difficult to hold the articles firmly.

Oil and water emulsions: Various types of animal, vegetable and mineral oils, together with an antiseptic, are blended and used with soap and alcohol to form a grinding liquid. As oil is present the solution possesses some lubricating properties and will not quickly corrode the freshly ground surface or the exposed portions of the machine. Water is added to bring about the desired dilution, hence the cooling and wetting properties of the liquid are fairly good. When mixing, the grinding solution should be added to the water, as this procedure ensures a homogenous oil-in-water emulsion.

Paste emulsion: A grinding solution may be prepared using paste compounds based upon (1) Soda soap, or (2) a potash soap compounded with a light mineral oil. The paste is used with water in proportions which suit the particular operation.

Straight mineral oils: The development of gear and thread grinding machines has led to the introduction of a straight mineral oil as a grinding fluid. The oils used for grinding are blended chemically with a suitable antiseptic, also with non welding substances such as sulphur and chlorine.

Then, given a fat free oil, the wheel cuts freely and does not clog or glaze. This class of grinding fluid gives an excellent surface finish, in that the blended mineral oil possesses some lubricating properties; the grinding oils are used in large volumes to keep the workpiece fairly cool; then the wheel is free from loading, smooth-cutting, needs fewer dressings and so has a longer life.

A factor which favours the use of a grinding oil is where the cuts most, of necessity, be light, if the fragile wheel form is to be retained over a reasonable period. Operational conditions, as when thread grinding, prevent the development of excessive heat, so that the lower heat-absorption powers of the oil do not present any difficulties.

For general grinding mineral oils are unsuitable. When being used for finish form grinding, centreless lapping and similar purposes, all objectionable fumes or spray should be withdrawn by a suitable exhaust system. The filtering of the oil should be efficient and the supply, at all times, must be adequate. Storage temperature for a grinding oil is about 55°F. (minimum)

Cleanliness: During a normal days grinding a large volume of dust, dirt, abrasive and metallic particles are carried away from the wheel face to settle in the 'suds' bosh.

Therefore, steps must be taken to remove this sediment at frequent intervals, at least, every two days, otherwise the volume of liquid available will diminish, be subjected to a temperature rise and carry an excess of suspended matter to the wheel face. It is then impossible to produce first-class work.

Volume: The delivery of a liquid for external grinding must be in ample volume. A wheel, say, 14 in. diameter, needs, per minutes, perhaps, five gallons of the liquid per inch of wheel face. With larger wheels the volume should be increased for an ample flow of a coolant across a grinding wheel face never yet spoil any work, or held up production. Given a good flow of coolant, the workpiece is kept cool, the quality of work improved, whilst the machine is cleaner when the liquid carries the debris into the bosh.

For internal grinding, the conditions are different and the use of a grinding fluid needs careful consideration as difficulty arises (1) from the need to dry the article, and test for size; 2) with the liquid remaining on the article, there are abrasive particles on the surface and when they make contact with the wheel, the latter cannot cut freely whilst the loose material scratches the ground surface. Hence, with internal grinding, the question of using a coolant must be decided when all relevant factors are available. On occasions it may be advisable to play the coolant over the external surface.

Operational requirements: The operational requirements for a coolant vary according to the wheel to be used, the workpiece material and the type of grinding. When grinding steel, and some of the irons, soda water may be used for both cylindrical and surface grinding one to five pounds of soda per 10 gallons of water is used.

The various grades of 'suds' are chosen for every class of grinding, external, internal, form and surface; the ratio of the emulsion varies, say, from ten to one, to sixty to one; the higher ratio being adopted when there is no risk of corrosion.

Cast iron is best ground using the lower water ratio, as this metal has a tendency to rust quickly. With a nickel chromium steel the sixty to one ratio meets operating conditions, as the material has a reasonable resistance to corrosion. With centreless grinding, and if using a rubber regulating wheel, the water content would be at the maximum, so that the oil content will not soften and destroy the bonding material.

When grinding steel, a solution from a paste compound will occasionally, give an improved surface finish in comparison with the finish obtained using a soluble oil mixture.

For centreless grinding, the grinding fluid should not 'gum' on the regulating wheel. If this does happen, accuracy cannot be maintained. Moreover, the grinding fluid should not cause the decomposition of the bonding material.

If grinding the light metals, including aluminium and its alloys, the possibility of reaction of the coolant upon the metal must be considered. Alkaline mixtures attack and corrode the surface of the light metals.

Paraffin, kerosene, turpentine and the low viscosity oils prove useful, as they do not stain the surface of the metal a suds compound can also be used.

Wheel balance: The balancing of abrasive wheels has been dealt with on page number 9, so that there is no need for recapitulation. It is perhaps necessary to stress the need to run the wheel, at the end of each shift, for a suitable time without any coolant playing upon its surface. Only in this way can the absorbed liquid be thrown out of the wheel.

Failure to perform this task causes the liquid to settle at the lower portion of the still wheel, so that immediately the machine is started the wheel is in an out-of-balancing condition.

Honing: For honing one may choose a hundred-to-one solution of a soluble oil emulsion. Other coolants or grinding fluids are paraffin, lard oil, and a paraffin mixture, kerosene, turpentine and a mineral 'seal' oil.

Lapping: For lapping, use any of the liquids mentioned for honing; conditions within each establishment will determine the choice when using diamond powder, olive oil may be chosen.

Superfinishing: With the micro or superfinishing process the main action of the liquid is lubrication, the cooling powers being secondary. Hence a sulphur containing oil or a mixture of mineral oil and paraffin or kerosene proves satisfactory.

Diamond grinding: When using a diamond wheel, the need for a coolant is not so urgent; only sufficient liquid is required to keep the surface wet. The best cooling medium is water, but the use of a dilute 'suds' solution eliminates the risk of corrosion. For finish grinding a soluble or light machine oil has the tendency to improve the finish, but greater care is needed as these types of oil unless the delivery per minute is increased.

Qualities needed: When the qualities needed in a grinding fluid are grouped together, the following list is obtained:

- Rapid cooling action.
- Low surface tension, as all suspended matter should be quickly precipitated into the bosh.
- Transparency, enabling the workpiece to be seen through the stream.
- No chemical reactions when in contact with the abrasive or bonding material.
- Stability, as the liquid should not (1) decompose (2) create bad odours (3) become septic (4) separate or precipitate from the solution.
- The coolant can readily be distributed over the contact zone.
- The fluid should delay any corrosive attack.
- The action of the coolant should assist the abrasive to produce a good surface.
- The liquid should be free from any tendency to 'gum-up' the pipe lines, steadies or regulating wheels nor should it form a sludge.
- Each batch should be uniform with the preceeding one.
- An emulsion should readily mix with water at room temperature long periods of agitation are undesirable.
- When in use, the solution must be free from foaming.
- The liquid must be non-inflammable.

Grinding stresses: The general effect of the various coolants, when grinding may be summarised as follows:

- If a water solution containing a rust inhibitor or miscible oil is being used, the stresses created are similar to those occuring with dry grinding.
- A straight mineral oil reduces the maximum tensile stress.
- A straight mineral oil gives rise to increased compressive stresses when measuring close to the surface.
- As far as the residual stresses created are concerned, the effectiveness of a grinding fluid depends upon the liquids ability to reduce the thermal and mechanical stresses created during the actual removal of the metal. That is, the actual cooling of the component around the grinding zone, immediately after the removal of the metal, is secondary to the lubrication characteristics.

Coolant and chip formation: Basically, an adequate supply of a grinding fluid is essential to keep the work cool. It also enables a comparison to be made between the chip formation as produced by the grinding processes.

Given dry grinding of steel components, the tendency is for the heat generated by the cutting speed of the abrasive particles, as they move over the surface of the component, to ignite the minute metal chips.

Assuming an adequate supply of a suitable grinding fluid, then, as with other metal cutting processes, the temperature of the parent body and that of the metal chips is greatly reduced, so that when due allowance has been made for the minute dimensions of each chip, the shape is very similar to the swarf produced when turning or boring.

When using a reasonably powered microscope an examination of the metal chips produced by the wet grinding technique will show (a) globule of metal that have been fused by the high grinding temperature and (b) stringy metallic chips similar to those obtained when turning. In the instance (c) the cooling action of the grinding fluid has prevented the minute metal particles from igniting. Hence, given a satisfactory flow of a fluid, the grinding process is very similar to that of turning.

Work holding devices - 1

Objectives: At the end of this lesson you shall be able to
- **name the work-holding devices used in grinding**
- **state the uses of each work - holding devices**
- **state the types of magnetic chucks and their description**
- **state the demagnetisation.**

Work holding: The most usual methods of holding work on the surface grinder are as follows: By clamping direct to the table, to an angle plate or some such fundamental set-up; Holding in a vise; Holding in some form of special fixture; Magnetic chuck.

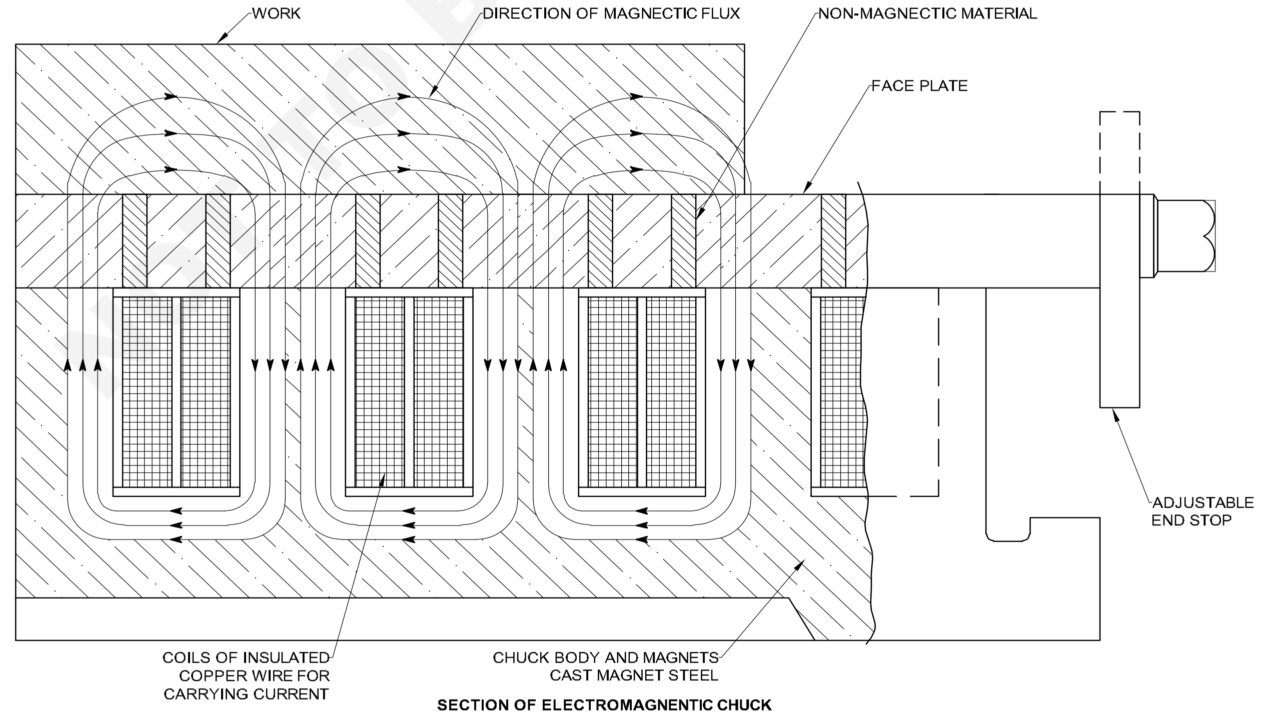
The first three methods are used in cases where the grinding to be done is not of the form in which a face has to be ground parallel with another face, both being external and of reasonable dimensions. For ferrous work on which this last condition holds good the magnetic chuck is employed, and as a large proportion of the output of surface grinders is of this type the magnetic chuck is a common auxiliary to the machine. Some machines have such a chuck incorporated in the design as the permanent table, and if a vice or fixture has to be used it must be rested on and held to this chuck by the magnetic force.

The vice: The general design of vises used on surface grinders is on the same lines as for milling machines, except that they are generally rather smaller and not so commonly equipped with a swiveling base. Rigidity and freedom from vibration are important so that grinding vises are as low and squat as possible. For angular work the universal vice is useful.

The magnetic chuck: Magnetic chucks are made in circular and rectangular form in sizes ranging from approximately 150 millimeters to 2 meters diameter for the circular, and 150 millimeters to 2 meters long in the rectangular shapes. The smaller sizes of such chucks may be obtained either with permanent magnets or as the electromagnetic type.

Electromagnetic chucks: These use the principle of electromagnetism by which a bar of iron, when enclosed in a coil of wire, is magnetized when an electric current is passed through the coil, its end having N and S polarity according to the direction of current flow in the coil. In its construction the body or base of the chuck is incorporated with pole pieces of special high permeability magnet steel. These pole pieces are surrounded with coils of insulated copper wire for carrying the electric current, the direction of winding being arranged so that the upper ends of the magnets have alternate N and S polarity. The top plate or pole face of the chuck is made up of alternate steel, and non-magnetic segments, the object being to break up the magnetic continuity so that the magnetic lines of force, instead of finding a path through the plate, are compelled to emerge from its upper surface and pass through the object requiring to be clamped. A diagram of a chuck, showing the direction of the magnetic flux, is shown at Fig 1.

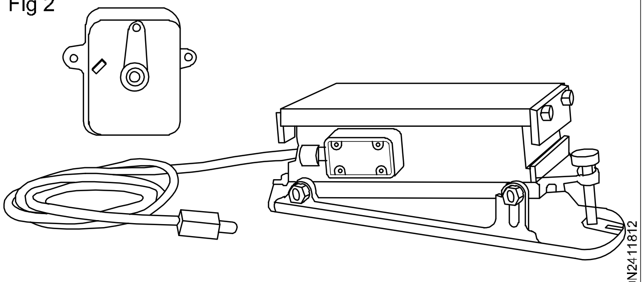
Fig 1



SECTION OF ELECTROMAGNENTIC CHUCK

The current to these chucks must be controlled by a special switch, and one of these is shown at Fig 2. The chuck may be switched on by moving the handle to either side, and when switching off, if it is reversed to the opposite side first, the reversal of current effecting a more complete demagnetization of the poles than merely disconnecting the current.

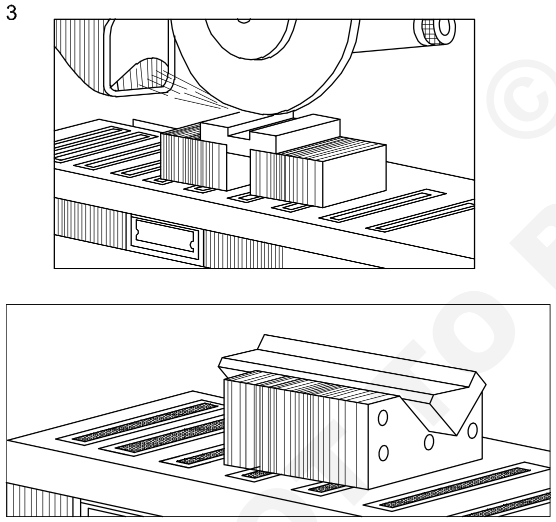
Fig 2



MAGNETIC CHUCK (TILTING PATTERN) WITH OPERATING SWITCH

If it is necessary to hold a component on the chuck with packing between the work and chuck face a packing of solid, continuous steel is useless, as it absorbs the whole of the magnetic flux leaving none emerging for the purpose of holding the upper piece. By using a packing made up of laminations of magnetic and non-magnetic material (e.g. steel and brass) some of the magnetic flux emerges and is available for holding work either to the upper surface or sides of the block (Fig 3). Electromagnetic chucks must be supplied from a direct current supply and are usually made for voltages of 100 -110 and 200 - 250

Fig 3



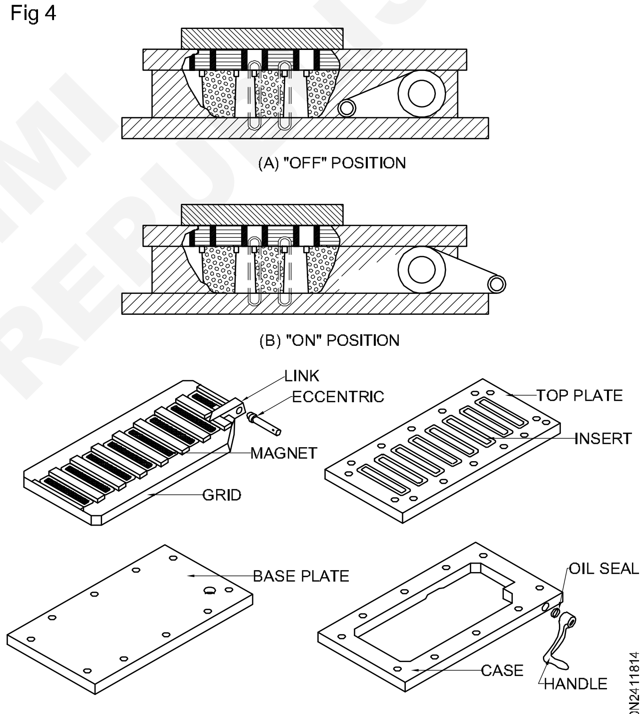
HOLDING IRREGULAR WORK VIA LAMINATED PACKINGS

The permanent magnet chuck: The general shape, construction and appearance of this chuck is similar to the electric type, the principal difference being that the magnets, instead of deriving their magnetism from an electric current, are permanently magnetized. For this purpose they are made of a special alloy steel having the property of taking on a high stage of magnetization and retaining it over a long period. In the 'Eclipse' chuck the magnets are assembled in a silicon iron grid to form a magnetic 'park'. This grid forms the power unit and the chuck is made up by enclosing the grid in a non-magnetic metal casing which is assembled between base and top plates, both of deal mild steel, the top plate having inserts of Armco iron separated magnetically from the steel plate by a layer of white metal.

The grid has a small longitudinal movement controlled by an eccentric shaft operating through a link. The above details may be followed from Fig.4 which shows the dis-assembled units of the chuck.

An interesting feature of the chuck is the method of switching it on and off, and this is achieved by a small movement of the grid. When this is in the 'on' position the solid members of the grid line up with the pole inserts of the top plate (Fig. 4(b)). In this position the magnetic flux follows the path shown dotted, i.e. S into outer pole (top plate), N into base plate, through the grid into the inner pole (insert), the circuit being completed by passing through the work. In the 'off' position (Fig. 4(a)) the magnetic pack has moved so that the grid and pole inserts are out of line. The path of the magnetic flux now is still through the base plate and grid, but the circuit is closed through the top plate and inserts instead of through the work piece.

Fig 4



DETAILS OF 'ECLIPSE' PERMANENT MAGNET CHUCK

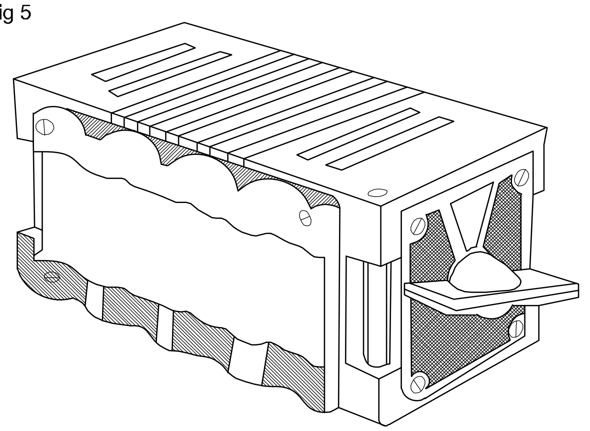
A very useful chuck in the "Eclipse' range is the 'Minor', a small portable article with working surfaces 125 x 62 mm, having a mass of about 4 kg. Both upper and lower faces may be magnetized, and the switch shown on the end is arranged so that the top, or bottom, or both, may be energized.

This chuck is useful not only for grinding operations but also for marking out, filing, supporting a dial indicator and the hundred and one other cases where thin fragile articles must be held (Fig 5).

In comparing the relative merits of the two types the permanent magnets chuck is independent of a DC electric supply, and of the special generation or rectification apparatus necessary in a plant supplied only with AC Since the chuck is self-contained, without any leads to an electric supply, it is more portable and may be set up on any machine where it might be useful.

In favour of the electric type there is practically no limit to the size or shape to which a chuck can be constructed, and for certain machines a circular chuck may form the permanent table. Provided the supply voltage is kept within 10% of its correct value the holding power of the chuck will not vary.

Fig 5



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The best permanent magnets tend to lose some of their magnetism, with time, particularly if subjected to shock or vibration, and the power of such a chuck may fall after some years of service necessitating re-magnetizing of the magnets.

Demagnetisation: After a component has been on a magnetic chuck it is necessary to demagnetise it as the residual magnetism may be detrimental in service. Hardened steel tends to hold its magnetism more than soft steel and cast iron, but all metals should be treated. The operation is performed by subjecting the article to an alternating magnetic field which quickly destroys any residual magnetism, and a demagnetiser consists of a powerful electromagnet energised by an alternating current supply.

On the platen type magnetised articles are placed on the platen and so become influenced by the field of the magnet located underneath. The armature type demagnetiser has two external laminated magnetic poles and articles may be treated by passing them through the space between. This type is useful for dealing with work which cannot conveniently be placed on a flat plate.

Work - holding devices - 2

Objectives: At the end of this lesson you shall be able to
- **name the work - holding devices used in grinding**
- **state the uses of each work - holding devices.**

In grinding -different work-holding devices are used to hold the work piece in position. The work-holding devices used in grinding are

- Centres
- Magnetic, mechanical or pneumatic chucks
- Spring collets
- Face plates or fixtures.
- Steady rests
- Mandrels

Holding work between centres

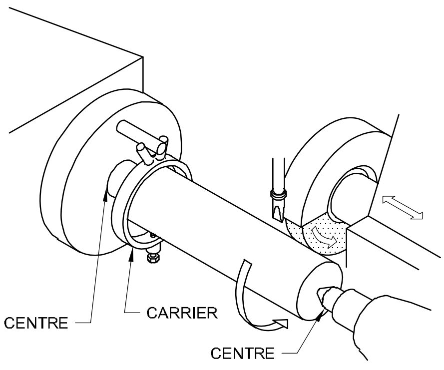
Centers are used to support the workpiece while performing an external cylindrical grinding operation on a plain or universal grinding machine. The workpiece is rotated by a carrier. (Fig 1)

The work is to be provided with a centre drilled hole on the face of the end. Carbide tip centres are used to support the work. The hard tip is wear resistant.

The plain centre is used in workhead and half centre is used in tailstock. The workpiece is rotated by a carrier.

Proper lubricant of centre hole is important

Fig 1



WORKPIECE HELD BETWEEN CENTRES

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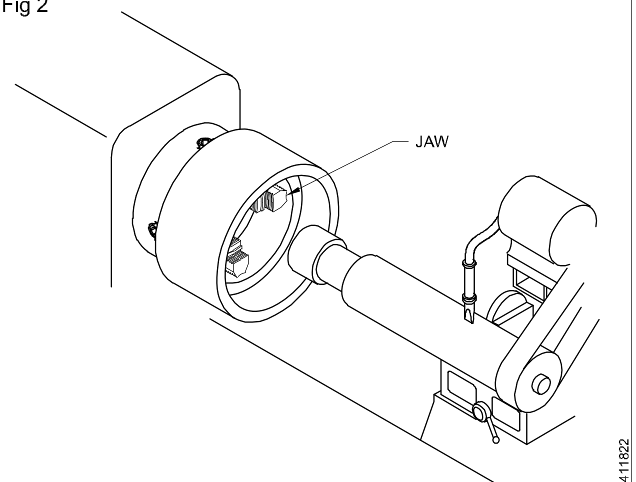
Mechanical chucks

These are used for holding short workpieces not suitable for supporting between centres. Centring of the workpiece is carried out by adjustment of the position of the radial jaws.

The jaws also clamp the workpiece in position. In a three-jaw self-centring chuck, the jaws are moved in uniform by operating a key.

Three or four jaw self-centring or independent jaws may be provided. The most accurate centring of the workpiece is obtained using a four-jaw independent chuck. (Fig 2)

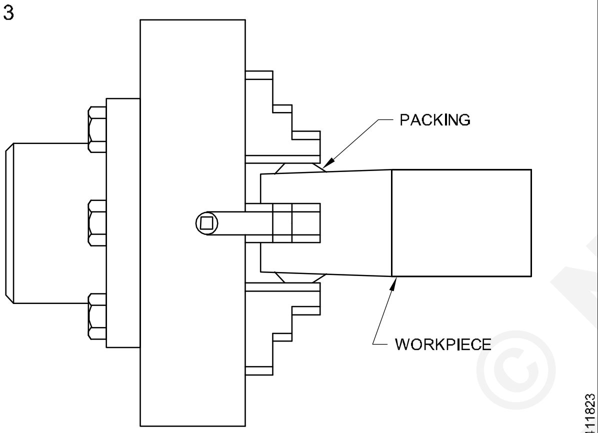
Fig 2



WORKPIECE IN A FOUR JAW MECHANICAL CHUCK FOR AN INTERNAL GRINDING OPERATION

To protect the workpiece from damage by the jaws, or when holding tapered workpieces, packing pieces of soft metal are used. (Fig 3)

Fig 3



PACKING PIECES USED TO SECURE A TAPERED SHAFT IN A MECHANICAL CHUCK

The workpiece is set in a four-jaw chuck using a dial indicator. The dial indicator is placed in position as shown (Fig 4) and the jaws adjusted individually for minimum eccentricity, or out of true, of the workpiece. The indicator is then moved to position B as shown and the position of the workpiece in the chuck adjusted again. This process is repeated until the required accuracy is obtained.

Holding in a magnetic chuck (Fig 5)

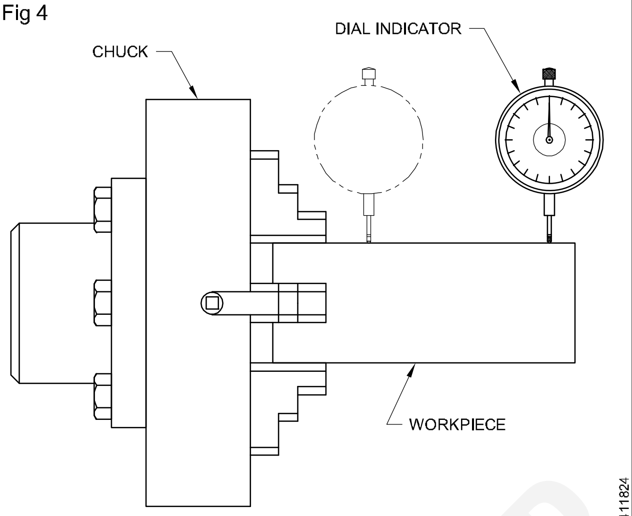
A magnetic chuck may be used to hold ferrous workpieces during cylindrical grinding operations. some magnetic chucks are designed to screw onto the headstock spindle and some to be clamped to a face plate.

The field generated by permanent magnets in the body of the chuck holds the work firmly on the chuck face.

This force is sufficient to make centring of the work difficult. A soft faced hammer may be used to carefully tap the workpiece and adjust its position as the chuck is rotated.

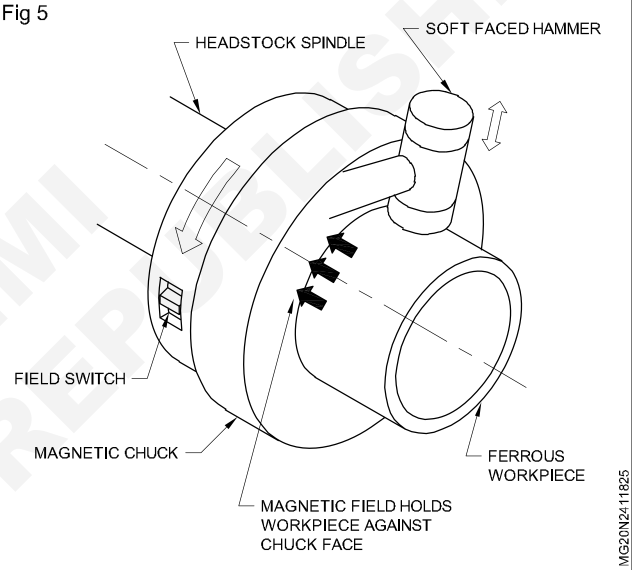
Holding the workpiece in a magnetic chuck is also useful where the workpiece has an unusual shape not suited to other mounting methods.

Fig 4



SETTING CYLINDRICAL WORKPIECE IN CHUCK USING A DIAL INDICATOR

Fig 5



The face of the chuck will attract metal particles. These must be cleaned off to prevent damage to the face of the chuck and faulty centring of the workpiece.

Caution

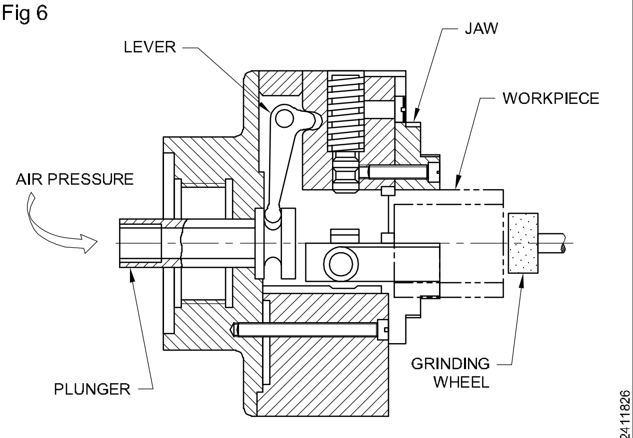
Turn the field off before locating the workpiece. The magnetic field action is quite strong and may snatch the workpiece from your hand as you approach the chuck. Do not forget to turn the field on again before releasing the workpiece.

Pneumatic chucks (Fig 6) : These are similar to mechanical chucks, but movement of the jaws is controlled by air pressure. They are used with workpieces of material hard enough to withstand the high jaw pressure produced.

The pressure on each jaw is constant and setting up can be performed quickly.

The chuck jaws are moved by levers within the chuck. The levers are moved in turn by a plunger which is operated by air pressure from a source remote from the machine.

Fig 6



PNEUMATIC CHUCK HOLDING WORKPIECE FOR INTERNAL GRINDING

Spring collets: Spring collets are similar to chucks.

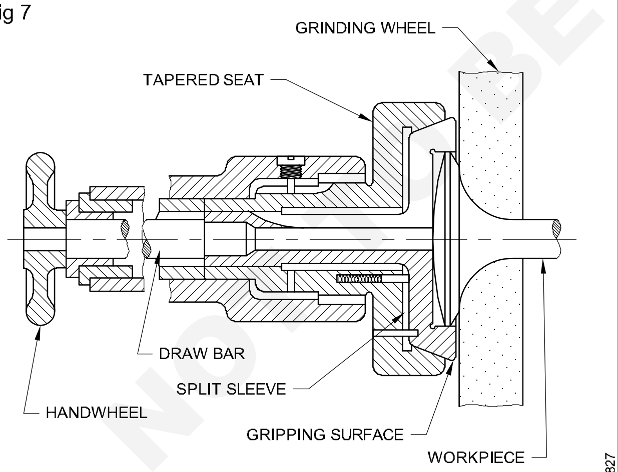
They are used for holding small parts where only light grinding loads are applied.

The collet has a split sleeve with a tapered conical end fitting in a similarly tapered seat. Lengthwise movement of the collet causes expansion or contraction of the workpiece gripping surfaces. This movement is made by rotating a handwheel and drawbar fitted to the collet. There are two types of spring collet;

- External spring collets
- Internal spring collets

External spring collets (Fig 7) : The workpiece gripping surfaces are arranged to grip the external surface of a workpiece in response to movement of the collet. The workpiece gripping surfaces of an external spring collet may be shaped to suit a particular workpiece.

Fig 7

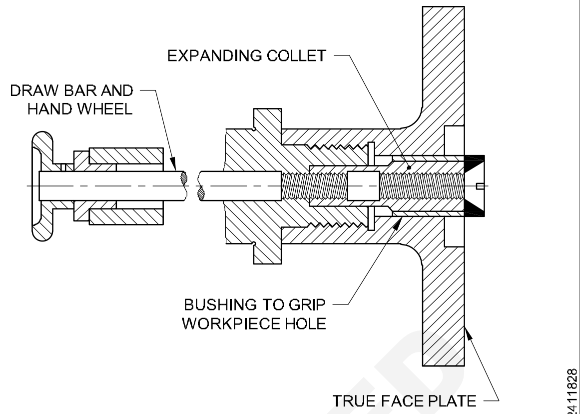


CROSS SECTIONAL VIEW OF EXTERNAL SPRING COLLET GRIPPING AN ENGINE VALVE. THE GRIPPING SURFACE HAS BEEN SHAPED FOR THIS SPECIFIC OPERATION

Internal spring collets (Fig 8) : The workpiece gripping surfaces of internal collects are arranged to grip the internal surface of a hollow workpiece. Their operation is otherwise the same as that of external spring collets.

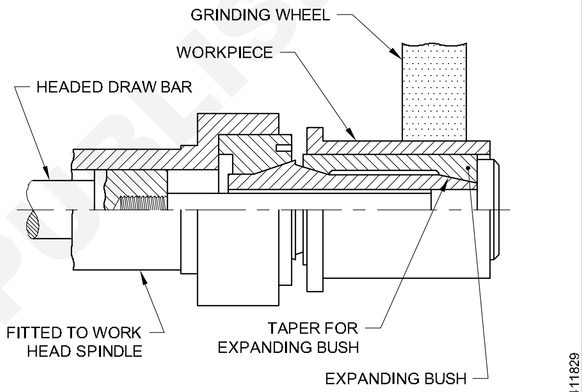
In a modified internal collet, an expansion bushing is included to grip the hole is washers, saw blades or other circular cutters. By operation of the handwheel the gripped workpiece is drawn workpiece for grinding. The bushing is removable to permit fitting of different sized bushing to the collet. (Fig 9)

Fig 8



DRAW-IN SPLIT COLLET FOR HOLDING THIN CIRCULAR WORKPIECES

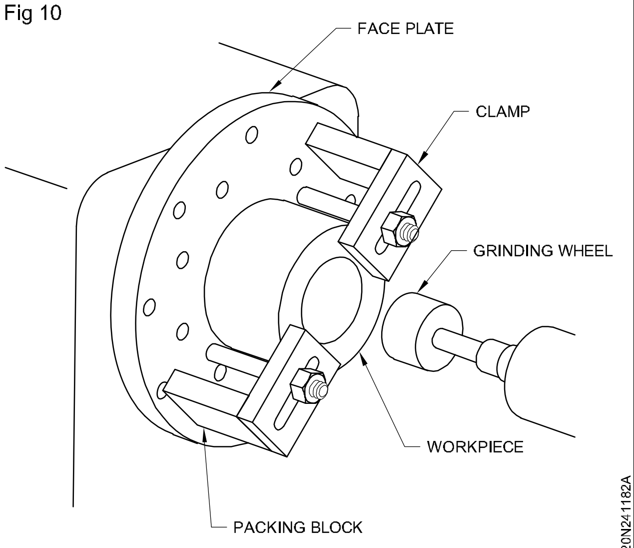
Fig 9



PART SECTIONAL VIEW OF INTERNAL SPRING COLLET GRIPPING HOLLOW WORKPIECE

Holding workpieces in a fixture (Fig 10) : This method is commonly used for internal grinding operations. It also has limited use in other grinding operations.

Fig 10



USE OF A FIXTURE FOR AN INTERNAL GRINDING OPERATION

The workpiece is fixed to a machine face plate using packing blocks and clamps. The clamps are fixed by bolts passing through the face plate. The workpiece is centred accurately on the plate before the bolts are firmly clamped.

Caution (Fig 11)

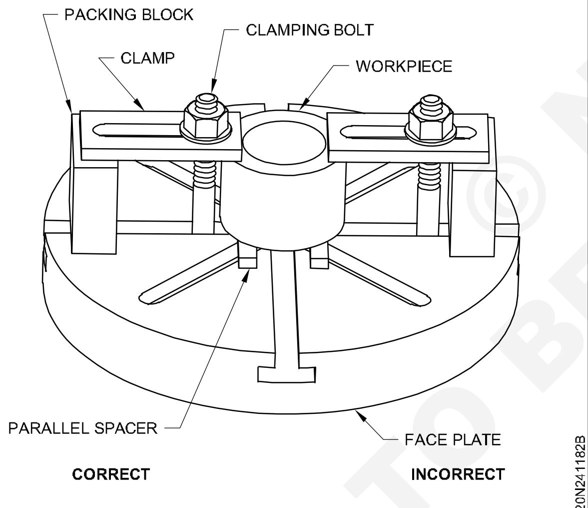
Use the correct method of clamping. This will avoid damage to the workpiece, inaccurate grinding, machine damage and personal injury.

- **The clamp must be parallel to the face plate. Select packing blocks of the correct height.**
- **The bolts must be fixed close to the workpiece to secure it firmly.**
- **If parallel clearance blocks are used, position them clear of the path of the grinding wheel.**

Holding work in a steady rest : There are two types of rest used in grinding operatings;

- The fixed steady rest
- The back steady rest.

Fig 11



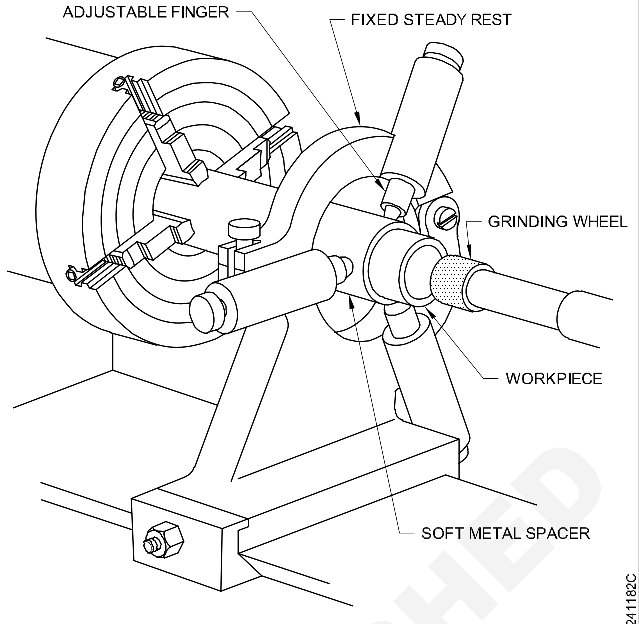
CLAMPING WORKPIECE TO A FACE PLATE

The fixed steady rest (Fig 12) : The fixed steady rest is used to support in end of a workpiece as in internal grinding, for example in this case, one end of the work is held in a mechanical chuck and the other end supported in the fixed steady rest.

The fixed steady rest has adjustable fingers to centre and support the workpiece. The fingers are adjusted to allow the work to turn freely without scoring its surface.

A soft metal spacer wrapped around the wrokpiece and placed between the fingers and the workpiece will also prevent scoring. The spacer is held in position around the workpiece by the jaws of the mechanical chuck.

Fig 12



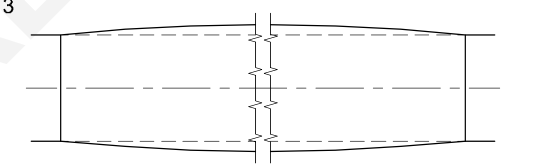
WORKPIECE SUPPORTED IN A MECHANICAL CHUCK AND A FIXED STEADY REST

The back steady rest (Figs 13,14 & 15)

The back steady rest is used wherever possible to support workpieces during cylindrical grinding operations.

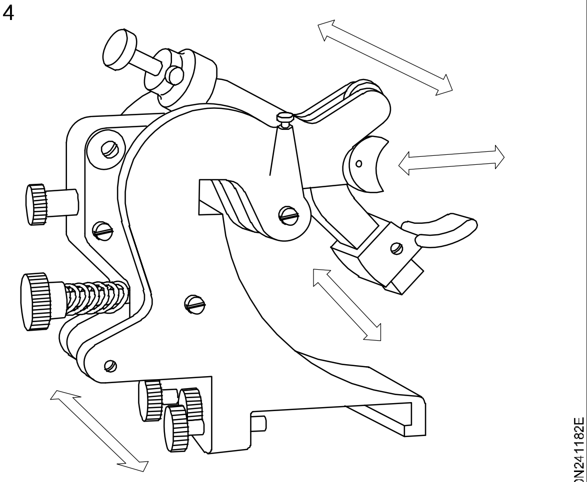
The use of back steady rests ensures that the workpiece is ground truly cylindrical. Without rests, the axis of the workpeice will be distorted by the pressure of the grinding external surface on the workpiece. (Fig 14)

Fig 13



TAPERED SURFACE ON CYLINDRICAL WORKPIECE WHEN BACK STEADY RESTS NOT USED

Fig 14



BACK STEADY REST

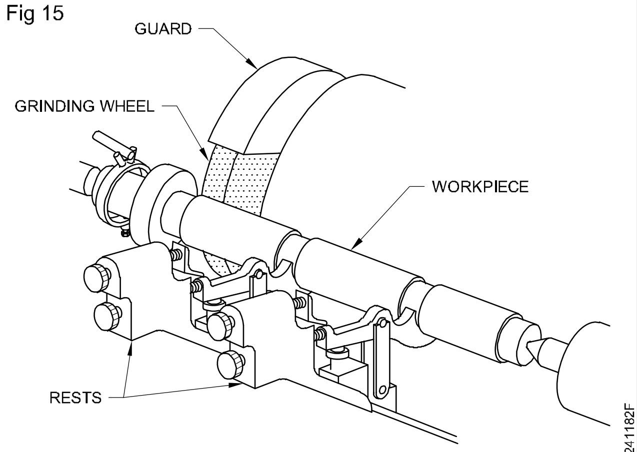


Fig 15

BACK STEADY RESTS IN USE DURING CYLINDRICAL GRINDING OF LONG THIN WORKPIECE

The proper number of back steady rests to use varies from case to case and must be determined by experiment. Heavy workpieces may be unsupported by back rests, but better accuracy will be achieved if back rests are used.

Holding work in a mandrel (Figs 16&17): A mandrel is a solid shaft with a centre-drilled hole at each end and a very slight taper of about 1:2000 from one end is the other.

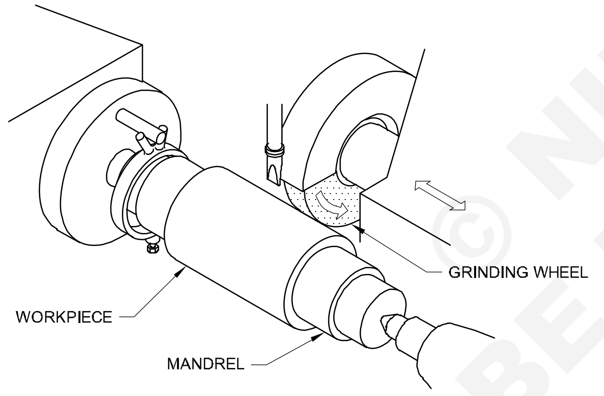


Fig 16

BUSHING SUPPORTED ON A MANDREL

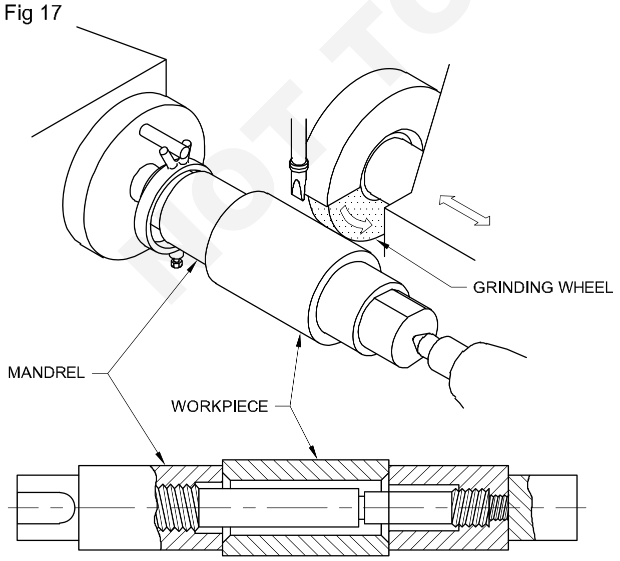


Fig 17

TUBE HELD BY AN END CLAMPING MANDREL

Mandrel are used to support accurately bored workpieces such as bushings, for external grinding.

A mandrel is inserted in the workpiece bore and the workpiece tapped onto the mandrel with a soft-faced hammer until a firm fit is obtained. The mandrel is then mounted between the grinding machine centres.

For hollow workpieces such as tubes, an end clamping mandrel is used to prevent distortion of the workpiece during grinding.

Wheel guards (Fig 18) : All grinding machines have a guard of strong metal fitted around the grinding wheel. Its purpose is to protect the operator from possible serious injury should the wheel break and to contain grinding matter and coolant liquid within the machine.

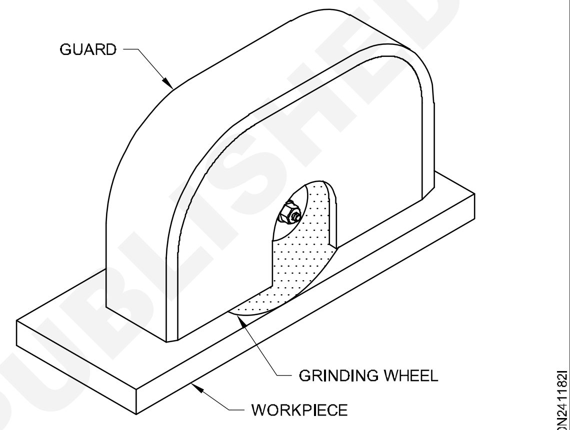


Fig 18

GUARD FITTED TO GRINDING WHEEL

Warning

Except when performing certain internal grinding operations where the workpiece itself offers adequate protection, a grinding machine must never be operated without a wheel guard in position.

Precaution to be taken before grinding

- **Always wear safety goggles**
- **Ensure the safety guards properly placed**
- **Before starting the machine the wheel must be inspected**
- **Ensure the holding devices are sufficient tightned**
- **Be sure to allowable clearance between hand and grinding wheel.**
- **Before starting of hydraulic system do not hold the job in between centre**
- **If the work is heavy shut the machine down when placing the work between centres.**

Cutting speed, feed and depth of cut

Objectives: At the end of this lesson you shall be able to
- **state what is wheel speed, work speed, table traverse, and depth of cut**
- **calculate machining time**
- **state grinding allowance.**

Cutting speeds and feeds

Wheel speed, work speed and table traverse required consideration when setting up a grinding machine.

Wheel speed

The faster a wheel is run, the more efficient it cuts but if it runs too fast, it will fly apart. Other adverse effects of using higher speeds are - clogging of wheels, smoothing of wheels (they will, then, not grind any more), overheating of workpiece, inaccuracy of surface and danger of accidents. On the other hand, if the speed is low, the abrasive is wasted without much work being done. It is best to run the wheel at the speed recommended by the manufacturer.

Recommended circumferential speed (cutting speed) of the grinding wheel (metres/second) is given in the table below.

Grinding method	Material			
	Steel	Cast iron	Cemented carbide	Zinc alloys light metals
Internal grinding	25 m/s	20 m/s	8 m/s	25 m/s
External grinding	30 m/s	25 m/s	8 m/s	35 m/s
Surface grinding	25 m/s	25 m/s	8 m/s	20 m/s

R.P.M. of the grinding wheel is calculated by the following formula :

$$n = \frac{V_3 \times 1000 \times 60}{\pi \times D}$$

Where,

V_3 = Circumferential speed of the grinding wheel in m/s

D = Diameter of the grinding wheel in mm

n = R.P.M. of the grinding wheel.

Work speed

Work speed is chosen based on the surface finish desired and to obtain highest rate of production. Table below gives the normal work speeds in m/min. For grinding of work that is out of balance, lower surface speeds are used. Rough grinding of automatic cams is done at about 5-10 m/min and finish grinding is done at half of that speed.

Grinding of non-ferrous and light metals is done at higher work speeds. Plunge grinding requires very low speed. For thread grinding extremely low work speed is used.

The slower the worpiece revolves the harder will be the wheel action. The work speed should not be lower than the minimum or above the maximum speed recommended. Too high speed may cause accidents and is also likely to damage the machine.

Method of Grinding	Materials to be ground			
	Soft steel	Hardened steel	Cast iron	Light metals
Internal grinding	18-20 m/min	20-24 m/min	20-24 m/min	28-32 m/min
External grinding rough	12-18 m/min	14-18 m/min	12-15 m/min	25-40 m/min
Finish	10-15 m/min	10-12 m/min	10-12 m/min	20-30 m/min
Surface grinding	8-14 m/min	8-14 m/min	8-14 m/min	8-14 m/min

R.P.M of the workpiece,

$$n_w = \frac{v_w \times 1000}{\pi \times d}$$

Where,

v_w = Circumferential speed of the workpiece in m/min.

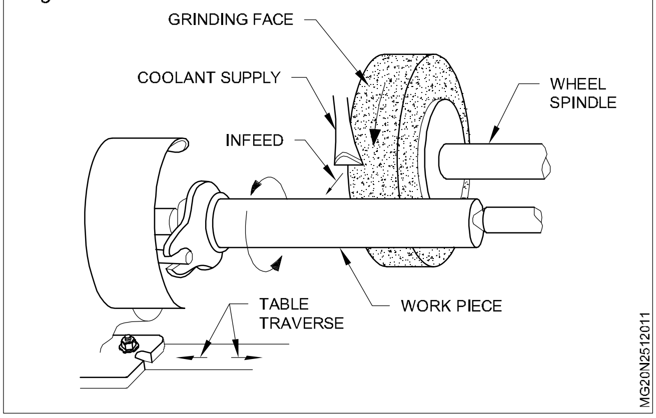
d = diameter of workpiece in mm.

Table traverse (Fig 1)

It depends upon the width of the wheel and the accuracy of finish required. For rough grinding, table travel should be about 2/3 of the width of the wheel per revolution of the workpiece. For finish grinding it should be 1/3 or even less of the width of the wheel face. For very smooth finish, very low table travel say 1/8 of the width of the wheel face may be used.

Traverse should not be such as may allow the wheel to extend fully beyond the work. The wheel should over run the end of the work about 1/4th to 1/3rd the width of the wheel face. This is done so that wheel may finish the cut. If there is no over-run of the wheel at all, the work will be over size at the end. Momentary stoppage of the wheel at the end of each traverse is important as it permits the wheel to grind the work to size.

Fig 1



Depth of cut

Infeed or depth of the cut depends upon the following factors:

Amount of metal to be removed.

Type of finish required.

Power and rigidity of the machine.

Coolant used.

Provision of work support (Steady rest).

Depth of cut used for roughing is 0.01 - 0.03 mm, and for finishing 0.0025 - 0.005 mm. The shower of sparks thrown off by grinding wheel is a convenient and sensitive indication of the depth of cut being taken. An experienced operator can judge the depth of the cut within close limits by seeing the shower of sparks.

Feeding of the grinding wheel to the work may be by hand or automatic. But it is advisable to use automatic feed except for bringing the wheel upto the work and to remove it away or when taking very fine cuts. The automatic feed takes from 0.006 to 0.10 mm for each traverse of the table.

The depth of cut depends upon the diameter at the hole being ground and may *********** from 0.02mm to 0.05mm roughing from 0.002 to 0.01mm in finishing operations.

Machining time for cylindrical grinding (Fig 2)

Where

l = Length of the workpiece in mm

L = Grinding length in mm

f = Feed in mm/revolution of workpiece

n_w = R.P.M. of workpiece

i = no. of cuts

= $f \times n_w$

Machining time:

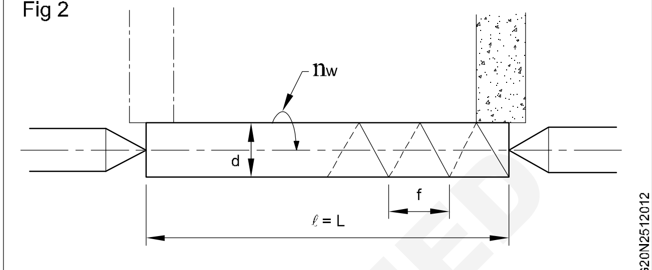
- With feed adjustment at every stroke of the table

$$= \frac{L \times i}{f \times n_w}$$

- With feed adjustment at every cycle

$$= \frac{2 \times L \times i}{f \times n_w}$$

Fig 2



MACHINING TIME FOR CYLINDRICAL GRINDING

Example

A steels shaft ∅ 50.3 mm, 500 mm long is to be ground to ∅ 50 mm, width of grinding wheel = 40 mm, feed adjustment per stroke = 0.005 mm circumferential work speed = 12 m/min feed =1/2 width of grinding wheel per revolution of workpiece.

Then, grinding allowance = 50.3 - 50 = 0.3 mm

Grinding allowance applied to radius = 0.3/2 = 0.15 mm

Feed, f = 40 mm x 1/2

= 20 mm per revolution of work.

$$\text{No. of cuts(i)} = \frac{\text{Grinding allowance}}{\text{Infeed adjustment}}$$

$$i = \frac{0.15}{0.005} = 30$$

R.P.M of workpiece,

$$n_w = \frac{v_w \times 1000}{\pi \times d}$$

$$= \frac{12 \times 1000}{\pi \times 50}$$

$$\text{Machining time} = \frac{L \times i}{f \times n_w}$$

$$= \frac{500 \times 30}{20 \times 76}$$

= 76 R.P.M

= 9.87 minutes.

Grinding allowances

The amount of stock to be left on the work for removal by grinding in case of cylindrical work depend upon :

- Diameter of work
- Length of work

The usual practice is to leave from 0.25 mm to 0.75 mm for grinding. The allowance on short, thick pieces of work is 0.25 m. For larger and thinner pieces of work, the grinding allowance is correspondingly increased. For example for a 12 mm diameter shaft of 150 mm length, grinding allowance will be about 0.25 mm, while for a 900 mm long shaft, it will e 0.50 mm. Grinding allowance for a 300 mm long shaft of different diameters will be as follows:

Diameter	Grinding allowance
12 mm	0.25 mm
25 - 50 mm	0.375 mm
75 - 100 mm	0.50 mm
125 - 200 mm	0.625 mm
250 - 300 mm	0.75mm

Other factors which need to be considered in deciding the allowance to be left for grinding are:

- The finish of the work before grinding.
- The condition of the work when being ground, whether hardened or not.
- If the work has been case hardened, the depth of penetration of case.

Surface grinder

Objectives: At the end of this lesson you shall be able to
- **state the types and parts of surface grinding**
- **describe the construction of surface grinder**
- **state the methods of surface grinding.**

Surface grinding machine

It is a precision grinding machine to produce flat surfaces on a workpiece. It is a more economical and more practical method of accurately finishing flat surfaces than filing and scraping.

Types of surface grinders

There are four types of surface grinders.

- Horizontal spindle reciprocating table (Fig 1)
- Horizontal spindle rotary table (Fig 2)
- Vertical spindle reciprocating table (Fig 3)
- Vertical spindle rotary table (Fig 4)

Fig 1

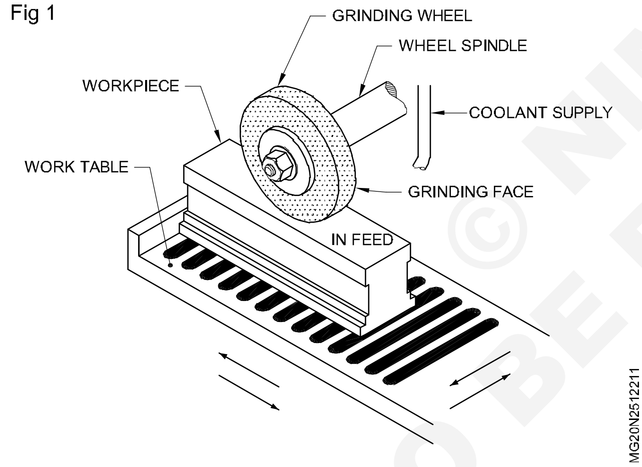


Fig 2

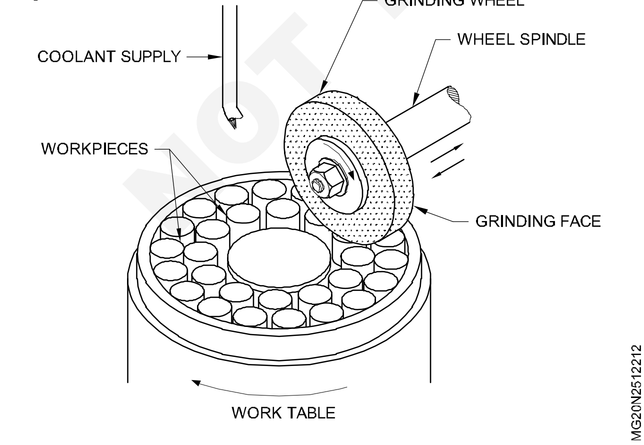


Fig 3

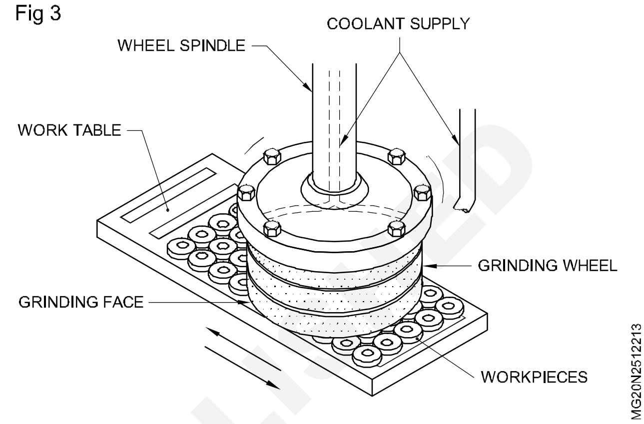
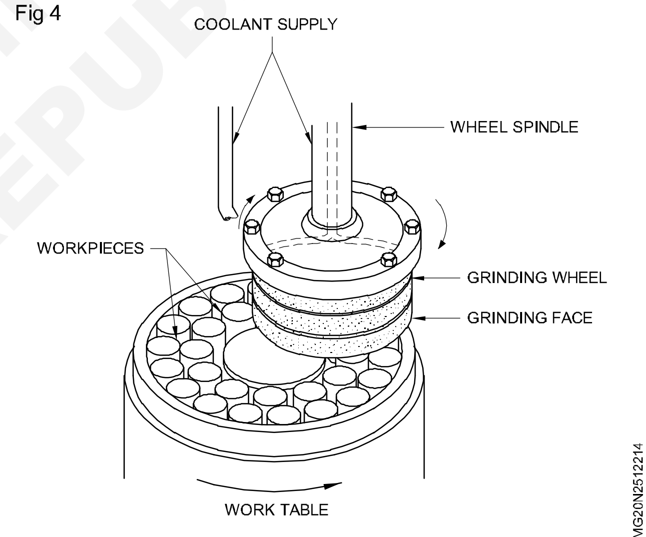


Fig 4



Parts

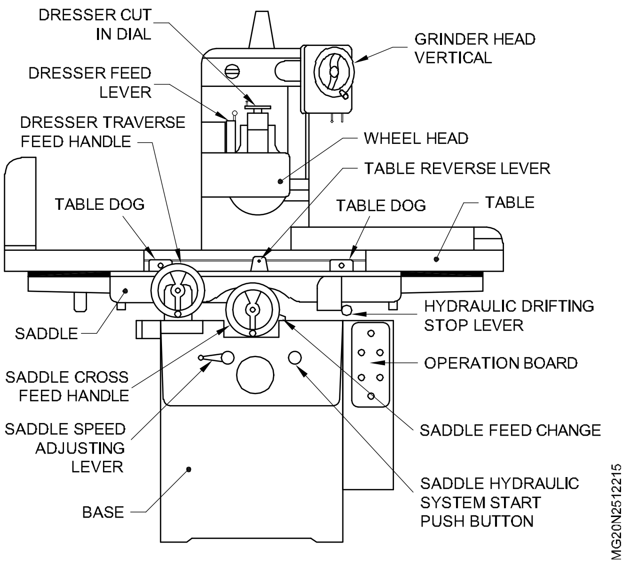
Horizontal spindle reciprocating table surface grinder main parts (Fig 5).

- Base
- Saddle
- Table
- Wheel head

Base

It is a rigid rectangular box contains the driving mechanism (hydraulic device tank and motor). It has a column at the back for supporting the wheel head on the top of the base provide precision guide ways for moving saddle.

Fig 5



Saddle

It is a frame. It contains the table in its cross wise movement. It is used to give cross feed to the work. It can be removed by hand or auto feed.

Table

It is fitted on the saddle. It is reciprocating along the guide ways to provide the longitudinal feed to the work. The surface is accurately machined and T-slots are provided for clamping of workpieces directly on the table or for clamping magnetic chuck and grinding fixtures. It is moved by hand or auto feed.

Wheel head

It is mounted on the column secured to the base. It can be moved vertically up and down to by rotating a hand wheel accommodate work piece of different height and set the wheel for depth of cut. The wheel rotates at a constant wheel speed. (1500 rpm)

Some surface grinding machines the dressing unit mounted on the top of the wheel head and slide for dressing the wheel with help of rotating micrometer collar handle. Dress the wheel 0.015 mm to 0.025 mm giving feed.

Surface grinding methods and operation

Objectives: At the end of this lesson you shall be able to
- **list the general hints on grinding operation**
- **brief the method of grinding parallel surfaces**
- **brief the method of grinding stepped surfaces.**

Surface grinding operations

General hints on surface grinding

As the limits of accuracy are very close in this case, it is absolutely important that all possible precaution are taken to obtain accurate settings. Even the most accurate machine if carelessly set up will give in accurate results. All chucks vice or fixtures etc. should be thoroughly wiped clean. When using a magnetic chuck, desirable practice is to fasten a dial indicator to a rigid part of the wheel-head and run the pointer over the surface to make sure that it is absolutely level. If a knee plate is used, the pointer is brought in contact with the vertical face and the machine table raised or lowered. This indicator will show whether the knee-plate is absolutely square or not.

After setting the work correctly, longitudinal traverse stops are set to approximately the correct position while making sure that the wheel will not foul the work of fixture. The machine is then started. If the stops are not correctly set, re-setting is done only after stopping the machine.

Raising the table for bringing the workpiece in contact with the wheel should be done very carefully to avoid hitting of the work with a heavy blow. The winding of table across while it is moving backwards and forward may cause mishaps due to irregularities on the surface.

Grinding a flat face

The following factors determine whether grinding can be done by single dressing of wheel or whether roughing out and then finish grinding is required.

- Surface area of the face to be ground
- Amount of material to be removed by grinding
- Surface texture of the workpiece

Steps involved are:

- Measure the workpiece check the flatness of its face as also parallelism and note high spots.
- Dress the wheel as required as stated above.
- Mount the workpiece on the magnetic check. Set table traverse stops.
- Start the wheel and align it over the highest spot. Feed the wheel-head down by hand till it is only about 0.25 mm above the workpiece. (Fig 1)
- Engage longitudinal traverse using fine feed being the wheel head until it just comes in contact with the workpiece.
- Move the workpiece clear from the wheel. Start supply of coolant. Apply 0.05 mm downfeed. Using cross traverse bring the side of the workpiece in line with the front side of the wheel. Let the wheel pass over whole face of workpiece. (Fig 2)

Fig 1

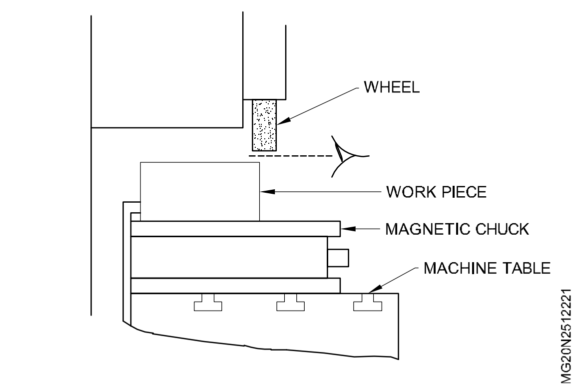
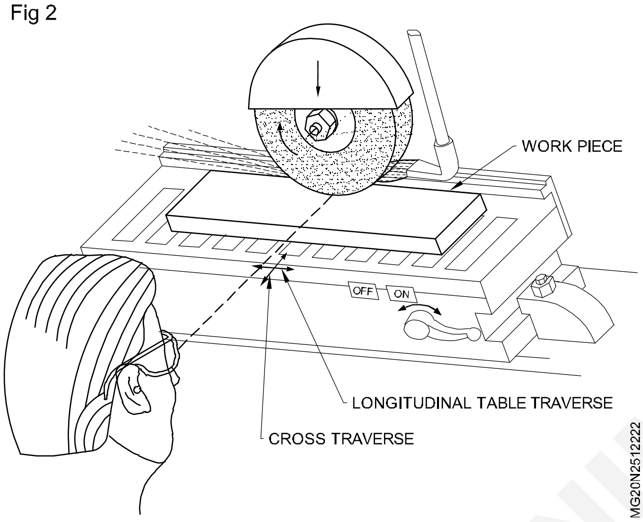


Fig 2

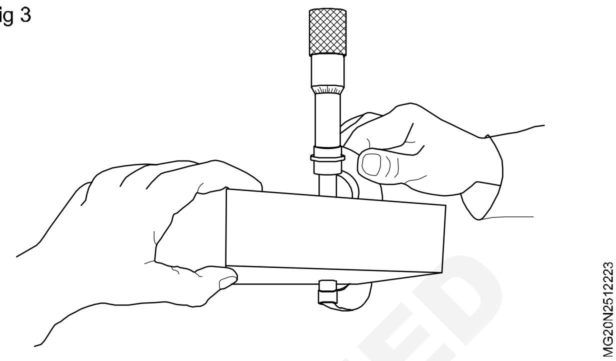


- Stop cross traverse of wheel-head. Apply further drawn feed and reset reverse traverse. Repeat the process until the face is fully cleaned up. Remove the workpiece from the chuck.
- Dress wheel for finish grinding.
- Set the workpiece again on the chuck
- Engage longitudinal table transeverse. With the help of cross traverse, bring the edge of the workpiece under the wheel.
- Feed the wheel-head down until the wheel is lightly in contact with the workpiece.
- Move the workpiece away from the wheel. Apply downfeed approximately 0.0125mm.
- Engage cross traverse, turn the coolant pump on and grind the face
- Repeat the process of applying downfeed and cross traverse until the face is completely ground.
- Remove the workpiece from the chuck. Check its flatness and surface texture. Remove sharp edges using a fine abrasive stone. Demagnetise the workpiece.

Grinding two opposite flat and parallel

- The procedure for grinding a flat has been described above. Steps given below are involved in grinding a workpiece flat and parallel.
- Measure the workpiece. Check its parallelism. (Fig 3)
- Dress the wheel for taking rough cuts.
- Mount the workpiece on the magnetic chuck. Adjust the position of traverse stops. Clean the face of the workpiece by removing minimum amount of material.

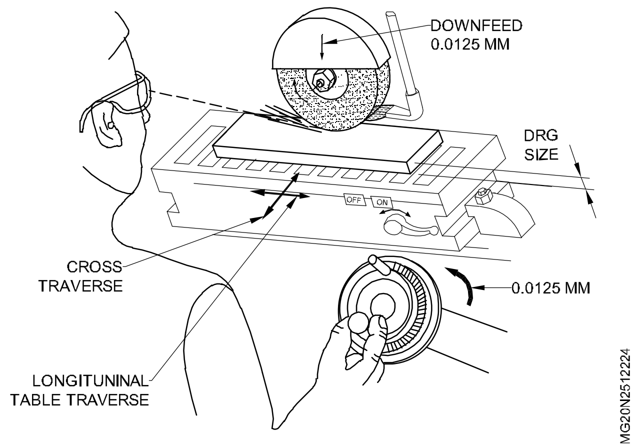
Fig 3



- Remove the workpiece from chuck. Measure it again to determine the remaining grinding allowance. Check also parallelism.
- Mount the workpiece for grinding the opposite side. Carry out rough grinding by removing 1/2 remaining grinding allowance minus 0.05 mm.
- Remove workpiece. Check its size and parallelism. Mount it on the reverse side for rough grinding the first face. Rough grind within 0.05 mm of finished size.
- Remove workpiece. Determine remaining grinding allowance. Dress the wheel for finish grinding.
- Mount the workpiece again making sure that the workpiece and chuck are perfectly clean.
- For finish grinding engage longitudinal table traverse when wheel is clear of the workpiece. Then position the edge of the workpiece under the wheel with the help of cross traverse.
- Feed the wheel-head down very slowly for bringing the wheel in very light contact with the workpiece. Not wheel-head index reading.
- Move the workpiece away from the wheel. Use 0.0125 mm down feed. Engage cross traverse turn the coolant on and let the wheel pass over the whole surface of the workpiece.
- Again apply 0.005 mm downfeed and engage reverse cross traverse.
- After the workpiece has cleaned the wheel, reverse the direction of cross traverse and like this let the wheel pass over the face once or twice without applying any cut.
- Stop all traverses. Set the workpiece on the reverse side without altering the wheel-head setting.

- Finish grind the reverse side by applying downfeed and traversing until the remaining grinding allowance is removed. After that let the wheel pass over the face once or twice to spark out.
- Remove the workpiece. Check its thickness, flatness, parallelism and surface texture.
- Remove sharp edges and de-magnetise the workpiece. (Fig 4)

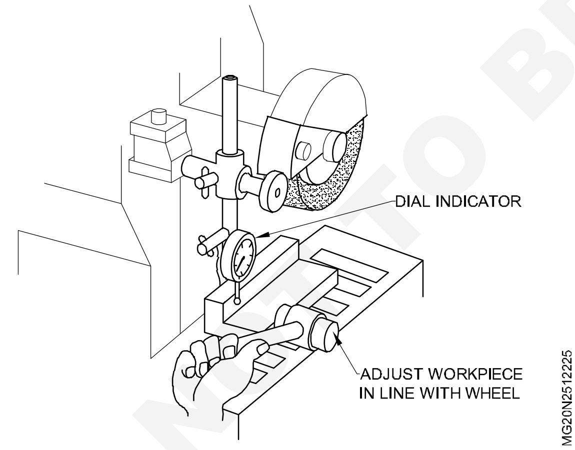
Fig 4



Grinding a flat face and shoulder

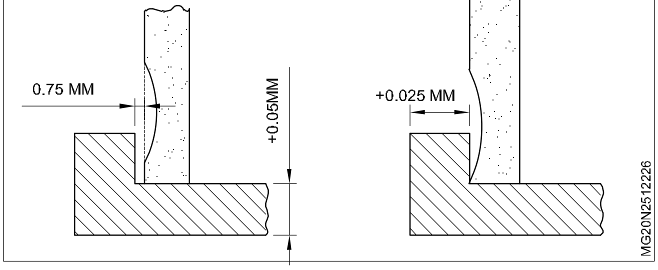
- Dress the face of the wheel. Relieve its rear.
- Mount the workpiece on magnetic chuck, first visually align workpiece shoulder face in line with wheel and then click and adjust alignment with a dial indicator. (Fig 5) If the chuck has a back plate, it can be used as a datum surface for correctly setting the workpiece. More over it can be helpful in re-setting the workpiece accurately after removal.

Fig 5



- Set longitudinal stops. Engage longitudinal traverse. Supply downfeed until wheel just starts grinding. Note zero graduated scale on hand wheel of wheel-head. Start supply of coolant.
- For rough grinding of horizontal face, apply 0.05 mm downfeed. With hand feed cross traverse, grind the surface to within 0.75 mm of vertical face. Apply further cuts until 0.05 mm is left for finish grinding. (Fig 6)

Fig 6



- For rough grinding of vertical face, cross traverse table until wheel lightly contacts vertical face. Use cross traverse cuts of 0.0125 mm to leave 0.025 mm for finish grinding. (Fig 6) Remove the workpiece.
- Dress the wheel face and side again for finish grinding.
- Re-set the stopper to engage longitudinal traverse and carefully bring down the wheel just touches the horizontal face. Note give final cuts to grind the workpiece to size.
- For finish grinding of vertical face, bring it lightly in contact with the wheel by cross traverse. Apply cuts of upto 0.0125 mm to bring workpiece to size.
- Remove workpiece from table. Clean and check workpiece.

Grinding two vertical faces parallel and central

In this operation grinding of two vertical faces parallel, square and central to a base are involved, the face and sides of base having been previously finish machined.

Dress the face of the wheel, relieve and dress the sides of the wheel.

Measure the workpiece to know the grinding allowance. Measure the width of Tenon. Inspect the position of Tenon so as to determine the direction of error.

Mount the workpiece on the chuck and set table traverse stops so that wheel will clear fully the vertical face of the workpiece.

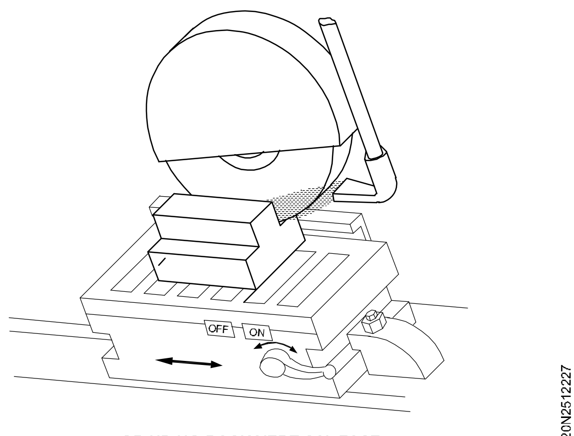
For cleaning up back vertical face, bring the wheel approximately 0.375 mm above horizontal face and 0.375 mm from vertical face. Feed the wheel-head down carefully until the wheel makes a light contact with the horizontal face. Then feed cross traverse until the wheel makes a light contact with vertical face. Apply 0.0125 mm cuts until face is cleaned up.

Remove and measure the workpiece. Check the distance from side of base to vertical face. Check parallelism of face to side of base, width of tenon and the amount of material to be removed.

Set the wheel again and rough grind the back vertical face by applying cuts until the face is within 0.05 mm of the finished size. (Fig 7)

Now clean up front vertical face of the workpiece. Remove it from the chuck and measure the amount of material to be removed from front face.

Fig 7



GRINDING BACK VERTICAL FACE

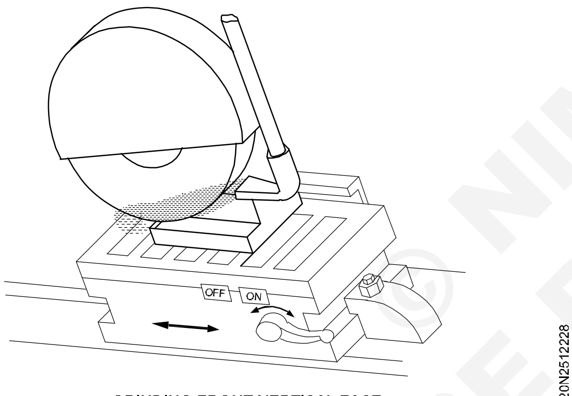
Re-set the workpiece and rough grind front vertical face by applying cuts until the face is within 0.05 mm of the finished size.

Dress the wheel again for finish grinding.

Set the workpiece and finish grind back vertical face.

Remove and re-set the workpiece for finish grinding front vertical face. (Fig 8)

Fig 8



GRINDING FRONT VERTICAL FACE

Check the workpiece to determine the position of the tenon relative to the base and its parallelism, squareness, width and surface texture.

Remove sharp edges and demagnetise workpiece.

Grinding angular faces

Faces having angular relationship are ground as shown in fig 9. The method used for holding and setting the workpiece depends upon the angular accuracy required. Steps involved in grinding are the same as for grinding of flat surfaces.

Grinding slots

This involves grinding of two vertical faces and one horizontal face which must be parallel and square to the previously machined datum surfaces. Steps involved are similar to those described in other cases earlier. After mounted and setting the workpiece using a dial indicator, horizontal face is cleaned and rough ground within 0.05 mm of the second vertical face is cleaned and rough ground within 0.025 mm of the finished size.

After dressing the wheel for finish grinding, the slot is finish ground. (Fig 10)

Fig 9

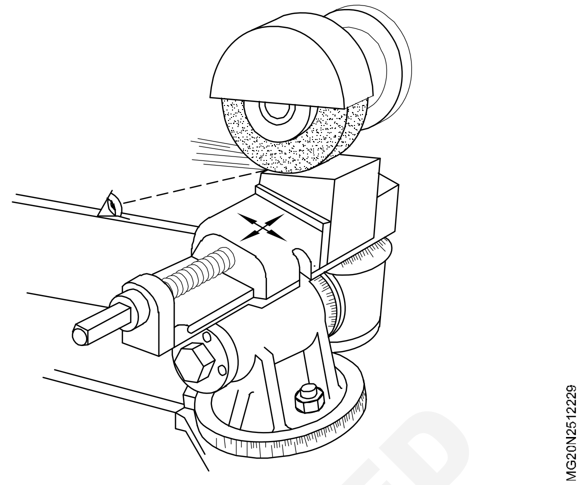
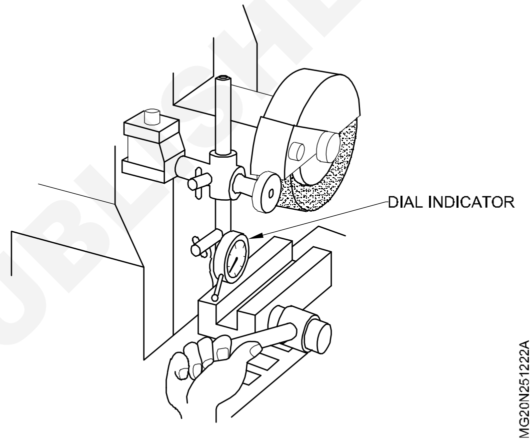
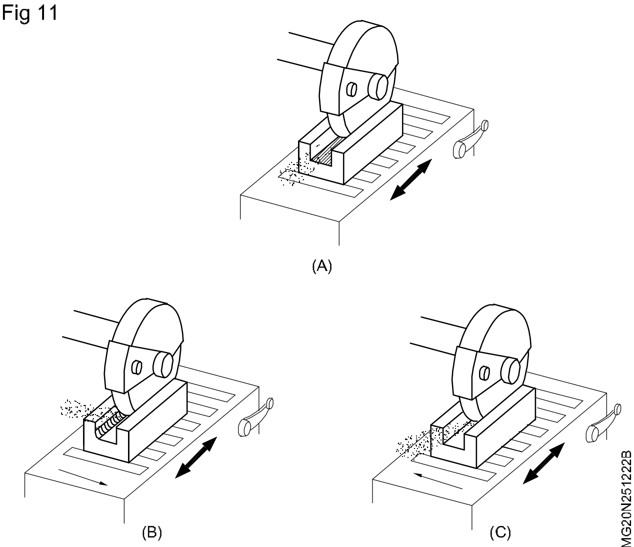


Fig 10



Other operations: There are a variety of other surface grinding operations which are done. Fig 11 indicates set-ups for:

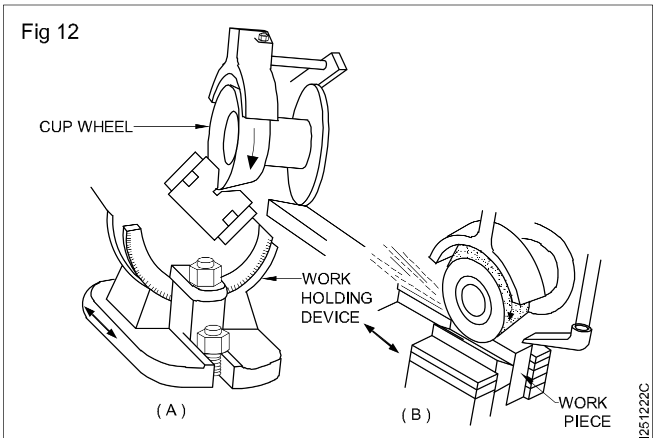
Fig 11



Grinding operations

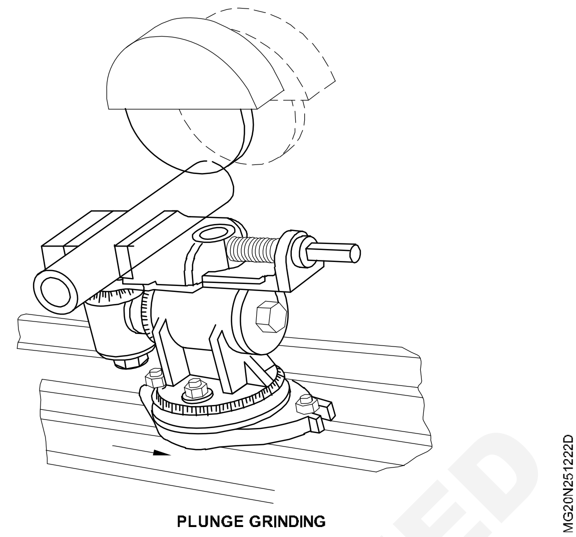
- Grinding vee using cup wheel. (Fig 12)
- Grinding dovetail using formed wheel
- Plunge grinding (Fig 13)

Fig 12



(A) GRINDING VEE USING CUP WHEEL.
(B) GRINDING DOVETAIL USING FORMED WHEEL.

Fig 13



PLUNGE GRINDING

Grinding speed, feed and depth of cut

Objectives: At the end of this lesson you shall be able to
- **define wheel speed and work speed**
- **state the formula to calculate the wheel speed**
- **define feed**
- **define depth of cut**
- **state the factors affecting speed, feed and depth of cut.**

Wheels speed is the rate of travel of the wheel surface past a point on the workpiece.wheel speed is otherwise called surface speed. It is expressed in metres per second.

$V = \pi d N / 1000 \times 60$

V = surface speed in m/sec.

d = dia. of the grinding wheel in mm

N = r.p.m of the machine spindle

1000 - to convert mm to metres

60 - to convert r.p.m to revolution per second

So the wheel surface speed depends on the:

- dia. of the spindle

- r.p.m of the spindle

Recommended bonds and wheel speeds for different grinding operations are shown in Table 1.

TABLE 1

Type of grinding	Wheel speed m/sec.
Rough grinding wheels with vitrified bond	25
Rough grinding wheels with resinoid bond	45
Surface grinding wheels with vitrified bond	20 - 25
Internal grinding wheels with vitrified bond	20 - 35
Centreless grinding wheels with vitrified bond	30 - 80

Type of grinding	Wheel speed m/sec.
Cylindrical grinding wheels with vitrified bond	30 - 35
Cutting off wheels with resinoid bond	45 - 80
Hand grinding of tools	20 - 25
Automatic grinding of tools	25 - 35
Hand grinding of carbide tools	18 - 25
Automatic grinding of carbide tools	4 -20

Work speed

It is the rate at which point on the work surface travels past a point on the grinding wheel surface.It is due to the reciprocating movement of the grinder surface.

Table 2 shows recommended work speeds.(m/min)

TABLE 2

Class of work	Rough grind m/min	Finish grind m/min
Soft steel	10 - 20	20 - 25
Hardened steel	25 - 30	30- 40
Cast iron	35 - 55	45- 65
Aluminium and fine brass	50 - 65	50- 65

To calculate the r.p.m of the work in the case of cylindrical grinding use the formula

N = V x 100 / π x d

Where V = surface speed in m/min.

d = dia. of the workpiece in mm.

Feed

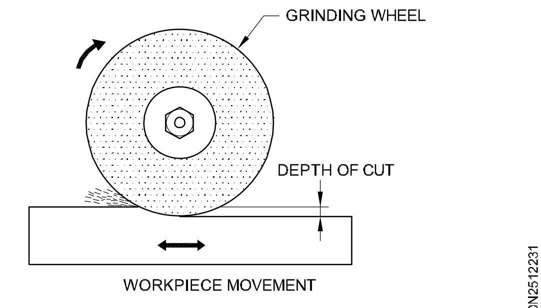
Feed in grinding refers to the movement of the wheel per stroke across the work surface.

The feed in grinding depends on the work speed, wheel width and the finish required. It is generally 3/4th to 2/3 of the wheel face width for rough grinding and 1/4th to 1/8th of the wheel face width for rough grinding and 1/4th to 1/8th of the wheel face width for finish grinding.

Depth of cut

It is the thickness of the material removed in surface grinding for one cut.(Fig 1)

Fig 1



SURFACE GRINDING

Depth of cut in grinding depends on the:

- cutting load
- power of the machine
- finish required

Generally the depth of cut is 0.02 to 0.03mm for rough cut and 0.005 to 0.01mm for finish cut.

Honing

Objectives: At the end of this lesson you shall be able to
- **State what is honing and its purpose**
- **State honing allowances**
- **State types of honing stores, their description and uses**
- **Explain the adjustment for elementry honing condition**
- **State honing fluid selection**
- **State surface roughness value, cutting speed, cutting pressure and tolerance for honing.**

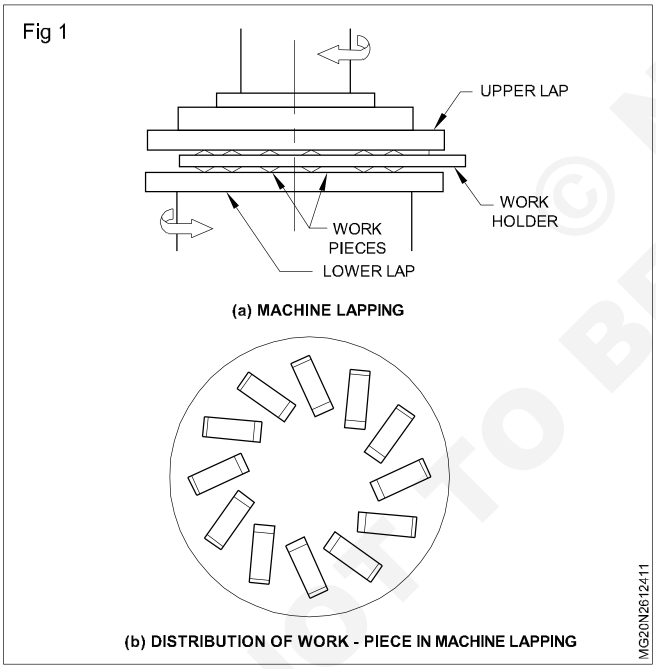
Honing

The different purposes for which honing may be done are:

a Correction of local irregularities such as ovality, waviness of axis or non-parallelism of cylindrical features.

b Development of a particular feature.

By honing, it is not possible to correct malposition of the axis or major errors along a cylinder which is very long as compared to the bore. By this process only a small amount of metal is removed.

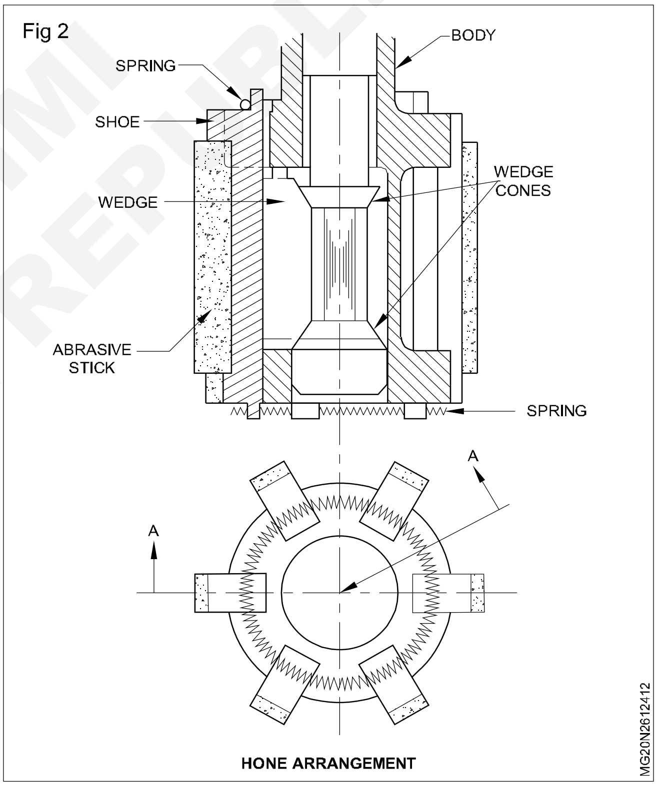


Honing is similar to grinding in certain respects. The difference lies in that abrasive is in the form of sticks which are spaced evenly about the surface to be honed.

The abrasive used in honing is aluminium oxide or silicon carbide. Bonded diamond grit is used for special operations. The size of the grain used is similar to that in case of grinding. Vitrified bond is most commonly used. But for rough honing or when cast iron or certain non-ferrous materials are finish-honed, resinoid bond is used.

The holder which holds the abrasive sticks cemented to shoes is called the hone.

The hone. Fig 2 Shows a typical hone arrangement. It has a hollow flanged cylinder having radial slots(usually six) into which shoes are mounted. The shoes are pushed outward radially by a cone adjustment device and they are retained by coil springs. Each shoe has an abrasive stick cemented to it. The honing head makes the hone to rotate and reciprocate. This is made to float so that it follows the 'mean' axis of the feature being honed This is achieved by making the hone itself floating. This can also be done by making the work holding device floating.



Cutting Action (Fig 3)**:** This is by a combination of:

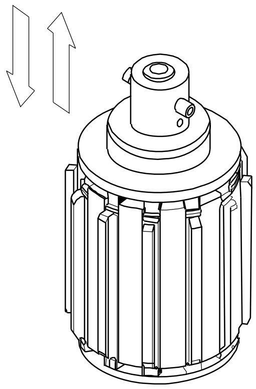
a Pressure normal to the workpiece which is obtained by the expansion of the hone.

b Motion of the hone tangential to the workpiece surface.

The rotational speed used depends upon the material of the workpiece and the degree of finish desired. The reciprocating movement serves the function of providing the generating action, distribution of wear over the whole length of the sticks and clearing the swarf. This reciprocating movement compared with the rotational speed depends upon the type of surface to be generated.

The typical speed used is 0.3m/s A lubricant say paraffin is introduced during cutting.

Fig 3



HONE CUTTING ACTION

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Lapping and honing

To avoid stick retracing its path, the stroke of the machine is set in such a way that there is an over-run. This way localised errors are avoided. The use of continuous rotation in one direction and the reciprocating action produces the characteristic criss cross texture. If is not required to have thin texture, an intermittent rotational action is used instead of continuous rotational movement. This intermittent non-uniform action prevents the abrasive sticks from retracing their own path.

Honing Machines: There are two types of honing machines

(a) Internal machines Which are of vertical type for honing normal length holes.

(b) External Machines. Usually used for external honing.

Materials suitable for honing: Most of the metals and also certain non-ferrous materials can be honed. It is more difficult to hone materials as they tend to cause loading.

Honing allowance

When sufficient metal has been provided, the previous machining operations will not affect the resultant surface finish. Yet rougher the boring operation and the greater the honing allowance the longer becomes the operating time.

The rapidity with which the abrasive sticks will remove the metals is controlled by (a) the grit, (b) the choice of abrasive, and (c) the material to be honed, Details relative to the grit and abrasive have been discussed above and, therefore, are not repeated. Because of the close relationship between production times, the class of machined finish, the honing allowance, and the final surface finish, the boring or grinding operation prior to honing must leave a suitable surface and be held to fine dimensional limits. Relating the honing allowance to the material Table 1 may prove useful.

Table 1 Honing Allowance

Size in the inches	Allowances on diameter in inch	
	Cast iron	Hardened steel
1to 5	0.0007 to 0.004	0.0003 to 0.0015
5 to 10	0.003 to 0.007	0.001 to 0.002
10 to 20	0.005 to 0.008	0.0015 to 0.0025

Materials suitable

The honing process is not confined to any one materials, for all metals that do not clog the sticks may be honed. Thus articles in both the ferrous and non-ferrous metals are accurately finished by process.

Types honing stone abrasive

Honing stones are normally divided into groups according to the type of abrasive grit and the type of bond used to hold the grits together. The stones in each of these groups are them rated according to Hardness.

Most honing is done with conventional abrasives because of their low price. However, the use of super abrasives is increasing rapidly, because high abrasive price does not necessarily mean high cost of honing.

The effective Hardness Rating of a honing stone is determined by the type and quantity of bond as well as the closeness of the grain spacing (or density) and, of course, the abrasion resistance of the type of abrasive grit.

The abrasion resistance of each type of abrasive grit is not always proportional to its hardness. For instance, diamond, being the hardest of all materials, might be assumed to be good for honing steel. However, diamond does not always perform well in steel. Theory has it that because of steel's affinity for carbon, the diamond, being carbon, is actually dissolved into the carbon-poor steel. While this theory holds for most applications of diamond in steel, the bond being used to hold the abrasive must also be considered before making a final judgement as to the appropriateness of the particular abrasive. For instance, because of its superior strength, diamonds is used on plated Single Stroke Honing and Cross-Grinding Tools for honing steel, but is not used in bonded abrasive sticks for conventional multi-stroke honing of steel.

It should be noted, that the Hardness Ratings of honing stones is not a measure of the stone's quality. The best stone for a job is one hard (or strong) enough to hold each abrasive grit in place just long enough to wear down its sharp cutting edge, and then allow that dulled grit to drop out, permitting the sharp grit underneath to take its place. Furthermore, different materials respond differently to each of the various abrasive grits; therefore, each type of abrasive grit and the material to be honed should be viewed individually.

The Abrasive Grits are normally separated into two groups: Conventional Abrasives such as aluminium oxide and silicon carbide, and Super abrasives such as Borazon(CBN-Cubic Boron Nitride) and diamond.

Aluminium oxide is best suited for stock removal in steel.

Silicon Carbide works best on cast iron, bronze, brass, aluminium and for fine finishing steel, and on some non-metallic materials, such as: Acrylic, Dapon, Delrin, epoxy, graphite, Kel-F, Lucite, nylon, phenolic, Plexiglass, polycarbonate, polyethylene, Teflon, Torlon, Zytel, etc.

Borazon, in metal bond, is useful for honing cast iron and any kind steel-hard or soft, high or low alloy.

And finally Diamond. Diamond is the only abrasive that works for tungsten carbide, glass and ceramics, and it is also effective in cast iron.

Unlike abrasive grits, Bonds are divided into groups according to the agent used in the bonding process. The Various types of bonding agents are vitrified, resin and metal.

Vitrified bond is most commonly used for conventional abrasive. A type of clay is mixed with the abrasive grits and then fired in a furnace to a glass-like(vitreous) consistency.

Resin bond used to be shellac, but now is usually plastic. Its use in honing is limited to very fine polishing.

Honing stone profile (Fig 4)

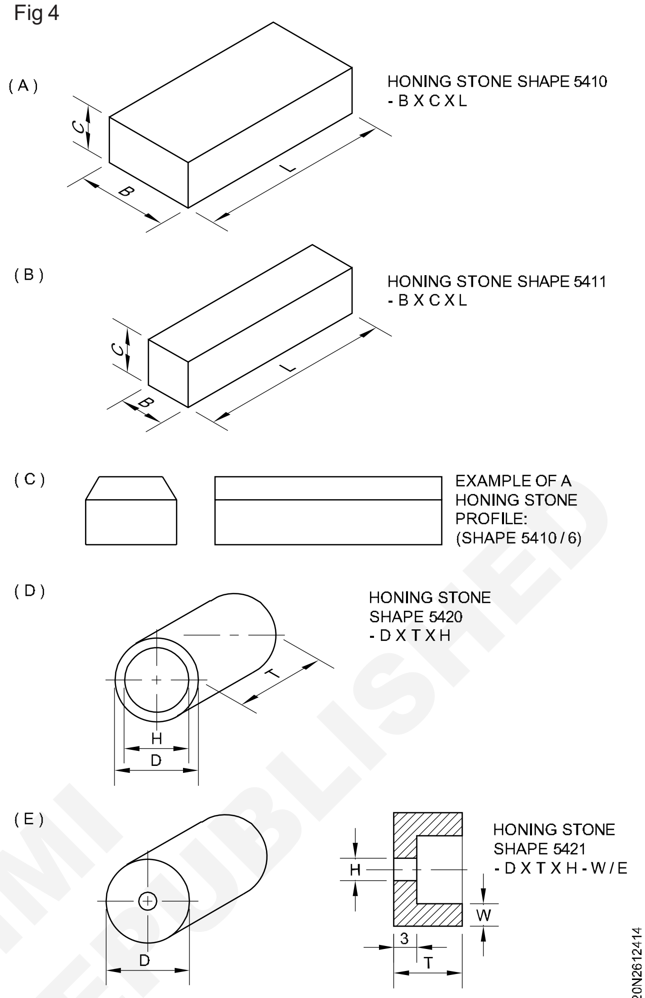
Manufacturing to customer drawing

The shape of a honing stone is standardized to ISO 525. Furthermore, these can supplied with various profiles as illustrated in Fig 4 other profiles can be manufactured to customer drawing.

Shapes of honing stones (Fig 5)

Honing stones are cut to specific shapes for application.

Fig 4

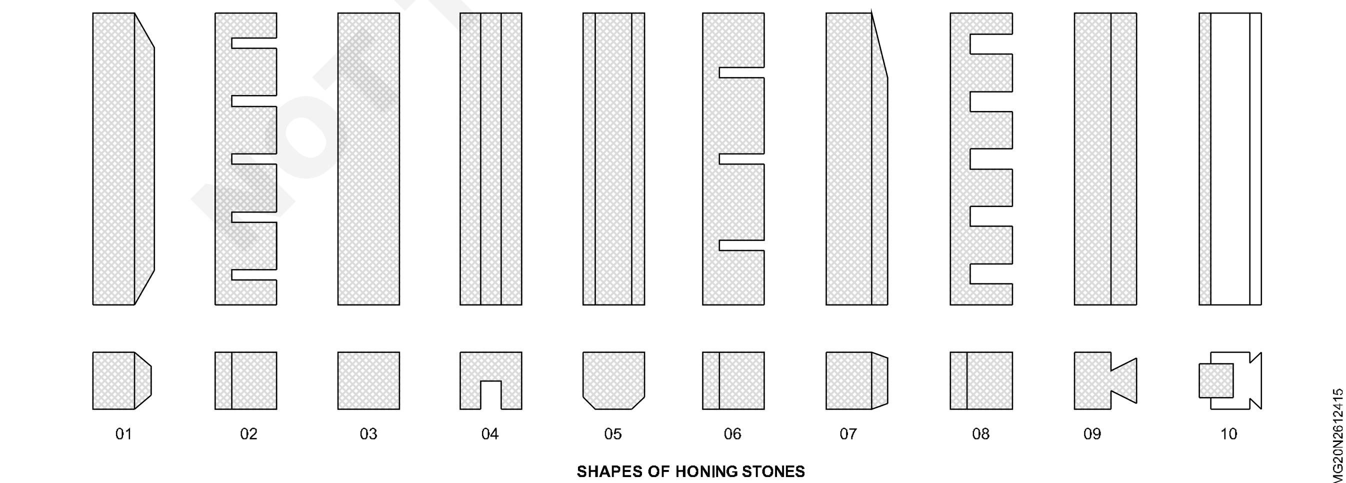


HONING STONE PROFILE

Some examples

Phasing-in, so that the edges do not break off when entering. Longitudinal and transverse slots for optimum flushing in special honing operations. Dovetail stone that eliminates the offensive and time consuming cementing of the honing stone and honing stones in a plastic casing with dovetail mounting.

Fig 5



SHAPES OF HONING STONES

Honing stone-ceramic and plastic bonded-designation and order key

Example

EKW	**100**	**F**	**3**	**KE**	**0090**	**S**	**F3**
Grain type	grain size	hardness	structure	bond type	recipe no.	impregnation	shape

Grain types

SCG	silicon carbide green	EKW	white fused alumina
SCD	silicon carbide dark	EKR	pink fused alumina
NK	regular fused alumina	EKW(SP)	single-crystal fused alumina
HEK	special semi-fused alumina	ZK	special fused zircon alumina

Grain sizes 8,10,12,14,16,20,24,30,36,40,46,54,60,70,80,90,100,120,150,180,200,220,240,280,320,360,400, 500,600,800,1000,1200

Hardness from B to U (in alphabetical order)

Bonds
KE = Ceramic
BA = Bakelite
HP = Bakelite, highly compressed
KB = other resin bonds such as epoxi-or pu-resins

Structure from 1 = very compact to 9 = very loose

Recipe no. internal manufactures' numbers

Impregnations
S=sulphur
V = plastic impregnation
W = plastic impregnation
Z = plastic impregnation
G = graphite additives

Standard honing stones

Universal honing stones for external and internal honing (Steels 100-800 N/mm²)

Rough honing: EKW 100 F7 ke/0090S
HEKW 100 G 8 ke/0125 S

Finish honing: EKW 320 D 11 ke/0096 s

Chrome and austenitic materials

Rough honing: EKW(SP)90 F ke/0053 S

Finish honing: EKW 320 D 11 ke/0096 s

(Universal stones for honing of high alloyed steels of strengths up to 2000 N/mm²)

Special honing stones

Materials	**honing stone quality**
Steels tensile strength 100-500 N/mm²	EKW 100 F7 ke/0090 S
St 10, TSt 10, WUSt 12, USt 12-14, R RSt 14…	EKW 320 D 11 ke/0096 S
St 35-45 unalloyed	EKW 70 R HP/3004
St 34-42 welded, SMnPb 20-23 cold-though steels	EKW 80 R HP/3000
	EKW 240 R HP/5000
	NK 400 O HP/5020
	EKW 500 D ke/0098 S
	HEKW 100 G 8 ke/0125 S

Material	Honing stone
Steels tensile strength 500-700 N/mm²	EKW 100 F7 ke/0090 S
St 52-70, St 54.4-55.4 drawn, 15-21 CrMov,	EKW 320 D 11 ke/0096 S
C 10-035, CK 35-CK-45 x 7-13, Cr 13-17,free-cutting steel, 15-35 S 20,	EKW 80 R HP/3000
nitride steels not quenched,	HEKW 100 G 8 ke/0125 S
tempered steels, heat-treated steels, case hardening steels	(NK 400 O HP/5000)
	HKW 500 D ke/0098 S
	EKW 800 D 10 ke/0100 S
Steels tensile strength 700-1000 N/mm²	EKW 100 F7 ke/0090 S
24 CrMoV 52-58, X12-40, MnCr 15-22, EC 30-80,	EKW 320 D 11 ke/0096 S
Ct 35-CF 70, X20-X9 CrNiMo, C45-C70, high-grade steels,	EKW (SP)90F ke/0053 S
Free-cutting steels 40-60S20	EKW 240 D 10 ke/0097 S
	HEKW 100 G 8 ke/0125 S
	EKW 600 D 10 ke/0099 S
	EKW 800 D 10 ke/0100 S
Steels tensile strength 900-2000 N/mm²	EKW (SP)90F ke/0053 S
EC 80-EX 100, 15-40 CrNi, 22-39.CrMoV, 34-50 CrMo,	EKW 240 D 10 ke/0097 S
Case hardening steels C 75-120, high-grade steels, alloyed tool steels,	EKW 320 D 11 ke/0096 S
X8 CrNi-X15 CrNiMo, V2A, V4A, 67 SiCr, 50-58 CrV4,	EKW 600 D 10 ke/0099 S
nitride steels, case hardening steels, tool steels,	EKW 800 D 10 ke/0100 S
tempered steels, high-speed cutting steels, hard alloys,	
cutting alloys X 250 CrCoW 50…	
silicon steels X 250 CoCrW453	serial production: CBN
normal gray-cast iron	SCG-stone
GG 10-40, GG 32-45, cast iron with nodular iron and	SCG 120 L ke/….
lamellar graphite, sand castings GGI 10-25	SCG 400 H ke/…
	serial production: diamond
special cast steel (with higher hardnesses)	SCG 80 ke/…S
stainless cast steel with Cr,Mn, 65 NiCu(malleable cast iron)	SCG 240
70(heavy malleable cast iron, creep-resistant cast-steel,	SCG 400
Heat-resistant cast steel with low Si-content).	
GGG 46-70 (cast iron with nodular iron)	serial production: diamond
GGI 36-40 (cast iron with lamellar graphite)	serial production: diamond

Adjustment for elementary honing condition

Whether you are using the highest priced machine available or the least expensive one, you must consider several factors when honing: Spindle speed, stroke rate, stroke length, and cutting pressure.

Spindle speed: Compared to grinding honing surface speeds are quite slow. Grinding wheels run at up to 7500 surface feet per minute (about 38 meters per second). A test, reported by W. Konig, Kemal Yegenoglu and Bernd Stuckenholz of the Aachen Technical University in West Germany, was even successful at 23500 surface feet per minute (120 meters per second). Honing speeds run at about 175 surface feet per minute (less than one meter per second). To find the correct spindle speed for a given diameter, refer to the Formulas shown below. Slow honing surface sped does not result in slow metal removal; large stone area and fast stroke make up for slow surface speed.

For inches

$$\frac{700}{\text{dia.in inches}} = \text{rpm}$$

example for $\varnothing$ 6" $\frac{700}{6}$ =117 rpm

For millimeters

$$\frac{17500}{\text{dia.in mm}} = \text{rpm}$$

example for $\varnothing$ 150 mm $\frac{17500}{150}$ =117 rpm

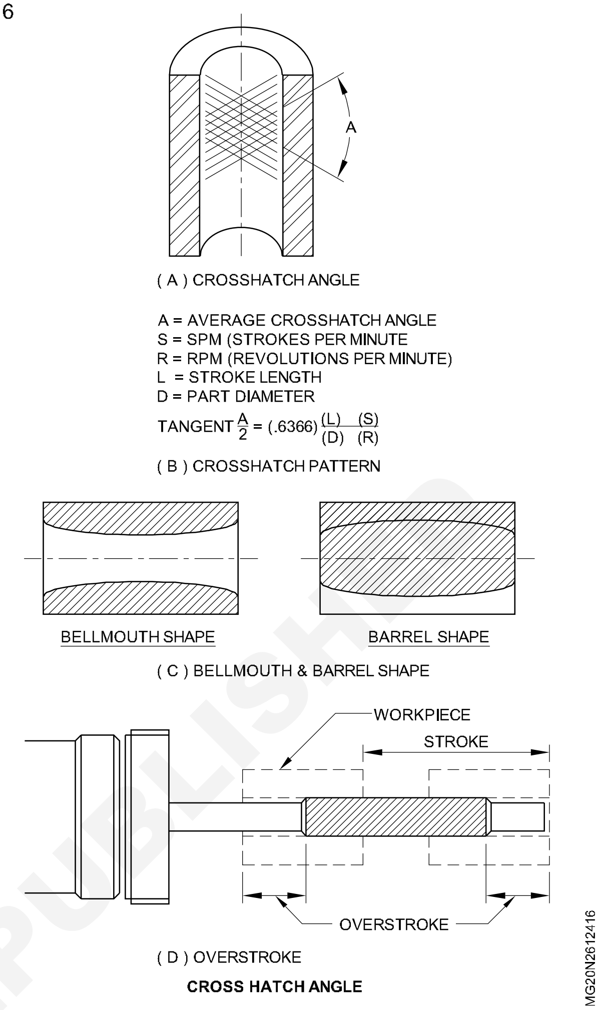
Stroke rate: A characteristic feature of a honed surface is the crosshatch pattern which is seen in Fig 6A. The pattern is generated on the bore surface as the part is stroked back and forth over the rotating honing tool. The faster the stroking rate (spm) in relation to the tool rotation (rpm), the larger the crosshatch angle. Limitations in the stroke speed capability of the honing machine will make it highly unlikely that the crosshatch angle will be too large. Although exact crosshatch angles can be calculated by controlling the ratio of spindle speed to stroke rate, using the formula shown in Fig 6B; most blueprints have ignored this angle. Regardless of whether or not the crosshatch angle is called oust on the blueprint, it should be pointed out that the pattern created makes for excellent oil retention and bearing surface.

Stock removal rates: The formulas shown in Fig 6B can be used to estimate the amount of time in minutes it will require to remove a given amount of stock, using a honing machine which provides three horsepower at the spindle. For small diameter parts it is more difficult to predict honing times than it is for larger diameters. But the honing time for small parts is usually just a few seconds, so it is not as important as for big workpieces.

Stroke length: The stroke length is not very important if the honing stone length is greater than the diameter of the bore being honed. On the other hand, honing tools used for large diameter bores ate very sensitive to stroke length, probably because the geometry of large diameter honing tools is designed more for high-volume material removal than for accuracy obtainable with the three-point contact of the small-bore honing tool. Changing the stroke length in large diameter bores by as little as 1/8 in. (3mm) on each end can make the difference between bellmouth and barrel shape (Fig 6C).

Overstroke: When adjusting the stroke length for any honing job, the stone must cover the entire length of the bore plus a little extra on each end, which is called the overstroke (Fig 6D). Overstroke each end by about 1/4 of the bore length or stone length, whichever is shorter.

Fig 6



CROSS HATCH ANGLE

Cutting pressure: It is very important to find the correct cutting pressure and rate of feed for the stone being used. Use the lowest cutting pressure that gives good cutting action. To determine which cutting pressure will result in the lowest cost when doing production honing, try different pressure settings and tabulate the results, as listed in table 1. As can be seen, a cutting pressure of 3 produced the best total cost per part in this example.

TABLE 1

Cutting pressure vs cost

Cutting pressure	Seconds 0.004 in. stock removal	Stone wear per part	Stone cost per part at $ 0.01 / Sec	Labor per part	Total cost per part
2	30	0.0001	$0.01	$0.30	$0.31
2.50	20	0.0003	$0.03	$0.20	$0.23
3	10	0.0005	$0.05	$0.10	$0.15
3.5	05	0.0015	$0.15	$0.05	$0.20

Honing fluids selection

Commonly, the fluids used for honing are referred to as ''coolants''. This is a misleading, because cooling is not one of the major functions of any honing oil or water-based product. By far the most important reason for using a honing fluid is its chemical activity.

A good honing fluid must be inactive at normal temperatures, so it does not corrode anything. But it must instantly become active when the temperature comes close to the melting point of the metal being honed. This high temperature occurs in microscopic spots at the points of cutting action and would result in welding of the metal guide shoe to the metal being honed. These tiny weld spots would be torn apart by the force of the honing machine, and the results would be rough surface finish and rapid wear of honing stone and guide shoe. However, capable ''coolant'' will prevent welding by chemically changing the hot spots from metal to a non-metallic compound, which cannot be welded. This welding problem is especially likely to happen with high-alloy materials, such as stainless steel.

Honing oils: It should be noted that, although it is considered desirable by some to refrigerate the honing oil, tests have shown that the honing action is actually faster when the oil is hot. Another idea was that cold oil would guarantee exact size of the finished part, without having to consider the shrinking of the bore diameter when the part cools off. This was also unsuccessful, because the input of heat during rapid honing is vastly greater than the very limited cooling ability of oil.

Another Common myth is that honing tools without guide shoes are immune to welding problems. But, here again it is a honing fluid problem. For if the honing fluid does not have enough chemical activity it will permit stone loading, which means that metal chips created by the cutting action of the honing stones stick to the stone surface. Therefore, when there is stone loading, there well be metal-to-metal contact and welding, with the same undesirable results as when using a honing tool with metal guide shoes.

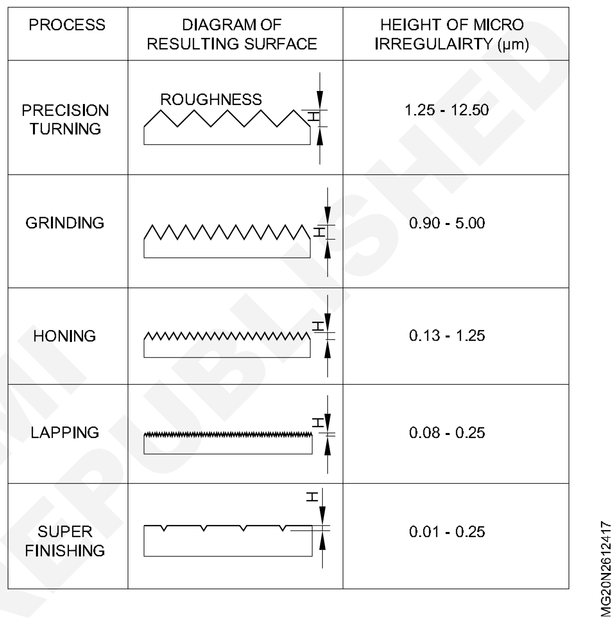
Water-based honing fluids: With tighter government regulations and greater concern for safe, biodegradable products, water-based honing fluid technology has come up with new products that seem to offer an alternative to the more conventional oil-based honing fluids. Tests on specially developed water-based honing fluids in the new Cross Grinding Machine and conventional honing machines look very promising. Unlike traditional water-based products used for grinding or cutting, these new products were developed for use in honing and Cross Grinding Machines. But before deciding to use water-based fluids need occasional replacement, and the cost of legally disposing used fluids is rising rapidly. Honing oils, on the other hand, don't need changing. Just separate the honing swarf from the oil by using filters, magnetic separators, or simply gravity.

Simply stated, always use a honing fluid (oil or water-based) which was properly blended for the process being used. Years of research, blending, testing, reblending and evaluating have gone into the development of quality honing fluids.

Fig 7 illustrates gradual improvement of surface roughness produced by various processes ranging from precision turning to superfinishing including lapping and honing.

Therefore, superfinishing processes like lapping, honing, polishing, burnishing are being employed to achieve and improve the above-mentioned functional properties in the machine component.

Fig 7



Honing is different from grinding

- 100-1000 times more grits participate
- Cutting speed is 1/50-1/120 of grinding speed
- Cutting pressure 1/6 to 1/10 of that in grinding

Applications

- In wide ranges of hole, i.e 3 mm-1000 mm
- Soft as well as hard work materials like silver brass, hard alloys, carbides and ceramics.

Attainable tolerance : 3mm on production basis

Buffing metal

Buffing is done with the purpose of removing oxide, scratching and other irregularities in the surface of metal. Hard buffing wheels made of rope or closely sewn cloth are fastened to grinder or buffing head.

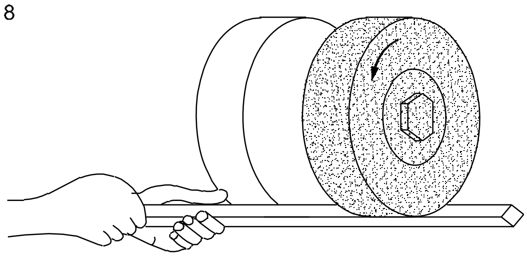
For efficient buffing

a Edges of the buffing wheels are coated with water glass or liquid glue. A row of abrasive powder is poured out on a clean piece of paper and the wheel is rolled in it to cover their edges. It is then allowed to dry for 24 hours.

(b) The wheel is mounted on the arbor of the buffing head or grinder.

(c) Power is turned on and the metal is held on the lower surface of the wheel. Buffing is done by working it back and forth. (Fig 8)

Fig 8



Types Of Cylindrical Grinding Operation

Objectives: At the end of this lesson you shall be able to
- **state types of cylindrical operation**
- **explain the cylindrical grinding methods such as traverse method, plunge cut method and form grinding method**
- **explain the cylindrical grinding operations such as taper, steep, double compound taper and shoulders.**

External cylindrical grinding

Types of work which are mainly included in external grinding are

1 Plain cylindrical grinding

2 Tapers and angular surfaces

3 Eccentric and out-of-round work

In general, wheel action, wheel and work speed are same in principle for all the three above -mentioned types or work.

Methods of grinding external cylindrical surfaces are:

1 Traverse method: In this method, the automatic cross feed for the wheel is adjusted to operate a certain in-feed for each pass. A definite traverse is also adjusted for each revolution of the work. Grinding is completed by taking several cuts.

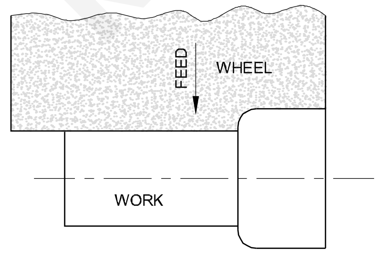
2 Plunge cut: This method is used when the width of the wheel face is more than the grinding length of the work. The table is left stationary while the wide face of the revolving wheel is fed into the revolving work. This is continued till the workpiece is ground to accurate diameter.

Plunge wheels may be as large as 225 mm across the face, This method of grinding is convenient for grinding a shoulder or stepped cylinder. It maintains a square corner between the cylinder and the adjoining shoulder on the workpiece.

3 Form grinding: Using a wide faced wheel which can be dressed to a given shape, irregular surfaces can also be ground.

Fig 1 shows an example the table is stationary and the wheel is fed into the work as in plunge cut grinding.

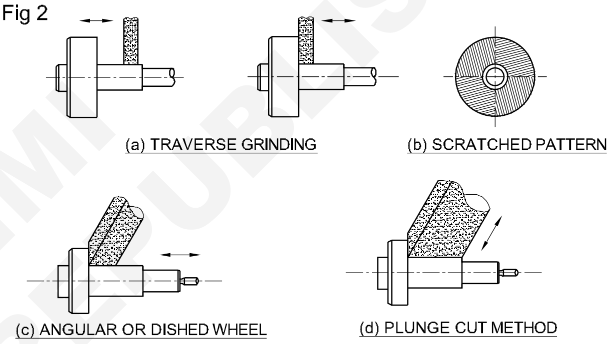
Fig 1



FORM GRINDING

Traverse grinding vs plunge cut grinding: It will be seen from Fig 2(a) and (b) how series of reverse across or scratch patterns are produced by traverse grinding upto a shoulder. This may be objectionable on a thrust bearing surface. An improved method would be to use a dished wheel or to set the wheel head at an angle as shown in Fig 2(c). A further improvement in the method would be to use plunge cut for grinding of the journal and the face simultaneously as shown in Fig 2(d) by setting the wheel at angle of 20-30 degree.

Fig 2



COMPARISON OF TRAVERSE AND PLUNGE GRINDING

When using traverse method most of the cutting is done by wheel edges which, therefore, break down fast. The result is the crowning of the wheel face which has a tendency to leave high surfaces at each end of the traverse Plunge-cut grinding is a solution to these problems to a great extent.

Grinding a plain cylindrical surface

1 Set the headstock and footstock for the length of the workpiece. The centre of the workpiece should be approximately over the centre of the table so that the thrust on the table pivot is equalized.

2 Check, clean and oil both centres of the work. Make sure that centres are properly seated in the centre holes of the work. Work centres and the centre holes should have an angle of 60°. There should also be a slight relief at the bottom of the holes.

3 Measure the size of the workpiece with a micrometer to know the amount of grinding to be done.

4 Choose and place the correct size of the grinding dog. If there are threads, keyways, etc. on the workpiece, protect them by putting thin pieces of brass, copper or other soft material between the work and the dog.

5 Adjust the table traverse depending upon the length of the work making allowance for the over-run of the wheel and the space occupied by the dog.

6 Start the machine and let it run for sometime so that it is warmed up.

7 Set the correct wheel speed, the table feed and automatic cross feed.

8 Dress the wheel for roughing out the work by passing the diamond across the face of the wheel quite- fast. Rough grind the work to within 0.025 to 0.075 mm oversize.

9 Pass the diamond slowly across the wheel face for dressing it for finish grinding.

10 Set the machine for fast work speed and slow traverse.

11 Finish grind the workpiece checking it frequently for size.

Fine finishes and the materials such as aluminium alloys, filter should be used in the coolant system.

Grinding an exterior taper

Several methods are in use for grind tapers on the cylindrical grinder.

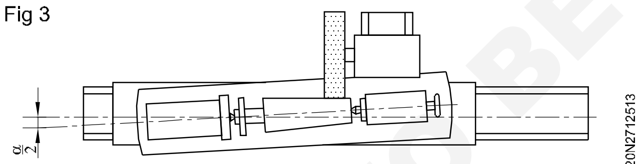
1 The work head, work table or wheel head may be swivelled.

2 The grinding wheel may be dressed at an angle.

The machine may be set for slight or steep tapers. If possible, the set up should be such that the wheel pressure is towards the headstock.

Grinding slight tapers : Grinding of tapers upto 8° is usually done by swivelling the swivel table. (Fig 3)

Fig 3



GRINDING SLIGHT TAPERS BY SWIVELLING THE TABLE

1 Swivel the table to an angle as required and clamp it in position.

2 Choose the correct type and size of the wheel, secure it in position True it, if required

3 Check, clean and oil both the centres of the work. Mount the workpiece between the centres making sure that the centres are properly seated

4 Chose and set the correct work and wheel speeds.

5 Adjust the table feed dogs in the normal manner.

6 Make sure that the wheel guard is properly in position. Take necessary precautions for personal safety.

7 Adjust the coolant piping and nozzle and turn on the coolant.

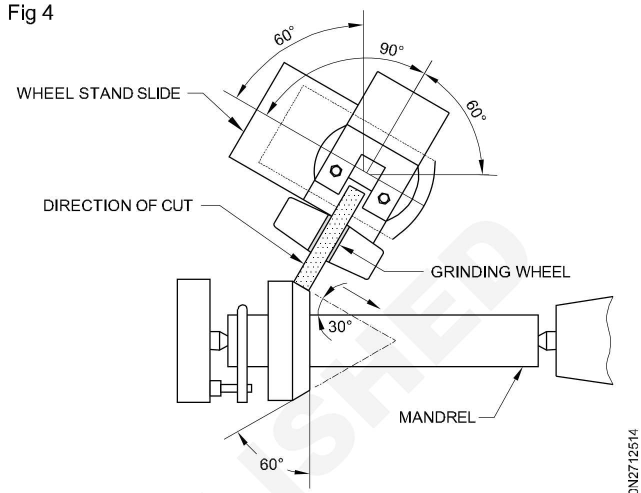
8 Start the machine and carry out grinding in the normal manner.

9 After completing the job, clean and restore the machine to the normal working condition.

Grinding steep or sharp exterior tapers

1 Say the angle of the taper is 300. Swivel and set the slide at 600(900-300) Fig 4 shows the wheel set in position for grinding 300 taper. Turn the plate in to bring the spindle parallel to the slide.

Fig 4



GRINDING A STEEP TAPER

2 Choose the correct type and size of the wheel, secure it in position. Turn it, if necessary.

3 Use chuck or other suitable device for mounting the work.

4 Find out recommended work and wheel speeds. Make necessary adjustments.

5 Make sure that the wheel guard is properly in position. Take necessary precautions for personal safety.

6 Adjust the coolant piping and nozzle. Turn the coolant on.

7 Start the machine. Using hand feed bring the work in contact with the revolving wheel. Move the wheel across the face of the work. If the face of the wheel happens to be of the same width or wider than the surface to be ground, movement of the cross feed is not necessary.

8 Advance the wheel a pre-determined distance depending upon the amount of stock to be removed after every cut by moving the sliding table forward.

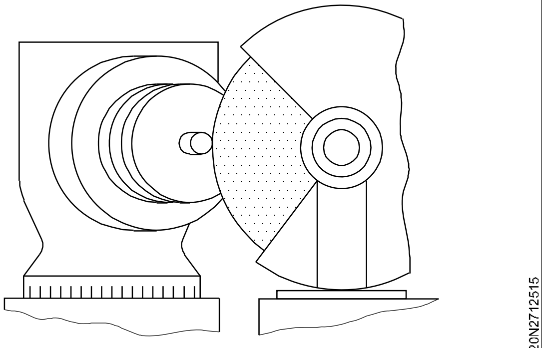
9 Take repeated cuts till the work is completed.

10 After completion of operation, clean and restore the machine to the normal position.

If the taper grinding is to be done by dressing the wheel at an angle, see that the diamond is set on the exact centre line of the wheel. If this is not done, the wheel will not be dressed at the correct angle.

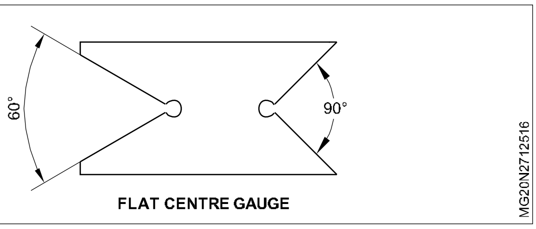
Fig 5 shows the set up for grinding a 60° machine centre. The work head has been swivelled to 30°. After dressing the wheel a trial cut is taken. In case, the trial doesn't follow the original point, the point is checked with the flat centre gauge, Fig 6, or the cone centre gauge and necessary arrangements are made to insure accurate results.

Fig 5



GRINDING A 60° MACHINE CENTRE

Fig 6



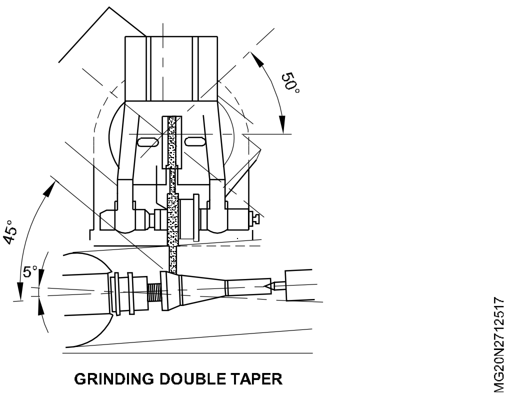
FLAT CENTRE GAUGE

After adjustments, grinding operation is proceeded further, Due to the steep taper, a change in work speed takes place which may cause burning of the centre. It is, therefore, necessary to take light cuts, Use a slow work speed, plenty of coolant and take the cut from the point back to large diameter of the centre.

Grinding double or compound tapers

Grinding of double or compound tapers can be done in one setting provided one of the tapers is within the range of the swivel table. Swivel table is adjusted to the smaller angle and the wheel slide to the large angle. (Fig 7)

Fig 7



GRINDING DOUBLE TAPER

The wheel is adjusted perpendicular to the longest surface and one corner is, then, bevelled correctly to suit the other surface. Grinding of one part is done by traversing the table and the other by movement of the wheel slide. In such cases, the wheel base is adjusted at an angle equal to the sum of the angles of both tapers as measured from the axis. In the set up shown, the sum of both the angles equal $50^{0.}$

Grinding shoulders

If it is required to grind a work to a shoulder, the grinding wheel is located up against the shoulder before starting to grind. Then by the method of plunge cut, the surface is ground to the required diameter. By this method, the finished diameter is left with a corner at the shoulder that is fairly sharp and square. After grinding the workpiece to size at the shoulder, the rest of it is ground by traversing the table.

Alignment of head stock and tail stock

Objectives: At the end of this lesson you shall be able to

- **state the alignment of the main spindle and the tailstock spindle of cylindrical grinding machine**
- **state the true running of a spindle with a test mandrel**
- **describe the method of checking the level of machine bed**
- **describe the testing, the tailstock sleeve movement relative to the machine bed.**

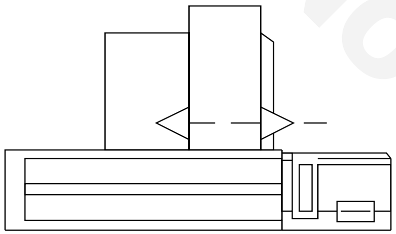
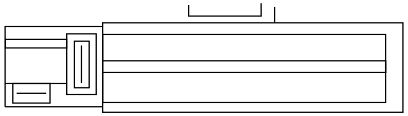
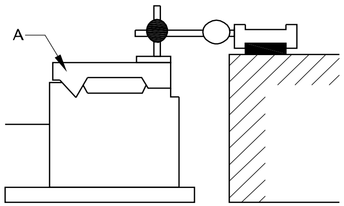
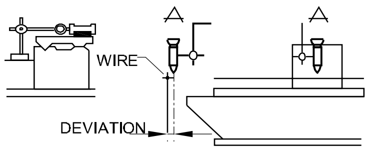
Cylindrical grinding machine of two types, plain and universal. Basically the design is same, where plain machine is generally used for work between centres and the universal machine provided with additional provision to do many variety of components in addition internal grinding also can be done.

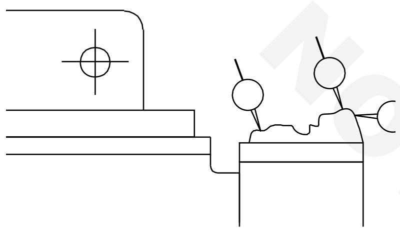
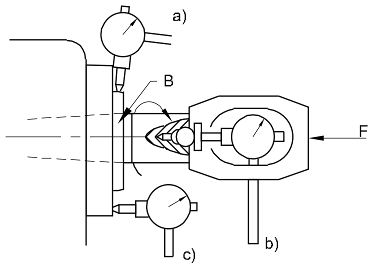
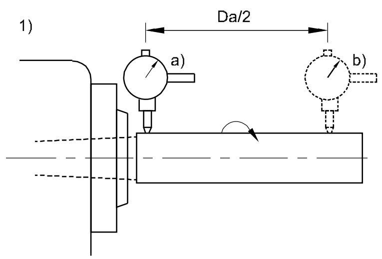
Before putting the machine under regular operations the machine bed, head stock, tail stock and wheel head should under go the geometrical test as per IS:2368:1993 (or) ISO:2433:1984.

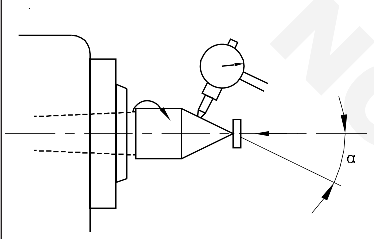
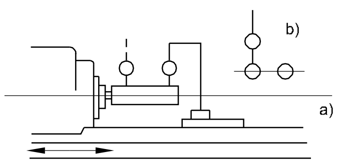
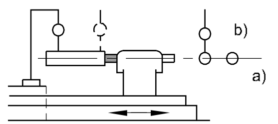
The various methods of tests, permissable deviation and measuring instrument etc is illustrated in the below given table 1.

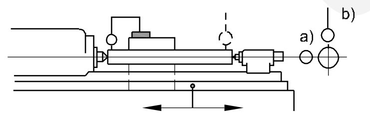
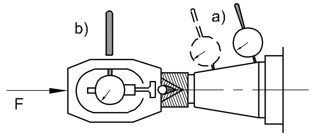
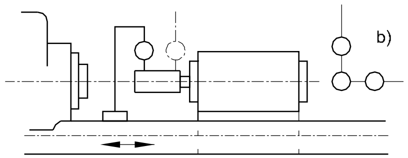
Geometrical tests

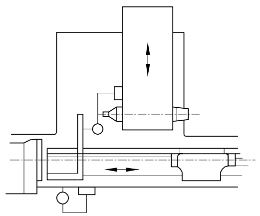
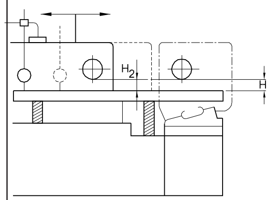
TABLE 1

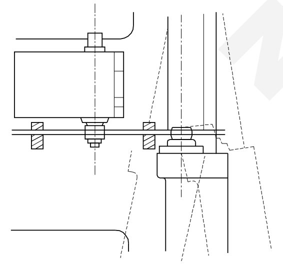
SL No	Diagram	Objects	Permissible deviation mm	Measuring instrument	Observations and reference to the test code ISO/R 230
1a		A-BED Levelling of the slideways a) Longitudinal inspection: Straightness of the slideways in the vertical plane. deviation:0,05 Local tolerance:0,005 over any length of 250	0,02 up to 1000 For each 1000 increase in length, add 0.015. Maximum permissible	Precision level, optical or other methods	a) Clauses 3.11,3.21,5.212.21 and 5,212,22 measurements - shall be made at a number of positions equally spaced along the length of the bed.
1b		b) Traverse inspection: Parallelism of the slideways in the vertical plane.	Variation of level: DC*<500:0.02/1000 DC*>500:0.04/1000	Precision level	
2	 Alternatives	Checking of straightness of the slideways in a horizontal plane.	0.02 up to 1000 For each 1000 increase in length add:0.02 Maximum permissible deviation:0.05 Local tolerance:0.006 Over any lenght of 300	Straight edge, support and dial gauge or micro -Scope and taut wire.	The dial gauge shall be fixed on a support 'A' of a suitable form such that it can slide in the slideways with the stylus touching a straight edge laid parallel to the slideways.
		(These alternatives are for small machines where the table is not to be dismantled). Checking of straightness of the longitudinal movement of the table in the horizontal plane.	0.01 up to 1000 For each 1000 increase in length add:0.01 Maximum permissible deviation:0.025		For alternative 1) The dial gauge support shall be placed on a fixed part of the machine, the stylus shall touch a straight edge laid parallel to the general direction of the longitudinal movement of the table.

SL No	Diagram	Objects	Permissible deviation mm	Measuring instrument	Observations and reference to the test code ISO/R 230
3		Checking of parallelism of the location surfaces for the workhead and tailstock to the longitudinal movement of the table (in the case of movable tables).	0.01 up to 1000 For each 1000 increase in length add:0.01 Maximum permissible deviation:0.03 Local tolerance:0.003 Over any length of 300	Dial gauge(s)	Clause 5.422.22 Place a dial gauge on a fixed part of the machine and and take measurement successively on the location surfaces for the workhead and the tailstock. The table setting carried out during this test shall not be modified for performing tests 6, 7 and 8.
4		**B-Workhead** a) Measurement of run-out of the external register diameter of the spindle. b) Measurement of periodic axial slip of the spindle. c) Measurement of camming of the register face of the spindle (including periodic axial slip).	a) 0.005 b) 0.005 c) 0.01		In the case of a tapered spindle nose the stylus of the dial gauge shall be set normal to the surface which is to be checked.
5		1) Measurement of run-out of the axis of the work spindle taper. a) at the outlet of the housing. b) at a distance from the outlet equal to $\frac{D_a}{2}$ or not more than	a) 0.005 b) 0.015 for a measuring length of 300		Dial gauge and test mandrel

SL No	Diagram	Objects	Permissible deviation mm	Measuring instrument	Observations and reference to the test code ISO/R 230
5		2) Measurement of run-out of the work spindle centre nose.	2) 0.005	Dial gauge	The dial gauge being set normal to the taper surface of the head centre and tolerance being given in a plane perpen dicular to the spindle axis, the reading observed shall there-fore be divided by cos α, α being the semi-cone angle of the taper. The value of force F to be applied shall be speci -fied by the manufacturer.
6		1) Dead spindle Checking of parallelism of the taper before of the workhead to the table movement: a) in a horizontal plane b) in a vertical plane 2) Live spindle Checking of parallelism of the axis of the rotating workhead spindle to the longitudinal movement of the table. a) in a horizontal plane. b) in a vertical plane	0.025 for a measuring length of 300(end of the test mandrel directed towards well and upwards) 0.01 for a measuring length of 300(end of test mandrel directed towards wheel and upwards).	Dial gauge and test mandrel	The table setting established for test 3 shall not be modified
7		**C-Tailstock** Checking of parallelism of the axis of taper bore of the tailstock to the table movement. a) in a horizontal plane	a) 0.015 for a measuring length of 300(end of test mandrel directed towards wheel)	Dial gauge and test mandrel	The table setting established for test 3 shall not be modified

SL No	Diagram	Objects	Permissible deviation mm	Measuring instrument	Observations and reference to the test code ISO/R 230
7		b) in a vertical plane for a measuring length of 300(end of test mandrel directed upwards)	b) 0.015 mandrel	Dial gauge and test	The table setting established for test 3 shall not be modified
8		Checking of parallelism of the movement of the table to the axis of the centres. a) in the horizontal plane b) in the vertical plane	a) 0.02 b) 0.02 (tailstock higher than the workhead)	Dial gauge and test mandrel between centres (or straight edge) or optical methods)	The table setting established for test 3 shall not be modified
9		**D-Grinding wheelhead** a) Measurement of run-out of the grinding wheel spindle (wheelmounting diameter). b) Measurement of periodic axial slip of the wheel spindle.	a) 0.005 for the two sections touched. b) 0.01	Dial gauge	See the observations for test 4. The measurement of the run-out shall be carried out at the two ends of the taper. The value of force 'F' to be applied for the tests a) and b) shall be specified by the manufacturer.
10		Checking of parallelism of the grinding wheel spindle axis to the table movement : a) in horizontal plane. b) in a vertical plane.	a) 0.03 for a measuring length mandrel of 300 b) 0.03 for a measuring length of 300 (end of test mandrel directed upwards)	Dial gauge and test	-

SL No	Diagram	Objects	Permissible deviation mm	Measuring instrument	Observations and reference to the test code ISO/R 230
11		Checking of squareness of the the in feed motion of the wheelhead to the longitudinal movement of the table.	0.02/300	Dial gauge and square	Place on the table a square an arm of which being adjusted parallel to the movement of the table. Connect a dial gauge to the wheel slide. Touch the other arm of the square during the transverse movement.
12		Measurement of difference between height H_1 of the work head spindle axis and the height H_2 of the grinding wheel spindle axis referred to plane parallel to the grinding wheel spindle axis also parallel to the transverse movement of the wheel head slide.	0.4	Test mandrels, dial gauge Straight edge and gauge blocks.	Test mandrels of the same diameter shall be interested into the workhead spindle and the grinding wheel spindle nose. Position the workhead spindle so that the centre sections of the two test madrels are approximately in a plane parallel to the grinding wheel spindle movement. Lay a straightedge on gauge blocks that are resting on a fixed part of the machine so that it is in the above reference plane. Connect a dial gauge to the grinding wheel head with the indicator in contact with the working face of the straightedge towards the test mandrels. Adjust the height of the gauge blocks to to bring the surface of the straight edge parallel to the plane of the movement of the grinding wheel spindle head over its full travel. Measure the respective distances of the test mandrels to the straightedge and compare their difference with the permissible deviation.

SL No	Diagram	Objects	Permissible deviation mm	Measuring instrument	Observations and reference to the test code ISO/R 230
13		Extra test in the case of swivelling tables. Checking of parallelism of the mounting and swivelling plane to the transverse movement of the wheel slide.	0.05 over the entire travel	Test mandrels, dial gauge Straight edge and gauge blocks.	Following the test procedure above, place and then clamp the table first in its centre position so that the straight edge alignment is made, then place the table in its extreme position of swivelling for the measurements.
14		Measurement of repeatability of the finishing approach of the wheel positioning.	Da*≤ 500 0.002 Da*> 500 0.004	Dial gauge	Six consecutive tests shall be carried out for the wheels positioning, the movement being obtained by a quick approach followed by a slow approach.

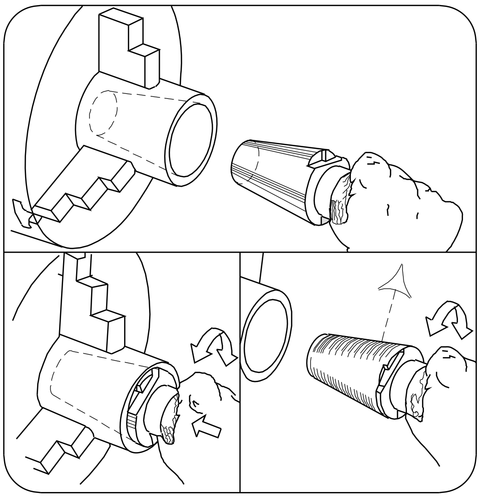
Checking the taper and angles by using taper plug and ring gauges

Objectives: At the end of this lesson you shall be able to
- **explain to check the taper & angles by using taper plug and ring gauges.**

Checking tapered bores (using taper plug gauge)

1 Check bore (Fig 1)

Fig 1



CHECK BORE
CHECKING TAPERED BORES
MG20N2712811

(a) Select appropriate taper gauge.

(b) Clean taper gauge.

(c) Clean bore of workpiece.

(d) Smear a light thin line of marking medium down gauge in three positions. (Prussion blue)

(e) Carefully insert gauge into bore.

(f) Apply inward pressure and turn gauge in bore, approximately three to four times.

(g) Remove gauge and visually check the marking medium.

Note

If taper is correct, marking medium should be smeared equally along, and around, taper. If taper is incorrect, marking medium will only be smeared in one position.

2 Check large diameter of taper (Fig 2)

(a) Ensure taper of workpiece bore is correct.

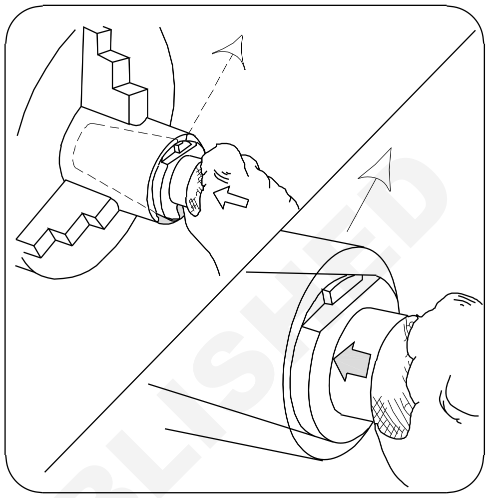
(b) Insert gauge into workpiece bore.

(c) Note distance gauge enters into bore.

Note

Large diameter of bore should lie between the high and low tolerance marks on the large end of the taper gauge.

Fig 2



CHECK LARGE DIAMETER OF TAPER
CHECKING TAPERED BORES
MG20N2712812

Checking tapers

1 Using taper ring gauge

(A) Check taper (Fig 3)

(a) Select appropriate taper ring gauge.

(b) Clean gauge and taper of workpiece.

(c) Smear a thin line of marking medium down length of workpiece taper, in three positions.

(d) Carefully insert workpiece taper into gauge.

(e) Push gauge on taper as far as possible and feel for any ‘’rock’’.

(f) Apply slight pressure and turn gauge on taper.

(g) Remove gauge and visually check marking medium is smeared equally along and around taper.

Note

If marking medium is unequal, taper is incorrect.

(B) Check diameter (Fig 4)

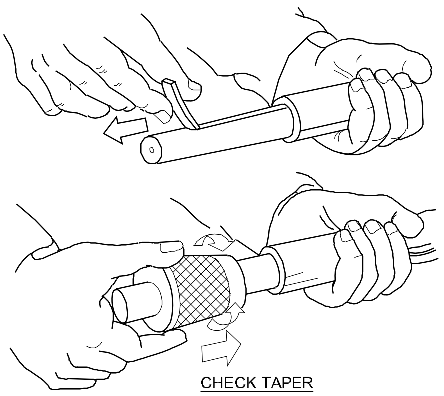
Note

Taper ring gauges are often made with their large end diameter equal to a stated dimension, and, when checking, its end must stand at a certain distance down the taper, from its largest dimension. This length is often stated on the drawing, but if not it must be calculated.

(a) Ensure taper of gauge is correct.

(b) Insert taper of workpiece into gauge.

Fig 3



CHECKING TAPERS

(c) Push gauge along taper until it lightly tightens.

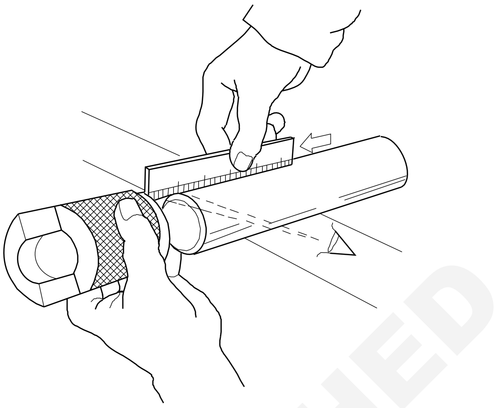
(d) Either

(i) Measure distance from end of gauge to datum on workpiece.

OR

(ii) Check that end of taper protrudes from gauge between the high and low tolerances allowed.

Fig 4



CHECKING TAPERS

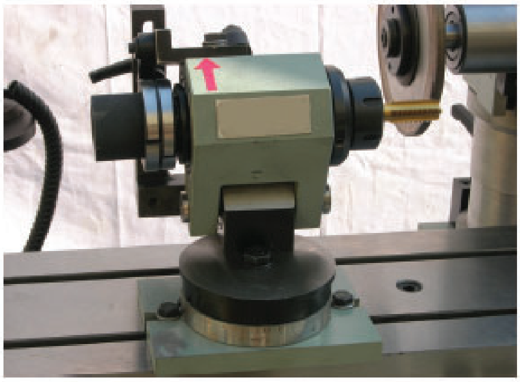
Universal work head

Objective: At the end of this lesson you shall be able to
- **explain the universal work head for angular grinding.**

Universal work head (Fig 1)

Universal work-head shown in Fig 1 is an essential part of the machine. It is used for holding smaller types of end-mills, Shell end-mills, angular cutter ext., during the course of grinding. A work-head with indexing mechanism is invaluable when regashing teeth etc. It has a greater indexing accuracy and further eliminates the use of tooth rest. The indexing arrangement to the cutter-head is use full for fine pitched cutters or when tooth rest cannot be used conveniently. Three graduated scales are provided on the cutter-head. These are clearance setting dial at one end of the spindle housing, and clearance setting dial at one end of the spindle housing, and clearance setting graduations for vertical and horizontal swivel movements. The main spindle of the cutter-head is taper bored at both ends to facilitate the grinding of taper shank cutters, e.g., T.S. end -mills. One side is bored to Morse Taper No. 5 or Brown & Sharp No, 12 and other side is bored to I.S. No.50. The side which is bored to international standard No.50 will accept all arbors and end-sockets, whilst the side which is either bored to M.T. 5, or B & S No. 12 will accommodate taper shank end-mills, arbors, sockets having this taper.

Fig 1



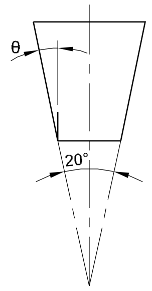
Measuring angle of tapered (external) components

Objectives: At the end of this lesson you shall be able to
- **name the elements of a taper which can be measured using a precision roller and slip gauges**
- **state the formula for measuring the angle of a taper**
- **calculate the angle of taper.**

A method used for measuring tapered components is by using precision rollers or balls along with the slip gauges in this method, the following(elements)measurements of tapers can be taken.

Angle of tapers (Fig 1)

Fig 1

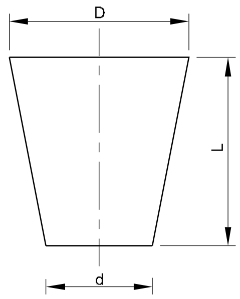


ANGLE OF TAPER

Small end diameter (Fig 2)

Large end diameter (Fig 2)

Fig 2



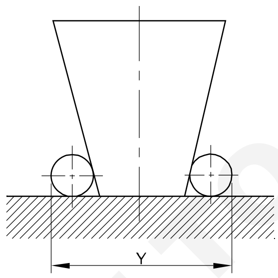
SMALL & LARGE END DIAMETER

Measuring the angle of taper

For determining the angle two measurements are needed, the X and Y. (Fig 3 and 4)

The measurement Y is taken by placing the component against a datum surface like a surface plate of marking lable Two precision rollers are then placed at the smaller end realign on the datum surface (Fig 3)

Fig 3



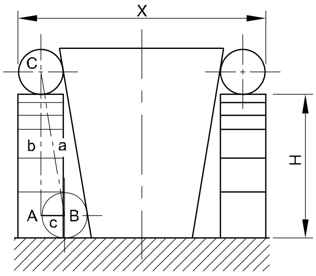
MEASURING THE ANGLE OF TAPER

Measurement 'X' is taken by lifting and placing the rollers on both sides with the help of two sets of slip packs having the same size The measurement is then taken with a micrometer over the rollers (Fig 4)

For computing the taper angle the following trigonometrical ratio is applied. (Fig 5)

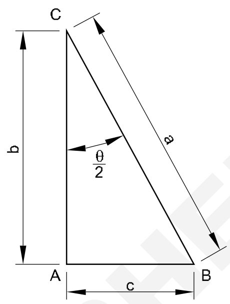
$$\text{Tan}\theta = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{AB}{AC}$$

Fig 4



MEASURING ANGLE OF TAPERED COMPONENETS

Fig 5



MEASURING ANGLE OF TAPERED COMPONENETS

From the two measurements taken and the height of the slip packs the ratio is established by subtracting the measurements Y from X and dividing it by 2(two).

This corresponds to the distance AB.(Fig 5)

$$AB = \frac{X - Y}{2}$$

The length AC corresponds to the size of the slip pack used on one side(Fig) Then the taper angle is

$$\text{Tan}\frac{\theta}{2} = \frac{X - Y}{2} \div H$$

$$= \frac{X - Y}{2} \times \frac{1}{H} = \frac{X - Y}{2H}$$

Where X is the measurement over the rollers placed on the slip gauge height, Y is the measurement over the rollers at the smaller end and H is the slip gauge height The included angle of the taper will be double the above angle.

Example

Calculate the included angle of the tapered component as shown Fig 6.

The measurement

X = 69.3

Y = 61.5

Height = 70 mm

$$\text{Tan}\frac{\theta}{2} = \frac{69.3 - 6.15}{2 \times 70}$$

$$\text{Tan}\frac{\theta}{2}=\frac{7.8}{2}\times 70$$

$$=\frac{3.9}{7.0}=0.05571$$

Referring to the table under natural tangent, we get

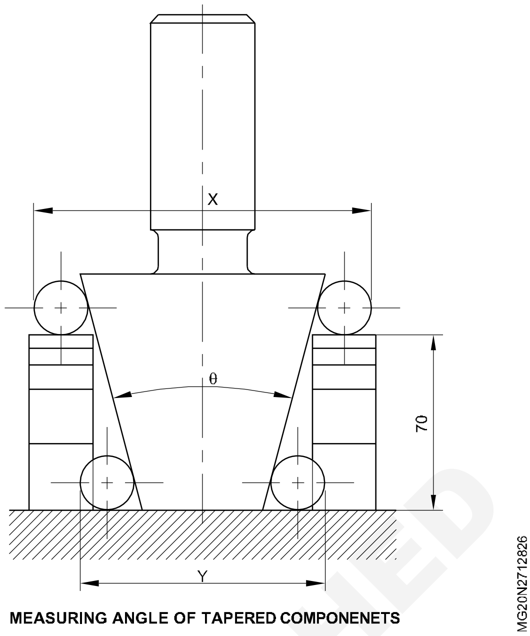
θ = 3°11′ x 2

Hence included angle of the taper

θ = 3°11′ x 2

= 6°22

Fig 6



MEASURING ANGLE OF TAPERED COMPONENETS

Determining diameters of a tapered component

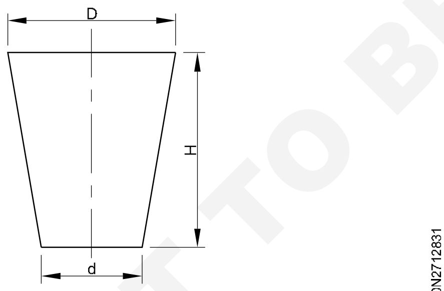
Objectives: At the end of this lesson you shall be able to
- **calculate the small diameter of tapered components**
- **calculate the large diameter of tapered components.**

Diameters at any position of tapered components can be determined when the angle of taper is known

For inspection of the tapered components the following diameters are measured.

- Small end diameter -d
- Large end diameter-D(Fig 1)

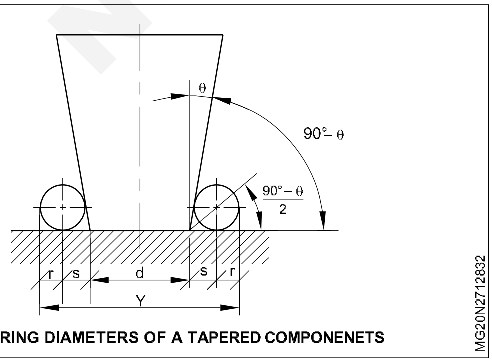
Fig 1



MEASURING DIAMETERS OF A TAPERED COMPONENETS

Determining the small end diameter (Fig 2)

Fig 2



MEASURING DIAMETERS OF A TAPERED COMPONENETS

The small end diameter (d) is = Y - 2 (S + r)

Y is the diameter over two precision rollers

r is the radius of the roller(there are two such rollers)

s is the distance from the centre of the roller to the end of the component

θ is the half included angle of taper

Calculating s (Fig 2)

$$\text{Tan}\frac{90°-\theta}{2}=\frac{r}{s}$$

$$s=\frac{r}{\text{Tan}\frac{(90°-\theta)}{2}}$$

Example

θ = 3°11′

Y = 61.5 mm

r = 6 mm (radius of roller)

$$\frac{90°-\theta}{2}=\frac{90°-3°11'}{2}=\frac{86°49'}{2}=43°25$$

$$S=\frac{r}{\tan\frac{(90°-\theta)}{2}}=\frac{r}{\tan 43°25'}=\frac{6}{0.9463}$$

= 6.34 mm

D = Y - 2(s+r)

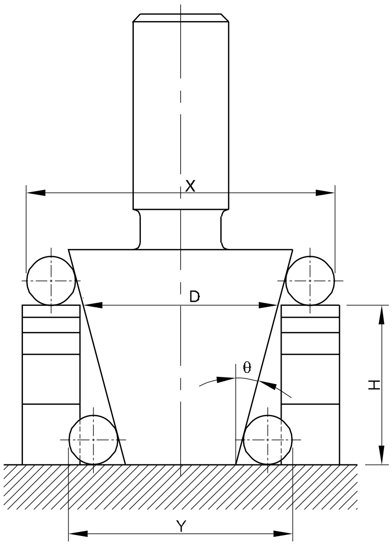
= 61.5 - 2(6.34 + 6)

= 61.5 - 24.68

= 36.82 mm

Determining the large diameter of taper at any desired height (H for example) (Fig 3)

Fig 3



MEASURING DIAMETERS OF A TAPERED COMPONENETS

By taking into consideration the measurement over the rollers placed at a known height ‘H’, the diameter of the roller and the angle of the taper, the formula is derived.

At the height H, the diameter (D) is

D = X - 2(s+r)

For determining s use the formula

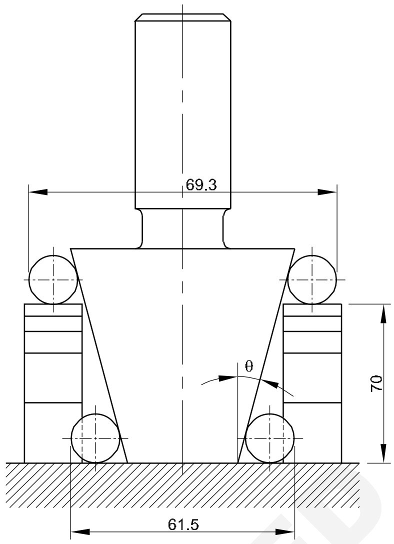
$$s = \frac{r}{\text{Tan}\,\frac{(90° - \theta)}{2}}$$

Example (Fig 4)

θ = 3° - 11′

X = 69.3 mm

Fig 4



MEASURING DIAMETERS OF A TAPERED COMPONENETS

H = 70 mm

r = 6 mm (radius of roller)

Steps

$$\frac{90° - \theta}{2} = \frac{90° - 3°11'}{2} = \frac{86°49'}{2}$$

= 43°25

$$s = \frac{r}{\tan\frac{(90° - \theta)}{2}} = \frac{6}{\tan 43°25'}$$

$$= \frac{6}{0.9463}$$

= 6.34 mm

D = X - 2(s+r)

= 69.3 - 2(6.34 + 6.0)

= 69.3 - 24.68

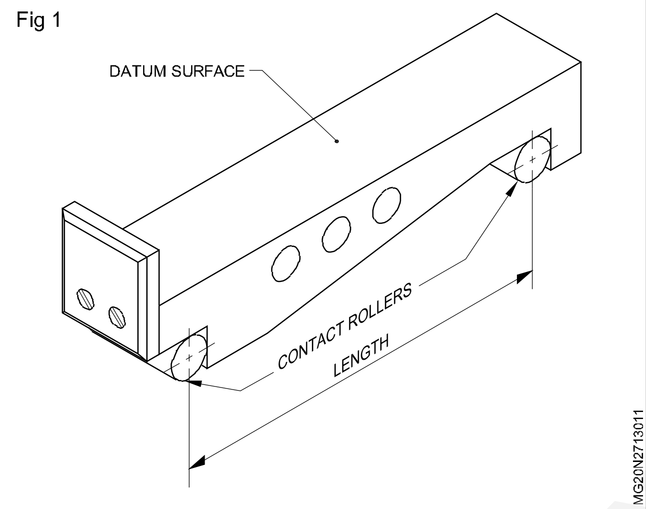
= 44.62 mm

Use of sine bar and slip gauge

Objectives: At the end of this lesson you shall be able to
- **state the principle of a sine bar**
- **specify the sizes of sine bars**
- **state the features of sine bars**
- **state the different uses of sine bars.**

A sine bar is a precision measuring instrument for checking and setting of angles. (Fig 1)

Fig 1

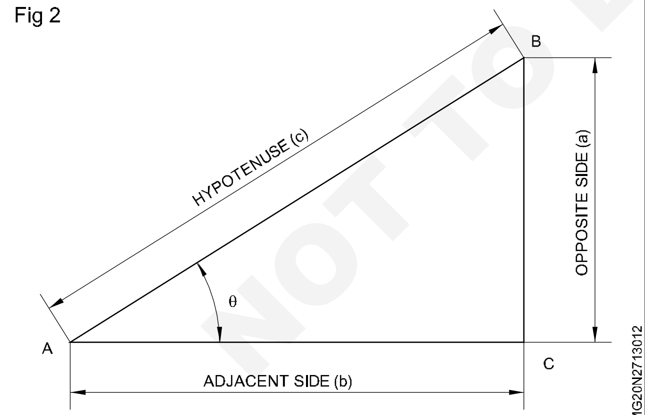


The principle of a sine bar

The principle of a sine bar is based on the trigonometrical function.

In a right angled triangle the function known as Sine of the angles is the relationship existing between the opposite side to the angle and the hypotenuse. (Fig 2)

Fig 2

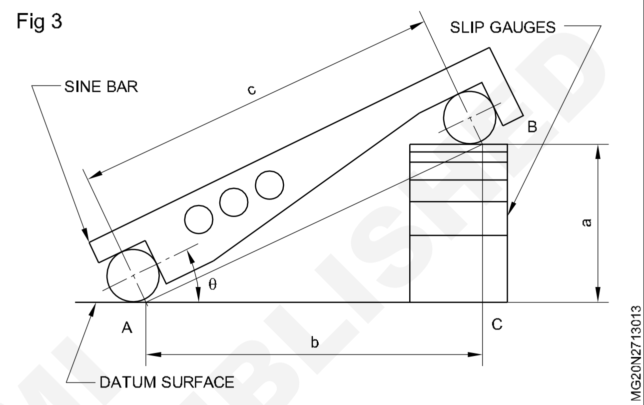


It may be noted that for setting the sine bar to different angles, slip gauges are used.

A surface plate or marking table provides the datum surface for the set up.

The sine bar, the slip gauges and the datum surface upon which they are set form a right angled triangle. (Fig 3)

Fig 3



The sine bar forms the hypotenuse (c) and the slip gauge stack forms the side opposite (a).

$$\text{Sine of the angle } \theta = \frac{\text{Opposite side}}{\text{Hypotenuse}}$$

$$\text{Sin } \theta = \frac{a}{c}$$

Features

This is a rectangular bar made of stabilized chromium steel.

The surfaces are accurately finished by grinding and lapping.

Two precision rollers of the same diameter are mounted on either end of the bar. The centre line of the rollers is parallel to the top face of the sine bar.

There are holes drilled across the bar. This helps in reducing the weight, and also it facilitates clamping of sine bar on angle plate.

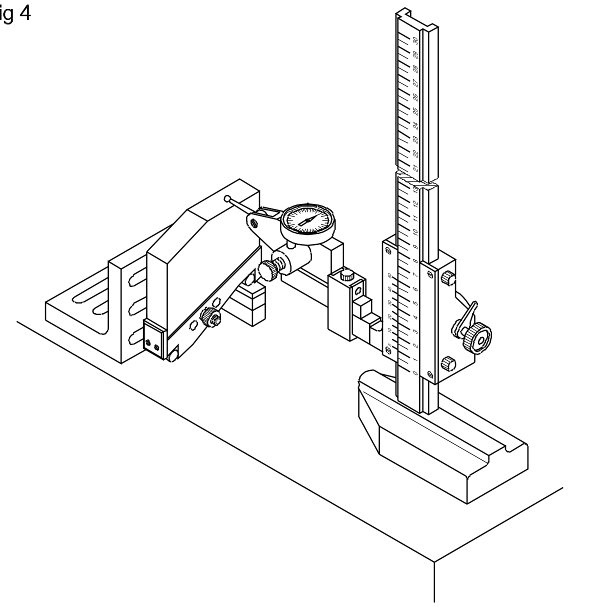
The length of the sine bar is the distance between the centres of the rollers. The commonly available sizes are 100 mm, 200 mm, 250 mm and 500 mm. The size of a sine bar is specified by its length.

Uses

Sine bars are used when a high degree of accuracy to less than one minute is needed for

– measuring angles (Fig 4)

Fig 4



– marking out (Fig 5)

– setting up for machining. (Fig 6)

Fig 5

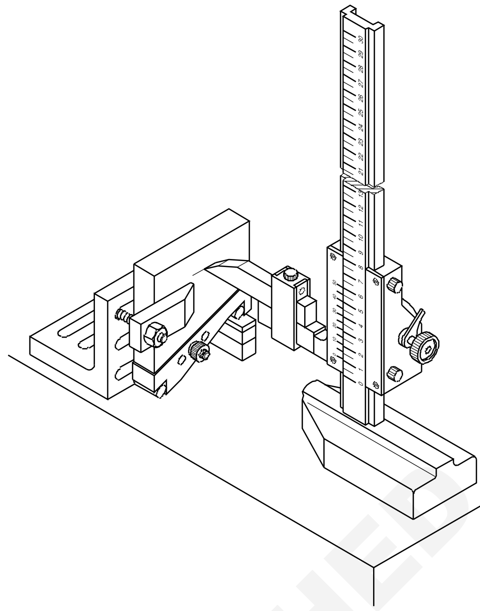
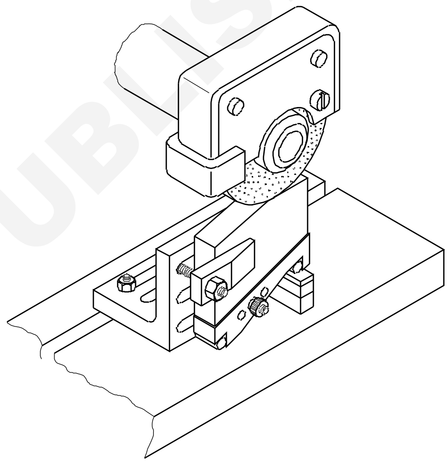


Fig 6



Determining taper using sine bar and slip gauges

Objectives: At the end of this lesson you shall be able to
- **determine correctness of a known angle**
- **calculate the height of slip gauges to a known angle.**

Sine bars provide a simple means of checking angles to a high degree of accuracy of not less than one minute upto 45º.

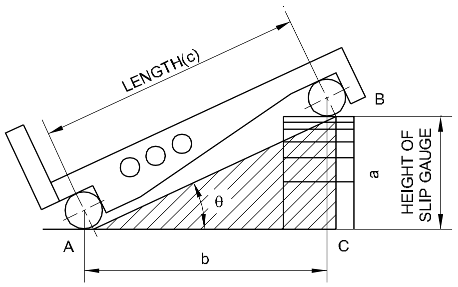
The use of a sine bar is based on trigonometric function. The sine bar forms the hypotenuse of the triangle and the slip gauges the opposite side. (Fig 1)

Checking the correctness of a known angle

For this purpose first choose the correct slip gauge combination for the angle to be checked.

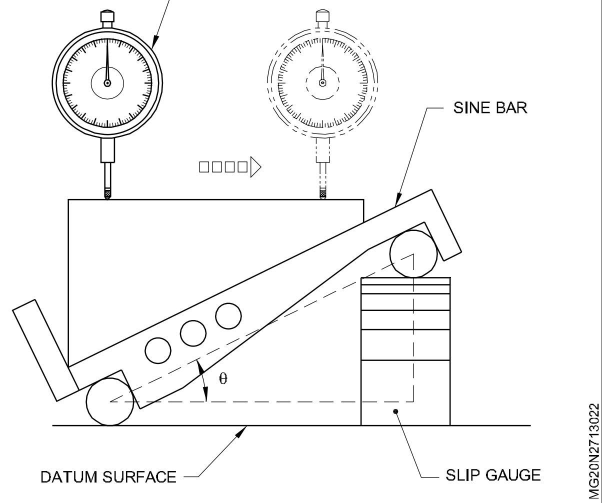
The component to be checked should be mounted on the sine bar after placing the selected slip gauges under the roller. (Fig 1)

Fig 1



A dial test indicator is mounted on a suitable stand or vernier height gauge. (Fig 2) The dial test indicator is then set in first position as in the figure and the dial is set to zero.

Fig 2

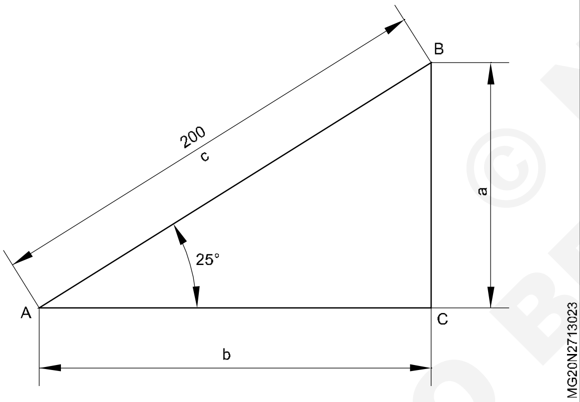


Move the dial to the other end of the component (second position). If there is any difference then the angle is incorrect. The height of the slip gauge pack can be adjusted until the dial test indicator reads zero on both ends. The actual angle can then be calculated and the deviation, if any, will be the error.

Method of calculating the slip gauge height

Example (Fig 3)

Fig 3



Exercise 1

To determine the height of slip gauges for an angle of 25° using a sine bar of 200 mm long.

$$\text{Sin } \theta = \frac{a}{c}$$

$\theta = 25^o$

a = C Sin q

= 200 x 0.4226

a = 84.52 mm

The height of the slip gauge required is 84.52 mm.

The value of sine θ can be obtained from mathematical tables. (Natural trigonometrical functions)

Tables are also available with readily worked out sine bar constants for standard sine bar lengths.

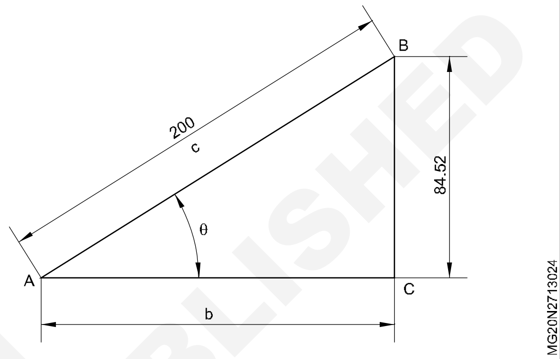
Calculating the angle for tapered components.

Exercise 2 (Fig 4)

The height of the slip gauge used is 84.52 mm. The length of the sine bar used is 200 mm.

What will be the angle of the component? (Fig 4)

Fig 4



$$\text{Sin } \theta = \frac{a}{c}$$

$$= \frac{84.52}{200}$$

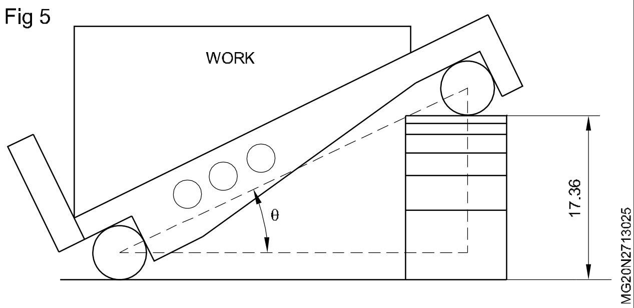
$\text{Sin } \theta = 0.4226$

The angle whose sine value is 0.4226 is 25^0. Hence the angle of tapered component is 25^o.

Classroom Assignment

1 What will be the angle of the workpiece if the slip gauge pack height is 17.36 mm and the size of the sine bar used is 100 mm (Fig 5)

Fig 5



Answer ____________________

2 Calculate the height of the slip gauge pack to raise a 100 mm sine bar to an angle of 3^0 35'.

Answer ____________________

Care and maintenance of slip gauges & sine bar

Objective: At the end of this lesson you shall be able to
- **state the preventive measures to be taken for protecting slip gauges and sine bar.**

Precision measuring instruments play an important role in maintaining the quality of the products. Measuring instruments are also very expensive. It is important that the instruments are well looked after and maintained by the person who uses it.

Protection against corrosion

High atmospheric humidity and sweat from hands can cause corrosion to instruments. Avoid this.

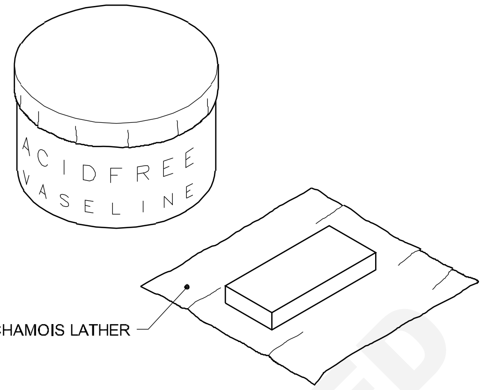
Acid-free vaseline (petroleum jelly) applied lightly on the instruments can give protection against corrosion. (Fig 1)

Be sure that the instruments are thoroughly cleaned and free from water or moisture before applying vaseline.

Use chamois leather for giving a light coating of vaseline.

Always clean the slip gauges with carbon tetrachloride and apply petroleum jelly after use.

Fig 1



Determining internal dovetail angle using rollers and slip gauges

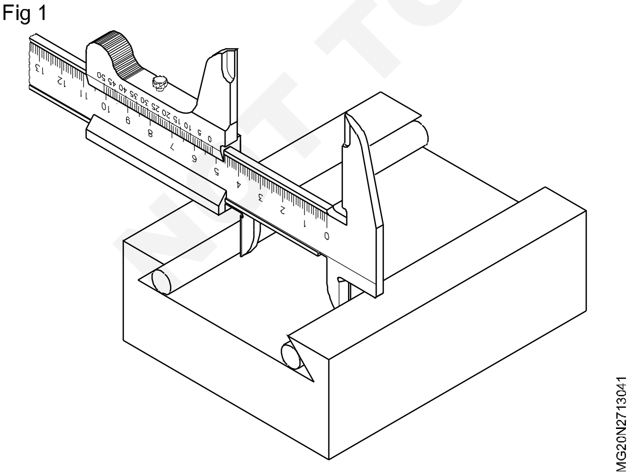
Objective: At the end of this lesson you shall be able to
- **state the purpose of using balls and rollers for measurement**
- **apply trigonometric ratios for calculation**
- **calculate internal dovetail angle using rollers and slip gauges.**

Use of precision balls and rollers

There are situations where measurements of components cannot be taken directly. A typical example of this is a dovetail (internal and external).

In such cases it is possible to calculate the size and taper accurately from the measurement taken over the balls or rollers placed between standard measuring instruments and the component. (Fig 1)

Fig 1



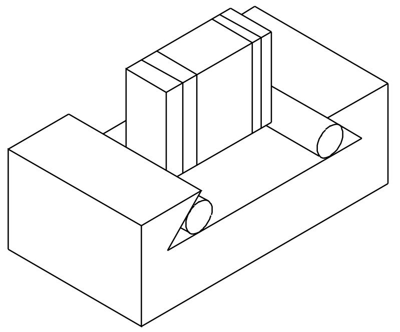
The purpose of the balls or rollers is to provide point or line contact in a known position.

Fig 1 shows how the distance between the rollers is measured with a vernier caliper. It also shows that the point of contact does not lie in the plane of measurement.

Calculating taper angle of internal parallel dovetail

After cleaning the dovetail and the matched pair of precision rollers, the rollers are positioned in such a way that the rollers will contact the angular faces as shown in Fig 2.

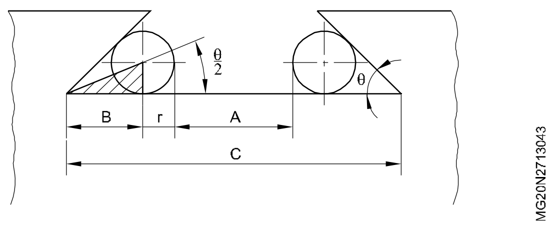
Fig 2



The gap between the rollers can be measured using a slip gauge or vernier caliper.

In the triangle (shaded) (Fig 3)

Fig 3



$$\tan\frac{\theta}{2} = \frac{r}{B} \text{ (r is the radius of the roller)}$$

$$c = A + 2r + 2B$$

$$2B = C - A - 2r$$

$$B = \frac{C - A - 2r}{2}$$

$$\tan\frac{\theta}{2} = \frac{r}{B} = \frac{r}{\frac{C - A - 2r}{2}}$$

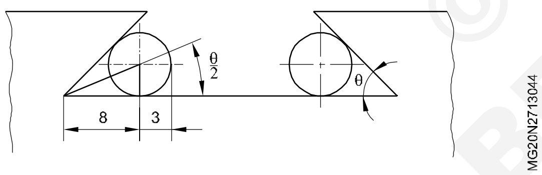
$$= \frac{2r}{C - A - 2r}$$

(The value of C,A,r, are known. Hence the angle $\frac{\theta}{2}$ can be calculated.) This is the half angle of the dovetail.

Example

Calculate the internal dovetail angle of a workpiece as per data given in the Fig 4.

Fig 4



$$\tan\theta = \frac{\text{Opposite side}}{\text{Adjacent side}}$$

$$\tan\frac{\theta}{2} = \frac{r}{B} = \frac{3}{8}$$

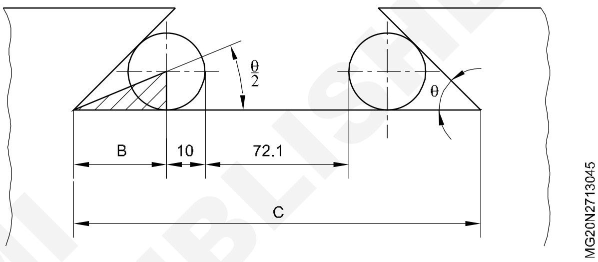
$$\frac{3}{8} = 0.375$$

$$\tan\frac{\theta}{2} = 20°\ 30'$$

Tan θ or dovetail included angle = 41° ... Ans

Classroom Assignment (Fig 5)

Fig 5



Calculate the distance C of the dovetail if the diameter of the roller is 20 mm, angle is 50° and the distance between the rollers is 72.1 mm.

Answer ____________________

____

Determining external dovetail angle using rollers

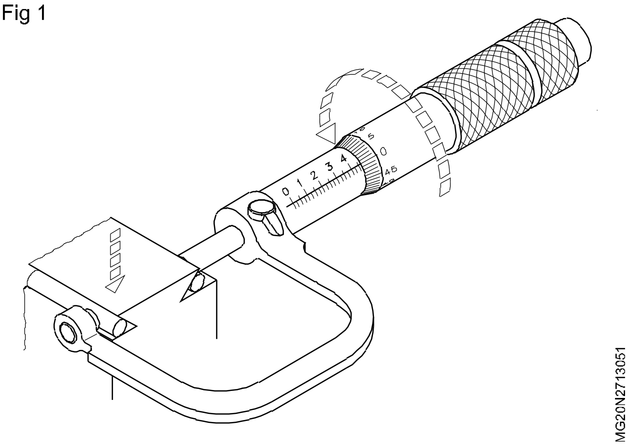
Objective : At the end of this lesson you shall be able to
- **calculate the external dovetail angle using precision rollers.**

As in the case of internal dovetail, measurements of external dovetail also can be taken using precision rollers.

Calculating external parallel dovetail angle

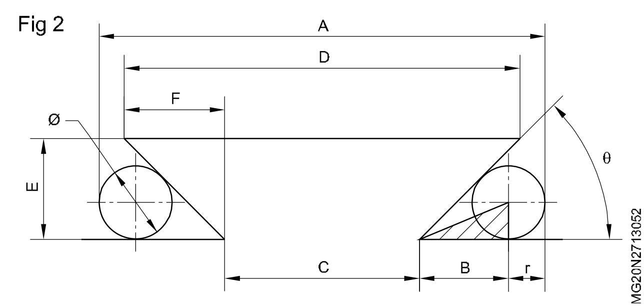
After cleaning the dovetail and matched pair of precision rollers of known size, the rollers are positioned in such a way that the rollers will contact the angular faces as shown in Fig 1. The distance (A) over the roller is measured with an appropriate, measuring instrument. Various features required can be determined by calculation.

Fig 1



To calculate 'B' (Fig 2)

Fig 2



$$B = \frac{r}{\tan \theta/2}$$

$$\tan \frac{\theta}{2} = \frac{r}{B}$$

r = ½ of roller diameter or opposite side to $\theta/2$

B = Adjacent side to $\theta/2$

2(B + r) = A - C

$$B = \frac{A - C - 2r}{2}$$

Where

A = distance over rollers

C = internal corner-to-corner distance

To calculate angle

$$\tan \frac{\theta}{2} = \frac{r}{B}$$

θ = External angle of the dovetail

Example

The angle of the dovetail can be computed when the following features of the dovetail are known.

The distance 'A' (The measurement over rollers)

The distance 'C'

The diameter of the precision rollers '2r'

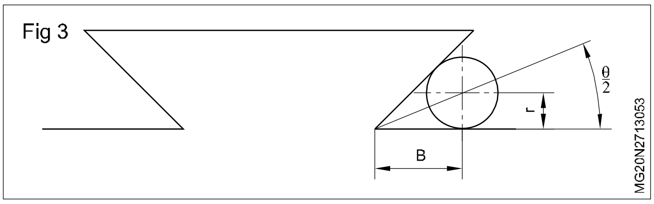
$$\tan \frac{\theta}{2} = \frac{r}{B}$$

The correctness of the angle of the dovetail made is determined by comparing the calculated and measured value of 'A'.

If the measured value of A is not the same then the angle needs correction.

Example (Fig 3)

Fig 3



Calculate the external dovetail angle using the data given below.

r = 16 mm

B = 52 mm

$$\text{Tan} \frac{\theta}{2} = \frac{r}{B} = \frac{16}{52} = 0.0376$$

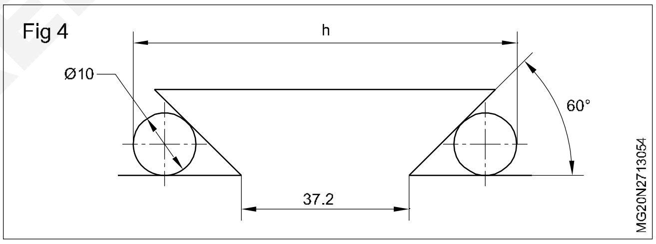
$$\frac{\theta}{2} = 17°10'$$

The angle of dovetail is = 17°10′ x 2

= 34° 20′

Classroom Assignment (Fig 4)

Fig 4



A dovetail has both angles 60°, the width at the bottom is 37.2 mm. The diameter of the roller is 10 mm. Calculate the distance (h) over the rollers.

Answer_______________

Calculating the depth of 'Vee' groove using rollers

Objective : At the end of this lesson you shall be able to

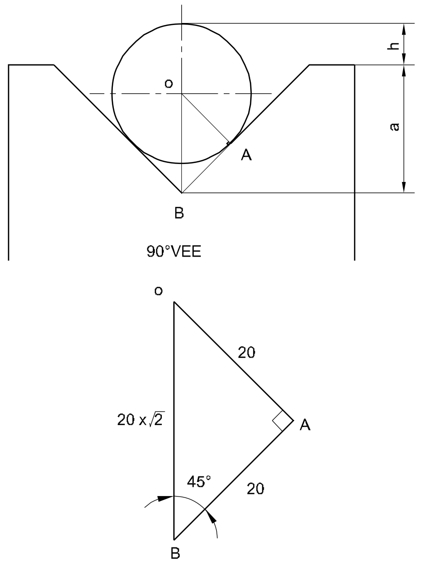
- **verify the depth of a 'Vee' groove using rollers.**

A precisely finished Vee groove depth can be accurately checked using rollers.

Figure 1 shows a 90° Vee groove being checked using rollers. If the angle of the 'Vee' is correct the projection (h) of the roller from the top surface of the 'V' block will differ depending on the depth (a).

Let us consider a 90° Vee groove to be checked for correctness of depth. The diameter of the precision roller used is 40 mm, the depth of the 'Vee' groove is 35mm. When the precision roller is placed in the 90° Vee groove, it forms a right angled triangle 0 AB as shown in Fig 1.

Fig 1



In this triangle

OBA = 45°

OB = OA x $\sqrt{2}$

= 20 x $\sqrt{2}$ = 28.28.

The distance a + h = 28.28+20

= 48.28 mm.

Since 'a' is the required depth of 35mm, then 'h' should be

= 48.28 - 35

= <u>13.28</u> mm.

Any deviation from this 'h' makes the depth of the Vee incorrect and this needs correction. The height can be verified using a vernier height gauge. (Fig 2)

Checking depth of 60° angle 'Vee'

Consider the roller diameter as 30 mm. What should be 'h' i.e. the distance over the rollers? (Fig 3) In this, not only the angle is different, but also the construction of the component itself.

In this case, the angle, the diameter of the roller and the distance 'a' are all known.

The measurement to be checked is the depth of Vee in relationship to dimension 'a'.

The correct distance 'h' i.e. the measurement over the rollers can be calculated as follows.

h = a + AB + radius of roller.

Fig 2

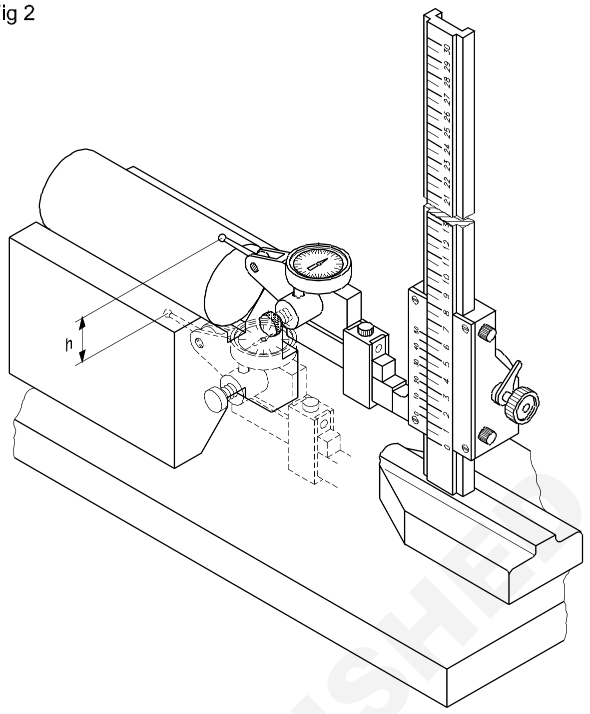
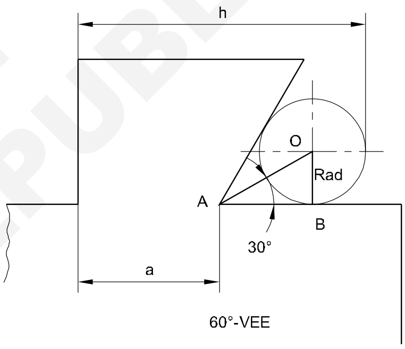


Fig 3



The triangle is OAB.

AB = OB x $\sqrt{3}$

= 15 x 1.732

= 25.98

h = a + 25.98 + 15

= <u>a + 40.98</u>

Note

Depending on the position of the 'Vee' in the component the instrument can be chosen for measuring h.

Checking depth of 45° angle Vee (Fig 4)

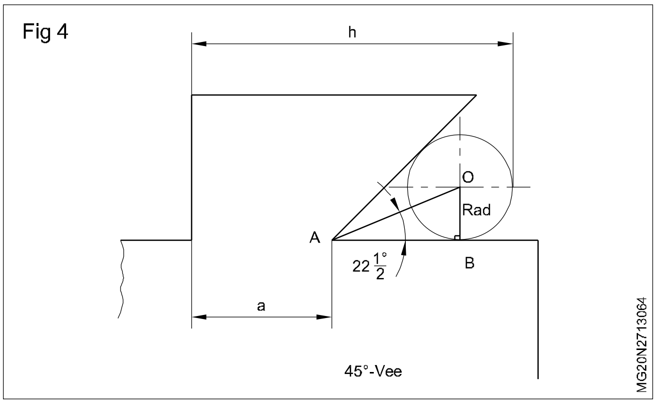
This is a component with 45° Vee angle.

The measurement 'a' is 18.5 mm and the diameter of the rollers used is 30 mm. What will be the measurement over the rollers if the angle is correct?

In this case

OAB = 22½°

Fig 4



$$\text{Tan } 22\tfrac{1}{2}^\circ = \frac{OB}{AB}$$

$$AB = \frac{OB}{\text{Tan } 22\frac{1}{2}} = \frac{15}{0.4142}$$

= 36.21 mm

h = a + AB + OB

= 18.5 + 36.21 + 15

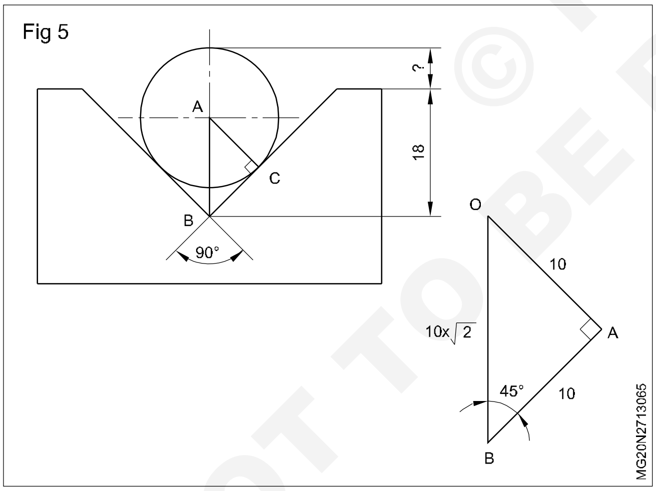
= <u>69.71</u>

Note

This formula can be applied for checking the depth of any Vee angle.

Example 1 (Fig 5)

Fig 5



The angle of 'Vee' groove = 90°.

'Vee' groove height = 18 mm

Roller dia. = 20 mm

Find the height of the roller above the top surface.

The height of the roller from the bottom of the groove is

AB + radius of the ball (10 mm).

AB = 10 x $\sqrt{2}$ = 14.14

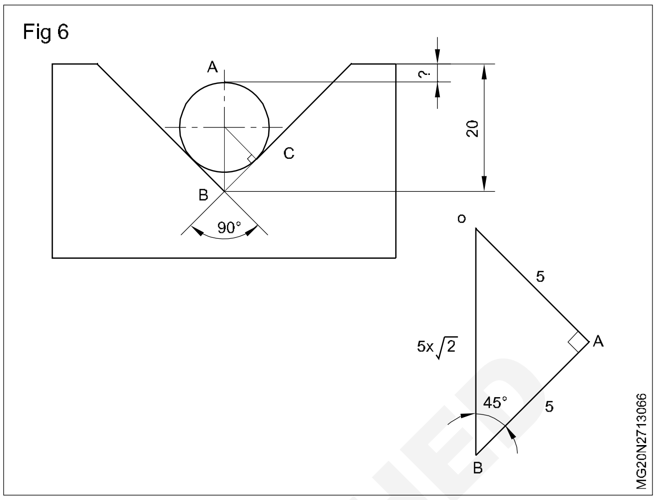
Height of roller = 14.14 + 10 = 24.14 mm.

Height of the roller above the top surface

= 24.14 18.00 = <u>6.14</u>

Example 2 (Fig 6)

Fig 6



The angle of 'Vee' groove = 90°

height of 'Vee' groove = 20 mm

Roller dia. = 10 mm.

Find the height of the roller below the top surface.

The height of the roller from the bottom of the Vee groove is AB + radius of the rollers.

AB = 5 x $\sqrt{2}$ = 7.07.

Height of the roller = 7.07 + 5

= 12.07

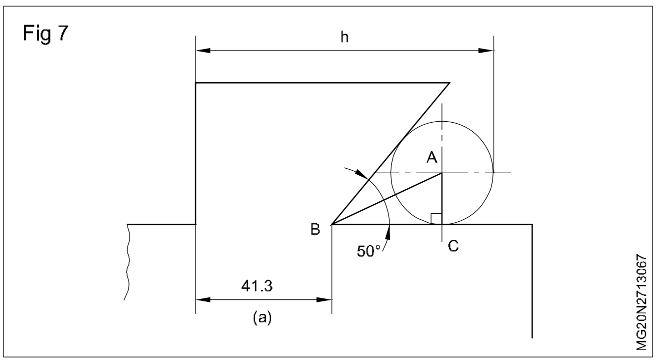
Height of the roller below

The top surface = 20.00 12.07

= <u>7.93</u>

Example 3 (Fig 7)

Fig 7



In a half dovetail the width a = 41.3 mm;

the angle of taper, being special, is 50°.

The dia. of rollers is 20 mm.

Find h.

h = a + BC + radius of roller

$$\tan 25^\circ = \frac{AC}{BC}$$

$$\text{So, } BC = \frac{AC}{\tan 25^\circ} = \frac{10}{0.4663}$$

$= \underline{21.44}$

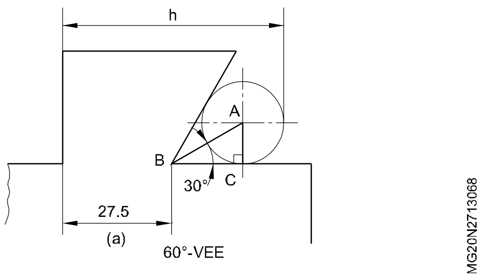
$h = 41.3 + 21.44 + 10$

$= \underline{72.74}$

Classroom Assignment

In a half dovetail the width a is 27,55 mm; the angle of dovetail is 60°; the roller dia. is 20 mm. Find the distance h. (Fig 8)

Fig 8



Determine the angle of vee groove using rollers

Objective: At the end of this lesson you shall be able to
- **determine the angle of a 'Vee' groove applying trigonometrical functions.**

The included angle of a given 'Vee' block can be determined if the following measurements are available.

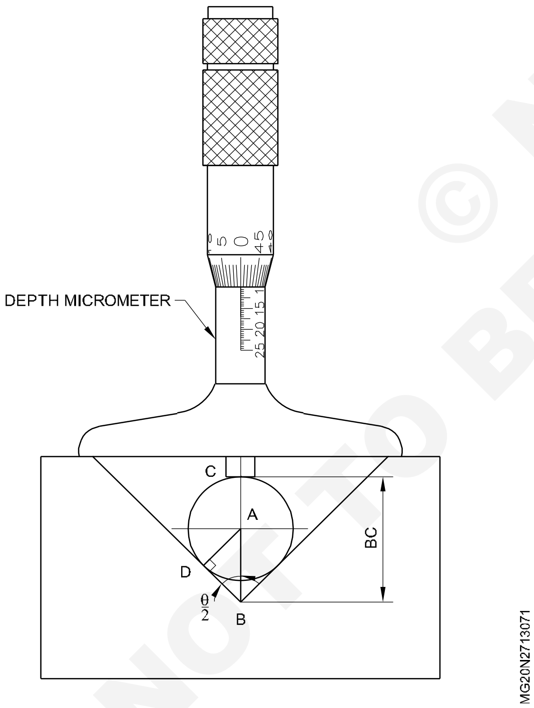
Depth of the 'vee' groove

and

Diameter of the rollers.

From this the distance AB can be computed. (Fig 1)

Fig 1



AB = BC - AC; AD is the side opposite.

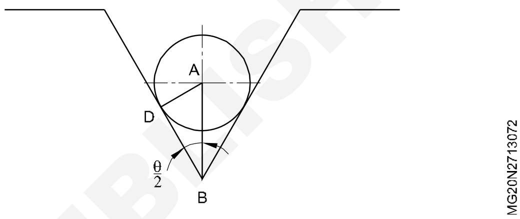
Since the values of AD, BC, AD are known $\frac{\theta}{2}$ can be determined.

Therefore the angle of 'Vee' groove = $2\frac{\theta}{2}$

$$\text{Angle of Vee groove} = 2\frac{(AD)}{(AB)}$$

Example (Fig 2)

Fig 2



Find the included angle of the Vee groove if AB is 17 mm and AD = 10 mm.

$$\sin\frac{\theta}{2} = \frac{AD}{AB}$$

$$= \frac{10}{17}$$

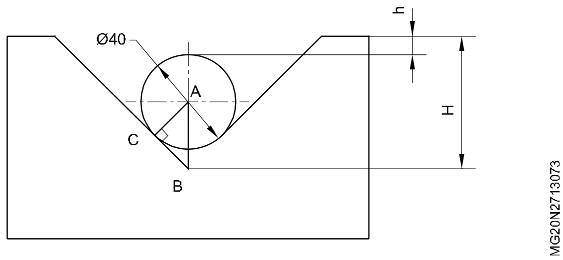
$$\sin\frac{\theta}{2} = 0.5882$$

(Referring to natural sine table)

$$\frac{\theta}{2} = 36^0 \qquad \theta = 72^o$$

Classroom assignment (Fig 3)

Fig 3



The depth of a 'Vee' groove is 60 mm. The difference between the top surface to the top of the roller is 10 mm. The dia. of the roller is 40 mm. Find the angle of the Vee groove.

Answer ______________________

Steady rest

Objectives: At the end of this lesson you shall be able to
- **state what is a steady rest**
- **name the types of steady rests**
- **distinguish between fixed steady rest and follower steady rest**
- **state the uses of a steady rest.**

A steady rest is a lathe accessory used to give extra support for a long slender workpiece in addition to the centre support during turning.

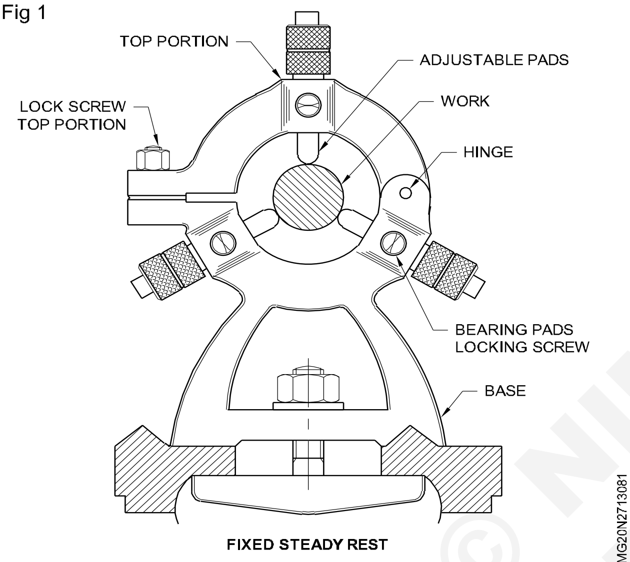
The most commonly used steady rests are the:

Fixed steady rest

Follower steady rest (travelling steady)

Fixed steady rest (Fig 1)

Fig 1



FIXED STEADY REST

The figure shows the parts of a fixed steady rest.

A fixed steady rest is fixed to the lathe bed and it is stationary. It gives support at one fixed place only.

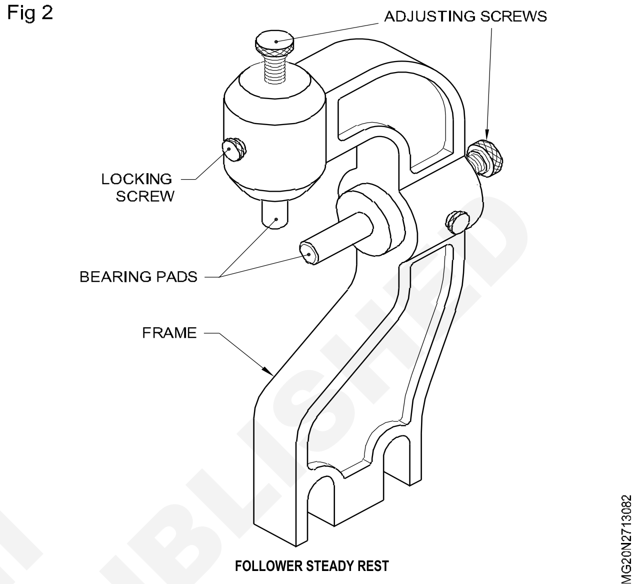
It consists of a frame containing three adjustable pads.

The base of the frame is machined to suit the inside ways of the lathe bed. The top portion is hinged at the back to permit the top to be lifted or assembled to the bottom half for allowing the work to be mounted or removed. The fixed steady can be clamped at any desired position on the lathe bed by the base clamping screw.

The three adjustable pads can be moved radially in or out by means of adjusting screws. The three pads are adjusted on a trued cylindrical face of the workpiece.

Follower steady rest (Fig 2)

Fig 2



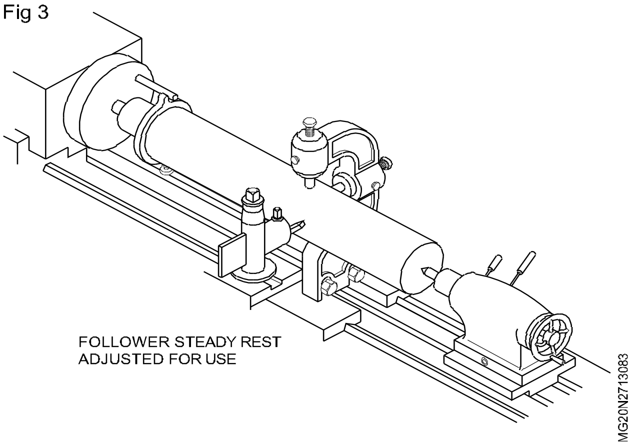
FOLLOWER STEADY REST

A follower steady is fixed to the saddle of the lathe. As if follows the tool it gives support just behind the cutting point. In the case of the follower steady the support is continuous to the entire length of cutting.

It has usually two pads. One pad is located opposite to the cutting tool and the other pad bears the top of the workpiece to prevent it from springing up.

Fig 3 shows the follower steady rest in position.

Fig 3



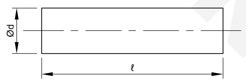
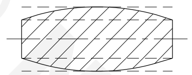
Out of round surface

Objectives: At the end of this lesson you shall be able to
- **state the reasons for out of roundness of work piece**
- **correlate the table containing checking parameters with permitted variation.**

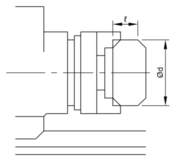
The jobs ground in cylindrical shape under go out of roundness due to many factors such as machine alignment, work holding methods, balancing of wheel, coolant etc. Different size and length of test piece hold in between centres and mounted on a plate. The parameters to be checked on round surface and permitted deviations for check to be applied are given in table 1.

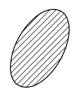
TABLE 1

Practical tests

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Diagram</th><th rowspan="2">Nature of test</th><th rowspan="2">Cutting Conditions</th><th rowspan="2">Checks to be applied</th><th>Permissible deviation</th><th rowspan="2">Measuring instruments</th><th rowspan="2">observations and to the test code ISO/R 230</th></tr>
<tr><th>mm</th></tr>
<tr><td>P1</td><td>
Diameter in millimeters<table><tr><th>DC*</th><th>l</th><th>d_{min}</th></tr><tr><td>DC < 315</td><td>160</td><td>16</td></tr><tr><td>315 < DC < 630</td><td>315</td><td>32</td></tr><tr><td>630 < DC < 1500</td><td>630</td><td>63</td></tr><tr><td>1500 < DC < 3000</td><td>1000</td><td>100</td></tr><tr><td>DC < 3000</td><td>1500</td><td>150</td></tr></table></td><td>Grinding of a cylindrical test piece mounted between centres.</td><td>Grinding without arbor support over the whole length of the test piece</td><td>a) Circularity (roundness) (see below)
b) Consistency of diameter
Variation of diameter measured at at both ends and in the middle of the test piece
</td><td>a) 0.003 for l < 630
0.005 for l > 630
b) for l = 160 : 0.003
for l = 315 : 0.005
for l = 630 : 0.008
for l = 1000 : 0.01
for l = 1500 : 0.015</td><td>Precise measuring instrument</td><td rowspan="2">Test for circularity should be made at several positions of the test piece, and the greatest value of the deviations obtained.

The measurement for consistency of diameter shall be carried out in a single axial plane.

NOTE: Any taper should be such that the major diameter is near the workhead.</td></tr>
<tr><td>P2</td><td>
Diameter in millimeters<table><tr><th>DC* < 1500</th><th>DC* > 1500</th></tr><tr><td>l = 0.5 d
d_{min} = 40
d_{max} = 100</td><td>l = 0.25 to 0.5 d
d_{min} = 100
d_{max} = 400</td></tr></table></td><td>Case of live spindles

Grinding of a cylindrical test piece mounted on a plate</td><td></td><td>Circularity (roundness) (deviation for circularity = difference between the maximum diameter and the minimum diameter of a section).
</td><td>DC < 1500
0,005
DC > 1500
0,005
for a 100 mm piece diameter.</td><td>Precise measuring instrument</td></tr>
</table>

*DC = Distance between Centres

Centerless grinding

Objectives: At the end of this lesson you shall be able to
- **state centreless grinding processes/methods**
- **state the advantages of centreless grinding**
- **state the effect of setting work above and below the wheel centre.**

Methods of centreless grinding and its advantages

Throughfeed and infeed are the two basic methods of centreless grinding. The fundamental difference between these methods lies in the type of feeding method employed when grinding is in progress. To grind a work using the throughfeed method, the work is axially fed through automatically between the two wheels, kept ready set (Fig 1a) whereas in the infeed method (Fig 1b), one of the two wheels is fed against the work, which does not move

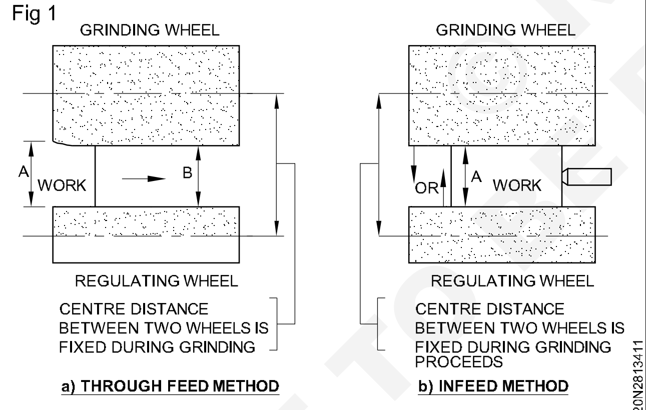
A initial diameter of the work

B Finished diameter of the work

-> Feed motion during grinding

axially during grinding. Besides throughfeed and infeed, there are two other methods; one of these can be said to be neither throughfeed not infeed, which is known as 'Endfeed' and the other one is a combination of both the throughfeed and infeed methods.

Fig 1



METHODS OF CENTRELESS GRINDING

Thus, there are the following four main methods of centreless grinding:

- Through feed
- Infeed
    - Plain infeed
    - Profile infeed
- End feed (neither through feed nor infeed)
- Combination of throughfeed and infeed

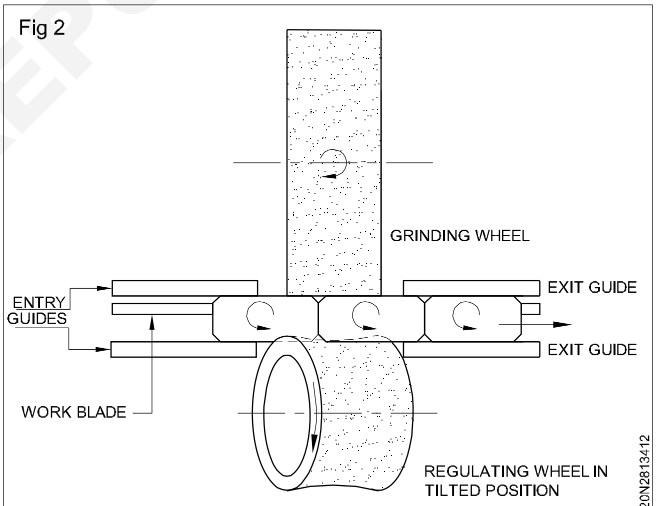
Throughfeed method

In the throughfeed type of grinding, the work is 'automatically' fed 'through' continuously between the grinding and the regulating wheels which have already been set with a particular gap, During its axial travel, it remains supported on the vee formed by the inclined top surface of the work blade and the regulating wheel.

Since the work has to remain or guides are necessary at the entry and exit sides of the wheel in order to support or guide the work while entering as well as while leaving the wheels. Figs 2 and 3 illustrate the set-up for throughfeed grinding. The words 'through' and 'automatic' have definite significance in expressing the following two special features of through feed grinding:

- The grinding starts as soon as the work starts entering between the already set grinding wheel and regulating wheel. The grinding operation is complete only when the work is completely 'through', i.e., when the entire work comes out of the wheels.

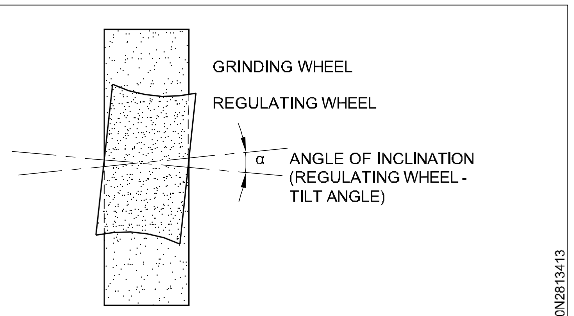
Fig 2



METHODS OF CENTRELESS GRINDING (THROUGH FEED)

- Axial feed, i.e., axial movement of the work is 'automatic' in the sense that, normally, no additional feeding mechanism is employed for this purpose. The regulating wheel, which otherwise is essential for controlling the rotation of the work, is also used for feeding the work axially by diverting a part of its rotational power for feeding purpose, by tilting it at a certain angle, called the angle of inclination (Fig 3). This will give rise to a horizontal component of rotational velocity.

Fig 3



METHODS OF CENTRELESS GRINDING

Work feed rate (Work traverse rate) F = Horizontal component of peripheral velocity at the point of contact between regulating wheel and work.

$F = \pi d N \sin a^*$ __________(1)

Where d = Diameter of the regulating wheel

N = Speed of the regulating wheel in RPM

a = Angle of inclination of the regulating wheel, i.e., regulating wheel tilt angle in degrees. (If d is expressed in mm, the work feed rate F will be in mm per minute). (Table 1)

TABLE 1

***Values of Sin a**

a	0°	2°	4°	5°	6°	8°
0°	.0000	.0035	.0070	.0087	.0105	.0140
1°	.0175	.0209	.0244	.0262	.0279	.0314
2°	.0349	.0384	.0419	.0436	.0454	.0488
3°	.0523	.0558	.0593	.0610	.0628	.0663
4°	.0698	.0732	.0767	.0785	.0802	.0837
5°	.0872	.0906	.0941	.0958	.0976	.1011

It can be seen from equation (1) that the work feed rate can be either increased by increasing the regulating wheel speed or by increasing the angle of inclination of the regulating wheel.

All grinding machines are either so designed that while viewed from the front, i.e., the work feeding side, when the regulating wheel is on the right hand side, it is supposed to rotate in a clock-wise direction (Fig 2), or when the regulating wheel is on the left hand side, it is designed to rotate in an anti-clockwise direction. Thus, with any one of these set -ups, the regulating wheel axis is always tilted in a vertical plane in such a way that it slopes down towards the rear so that the work travel is always from the front to the rear. Sometimes, this automatic feeding action due to a tilted regulating wheel may not be effective, if the work is very heavy. In such cases, additional feeding devices are employed.

Once set, the throughfeed method offers a great advantage of grinding continuously one work piece after another, requiring practically no attention as long as the work pieces coming out are within the required tolerance limits of size and surface finish.

The throughfeed is thus the quickest method of production it is most widely used in preference to other methods of grinding.

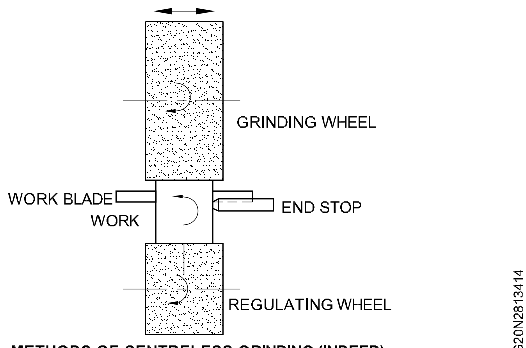
Throughfeed grinding limitations

- The use of the throughfeed method of centreless grinding is normally limited to grinding of plain cylindrical work. However, by using a special loading attachment and a specially formed regulating wheel, taper rollers can be ground quite satisfactorily on a production basis by utilising the throughfeed principles.
- If stock removal-required is high then it may not be possible to remove all the stock in a single pass, because in the throughfeed set-up the amount of cut is fixed for a particular pass; and for any additional cuts, additional throughfeed passes will be necessary. Thus, for a limited number of work pieces requiring heavy stock removal, the through feed method .

Infeed (plunge cut) method

In this type of grinding, the work does not move axially as in the throughfeed method, but it is kept supported against an end stop In a fixed position and resting in the vee formed by the inclined top surface of the work blade and the regulating wheel, as shown in Figs 4 and 5b. Grinding action is affected by feeding gradually either the regulating wheel or the grinding wheel on to the work.

Fig 4



METHODS OF CENTRELESS GRINDING (INDEED)

When the work diameter approaches the required diameter, the feeding movement of the wheel is stopped. After allowing the work to be ground for a short time in this fixed set-up, one or both of the wheels are withdrawn to facilitate unloading of the ground work by pushing it backward or forward or by lifting it up or dropping it sideways. The next work piece is then placed in position against the end stop and the same cycle of operation is repeated for grinding it.

Because the work does not require axial feeding while using the infeed method, it is not necessary to tilt the regulating wheel from the theoretical point of view. However, in practice, even in Infeed grinding, the regulating wheel is given a certain tilt angle, not exceeding $I/4^{o}$, to keep the work always pressed against the fixed end stop.

Sometimes, to obtain a better surface finish, an oscillating attachment is provided on the machine which gives an axial oscillating motion to the grinding wheel during the infeed grinding. The amplitude of the grinding wheel oscillation may be about 2 mm to 6 mm.

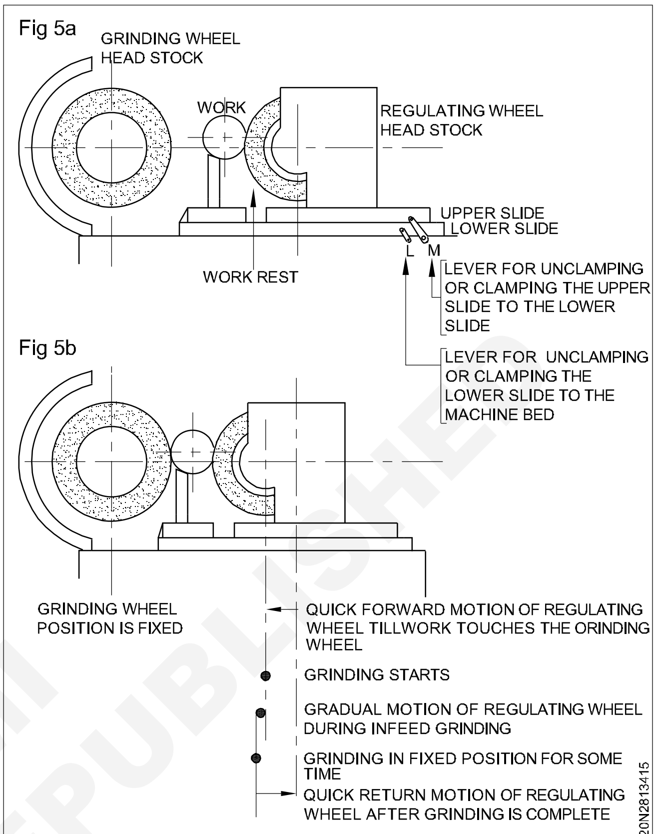
Depending upon the wheel motions available on a particular machine, the type of work and the type of loading and unloading devices employed, different sequences of operations are followed for infeed grinding.

Sequence of infeed grinding operations on a machine where grinding wheel is fixed and only regulating wheel is movable.

Many makes of machines, such as, the Cincinnati, Churchill, Wickman-Scrivener, efc., have their grinding wheel headstock rigidly fixed to the bed and only the regulating wheel headstock is movable. In such cases, the regulating wheel headstock is mounted on two movable slides, the upper and the lower. The work rest and the upper slide carrying the regulating wheel headstock are fitted to the lower slide, as shown in Fig 5a. The sequence of infeed grinding operations on such machine is described below.

- Fig 5a shows the work set in position before grinding. The upper slide carrying the regulating wheel headstock is locked by means of lever M to the lower slide carrying the work rest. Thus, the regulating wheel, the work and the work rest can all be moved as one unit on the machine bed by operating the hand wheel of the regulating wheel with lever L in unlocked position.
- The regulating wheel together with the work and the work rest, as one unit, are quickly moved forward, so that the work just touches the grinding wheel as shown in Fig 5b and faint sparks appear.
- The feeding of the regulating wheel together with the work and the work rest is continued but at a slower rate for infeed grinding.
- When the work diameter approaches the required diameter, the feeding motion of the regulating wheel is stopped and the work is allowed to be ground a little longer in this fixed set-up.
- After grinding is complete, the regulating wheel is quickly returned backward to its original position and the finish ground work is unloaded by lifting up or pushing. The next work piece is then placed in position and the same sequence of operations is repeated for grinding it.

Sequence of infeed grinding operations on a machine where grinding wheel as well as regulating wheel both are movable, and work rest position is permanently fixed.



METHODS OF CENTRELESS GRINDING

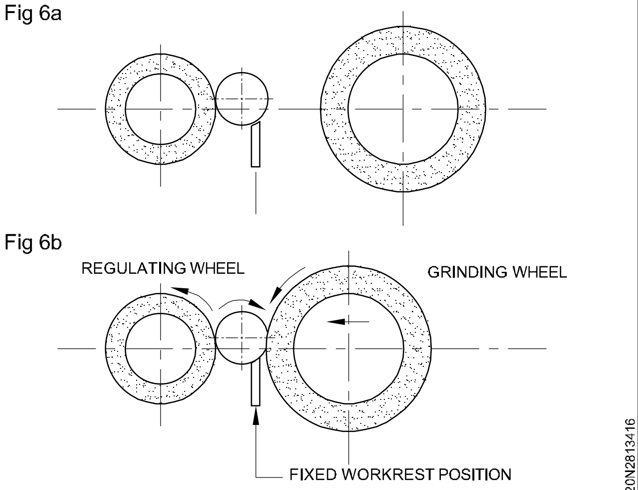
- Such a type of wheel and work rest arrangement is provided on many makes of machines, such as, Lidkoping, Norton, Hartex, Landis, etc. For this type of machines, the sequence of infeed grinding operations depends upon the type of the unloading arrangement. Two cases differing in the type of unloading arrangement have been dealt with below:

A Work unloading by pushing or lifting

- The work is set in position, supported by the work blade and the regulating wheel; the grinding wheel is kept away from the work as shown in Fig 6a.
- The grinding wheel is then moved forward so that it just touches the work, as shown in Fig 6b, and faint sparks appear.
- The forward motion of the grinding wheel is continued but at a slower rate. During the whole of the grinding cycle, the regulating wheel remains stationary.
- When the work diameter approaches the required diameter, the feeding motion of the grinding wheel is stopped and the work is allowed to be ground for a little longer time in this fixed set-up.
- After grinding is complete, the grinding wheel is quickly returned backward to its original position and the finish ground work is pushed out or lifted

Fig 6a

Fig 6b



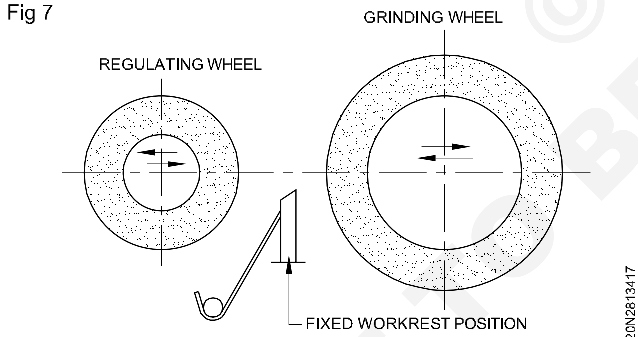
METHODS OF CENTRELESS GRINDING

up. The next work piece is then placed in position and the same sequence of operations is repeated for grinding it.

B Work unloading by gravity ejection chute

The sequence of operations of from No. I to No. 4 are the same as described in the preceding case. After grinding is complete, the grinding wheel as well as the regulating wheel are quickly returned backward and the finish ground work is allowed to fall into the ejection chute shown in Fig 7. The regulating wheel is then quickly moved forward to permit loading of the next work piece. Till then the grinding wheel stays in the original position. After loading of the next work piece is complete, the same sequence of operations is repeated for grinding it.

Fig 7



METHODS OF CENTRELESS GRINDING

Limitations of infeed grinding method

- A work of a length greater than the width of the grinding wheel cannot be ground by this method because the work remains stationary during infeed grinding.
- Because it is not a continuous operation, only one work piece can be ground at a time.

Though the infeed method can be satisfactorily used for grinding cylindrical work yet because of the above two limitations this method is usually not employed in preference to throughfeed.

However, modern centreless grinding machines are equipped with automatic infeed grinding mechanisms which can perform a complete sequence of operations, e.g., loading, grinding, unloading, etc., automatically.

Also the complete sequence can be repeated automatically to grind subsequent work pieces. Thus, for certain types of work, particularly where the grinding allowance is high, automatic infeed grinding can give better production rate than throughfeed grinding.

Infeed grinding in general is primarily used for grinding work other than a plain cylindrical one, such as, stepped, headed Shoulderd, tapered, spherical, intricate shaped, etc.

Different types of infeed methods

Basically, there are two types of infeed methods—Plain and Profile.

1 Plain infeed grinding

This is the method for grinding plain cylindrical work using infeed principles.

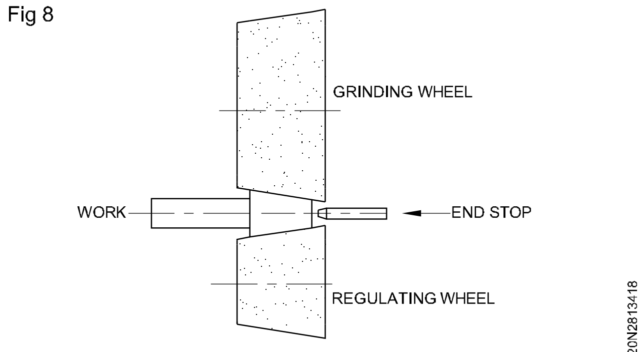
2 Profile grinding

Many types of profiled work places can be ground by the centreless grinding method using infeed principles; but since the grinding wheel has to be shaped to the profile corresponding to the work profile, it is called ‘profile’ or ‘form’ grinding.

Endfeed method

The endfeed method is used only for grinding taper work. In this method, taper work is fed in between tapered grinding and regulating wheels, the centre distance of which has been already set. It resembles the throughfeed method in the respect than the work is fed between fixed positioned grinding and regulating wheels; but it does not satisfy the other requirement of the throughfeed method, in which case the grinding process is said to be complete only when the entire work comes our of the wheels on exit side. In this endfeed method the work does not come out at all, but is stopped by a fixed stop and at that moment, the grinding operation is supposed to be over and the work is taken out either by lifting it up or by moving one of the wheels back. Further, in throughfeed grinding, the axial feed of the work is obtained by tilting the regulating wheel, whereas in endfeed grinding, the regulating wheel is not tilted for feeding the work but manual or mechanical feeding is employed. Fig 8 shows the work being ground by the endfeed method.

Fig 8



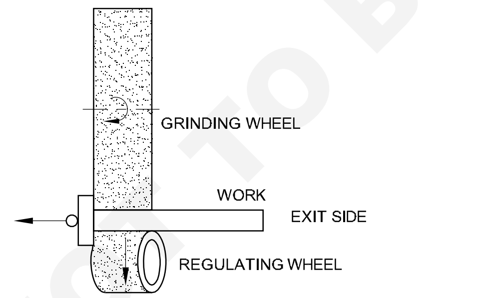
METHODS OF CENTRELESS GRINDING (END FEED)

Combination of throughfeed and infeed methods

Both the throughfeed as well as the infeed methods have their own limitations and advantages with regard to each other. For certain types of work, both the methods can best be utilised so as to benefit from their respective advantages and to over-come their limitations. Two such applications have been dealt with below.

- For a two-diameter work, such as, a headed pin where only the smaller diameter portion of a length than the grinding wheel width is required to be ground, a pure through-feed method cannot be applied because of its other portion, being of greater diameter, cannot be passed through. Also the pure infeed method cannot be employed as the length of the work portion to be ground is greater than the width of the grinding wheel. However, both the methods can be partially utilised to their good advantage in the following manner:
- The work is set for conventional infeed grinding except that the regulating wheel is tilted and trued for negative through-feed grinding. Negative means that the tilt angle is kept negative and truing is also done accordingly so that the work, instead of moving forward from the entry to the exit side, moves from the exit side to the entry side while through-feed grinding. However, with this set-up, as shown in Fig 9, in the first step of grinding, the throughfeed action is not allowed by using an end stop while the portion of the work between the wheels is infeed ground. When the required size is obtained during infeed grinding, the end stop is removed; now the work starts travelling through the wheels towards the front to the machine and the rest of the work is, thus, throughfeed ground to the size set at the end of infeed grinding. A special work blade is required to support the head of the pin as it feeds backward during the second step of the grinding operation.

Fig 9



METHODS OF CENTRELESS GRINDING

- A work of comparatively short length requiring heavy stock removal can be ground in a single pass by utilising both the methods. The regulating wheel is tilted for throughfeed operation, but the distance between the wheel is set for infeed operation. The work is placed between the two wheels with its one end as near to the entry side as possible. After starting grinding, the infeed cut is gradually increased, while the work is travelling, the infeed cut is gradually increased, while the work is travelling. This increase in cut should be so adjusted that when the rear end of the work comes close to the exit side, the gap between the wheels corresponds to the finished diameter of the work. At this stage, the infeed cut is stopped so that the rest of the grinding takes place as throughfeed. This method is, however, not recommended on a full production basis as it gives rise to uneven wheel wear, necessitation constant attention.

Advantages of centreless grinding

The advantages of the centreless type of grinding process for the appropriate type of work are many:

- Work chucking and its centering or its placing on a mandrel is not necessary, thereby the setting time for subsequent identical work pieces is saved once the setting is done for the first work piece.
- As the work is not positively gripped during the grinding operation, true floating conditions exist, so that the errors associated with centering are absent, and thus grinding allowance can be reduced.
- Since the work is adequately supported on the vee formed by the inclined surface of the blade and the regulating wheel, no deflection takes place during the grinding operation. This allows heavier cuts to be taken, if necessary.
- Errors in setting of the work or due to grinding wheel wear are reduced by half because stock removal is measured on the diameter of the work and not on its radius, unlike other grinding operations.
- Excellent accuracy and fine surface finish can be achieved.
- Work pieces of a wide range of dimensions can be finished by this method. Work diameters approaching zero to 600 mm and lengths from 1 mm to 15000 mm have been successfully ground.
- Centreless grinding is applicable to external grinding not only of cylindrical work, but stepped, tapered, spherical, and even ovel and intricate profiled work can be centreless ground economically. Internal centreless grinding is also possible.
- A wide variety of materials can be ground.
- The grinding process is practically continuous, especially if throughfeed type of centreless grinding process is adopted. Even with infeed grinding, the idle machine time required for unloading and loading of the work generally represents a very small part of the total time.
- Centreless grinding lends itself extremely well to fully automatic operation with regard to loading, grinding and unloading and thus very high rates of production can be achieved. The highest output claimed by Lidkoping on their machine is 60,000 work pieces per hour using the single pass throughfeed grinding method.
- Centreless grinding machines are usually simple yet robust in design, incorporating an automatic lubrication system for spindle bearings and for other movable

parts. Thus, the machine maintenance cost is comparatively low.

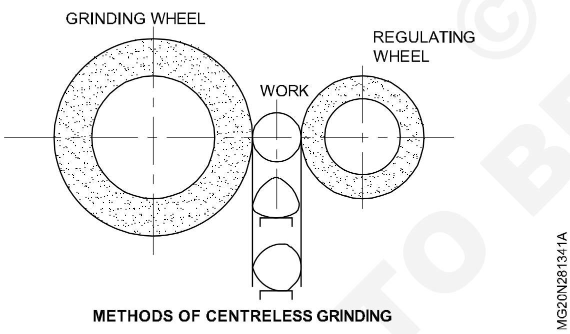
- Unskilled labour with little training can operate the machine. In short, centreless grinding is a highly productive method of finishing work requiring accurate size control and superior finish.

Theoretical explanation for raising or lowering the work centre height

The following principles of geometry can be applied explain the effect of the work centre height:

'Any rotating curve touching two crossing lines and at the same time passing through a fixed point, must be a circle'. Whereas, 'any rotating curve touching two parallel lines and at the same time passing through a fixed point, need not necessarily be a circle'. In case of centreless grinding, the two lines correspond to the tangents passing through the points of contact between the work and the two wheels and the fixed point corresponds to the work blade. If the work centre and the wheel axis are at the same height, the two tangents are parallel. Therefore, the body generated after grinding need not be circular but may be triangular (Fig 10) if originally there is one high spot on the work; otherwise it may be multiangular in the case of a work with many high spots. If the work centre is kept above (Fig 11a) or below (Fig 11b) the line joining the wheel centres, the tangents passing through the points of contact will cross each other and the work also will be constantly kept supported on a fixed point, i.e., the point of contact between work and work blade; therefore a circle will be generated.

Fig 10



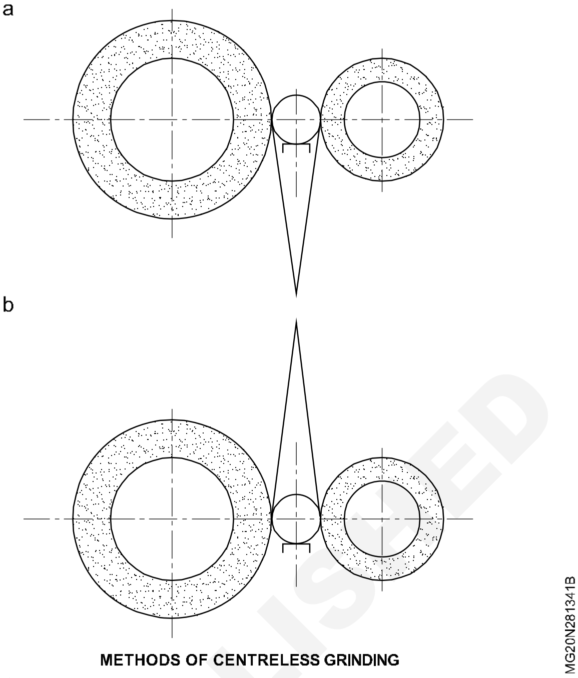
Work centre height

The work centre height is defined as the height of the centre of the work above the line joining the centres of the grinding and regulating wheels.

The work centre height has a definite influence on the accuracy of roundness produced. The higher the work is placed between the wheels, the better is the rounding action on an out-of-round work but at the same time, there is a limit to the increase of the work centre height. The higher the work, is placed, the greater is the tendency of the wheels to squeeze the work upward due to increased vertical component of cutting contact pressure. In such a condition, the work for a moment loses its contact with the wheels and is pushed upwards and then falls back into the grinding position due to gravity and again it is pushed up. This process is repeated, the action being very rapid and continuous, resulting in spoiling of the surface finish of the work. This difficulty can be overcome by one or more of the following methods.

Fig 11a

Fig 11b



- By reducing the cutting contact pressure between the grinding wheel and the work. This can be done by one or more of the following ways:

  a) Use of softer wheel

  b) Reduction of depth of cut

  c) Increase of grinding wheel speed, if it is lower that the permissible

  d) reduction of work speed

- By reducing the vertical component of cutting contact pressure between the grinding wheel and the work by one of the following methods.

  a) reduction of work centre height

  b) Increase in blade angle

  c) Increase of grinding wheel diameter

- By partially neutralising the effect of the vertical component of cutting pressure by increasing the weight of the work. However, this is not practical proposition.

- By using an overhead guide.

Methods, reduction of centre height and by using an overhead guide are normally recommended to prevent jumping of the work.

Amount of work centre height

Since there are many variable are causing the work centre height there is a definite formula available for finding out the optimum value for work centre height which can give the best grinding results. However, it has been found that the rounding action is effective when the sum of angles subtended by the work centre with respect to the grinding wheel and regulating wheel centres is between 5° to I5°.

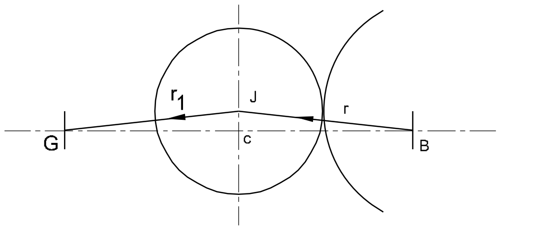
Referring to Fig 12 let
R = Grinding wheel radius
r = Regulating wheel radius
r_1 = Work radius
H = Work centre height

Considering triangles JGC and JCB

$$\sin a_1 = \frac{H}{R + r_1}$$

$$\sin a_2 = \frac{H}{r + r_1}$$

Fig 12



WORK CENTRE HEIGHT

Thus, having chosen an arbitrary value for H and knowing the grinding wheel, the regulating wheel and work radii, we can find one the values of a_1 and a_2. If the sum of a_1 and a_2 comes out between 5^0 to 15^0, then the arbitrary value of H chosen may be satisfactory

Usually the work centre height between 3/16th to 5/16th of the work diameter has proved quite satisfactory. For a shouldered or multi-diameter work, the determination of the work centre height should be based on the greatest diameter available.

For small diameter work, particularly tubes and rings, the work height may have to be increased to obtain a proper rounding from experience or trials with the help of good measuring can determine the best centre height for a particular and under the prevailing conditions of the grinding operation.

Work centre below the centre and of the wheels

Long but work particularly of small diameter and with slight bend of is often ground with the work centre below the line of the wheels. This position is contrary to be usual of keeping the work centre height above, but it is necessary by whipping or chattering of the work by holding it down the blade and in between the wheel.

Internal centreless grinding

Objectives: At the end of this lesson you shall be able to
- **state internal centreless grinding and holding/grinding set-up of job**
- **explain the selection of wheels.**

Internal centreless grinding

The basic centreless principle can also be used for internal grinding of bores. Thus, in internal centreless grinding, the work is not positively gripped and, therefore, does not have any fixed centre, but rolls on its own outside diameter in a centreless workhead. The grinding of the bore takes place with the outside diameter of the work as a reference and not the centre line of the bore or of the work as reference.

Internal centreless grinding has proved to be successful for finish grinding of a bore, parallel as well as tapered, whether through or blind, in cylindrical work.

Elements of internal centreless grinding machine

An internal centreless grinding machine incorporates the following basic elements.

- **Grinding wheel**

  It is connected with an electric motor and has a provision for axial movement so that it can be taken into the work for the internal grinding cut.

- **Regulating wheel**

  It is connected to a separate motor which is responsible for rotating the work at the desired speed, It is adjustable transversely to accommodate work of different outside diameters.

- **Work support**

  For smaller diameter work, say upto 30mm, the work support is usually in the form of a work blade, where as for larger diameter work, it is in the form of a roller called a ‘support roll’.

- **Pressure roller**

  This is usually spring loaded with mechanism for adjusting The pressure, It is mounted in a swinging bracket and holds the work against the regulating wheel and the work support.

Where the accurate endwise location of a work is essential, as when grinding taper bores, a rotating backing plate is also necessary to hold the end face square with the axis. To hold the work against the backing plate, the rolls are inclined at a slight angle, the effect being the same as that obtained by inclining the regulating wheel when grinding the work externally by the infeed method.

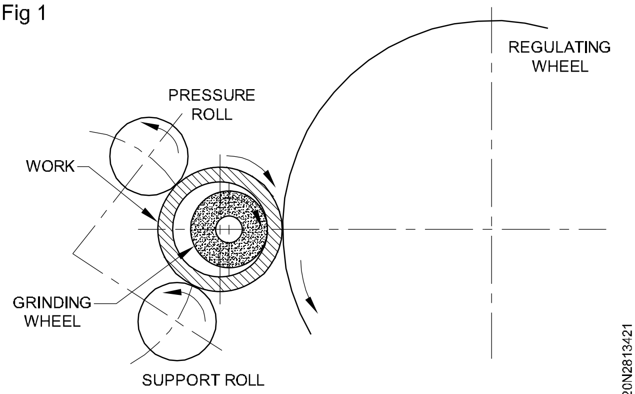
Grinding set-up

The basic element s of an internal centreless grinding machine described above can be set in one of the following two ways.

1 **On-centre arrangement**

  In this arrangement (Fig 1), the work, grinding wheel and regulating wheel are all on the same horizontal centre line. This arrangement gives the maximum support to the work which makes it possible to grinding accurately without distortion, particularly work having a thin wall section.

Fig 1

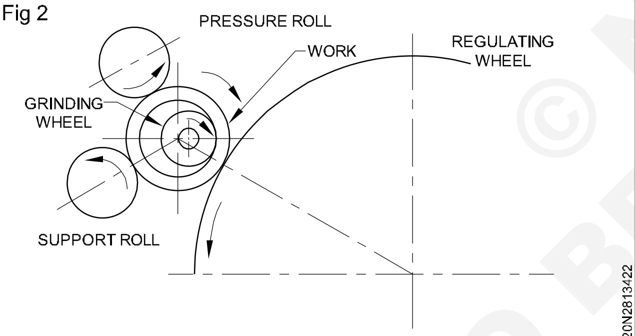


INTERNAL CENTRELESS GRINDING (ON CENTRE)

2 Off-centre arrangement

In this arrangement (Fig 2), the work-wheel centre line is above that of the regulating wheel, the angular relationship of the support and the regulating wheel being such that successively loaded work pieces, even with considerable variation of the out-side diameter, remain on the same vertical centre line. As a result, it is possible to grind such work pieces to close limits. The off-centre method also permits the grinding of multiple work simultaneously, all to the same tolerance.

Fig 2



INTERNAL CENTRELESS GRINDING (OFF CENTRE)

Advantages of internal centreless grinding

- Accurate concentricity of the internal and external diameters together with uniform wall thickness is ensured.
- High production rates can be achieved as the internal centreless grinding operation can be made full automatic with regard to loading, grinding and unloading.

Limitations of internal centreless grinding

- Since the grinding of the bore takes place with the outside diameter of the work as a reference, this limits its field of application. Work with an inaccurate outside diameter cannot be internally ground accurately. Accuracy of the finished bore depends upon the accuracy of the outside surface. As such, it is necessary that the outside diameter of the work should be finished to close limits for roundness and size before proceeding to internal grinding.
- Only those bores which are required to be concentric with the outside diameter can be ground. It does not matter whether the required hole is cylindrical or taper as long as it is concentric with the outside diameter of the work, However, for internal centreless grinding of taper holes, some provision for inclining the grinding wheel spindle should exist on the machine.

Internal centreless grinding is not much in use now a days, as other types of internal grinding methods have been developed which, being more productive, are preferable.

Selection of wheels for centreless grinding

The proper selection of the grinding wheel is very important for a successful grinding operation on a particular work under the prevailing circumstances and conditions. The following are the wheel specifications that require careful consideration, as they govern the cutting behaviour of the grinding wheel, which ultimately affects the economics of production.

- Wheel shape
- Wheel size
- Wheel characteristics
- abrasive
- grain or grit
- grade or hardness
- structure
- bond

Wheel shape

For centreless grinding, a plain cylindrical wheel is normally needed. However, it may require to be dressed to a certain profile to suit the grinding of a profiled work.

Wheel size

Every centreless grinding machine has a limitation as to the size of grinding wheel which it can accommodate. In general, a grinding wheel of the maximum permissible diameter and width should be selected. A grinding wheel of the maximum diameter is to be preferred from the operational point of view, as a smaller wheel well be consumed faster, involving frequent replacement, frequent setting, etc., which will decrease the production rate.

As regards the width of the grinding wheel, it depends upon the type of grinding operation and the length of the work. In case of throughfeed grinding, maximum output is generally obtained by using as wide a grinding wheel as the machine permits. With wider wheels the grinding load is distributed and a greater cut can be taken, particularly by truing the wheel slightly tapered. Also better results are obtained with regard to accuracy and finish as a greater length of the work is gripped at any time during grinding. In case of infeed grinding, longer work can be handled with a wider wheel. However, the width of the grinding wheel for infeed grinding should not be abnormally greater than the length of the work as extra width does not serve any purpose; on the contrary it necessitates a longer end stop, which may produce vibrations resulting in poor finish.

Having decided on the proper shape and size of the grinding wheel, the proper wheel characteristics should be selected to specify a wheel completely. The various wheel characteristics and their selection criteria are discussed below.

Ideal grinding wheel

An ideal grinding wheel should possess the following qualities:

- It should wear the minimum possible so as to :-
- Maintain the abrasive particles of the grinding wheel sharp for rapid stock removal and thus produce the maximum number of work pieces per unit time
- keep the cost of the grinding wheel consumption per ground work to minimum.
- It should be 'self-sharpening' at 'optimum speed'. The latter action is called 'self-sharpening', which means that the grinding wheel should retain abrasive particles as long as they are sharp, and as soon as they become seriously dull, the grinding pressure, developed at that stage, should be sufficient to fracture the dull particles, bringing in front fresh sharp particles. This type of self-sharpening action should be repetitive to maintain the wheel's sharpness and to avoid frequent dressing. Further, the optimum speed is also an important criterion, because the wheel can be made to act self-sharpening if the grinding wheel speed is reduced. But reduction in speed will reduce the grinding efficiency; hence, the self-sharpening action at optimum speed only is one of the qualities of an ideal grinding wheel.
- An ideal grinding wheel should also give the desired finish at all times.
- An ideal grinding wheel should be cool cutting. Coolness of cut minimizes the deformation of the work piece from grinding heat and allows close tolerances to be produced quickly and continuously.

Selection of regulating wheel

The regulating wheel is primarily used to regulate the speed of rotation of the work. During throughfeed grinding, it also serves to provide longitudinal feed to the work. The regulating wheel is subject to high pressures as it acts as one of the supports during grinding This wheel should, therefore, be strong and coarse enough to produce sufficient inction against the work without scratching it, to control its speed. For most grinding work, an aluminium oxide fine grained, hard with a close structure and rubber bonded wheel has proved quite satisfactory. Vitrified and resinoid bended wheels can some times be used as regulating wheels.

Jigs and Fixtures

Objectives: At the end of this lesson you shall be able to
- **state the advantages of using jigs and fixtures**
- **distinguish between the functions of jigs and fixtures.**

Great deal of importance is placed today on improving productivity in manufacturing processes. Application of jigs and fixtures has contributed a lot towards this direction.

Jigs and fixtures (Figs 1 and 2) are devices used in manufacturing or assembling. They are facilitate in carrying out special operations accurately.

Fig 1

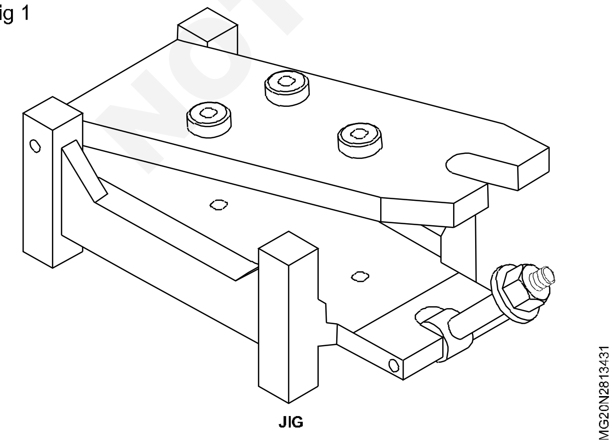
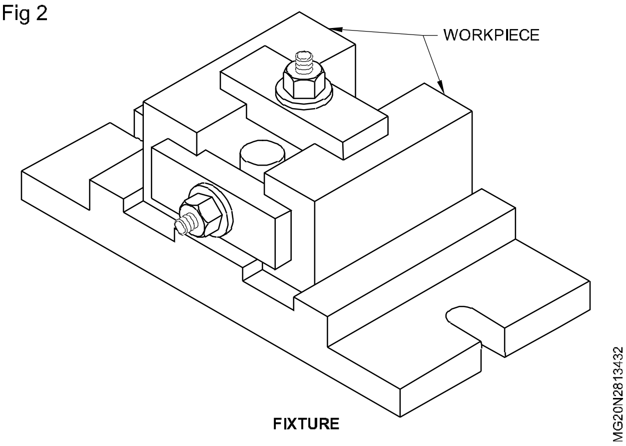


Fig 2



Advantages of using and jigs and futures

- Faster rate of production.
- Easy to perform the operations even by unskilled workers.
- Layout and marking on individual parts eliminated.

Jigs

A jig is a special device which holds, supports, locates the work and also guides the cutting tool during operation. Jigs are designed to accommodate one or more components at a time. (Fig 1)

Jigs are available for drilling or boring.

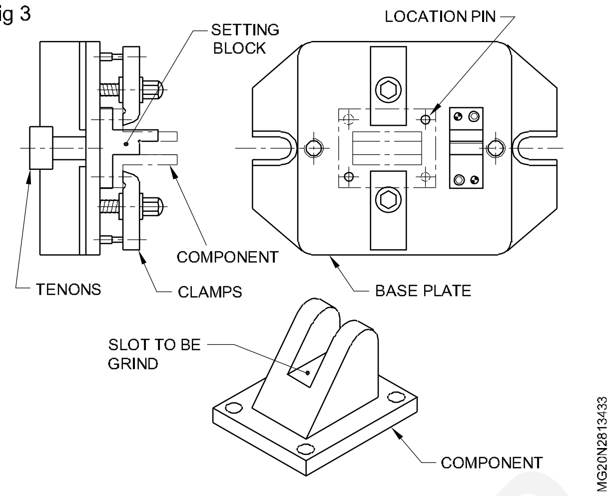
Fixtures

A fixture is a production tool that locates and holds the workpiece. It does not guide the cutting tools, but the tools can be positioned before cutting with the help of setting blocks and feeler gauges etc. (Fig 2 & 3)

Fixture of different types are made for

- Milling
- Grinding
- Welding
- Assembly
- Welding etc.

Fig 3



Work holding devices

Objectives: At the end of this lesson you shall be able to
- **identify various work holding devices used in grinding machines**
- **brief the method of holding workpiece.**

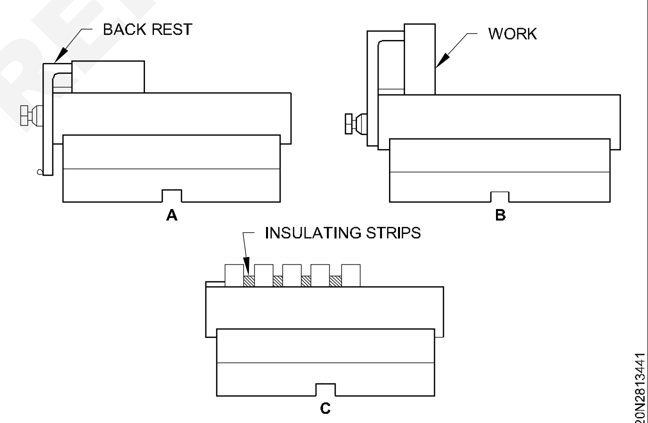
Magnetic chucks

Although magnetic chucks are available in variety of shapes and sizes, they find maximum use in surface grinding machines-reciprocating and rotary types. Their use for grinding is some what limited.

Magnetic chuck are easy and quick to operate, they have ensure greater degree of accuracy then would be possible with quick mounted with clamps and bolts. There are two types of magnetic chucks-those employing electro-magnets and other with employ permanent magnets. In chucks of the first type, the top surface has a series of positive and negative poles which are separated by an insulating material. The chuck is clamped on to the table of the machine. It holds work by magnetic force when current is switched on.

Fig 1(A) and (B) shows one of the types of magnetic chucks which is rectangular in shape. It is fitted with thin steel aligning strips attached to the rear side of the chuck as well as a back-rest which is vertically adjustable. The back-rest helps in supporting the work which may be high in proportion to its width. A vertically adjustable end-stop is also there. The work requiring grinding is simply placed on the chuck against the end stop and the back rest.

Magnetic chuck can also be used for holding a number of strips simultaneously as shown in Fig 1(C). In such cases it is a good practice to separate the strips by placing insulating strips of brass, etc. In-be tween. This ensures independent grip of each strip against the face of the chuck.



MAGNETIC CHUCK

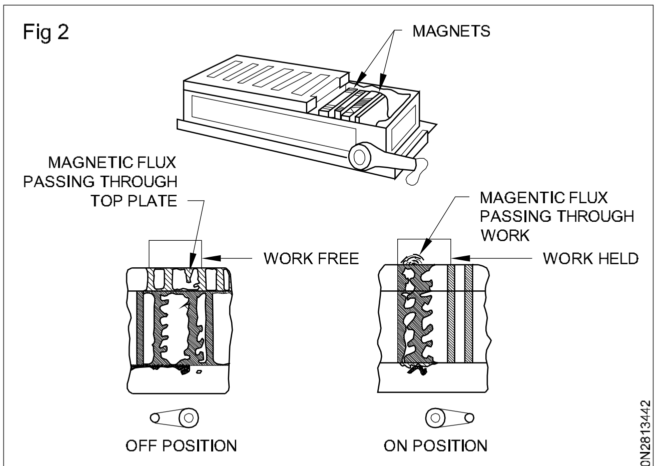
A type of non-electric magnetic chuck using permanent magnets of high frequency is shown in Fig 2. When the operating lever is in off-position, the conductor bars and separator are shifted so that magnetic flux passes through the top plate and is short circuited from the work.

Setting the operating levers in on-position lines up the conductor bars and non-magnetic separators such that the magnetic flux following the line of least resistance, goes through the work in completing the circuit.

Non-electric magnetic chuck

Non-electric magnetic chucks are also very popular as they not only posses the same holding capacity as the

Fig 2



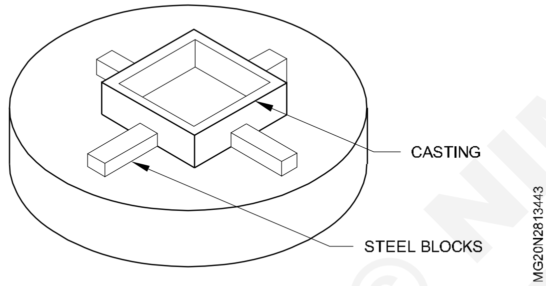
NON-ELECTRIC MAGNETIC CHUCK

electric type, but also have the advantage of being free from encumbering wires.

Holding of work in magnetic chucks are secure enough to withstand the action of grinding wheels.

If it is required to hold work of non-magnetic material in a magnetic chuck, method shown in Fig 3 can be used.

Fig 3



In this four small blocks are placed and held on the magnetic chuck which prevent the casting from shifting while grinding is being done.

Box type non-magnetic workpieces can be held by placing blocks of steel inside the piece to be ground. Magnetic attraction of the blocks will be sufficient to hold the work provided the chuck is of the order of only 1.6 mm.

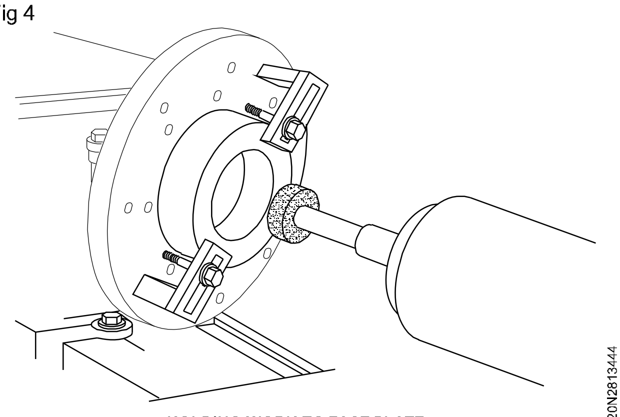
- Holding a work on face plate is illustrated in Fig 4.
- Universal vice

Plain vice finds use on surface grinders for holding rectangular work piece, if there is no provision for a magnetic chuck.

Tilting vice (Fig 5) can be adjusted at an angle from the horizontal to the vertical about a hinge. A protractor provided measures the angle of tilt.

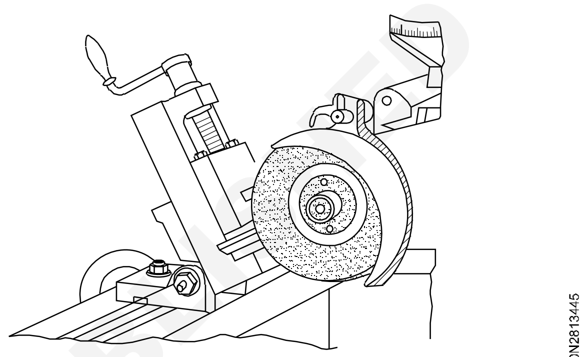
Care should be taken so that too high pressure is not applied on the work piece held in a vice particularly while grinding pieces which have been hardened.

Fig 4



HOLDING WORK TO FACE PLATE

Fig 5

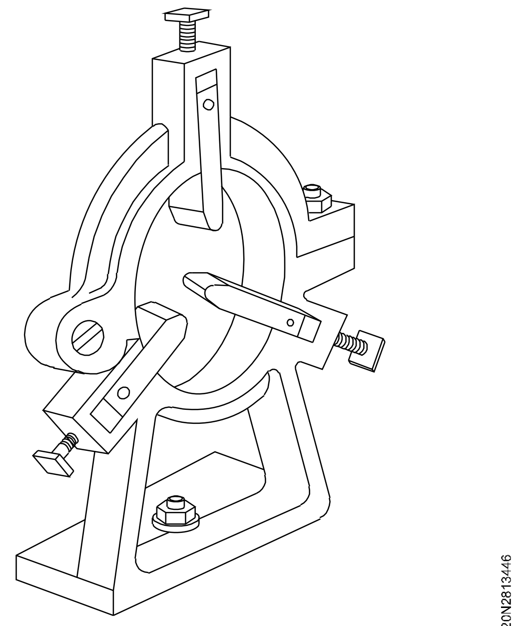


TILTING VICE FOR HOLDING WORK

Holding work with steady rest

Use of steady rest is necessary for supporting long and slender workpieces (So as to prevent them from vibrating) which are ground by mounting between centres Fig 6 shows a back rest. In general steady rests are placed 300 mm apart if the work is over 75 mm in diameter. Always the first one is located at the centre of the work if it is symmetrical and a like number on either side are used.

Fig 6

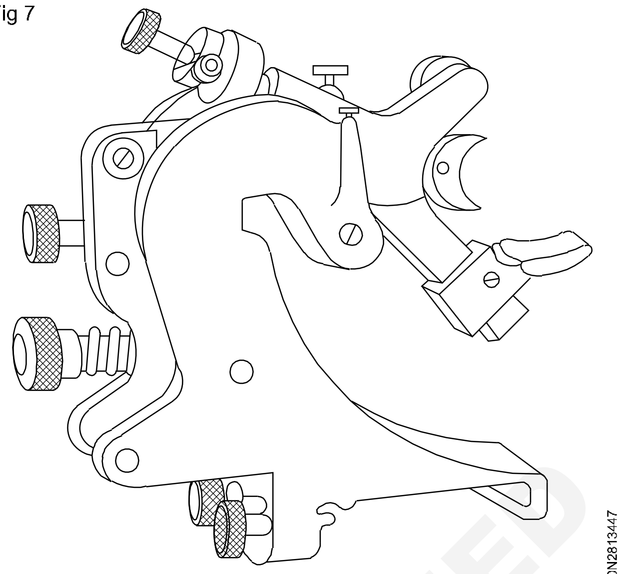


FIXED STEADY REST

Back rest

Back rest (Fig 7) resembles the follower rest used on lathe. Back rest mounted on the table supports the work against the pressure of the grinding wheel. The supports also help in prevention of vibrations when heavy cuts with high table speeds are being taken. Jaws must be properly adjusted when using steady rests as otherwise work may get caught between the lower jaw and the grinding wheel and be thrown from the machine or it might break the grinding wheel.

Fig 7



BACK REST

Thread grinding

Objectives: At the end of this lesson you shall be able to
- **state the different methods of thread grinding**
- **explain the different types of dresses and dressing process**
- **state the selection of coolants**
- **state the thread grinding operation**
- **state the wheel for thread grinding**
- **principal movement of thread grinding machine.**

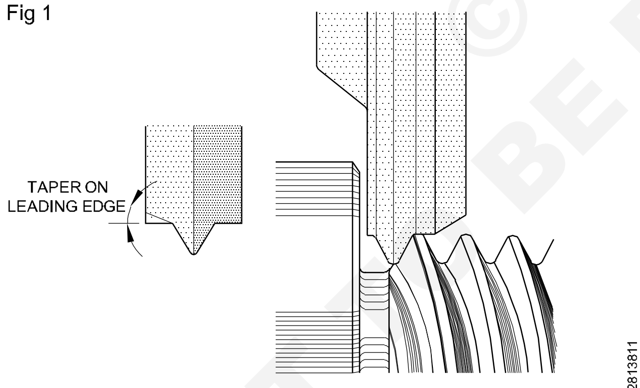
Centreless thread grinding methods

There are four types of centreless thread grinding in general use, viz.

- Single-rib wheel grinding (Single-Rib-Method). (Fig 1)
- Dual-rib wheel grinding (Dual-Rib Method).
- Multi-rib wheel plunge grinding (Multi-Rib Plunge-Cut Method).
- Multi-rib wheel traverse grinding (Multi-Rib Traverse Method).

All these methods have their own particular advantages and the choice of which one of them is most suitable for any given job depends upon conditions peculiar to the equipment used, the degree of accuracy required, the material to be ground, the method of wheel dressing, the shape of the workparts and time factor.

Fig 1



SINGLE - RIB WHEEL CUT AWAY TO PERMIT GRINDING THREAD CLOSE TO SHOUDER

1 Single-rib method

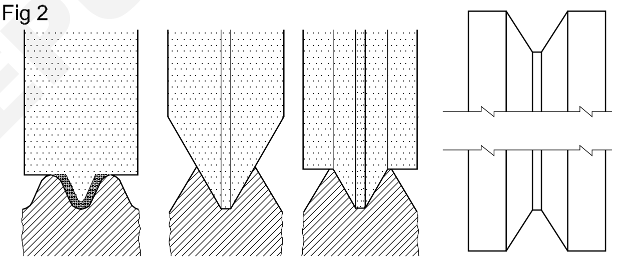
The advantages of a single-rib wheel in comparison with a multi-rib wheel are as follows.

- Due to the fact that only one complete thread ridge has to be formed on the periphery of the abrasive wheel, it is obvious that more scope is available in the design of the wheel-turning mechanism. This results in the operation of wheel forming being accomplished conveniently and rapidly. The setting-up time for this method is usually small.
- The area of contact between the wheel and the product is, in comparison with other methods, very small, being restricted to the single-thread ridge of the abrasive wheel and one space in the work. Thus less heat and friction is encountered. The latter factor allows the use of higher grinding speeds and deeper cuts.

Profile crushing of single-rib wheels

Only when the wheel spindle and its assembly is so designed and proportioned that it can safely withstand the thrusts set up by the pressure of the crushing roller, should profile crushing of single-rib wheels be employed. (Fig 2)

Fig 2

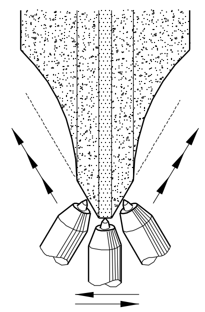


a) WHEEL FORMED FOR THREAD WITH CONTROLLED RADIUS
b) WHEEL FORMED WITH DIAMOND TOOLS FOR AMERICAN TYPE OF THREAD
c) WHEEL FORMED WITH CRUSHING ROLLER FOR AMERICAN TYPE OF THREAD
d) CRUSHING ROLLER FOR WHEEL SHOWN AT (c)

SINGLE - RIB WHEELS

Generally it will be found that single-rib wheels are dressed to form by means of diamond tools (Fig 3), whilst multi-rib wheels are formed either with diamond tools or with crushing rollers.

Fig 3

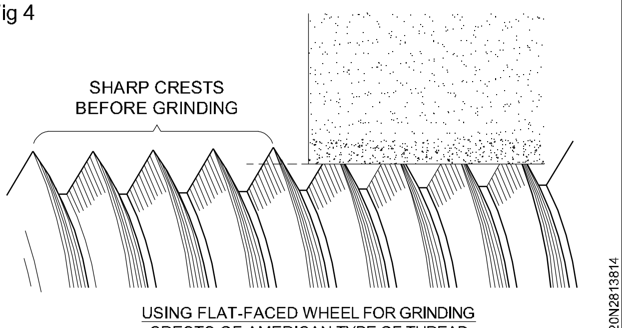


SINGLE RIB WHEEL THINNED TO AVOID NEEDLESS WEAR OF DIAMONDS

SINGLE - RIB WHEELS

Flat faced wheels are used to grind crest of the thread. (Fig 4)

Fig 4

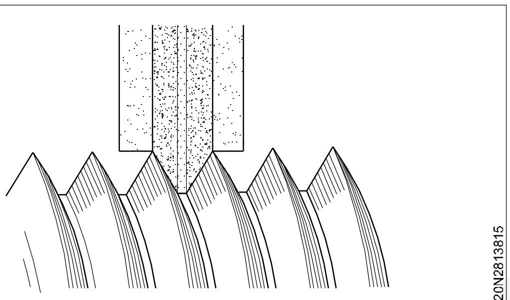


USING FLAT-FACED WHEEL FOR GRINDING CRESTS OF AMERICAN TYPE OF THREAD

Plunge grinding (Fig 5)

With single-rib wheels plunge grinding is practicable only in the grinding of annular grooves such as are required on disc-type cutters, thread milling hobs, and crushing rollers. Plunge grinding is characteristically a multi-rib wheel method.

Fig 5



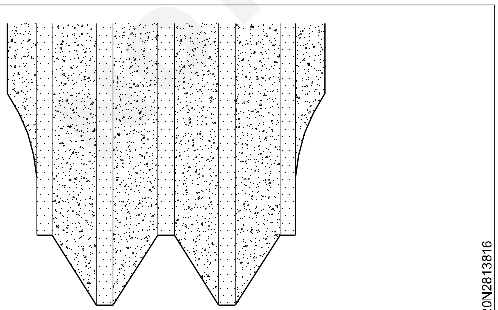
CRUSHED WHEEL GRINDING A COMPLETE THREAD FORM

2 Dual-rib method

Dual-rib wheels have certain characteristics similar to those of single-rib wheels. They are successfully used for grinding coarse pitch and two-start threads. However, there are definite limitations to their use for grinding threads of very steep helix due to the inherent helical interference. The latter item increases importance with the higher degrees of accuracy that may be required.

Generally speaking, the use of standard diamond-dressing equipment suffers some restrictions in adaptation for dressing a dual-rib wheel-often referred to as a ''twin-ribbed wheel.'' As a result of this difficulty a crushing roller is often used. A typical dual-rib wheel is shown in Fig 6.

Fig 6



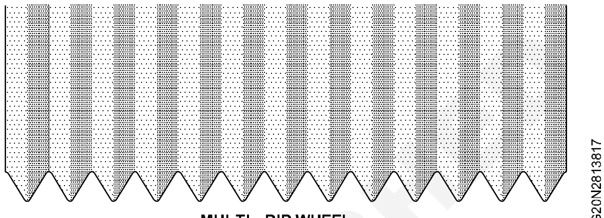
DUAL RIB WHEEL

One advantage of using this type of wheel for grinding single-start threads is that the leading ridge on the wheel can be formed for the purpose of roughing-out the thread, whilst the following ridge can be used for the finish cut.

3 Multi-rib method-plunge grinding

The abrasive wheel is formed with a series of thread-form annular grooves which usually extend across the whole face-width of the wheel, as shown in Fig 7. Where, however, the length of thread on the workpart is considerably less than the face-width of the wheel it is recommended that part of the wheel which is not used for the actual grinding should be dressed away to avoid needless wear of the wheel-forming tool. It is a good rule to restrict the number of thread ridges on the wheel so that the working face-width of the wheel is greater than the length of thread on the workpart by about two of three times the pitch.

Fig 7



MULTI - RIB WHEEL

At the starting position (Fig 8 (b)) the headstock and tailstock units are so positioned that the workpart is directly in front of the abrasive wheel. The wheel is ''Plunged'' radially into the workpart as the latter commences its rotation and axial traverse. The ''plunging,'' of in-feed, to an amount equal to the correct depth of thread, takes place during approximately one-third of the revolution of the work. The grinding to size takes place in approximately one further complete revolution.

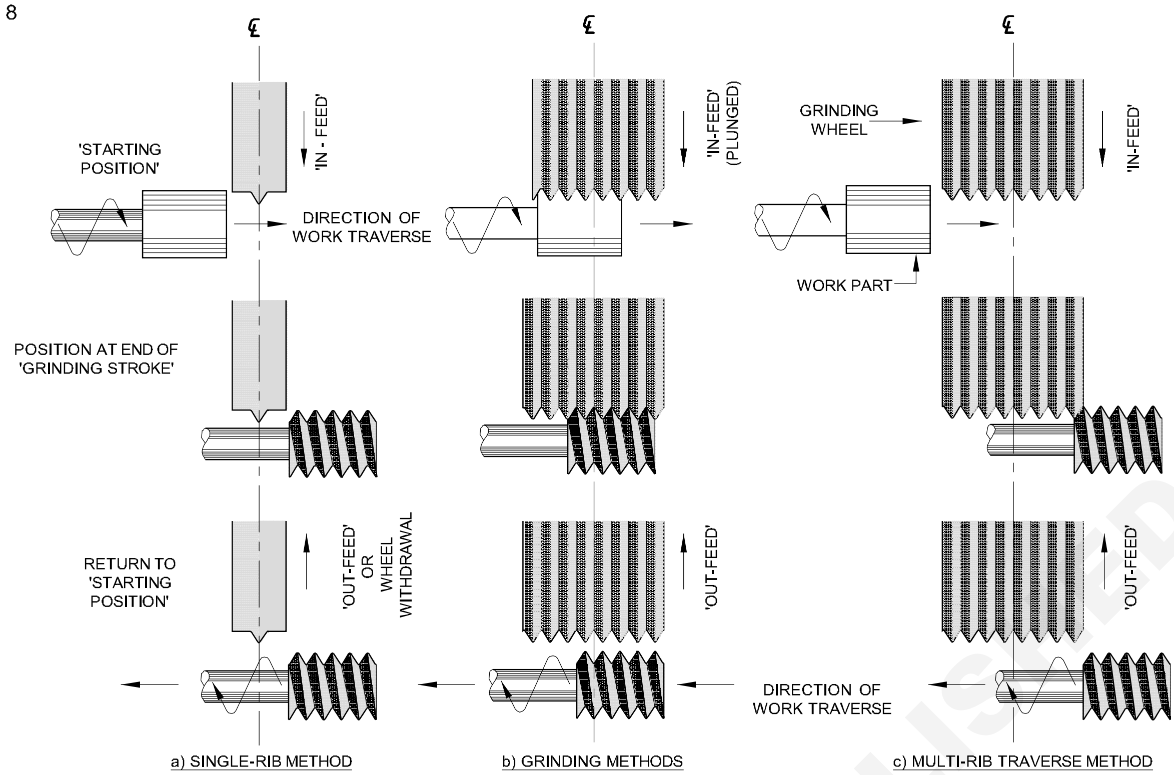
While the work is rotating it also receives an axial traverse so that the helix having the appropriate thread form is ground into its surface. The length of thread to be ground is less than the face-width of the abrasive wheel, then the complete thread is ground during about one and one-third revolutions and one and one-third pitch-length of work traverse. When the length of thread to be ground exeeds the face-width of the wheel it is necessary to use a correspondingly longer length of work traverse.

In the latter case the operation is really a combination of the ''plunge-cut'' and the ''traverse-grinding ''methods. Abrasive wheels up to about 50 mm face-width are frequently used. Thus the plunge-cut method is seedy. However, plunge grinding is a heavy-duty method, from which it follows that it is not always accompanied by a high degree of accuracy in the product.

4 Multi-rib method-traverse grinding

One difference between plunge grinding and traverse grinding, revealed by a glance at Fig 8, lies in the difference between the relative positions occupied by the abrasive wheel and the workpart at the respective ''starting position.'' Another difference is in the respective lengths of the work traverse. In the traverse grinding method (sometimes called the ''straightover'' method)the abrasive wheel is not plunge radially into the workpart, the latter being so located at the ''starting position'' that its leading edge or front lies immediately at the left of the leading edge of the wheel.

Fig 8



GRINDING METHODS

See Fig 8 (c). Thus, at the moment when in-feed of the wheel commences, the wheel does not make contact with the work. In plunge grinding, however, the wheel is plunged, or fed, directly into the workpart.

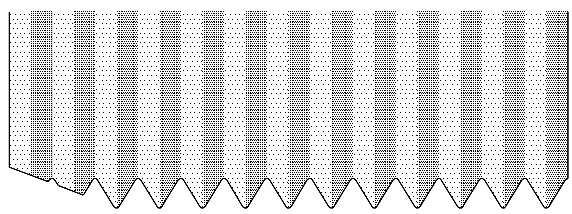
At the ''starting position'' in traverse grinding, as shown in Fig 8(c), the wheel is fed inwards, i.e. towards the axis of headstock and tailstock, the amount of in-feed being dependent on the depth of cut to be taken and the diameter of the thread to be ground. The wheel approaches the axis of the workpart as the latter commences its rotation and its traverse towards the leading edge of the wheel, these motions of the workpart continuing until the complete thread has been ground. This stage having been reached. The wheel is withdrawn from the workpart,the latter meanwhile reversing its direction of rotation and of traverse and so returning to the ''starting position.'' Where more than one cut is necessary the cycle of operations is repeated until the thread is ground to the required size and to the desired quality of surface finish.

Where there is no shoulder to foul the passing of the workpart across the whole face-width of the wheel it is practicable to obtain a very high degree of accuracy in the product. Multi-rib traverse grinding is employed for grinding thread gauges, gear-cutting hobs, and similar work carrying precise limits in regard to diameter, pitch, form, and surface finish. The minimum length of work traverse needed to enable this method to operate is equal to the face-width of the wheel, plus the length of threading on the workpart.

The difference between traverse grinding by the multi-rib and single-rib methods lies simply in the fact that in the former a multi-rib wheel is used,whereas in the latter a single-rib wheel is used. Due to the fact that some error, however minute, may be present in the spacing and parallelism of the thread ridges formed on a multi-rib wheel it is fair to state that, other things being equal, a higher degree of accuracy is normally obtainable with a single-rib wheel. However, many factors enter into a precision grinding operation and we should add that some experts contend that by and large it is generally easier to produce an accurate product with a multi-rib wheel than with a single-rib wheel. The authors prefer a single-rib wheel for gauge grinding where extreme precision is called for.

Where the shape of the workpart permits it to pass across the whole face-width of the wheel it is advantageous to taper the leading edge of the wheel as shown in Fig 9 This enables the leading edge to perform a roughing-out operation-an advantage when grinding troublesome work requiring many cuts. It is also conducive to longer life of the full-form ridges of the wheel.

Fig 9



MULTI - RIB WHEEL WITH TAPER ON LEADING EDGE

Comparison of grinding methods

In (a), (b), and (c) in Fig 8 the uppermost three diagrams, from left to right, show relative positions of the grinding wheel and workpart at the ''starting position.'' All examples refer to right-hand threads ground by the one-way directional grinding method explained later in this chapter. Note that at the ''starting position'' the wheel is fed radially towards the axis of the workpart as the latter commences rotation and axial traverse.

The middle three diagrams show relative positions at the end of the ''grinding stroke,'' i.e. when the thread has been ground completely. The bottom three diagrams show the reversal of work rotation, the reversal of work traverse, and the backing away of the wheel radially from the axis of the workpart.

a **Single-rib method.** Sequence of operations-

- The grinding wheel is fed towards the axis of the workpart as the latter commences rotation and traverse.
- The thread is ground as the workpart rotates and traverses across the face of the wheel.
- The grinding wheel is withdrawn from the workpart at the end of the ''grinding stroke.''
- The workpart momentarily pauses, then reverses its directions of rotation and traverse, so returning to ''starting position.''

b **Plunge-cut method.** Sequence of operations-

- The grinding wheel is fed radially and directly into the workpart as the latter commences rotation and traverse. Note that at the ''starting position'' the work is in contact with the wheel. Therefore the work need only make one complete rotation and one pitch length of traverse to enable the complete thread to the ground.
- The work having reached ''the position at end of grinding'' the wheel is backed away from it.
- The work momentarily pauses, reverses its directions of rotation and traverse, and so returns to the ''starting position.''

c **Traverse-grinding method.** Sequence of operations-

- The grinding wheel is fed radially towards the extended axis of the workpart as the latter commences rotation and traverse. See the diagram, noting that the wheel does not contact the work at this stage.
- The work continues rotation and traverse, moving towards the wheel.
- The work reaches the grinding wheel and thread grinding takes place as the work rotates and traverses across the whole face-width of the wheel.
- The work having reached the ''position at end of grinding,'' it momentarily pauses while the wheel is withdrawn. The work then reverses its directions of rotation and traverse and so returns to ''starting position.''

The two "directional" grinding methods

"One-way'' and ''two-way'' are terms used to describe two kinds of ''directional grinding'' by means of any of the four types of abrasive wheel previously referred to.

One-way grinding

In this method the wheel is fed into the work, the thread being ground while the revolving work travels in one direction only. When the wheel reaches the end of the thread it is backed It must be pointed out, however, that the higher speeds do not necessarily give the best results in all cases.

Machines designed for using multi-rig wheels only have a speed range of 3000 to 7000 s.f.p.m. Due to the greater area of contact when using multi-rib wheels it follows that more heat and friction is generated than is the case when single-rib wheels are used. Thus it becomes necessary to have a lower speed range for multi-rib wheels.

Wheel section

It is often possible to choose a wheel specification that has previously been satisfactory for a similar class of work to be ground. Occasion does arise, however, when the type of tread and material has not been experienced. In such an event the reader will find it useful to refer to the list of recommended grinding wheels for thread grinding at the foot of this page.

The choice of the correct wheel will depend, of course, upon many factors pertaining to a given job. The following are among the points which should be given due consideration; pitch and form of thread; accuracy desired; size and shape of workpart; the material used; method of holding work; speed of the grinding wheel; work speed; rigidity of machine; quantity of workparts to be ground; the time allowed for the grinding operation; whether the work has been pre-cut by roughing-out on a lathe or other machine; the method of dressing the grinding wheel; frequency of re-dressing; type of wheel (i.e. single or multi-rib); method of grinding, etc.

As so many unrelated factors have a bearing on the matter it is obvious that no possible table could yield information which would cater for every wheel problem encountered in thread grinding. It must therefore be emphasized that the following list of grinding-wheel specifications is intended to serve as a useful starting -off point. The reader, when about to tackle a new job, should first choose the appropriate wheel from the list and give it a fair trial. Results will indicate whether selection of a wheel with other characteristics is advisable.

Recommended grinding wheels for thread grinding

Whitworth and U.S. (UNC/UNF) threads

TPI	Norton		Carborundum	
	Vitrified	Resinoid	Vitrified	Resinoid
3 to 8	3880-J8-BE	100-S9-TH	A803-P-180	E803-K4Y
3 to 11	38100-M8-BE	100-W9-TH	A100-P-180	E1003-K4Y
12 to 16	38120-K8-BE	150-T9-TH	A1203-P-180	E1203-K4Y
16 to 20	38160-K8-BE	180-T9-TH	A1203-P-180	E1203-K4Y
20 to 26	38180-M10-BE	180-T9-TH	A150-L-180	E1503-K4Y
26 to 32	38220-M10-BE	220-T9-TH	A180-L-180	E1803-K4Y
32 to 36	38220-K9-BE	220-T9-TH	A220-L-180	E2203-K4Y
36 to 48	320-09T		A1F-L-180	E2203-K4Y
50 to 80	38500-L		A3F-L-180	E2203-K4Y

British association threads

B.A.No	Norton		Carborundum	
	Vitrified	Resinoid	Vitrified	Resinoid
0 to 3	38180-M10-BE	180-T9-TH	A180-L-180	E1803-K4Y
3 to 6	38220-K9-BE	220-T9-TH	A220-K-180	E2203-K4Y
6 to 8	38320-L8	320-O9-T	A1F-L-180	E2203-K4Y
8 to 10	38500-L		A3F-L-180	

ACME and worm threads

TPI	Norton		Carborundum	
	Vitrified	Resinoid	Vitrified	Resinoid
3 to 7	3880-K8-BE	100-S9-TH	A803-P-180	E803-K4Y
7 to 10	38100-M8-BE	100-W9-TH	A100-P-180	E1003-K4Y
10 to 12	38120-J7-BE	120-T9-TH	A1203-P-180	E1203-K4Y
12 to18	38150-K8-BE	150-W9-TH	A1203-N-180	E1503-K4Y
18 to 26	38180-M10-BE	180-T9-TH	A180-L-180	E1803-K4Y
24 to 32	38220-K8	220-T9-TH	A220-K-180	E2203-K4Y

Internal threads

TPI	Norton		Carborundum	
	Vitrified	Resinoid	Vitrified	Resinoid
10 to 16	38120-M9-BE	120-T9-TH	A1203-N-180	E1003-K4Y
16 to 20	38180-M10-BE	180-T9-TH	A150-N-180	E1503-K4Y
20 to 30	38220-K9-BE	220-T9-TH	A220/F-N-180	E1803-K4Y

Production rates are of great importance in the shops and therefore have an influence on the choice of a wheel that will give a high rate of stock removal consistent with tolerable quality. This aspect of the matter is given noticeably more consideration in shops where incentive methods of payment are in operation.

Wheel-form errors

The most prevalent wheel trouble is a collapsing of the thread profile on the peripheral rib, this being especially noticeable when grinding sharp corners or small radii on the smaller ranges of threads.

Types of dressing and processes

- Crush dressing
- Cambox dressing
- Single rib wheel dressing
- Crush dressing multi rib

A Crush dressing

Crush dressing is a method of producing a contour (or form) on the periphery of a grinding wheel. A crushing roll machined to the desired shape, is fitted in a suitable bracket then pressed into a slowly revolving wheel, so that the reverse contour of the roll is formed on the periphery of the abrasive wheel.

1 Mounting the crushing roll (Fig 10)

a Select crusher.

b Inspect for damage or worn form.

c Clean arbor, inspect for damage.

d Fit crusher to arbor, using spacing bushes to centralise roll with abrasive wheel to create a complete thread form. (Fig 11)

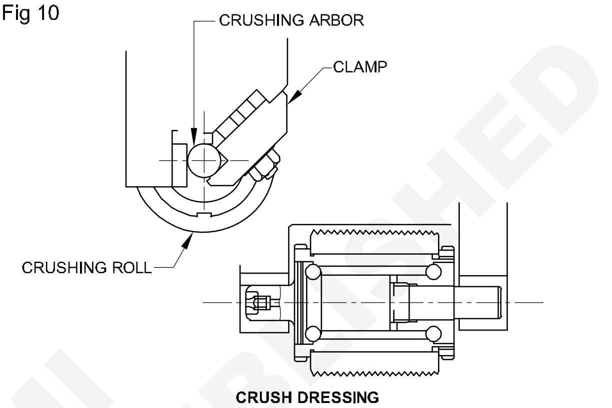
e Secure arbor to machine with clamps.

f Position clean wire brush to clean crushes when in operation.

g Position guard.

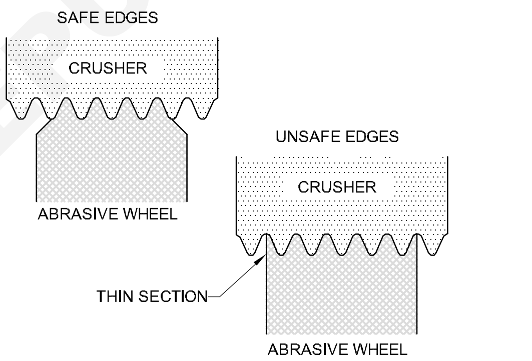
When possible use a worn crusher to rough out the thread form, this saves undue wear on the crusher.

Fig 10



CRUSH DRESSING

Fig 11



CRUSH DRESSING

Safety

Whenever a form is to be crushed all the way to the edges of a given wheel, chipping of the wheel edge may develop. This can be prevented by first chamfering the edge of the wheel at a 45º angle.

2 Forming wheel (Fig 12&13)

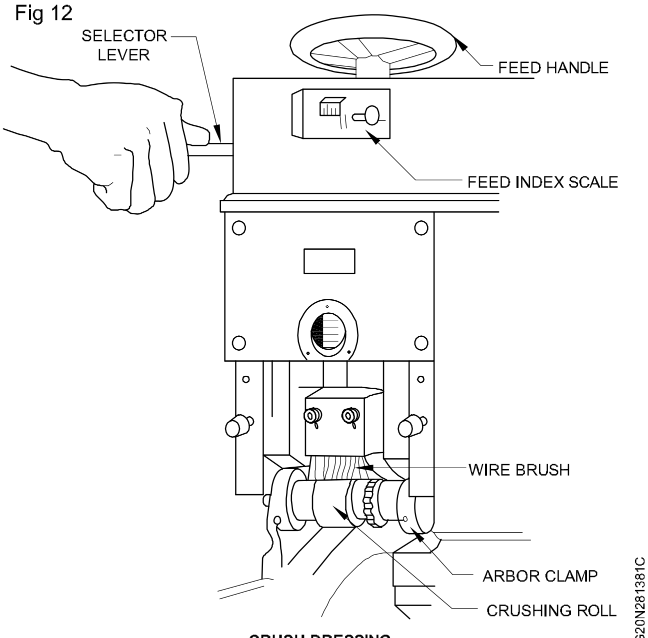
a Select crushing selector lever in the engaged position.

b Apply downward feed to the crushing roll until contact is made with the wheel.

c Apply light pressure.

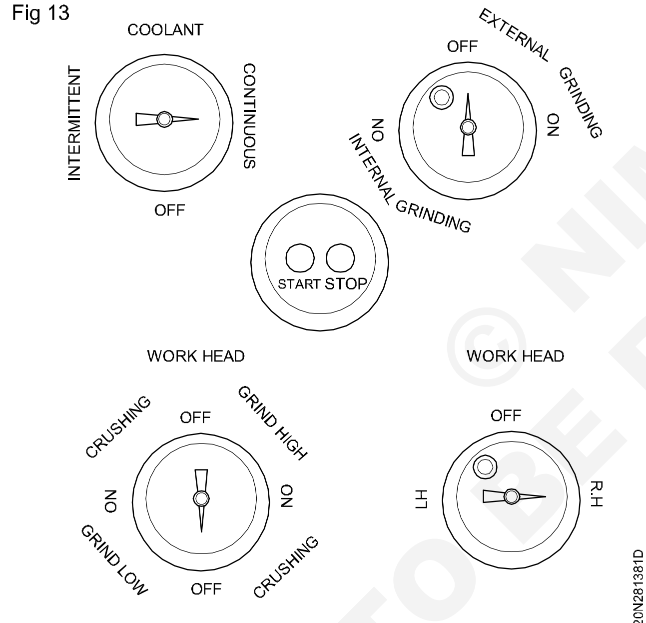
If pressure is not sufficient the wheel will not start.

Fig 12



CRUSH DRESSING

Fig 13



CRUSH DRESSING

d Turn selector switch to ''hand''.

e Apply coolant.

f Start wheel.

g Down feed crusher until full depth of form is produced.

h Release selector lever and wheel will stop.

OR

To set for automatic dressing

a Select crushing selector lever in the engaged position.

b Apply downward feed to the crushing roll until contact is made with the wheel.

c Apply light pressure.

d Turn selector switch on the panel to '' Auto''.

e Apply coolant.

f Start wheel.

g The machine must be operated until full depth of form is produced.

h Set amount of feed on index scale.002''(.050mm)

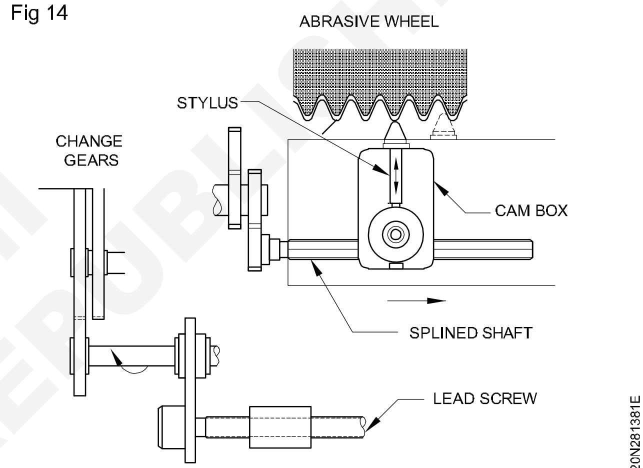
i Lock index scale in position.

j Release selector lever and wheel will stop.

B) Cam box dressing

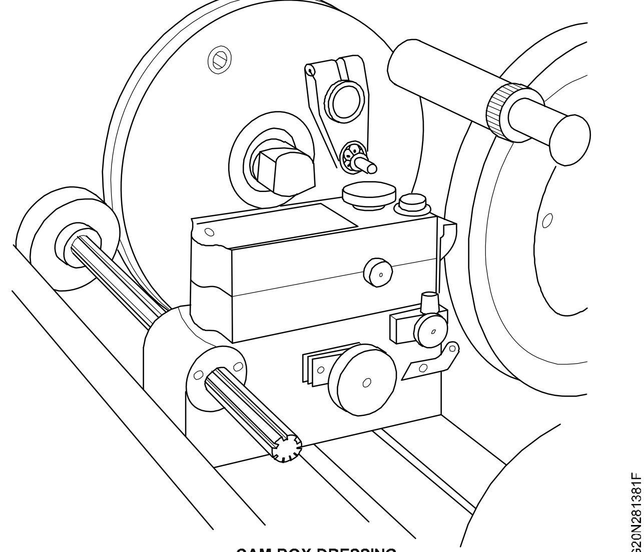
Cam box dressing is a method usually employed for gauge or high precision work.

Fig 14



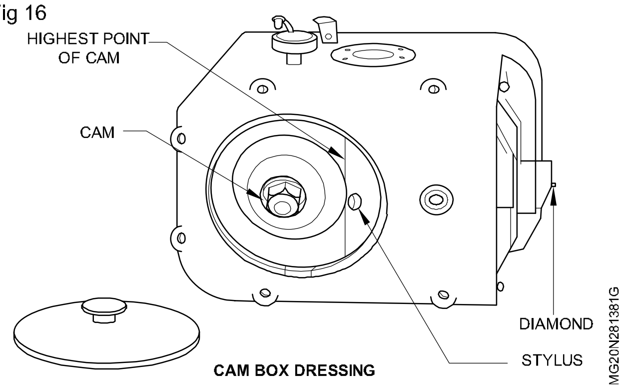
CAM BOX DRESSING

Fig 15



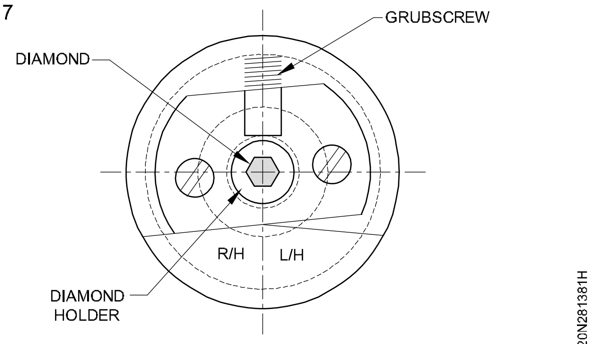
CAM BOX DRESSING

Fig 16



CAM BOX DRESSING

Fig 17



CAM BOX DRESSING

The cam box is driven by the change gears through the medium of a splined shaft. (Fig 14)

The cams are interchangeable, and are selected to produce the particular thread pitch required. (Fig 15)

1 Select and mount wheel

a Ensure spindle has reached working temperature.

b Ascertain thread form and pitch from drawing.

Safety

Isolate machine.

c Select and fit change gears to produce pitch.

2 Mounting cam box (Fig 16)

a Wipe locating surface clean.

b Place cam box on machine bed and secure in position.

c Remove protection cap from driving dog in workhead.

d Locate splined shaft in driving dog.

3 Setting thread form in cam box (Fig 17)

a Select appropriate cam for thread pitch to be produced.

b Withdraw stylus clear of cam.

c Place selected cam in position.

d Select and fit vee diamond for roughing, according to type of thread being formed .

Note

- vee diamond = roughing
- cone diamond = finishing

c Incline diamond for left or right hand threads to compensate for helix angle.

d Start wheel.

e Feed in wheel head to the approximate depth of thread form.

f Wind back wheel

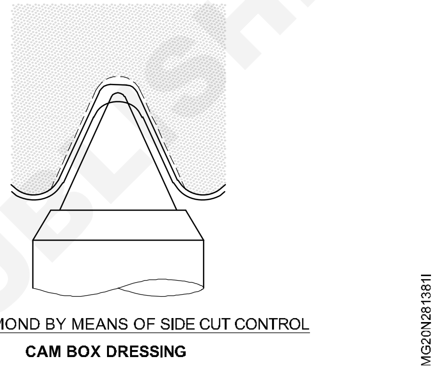
g Allow cam to rotate to highest point.

h Repeat operations (g),(h),(i) until required number of ribs have been produced.

k Remove roughing diamond.

4 Finish dress

Fig 18



ADJUST DIAMOND BY MEANS OF SIDE CUT CONTROL

CAM BOX DRESSING

a Select and fit finishing diamond.

b Allow stylus to rest on cam.

c Revolve cam until the highest point is in line with the stylus.

d Pick up in root of rough formed wheel with side cut control. (Fig 18)

e Apply feed in (0.001) (0.025) mm approx. Unit form has been produced.

Note

Excessive infeed will cause damage to the diamond stylus.

f Check form with a test piece.

C Single rib wheel dressing

Safety

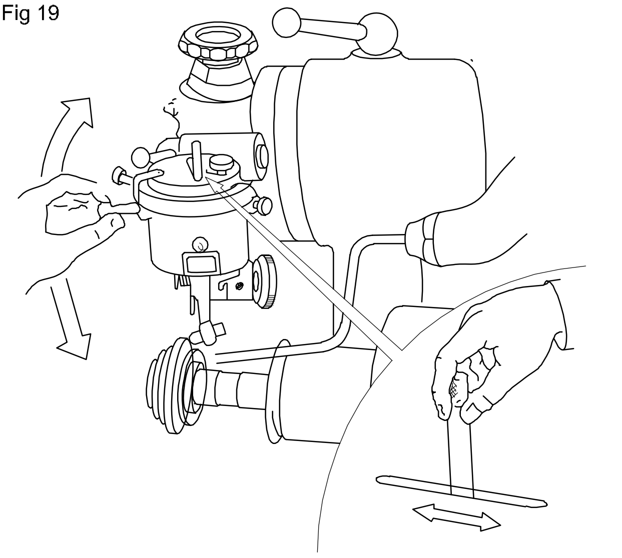
Refer to chart for permissible overhang.

1 Mount wheel

a Mount size of wheel within the limits of the spindle.

b Set dressing attachment clear of wheel.

Fig 19



SINGLE RIB WHEEL DRESSING

2 **Start wheel and allow spindle to attain normal working temperature.**

3 **Setting dressing attachment** (Fig 19)

   a Study drawing for type of form to be ground.

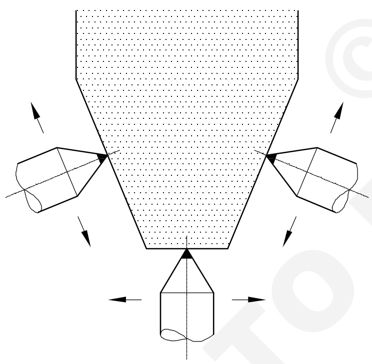
   b Set left hand index stop to specified angle required.

   c Set right hand index stop to specified angle required.

   d Set diamond for radius. (Fig 20)

4 **Dress wheel**

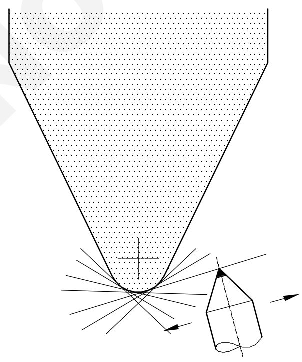
Fig 20



TANGENTIAL MOTION

SINGLE RIB WHEEL DRESSING

Fig 21



FORMING RADIUS ON SINGLE RIB DRESSING

SINGLE RIB WHEEL DRESSING

   a Start wheel.

   b Apply coolant.

   c Turn control switch to truing.

   d Wind in diamond feed handle until diamond makes light contact.

   e Hand operate diamond down one angle to the radius.

   f Repeat on opposite angle

   g Form radius. (Fig 21)

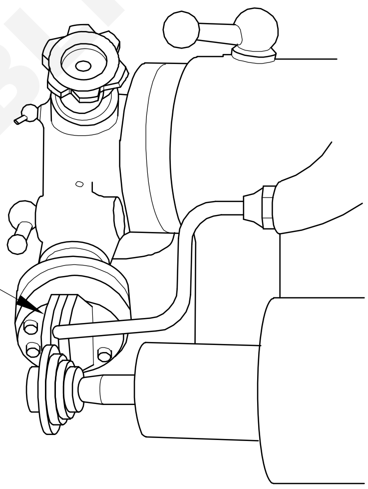
   h Check form on test piece.

   i Correct if necessary.

Always rough the form out first when a new wheel has been mounted or when changing a previously formed wheel, by abrasive stick or worn diamond.

Single rib wheel dressing for internal grinding is shown in Fig 22.

Fig 22



CRUSH DRESS FOR INTERNAL GRINDING

SINGLE RIB WHEEL DRESSING

D Crush dressing multi-rib

1 **Mount wheel**

   a Mount size of wheel within the limits of the spindle.

   b Ensure that the wheel will accommodate full thread form.

   c Set crushing attachment clear of wheel.

2 **Start wheel**

Allow spindle to attain normal working temperature.

3 **Setting crushing attachment**

   a Study drawing for type of form to be ground.

   b Select crusher.

   c Inspect for damage or worn form.

d Fit crusher using spacing bushes to centralise crushing roll with abrasive wheel.

e Secure in position.

4 Forming wheel

a Turn switch on control panel to ''Crushing''.

b Wind in crusher feed handle until crusher makes positive contact.

c Apply coolant.

d Start wheel.

e Feed in approximate depth of form.

f Wind off feed until crusher is clear.

g Check wheel with a test piece for correct form.

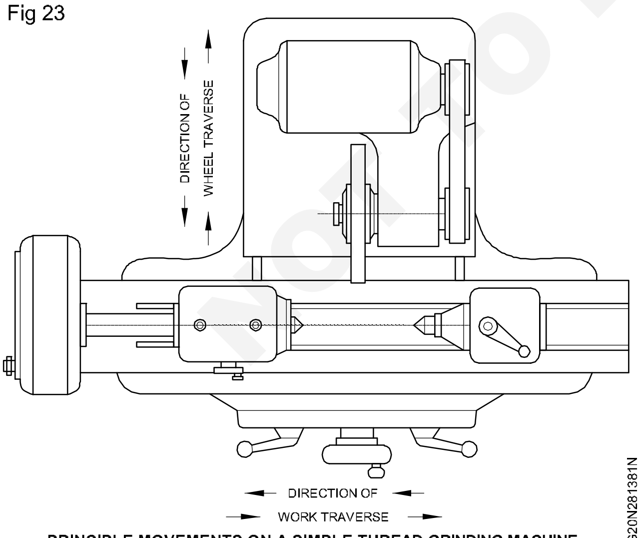
Principle movements of the thread-grinding machine

The Movement of the Wheel: The grinding wheel, with its electric motor, is mounted on a base which can slide in a direction perpendicular to the line of centres of the headstock and tailstock units, such movement being controlled by means of an in-fed mechanism, such as the handwheel and screwed-spindle assembly.

Alternatively an automatic in-feed mechanism may be employed. Thus the wheel may be fed into the work or away from the work. Of course,the amount by which the wheel is fed towards the axis of the workpart controls the dimensions of the thread diameters produced on the latter.

The Movement of the Workpart: The headstock and tailstock units are mounted on a bed which can be traversed in a direction parallel to the axis of the grinding wheel by means of a train of gears connecting the work driving spindle with the leadscrew. Thus the rotary motion of the workpart is derived from the work driving spindle, whilst its axial traversing motion is derived from the leadscrew. (Fig 23)

Fig 23



PRINCIPLE MOVEMENTS ON A SIMPLE THREAD-GRINDING MACHINE

Machine setting and sequence of operations in thread grinding

This chapter is, in the main, intended for readers who are directly concerned with the setting and operating of thread-grinding machines.

Essential data: Before setting up a thread-grinding machine for any given job the following particulars must be known:

- The pitch and the lead of the thread.
- The form of the thread.
- The hand of the thread.
- Basic diameters and limit dimensions.
- Whether the thread is to be of standard parallel form, or whether it is to be tapered, relieved, interrupted, or is in any way to be of nonstandard proportions or form.

The foregoing particulars comprise the minimum essential information necessary to enable all other related particulars to be determined either by calculation or by reference to table.

Included among additional particulars are:-

Helix angle or lead angle.

Quality of surface finish.

Sequence of operations

Change wheels

Selecting and mounting the grinding wheel

Preliminary wheel truing: For this truing operation it is advisable to use heavy-duty diamond tools to withstand the hammering effect set up by the rough state of the wheel.

Wheel removal: After the face and the sides of the grinding wheel have been trued, it is taken off the wheel spindle so that it may be tested and adjusted for running in proper balance.

Wheel balancing

Helix angle setting: Usually the wheelhead housing is swivelled over to the helix angle of the thread required on the workpart. A scale attached to the wheelhead shows the angle to which the wheel is tilted. This angle is usually called the helix angle on screw threads and lead angle on worm threads. In the case of the Newall range of machines the worktable, and not the wheelhead, is swivelled to the helix angle of the thread.

On ordinary screw-thread work, apart from worms, the term helix angle depend upon (1) the diameter of the work, and (2) the lead of the thread.

$$\text{Tangent of helix angle} = \frac{\text{lead of thread}}{\text{circumference of work}}$$

$$= \frac{\text{lead}}{\pi \times \text{diameter}}$$

Notes

When the thread is single-start, pitch and lead are identical; when the thread is two-start, lead equals twice pitch, when the thread is three-start, lead equals three times pitch, and so on.

The diameter(D) referred to above is the mean diameter, called the simple effective diameter on a screw thread, or the pitch diameter on a worn.

Lead angles of worms: The lead angle on a worm corresponds to the helix angle on an ordinary screw thread. On a worm the lead angle (λ) is the complement of the spiral angle (γ) this means that $\lambda + \gamma = 90°$. Thus, if the spiral angle is 82° 21′, the lead angle is 90° - 82° 21′ =7° 39′.

tan λ=lead/π x diameter. Of course the value of π is indeterminate, but on most work of this kind it is satisfactory to take its value as 3.142, or as 22/7.

Example

Single-start worm; pitch diameter 0.6418 in.; lead 0.0714 in.

$$\text{Tan of lead angle } (\lambda) = \frac{\text{lead}}{\pi \times \text{diameter}} = \frac{0.0714}{\frac{22}{7} \times 0.6418}$$

$$= \frac{7 \times 0.0714}{22 \times 0.6418} = 0.0354$$

∴ Lead angle (from tables) = 2°2'.

Mean Diameters

- On a standard screw thread the mean diameter is taken to mean its effective diameter, in other words it is equal to the '' outside'' diameter minus the full depth of a single thread.
- On a worm the mean diameter is generally taken to mean its pitch diameter, in other words it is equal to the outside diameter minus twice the addendum.
- On a gear-cutting hob the mean diameter is usually taken as the basic outside diameter minus twice the nominal dedendum.

Positioning coolant nozzles: It is worth reiterating that the coolant supply nozzles must be so positioned as to direct a flow of coolant to the area of contact between the wheel and the work.

Oil-splash guards: It is an advantage to be able to dispense with oil-splash guards, and sometimes this is possible by re-planning the positions of the coolant nozzles.

Positioning the headstock and tailstock units

Arrange the length of table traverse: The length of traverse of the worktable is controlled by adjustable limit stops or trip dogs. These stops are set so that the distance between them equals the desired traverse, the length of which for any job depends on (1) the length of thread to be ground, (2) the method of grinding. Thus in plunge-cut grinding the length of traverse is slightly greater than the pitch of the thread-provided that the width of the grinding wheel is greater than the length of threading.

Selecting the work speed

Fast Speed: This speed range applies from about 160 to upwards of 450 inches per minute surface speed of the work.

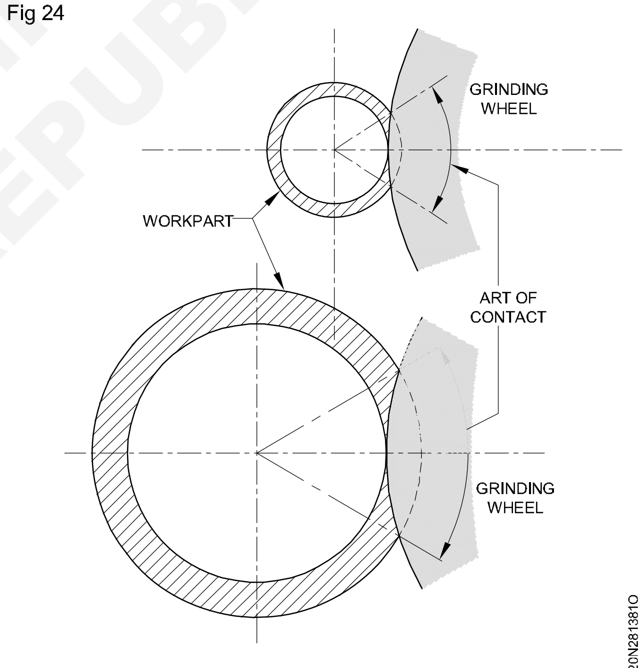
Slow Speed: This speed range applies from about one inch per minute to about 150 inches per minute surface speed of the work. A slow speed is employed when heavy cuts are taken.

1 **Arc of Contact:** Reference to Fig 24 shows that the arc of contact between the wheel and the work increases in magnitude with increases in (1) diameter of the work and (2) depth of cut.

   a The speed of the work must bear relation to its dia meter. As the diameter of a workpart is decreased the faster may be the work speed.

   b The deeper the cut the greater the arc of contact. Hence work speed must be reduced when the depth of cut is increased.

Fig 24



THE ARC OF CONTACT

2 **Material:** It must borne in mind that the work speed has a direct effect upon the cutting action of the grinding wheel; furthermore it influence the rate of stock removal. ''The slower the speed of the work, the deeper the cut that can be taken.''

3 **Degree of accuracy required:** In general it can be said that the higher the standard of accuracy required in the product.

Grinding a trial thread: Dressed the grinding wheel and set the machine to accommodate the given workpart, the beginner may be well advised to grind a specimen thread on a sample or test piece, before proceeding to thread-grind the actual workparts.

Grinding major diameters: It is emphasized that the major diameter on a worm or on a flat-crested thread is ground by means of a flat-faced grinding wheel.

When the major diameter is ground in a separate operation the operator must see that workparts are mounted so that the major diameter will be ground concentrically with the pitch diameter.

When major diameters are ground separately it is essential that a reasonable amount of surplus material, or ''stock allowance,'' be provided to ensure that all ''witness marks,'' left from the roughing-out of the blank, can be ground away. When the thread grinding of a workpart follows its heat treatment a sufficient stock allowance should be provided to allow for the removal of scale and minor shape distortions.

Stock allowance more fully considered: A workpart to be thread ground from the solid blank should have enough surplus material on the major diameter to allow for eccentricity and out-of-roundness, as well as to enable the grinding wheel to clean up the surface completely-leaving it without witness marks from previous operations.

Stock allowances, as tabulated in table 1, will be found satisfactory for the general run of work.

TABLE 1

Table of stock allowances
(Applicable to blanks which run concentrically and are truly round)

T.P.I	**Diameters**		
	Up to 1½ in.	**1½ to 3 in.**	**3 in. upwards**
6 and coarser	0.008 in.	0.010 in.	0.012 in.
7 to 12	0.006 in.	0.008 in.	0.010 in.
13 to 20	0.005 in.	0.007 in.	0.009 in.
22 to 30	0.004 in.	0.005 in.	0.007 in.
32 and finer	0.003 in.	0.004 in.	0.006 in.

Stock allowance for pre-cut threads: On workparts with pre-cut threads a larger stock allowance must be left than on unthreaded blanks. The actual amount of the stock is fixed in relation to several factors, including (I) the size consistency of the previous threading operation, (2) the degree of accuracy with which the mounting of the work can be duplicated, (3) the method of aligning the roughed out thread grooves with the thread ridges on the grinding wheel.

The stock allowance on the pitch diameter may advantageously be more than the allowances on the major and minor diameters. A general rule is to stipulate twice the allowance of stock on the pitch diameter that is allowed on the major and minor diameters.

Jones and lamson hobbing box: A special-purpose hobbing box can be used on the Jones & Lamson thread grinding machines. This item incorporates a geared Geneva plate mechanism for the accurate spacing of annular grooves. In action, the work spindle rotates constantly and after one groove has been ground the grinding wheel is withdrawn from the work and the worktable moves axially a distance equal to the pitch of the grooves. The table traverse mechanism is then disengaged and the grinding wheel is fed into the work to grind the second groove. Repetition of these movements results in a series of annular grooves, the pitch of which is controlled by change gears-the entire operation being automatic.

Grinding internal threads

The high degree of accuracy, together with simplicity in operation associated with modern thread-grinding machines, enables internal threads to be ground as both toolroom and commercial operations. Different pitches are obtained by using different change wheels or suitable leadscrew-and-nut assemblies in the same manner as when grinding external threads.

The different methods of forming and form-dressing grinding wheels, are all applicable to internal thread grinding. In addition, all four methods of grinding are used, the method employed in most cases being single-rib traverse grinding. Crushing rollers are sometimes used for wheel-forming but are not generally recommended in connection with internal grinding wheels.

Two types of machines: For grinding internal threads two types of machines are used. The type most widely used is referred to as a universal machine, this type of machine being adaptable for grinding both internal and external threads. For internal grinding a special spindle and drive assembly is mounted to the wheelhead which normally houses the external thread-grinding wheel.

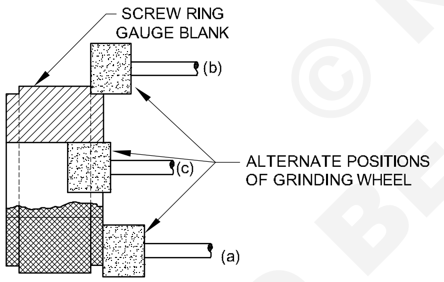
Size range of internal thread grinding: Thread pitches as fine as 40 t.p.i. and as coarse as 1 t.p.i. are ground on modern machines. Both single-and multi-start threads may be ground on diameters of less than 1/2 in. and as large as 18 in. The length of thread that can be ground depends, of course, on the capacity of the machine and physical dimensions of the workpart. In some cases the length of ground thread exeeds 15 in.

By using special equipment it is possible to grind relieved or '' backed-off'' internal threads such as are sometimes used on solid and adjustable types of thread dies.

Work mounting: The workpart to be ground is mounted in a chuck, on a faceplate, or jig attached to the headstock and work-driving spindle. When a number of similar parts are to be ground special work-holding devices may be employed, these being air-operated, magnetic, or worked by a drawbar action. It is essential in all cases that particular care be taken to ensure that workparts are rigidly held and are well balanced.

When grinding screw ring gauges, or similarly shaped workparts, it is recommended that they be clamped to a faceplate. A method usually employed when grinding a number of screw ring gauges is first to grind the ''blanks''. Note that the face of the gauge is ground to ensure that when mounted on the faceplate of the thread-grinding machine the gauge will have a good register face and that the axis of the thread will be square to the face of the gauge. The position of the grinding wheel when grinding the face of the gauge is shown in Fig 25(a).At the same setting, that is without moving the gauge, the centralizing diameter is ground as shown in Fig 25(b). The latter operation enables the thread-grinding operator to adjust the blank so that it is mounted concentrically on the faceplate of the thread-grinding machine.

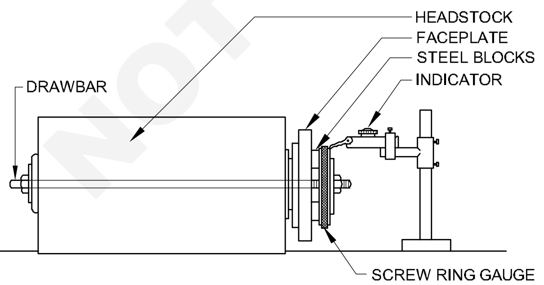
Fig 25



PRELIMINARY STEPS IN GRINDING A SCREW RING GAUGE

Fig 26 shows the set-up for centralizing the gauge on the faceplate.

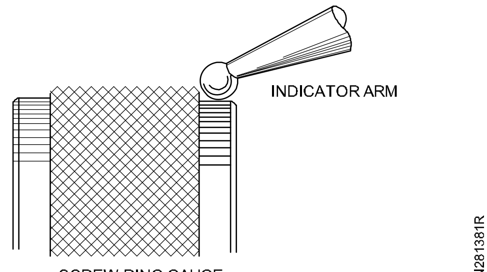
Fig 26



SET-UP FOR CENTRALIZING WORK FOR GRINDING AN INTERNAL THREAD

Note that the gauge is clamped to the faceplate by means of a drawbar. By using an indicator or ''clock'' gauge the blank can be positioned centrally. The indicator arm is placed on the ground centralizing diameter, Fig 27, and by rotating the faceplate, the amount by which the gauge has to be moved to rotate concentrically is shown on the dial of the indicator. (Fig 27)

Fig 27



USING AN INDICATOR WHEN SETTING UP THE BLANK

The bore of the gauge is ground at the same setting as grinding the face and the centralizing diameter.

Accuracy: The degree of accuracy that can be obtained depends to a large extent upon the proficiency of the machine operator. Under average conditions work can be produced within ±0.0002 in. of prescribed diameter dimensions. Accuracy in pitch and lead is usually within 0.0002 in. per inch length of thread.

Test plugs and or measuring instruments are used for checking the thread diameters. The use of test or ''check'' plugs is fully explained in Note on screw gauges (H.M.S.O.) The pitch of thread can be checked on a pitch measuring machine. The form of the ground thread may be checked by taking a mould or ''cast'' of the thread, and comparing it with a reference or standard form on an optical projector.

Stock allowance: The list of stock allowance recommendations Table 1 may be used when deciding the quantity of surplus material to be allowed for in internal to be allowed for in internal thread grinding. It is generally recommended that threads with pitched coarser than 12 t.p.i. be pre-cut by screw-cutting on a lathe, by tapping, or by thread-milling, Equipment is usually supplied for matching-up the roughed-out groove with the thread form on the grinding wheel.

Work speed: The work speeds used are, to a large extent governed by the nature of the material and the depth of thread.

Depth of cut: With the exception of threads coarser than 12 t.p.i., which are usually pre-cut, internal threads are ground from the solid blank. Initial cuts of 0.03 in. to 0.1 in. depth are not uncommon but most suitable depths are found by trial. Under average conditions final sizing cuts between 0.004 in. and 0.008 in. on diameter give best results. When dealing with work required to extremely close limits the finishing cuts may advantageously be of 0.001 in. depth or less.

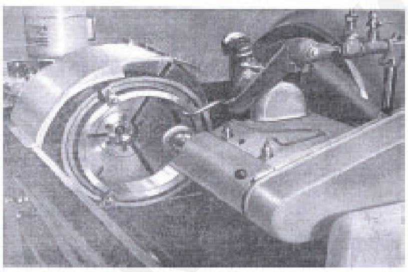
Use of coolant: The importance of correct cooling cannot be overstressed. More difficulty in applying the coolant is met with when grinding the smaller diameters of internal threads as it is not always practicable to arrange for the coolant nozzle to enter the bore of the workpart. Auxiliary coolant supplies are often necessary. Best results are obtained when coolant is applied through the bore of the headstock spindle. This supply can be augmented by arranging another supply of coolant to impinge upon the contact area of the wheel and workpart. Care should be taken to arrange the supply of coolant in such a manner that the particles of swarf and abrasive are washed away from the grinding wheel.

Selection and mounting of quills: The grinding wheel is mounted on the end of a quill or ''spindle extension.'' The quill, in turn, is fitted to the internal grinding spindle, usually by inserting the tapered end of the quill into the tapered bore of the spindle. A threaded drawbar is used to secure quill and spindle and should be tightened to a degree sufficient only to seat the quill properly in the tapered bore. Both quill and spindle should be perfectly clean before being fitted together.

A cold quill must never be fitted to a warm spindle as expansion of the quill and contraction of the spindle will cause seizure. Allowing the quill to rest loosely in the spindle for a few minutes will help to equalize the temperatures.

A set of quills of different sizes is usually supplied as standard equipment. The selection of the most suitable quill depends on the nature of the work. The aim should be to select a quill that has most rigidity under actual working conditions. Thus, the quills should be as short and as robust as it is possible to use. Long qills are used for grinding long lengths of thread or when the thread to be ground has a ''facing,'' i.e. an ''unthreaded diameter.'' The larger the quill diameter the slower should be the wheel speed.

Internal grinding spindles (Fig 28): Success in grinding internal threads can be obtained only when the grinding spindle is in first class condition. Under heavy loads the spindle should operate with complete freedom from vibration. Most spindles are of ball-bearing type and are manufactured and assembled with extreme precision. Due to the extraordinary care required in the use and care of spindles it is generally recommended that they be returned periodically to the makers for service and overhaul.



INTERNAL THREAD-GRINDING ATTACHEMENT FITTED TO A MATRIX GRINDING MACHINE

The speed of the spindles is, in many cases, predetermined by the makers and different spindles are supplied for operating at prescribed speeds. In selecting a spindle the load-carrying capacity should be considered. Evidently a slower-running heavy spindle has a much greater load-carrying capacity than a faster-running lightweight spindle. The slower the spindle speed the heavier the cut that can be taken. The slower the spindle speed the larger may be the quill diameter. Rigidity of support governs efficiency of the grinding wheel.

Internal helix angle: Helix angles of internal threads are calculated in the same manner as for external threads.

The greater the helix angle of the work the shorter becomes the length of thread that can be ground. This is due to interference caused by the tilting of the grinding wheel housing which brings the quill nearer to contact with the mouth of the work.

In setting up the machine it must be remembered that the helix angle of an internal thread is opposite to that of an external thread of the same hand. When dealing with quantity production of work parts to commercial tolerances it is customary to leaver the grinding wheel set at zero helix for threads not exceeding 30 helix angle.

General notes: Factors which govern success or failure in grinding internal threads are similar to those which apply to grinding external threads. Therefore, appropriate sections of this book should be referred to for particulars concerning selection and mounting of grinding wheels; coolants; forming and form-dressing; machine-setting operations, wheel and work speeds; diamond tools; etc.

Grinding coolants

Grinding Coolants have a fourfold value depending on the nature of material to be ground.

- To conduct the heat of grinding away, thus preventing the work from being robbed of its hardness value, and controlling the depth of cut by keeping the work at an even temperature.
- To assist the wheel in its work of cutting by.
- lubricating the cutting points and reducing friction
- decreasing the rate of dulling and loading of the wheel face, which in turn prevents wheel wastage.
- To carry away chips and loose abrasive particle which would interfere with the cutting and finishing characteristics of the wheel.
- To prevent oxidisation of the workpiece and machine.

Two common types of coolant used

1 Soluble Oil

General

For high surface speed of work (30 to 150 feet per minute) water is used. This usually has an additive of somewater-soluble oil of which there are many varieties. Selection is dictated by the need of the user. The mixture of water to oil is usually in the range of 50:1 to 100:1 and should be used in conjunction with an efficient coolant cleaning system. It should be noted that the addition of more soluble oil will give a higher surface finish, but could cause burning it over done.

2 Straight Cutting Oils

For slow feed, full form grinding, as in certain gear grinding, thread and centreless grinding operations, oil is used.

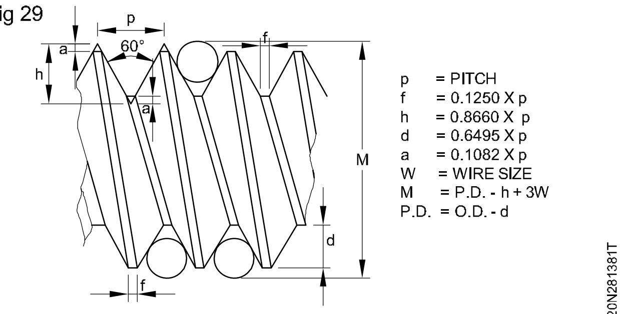
Cutting oil is chosen for its lubrication value and its heat dissipation properties.

Safety

> **When using straight cutting oil comply with the maker's instructions with reference to periodic cleaning to avoid fire and health risk.**

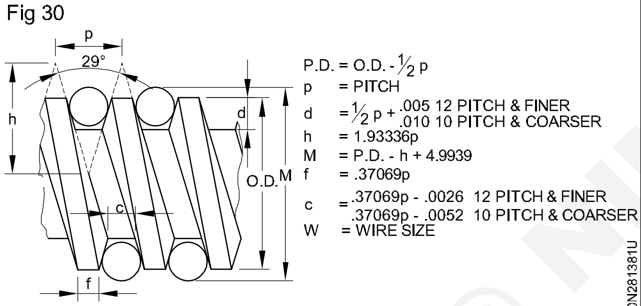
Different form of threads and their proportionate are shown in Figs 29 to 35.

Fig 29



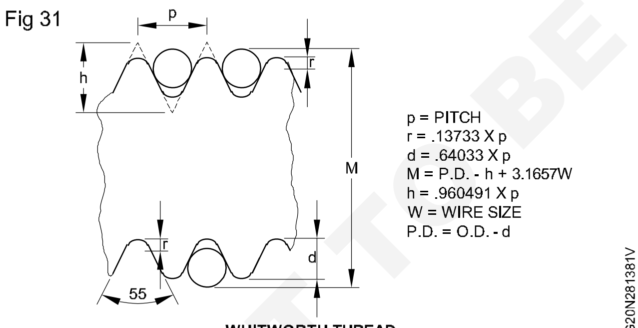
NATIONAL FORM THREAD

Fig 30



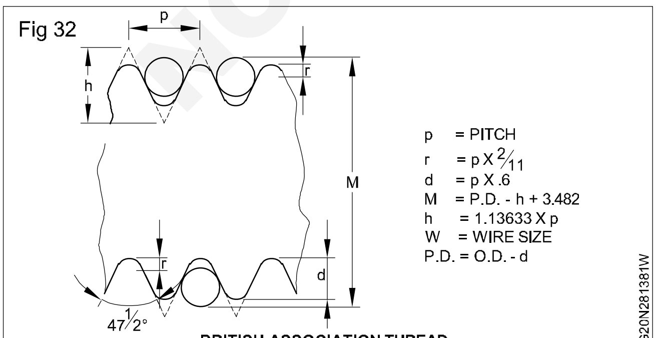
ACME THREAD

Fig 31



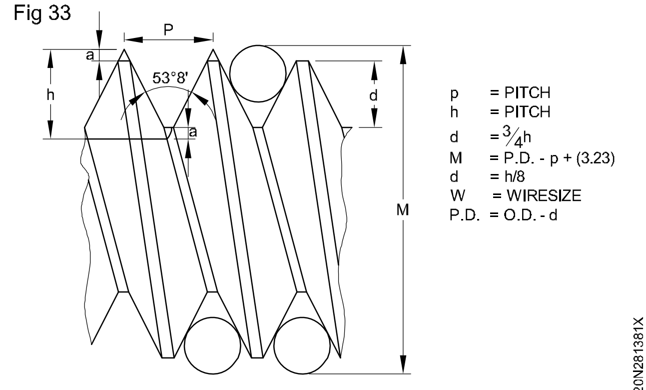
WHITWORTH THREAD

Fig 32



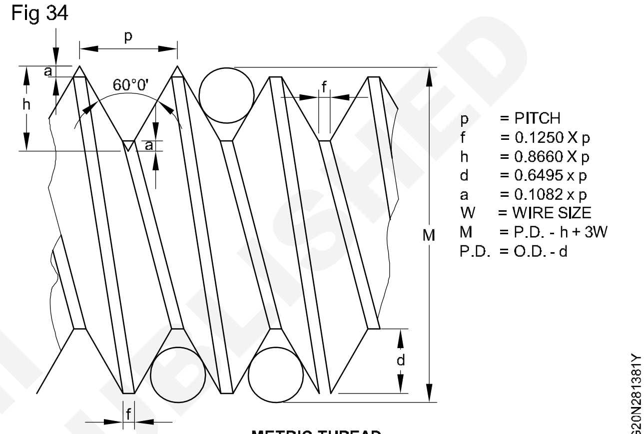
BRITISH ASSOCIATION THREAD

Fig 33



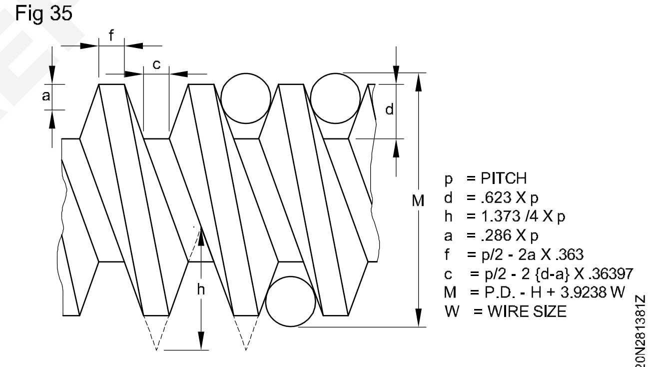
LOWENHERZ THREAD

Fig 34



METRIC THREAD

Fig 35



20° PRESSURE ANGLE WORM THREAD FOR TRIPLE AND QUADRAPLE THREADS

Internal grinding

Objective : At the end of this lesson you shall be able to
- **describe two methods of internal grinding.**

Cylindrical or tapered holes are ground in internal grinding machine by two methods:

- Job rotates at low speed and grinding head spindle rotates at high speed and reciprocates inside the bore to be ground e.g. Rings, bushers.
- Job will not rotate and grinding head spindle rotates and reciprocates.

1 Rotation and reciprocation of Job and wheel head method

In this method there are four action takes place:

1 Job fixed in head stock (By means of chuck, collect or magnetic plate) rotates

2 Grinding wheel head rotates

3 & 4 Grinding wheel head reciprocates in and of job bore.

The above actions shown in Figs 1 & 2

Fig 1

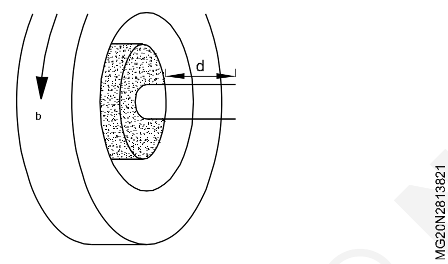
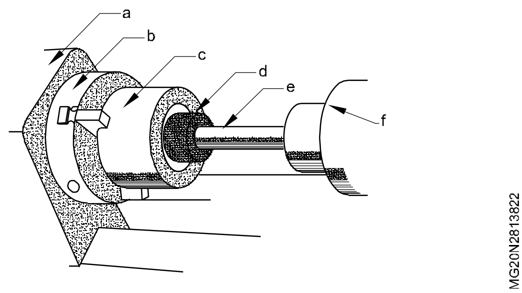


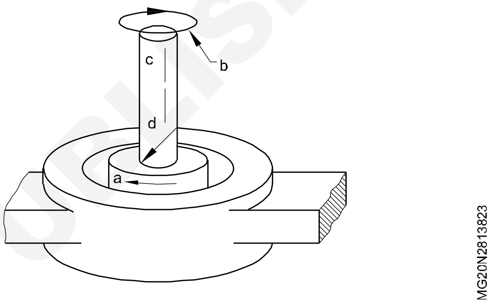
Fig 2



2 Fixed Job and wheel head rotation and reciprocation method.

The job fixed on to machine bed the wheel head rotates and moves down to up inside bore area to be ground. The above action shown in Fig 3.

Fig 3



Internal grinding allowance

Objectives : At the end of this lesson you shall be able to
- **list the factors determine the excess material kept for internal grinding**
- **state the excess material kept, tolerances and depth of cut for different diameters while internal grinding.**

The excess material kept on workpiece for internal grinding operation depends on:

- Size of the work piece.
- Pre operation carried out.
- Heat treated work piece.
- Surface finish required
- and the accuracy required.

Normally the stock material kept on holes up to 3mm dia is 0.1 mm and up to 200 mm dia bore is 0.8 mm.

Tolerances less than 0.025 to 0.075 mm are easily ground by non abrasive methods.

Tolerance 0.0025 mm is obtained by commercial grinding. Grinding also can be done very close tolerance up to 0.00050mm.

The depth of cut depends upon the diameter of the hole being ground and may vary from 0.02 to 0.05 mm roughing from 0.002 to 0.01 mm in finishing operations.

Selection of grinding wheels for internal grinding

Objectives : At the end of this lesson you shall be able to
- **list the nine factors considered while selecting grinding**
- **list three types of applications of internal grinding.**

Internal grinding are widely used in bearing and automobile industry. Such as bore grinding of inner rings, bore grinding of gears, track grinding of outer rings and streering nuts etc.

In internal grinding, the grinding of internal surfaces the conformity between the wheel and workpiece, is substantially higher.

For selection of grinding wheels IS : 1249 - 1958 provides recommendations on the general considerations, which guides the selection of grinding wheels for different applications.

The main factors considered while selecting grinding wheel are:

- Material to be ground and its hardness
- Stock removal
- Severity of operation
- Surface finish
- Area of grinding contact
- Wheel speed
- Wet and dry grinding
- Machine condition
- Work speed

The illustration and working application of internal grinding wheels one shown in Figs 1 and 2.

Fig 1

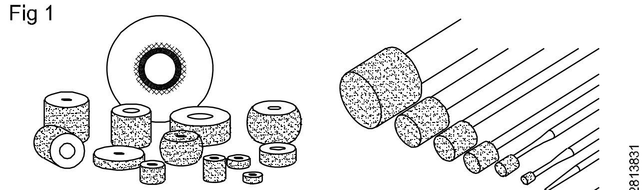
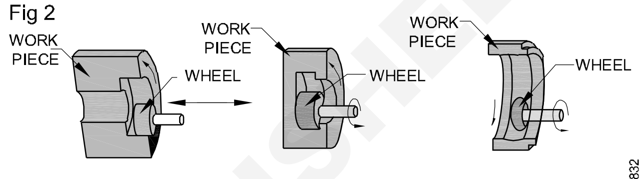


ILLUSTRATION OF INTERNAL GRINDING WHEEL & MOUNTED WHEELS FOR SMALL DIA

Fig 2



APPLICATION OF INTERNAL GRINDING WHEEL

Selection and use of grinding wheels for different application are usually given in grinding wheel manufactures catalogue

Standard size of wheels available are shown Table 1

For smaller diameter mounted wheels in various sizes available.

TABLE 1

Dia.(In)	Thick. (In.)	Bore (In.)	Recess (In.)	Dia. (mm)	Thick. (mm)	Bore (mm)	Recess (In.)
1/2	1/2	1/4	-	13	13	6.35	-
3/4	3/4	1/4	3/8x3/8	20	20	6.35	9x9
1	1	3/8	1/2x1/2	25	25	9	12.7x12.7
1	1	1/4	1/2x1/2	25	25	6.35	12.7x12.7
1 1/4	1	3/8	5/8x1/2	31.75	25	9	16x12.7
1 1/2	1	3/8	3/4x1/2	38.1	25	9	20x12.7
1 1/2	1	3/8	5/8x1/2	38.1	25	9	16x12.7
2	1	3/8	3/4x1/2	50	25	9	20x12.7
2	1 1/2	5/8	1x3/4	50	38	16	25x20

Lapping

Objectives: At the end of this lesson you shall be able to
- **State lapping and its purpose**
- **Explain the types of laps, lapping abrasive and lapping lubricant**
- **State hard lapping and machine lapping process**
- **Explain flat surface and cylindrical surface polishing/lapping method.**

Lapping is a precision finishing operation carried out using fine abrasive materials.

Purpose: This process

– improves geometrical accuracy

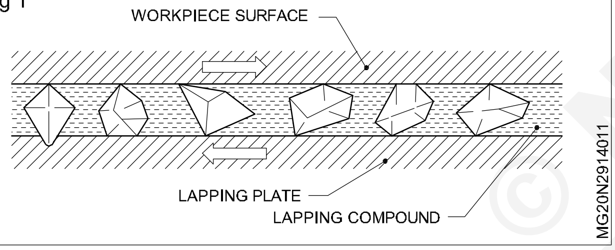
– refines surface finish

– assists in achieving a high degree of dimensional accuracy

– improve the quality of fit between the mating components.

Lapping process: In the lapping process small amount of material are removed by rubbing the work against a lap charged with a lapping compound. (Fig 1)

Fig 1



Lap materials and lapping compounds

The material used for making laps should be softer than the workpiece being lapped. This helps to charge the abrasives on the lap. If the lap is harder than the workpiece, the workpiece will get charged with the abrasives and cut the lap instead of the workpiece being lapped.

Laps are usually made of:

– close grained iron

– copper

– brass or lead

The best material used for making lap is cast iron, but this cannot be used for all applications.

When there is excessive lapping allowance, copper and brass laps are preferred as they can be charged more easily and cut more rapidly than cast iron.

Lead is an inexpensive form of lap commonly used for holes. Lead is cast to the required size on steel arbor. These laps can be expanded when they are worn out. Charging the lap is much quicker.

Lapping abrasives: Abrasives of different types are used for lapping.

The commonly used abrasives are:

– Silicon Carbide

– Aluminium Oxide

– Boron Carbide and

– Diamond

Silicon carbide: This is an extremely hard abrasive. Its grit is sharp and brittle. While lapping, the sharp cutting edges continuously break down exposing new cutting edges. Due to this reason this is considered as very ideal for lapping hardened steel and cast iron, particularly where heavy stock removal is required.

Aluminium oxide: Aluminium oxide is sharp and tougher than silicon carbide. Aluminium oxide is used in un-fused and fused forms. Un-fused alumina (aluminium oxide) removes stock effectively and is capable of obtaining high quality finish.

Fused alumina is used for lapping soft steels and non-ferrous metals.

Boron carbide: This is an expensive abrasive material which is next to diamond in hardness. It has excellent cutting properties. Because of the high cost, it is used only in specialised application like dies and gauges.

Diamond: This being the hardest of all materials, it is used for lapping tungsten carbide. Rotary diamond laps are also prepared for accurately finishing very small holes which cannot be ground.

Lapping vehicles: In the preparation of lapping compounds the abrasive particles are suspended in vehicles. This helps to prevent concentration of abrasives on the lapping surfaces and regulates the cutting action and lubricates the surfaces.

The commonly used vehicles are

– water soluble cutting oils

– vegetable oil

– machine oils

– petroleum jelly or grease

– vehicles with oil or grease base used for lapping ferrous metals.

Metals like copper and its alloys and other non-ferrous metals are lapped using soluble oil, bentomite etc.`

In addition to the vehicles used in making the lapping compound, solvents like water, kerosene, etc. are also used at the time of lapping.

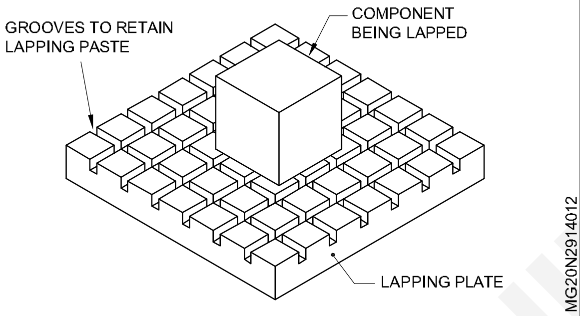
Abrasive of varying grain sizes from 50 to 800 are used for lapping, depending on the surface finish required on the component.

The lapping compound consists of fine abrasive particles suspended in a 'vehicle' such as oil, paraffin, grease etc.

The lapping compound which is introduced between the workpiece and the lap chips away the material from the workpiece. Light pressure is applied when both are moved against each other. The lapping can be carried out manually or by machine.

Hand lapping of flat surfaces: Flat surfaces are hand-lapped using lapping plate made out of close grained cast iron. (Fig 2) The surface of the plate should be in a true plane for accurate results in lapping.

Fig 2



The lapping plate generally used in tool rooms will have narrow grooves cut on its surface both lengthwise and crosswise forming a series of squares.

While lapping, the lapping compound collects in the serrations and rolls in and out as the work is moved.

Before commencing lapping of the component, the cast iron plate should be CHARGED with abrasive particles.

This is a process by which the abrasive particles are embedded on to the surfaces of the laps which are comparatively softer than the component being lapped. For charging the cast iron lap, apply a thin coating of the abrasive compound over the surface of the lapping plate.

Use a finished hard steel block and press the cutting particles into the lap. While doing so, rubbing should be kept to the minimum. When the entire surface of the lapping plate is charged, the surface will have a uniform gray appearance. If the surface is not fully charged, bright spots will be visible here and there.

Excessive application of the abrasive compound will result in the rolling action of the abrasive between the work and the plate developing inaccuracies.

The surface of the flat lap should be finished true by scraping before charging. After charging the plate, wash off all the loose abrasive using kerosene.

Then place the workpiece on the plate and move along and across, covering the entire surface area of the plate. When carrying out fine lapping, the surface should be kept moist with the help of kerosene.

Wet and dry lapping : Lapping can be carried out either wet or dry.

In wet lapping there is surplus oil and abrasives on the surface of the lap. As the workpiece, which is being lapped, is moved on the lap, there is movement of the abrasive particles also.

In dry method the lap is first charged by rubbing the abrasives on the surface of the lap. The surplus oil and abrasives are then washed off. The abrasives embedded on the surface of the lap will only be remaining. The embedded abrasives act like a fine oilstone when metal pins to be lapped are moved over the surface with light pressure. However, while lapping, the surface being lapped is kept moistened with kerosene or petrol. Surfaces finished by the dry method will have better finish and appearance. Some prefer to do rough lapping by wet method and finish by dry lapping.

Lapping

It is fundamentally an abrasion process which results in four major refinements in the workpiece:

(a) Extreme accuracy of dimension.

(b) Correction of minor imperfections of shape.

(c) Refinement of surface finish.

(d) Close fit between mating surfaces.

The process of lapping consists in working the surface to be lapped in contact with another one charged with a suitable fine abrasive with a sliding of rotary or combined motions. The lap used is of a softer metal than that of the surface to be lapped. The lap is re-charged with fresh abrasives from time to time as the grains lose their cutting ability after a certain period of use by becoming blunt.

The surfaces to be lapped are pre-machined by grinding, fine turning, broaching, reaming or any other fine machining method and as low as 0.005 to 0.010 mm material is left for lapping allowance.

The process of lapping can be done manually or by machine. Hand lapping is tedious, but machine lapping is very quick.

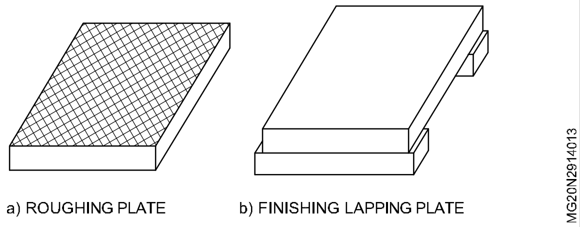
Lapping abrasives. For hardened materials silicon carbide and for softer materials aluminium oxide is used. For small precision work e.g. in tool rooms, watch factories etc, diamond dust is used. Certain other abrasives are also in use such as four of emery, oxide of chromium etc.

Types of Laps

(a) Flat laps (b) Internal laps (c) External laps.

Flat Laps Laps used for producing flat surfaces are made of close-grained cost iron They are heavily ribbed and fairly thick so that they don't distort. For roughing operation, scored lapping plates (Fig 3a) are used to form a square or diamond pattern. For finish lapping smooth cast iron are used. (Fig 3b)

Fig 3



a) ROUGHING PLATE b) FINISHING LAPPING PLATE

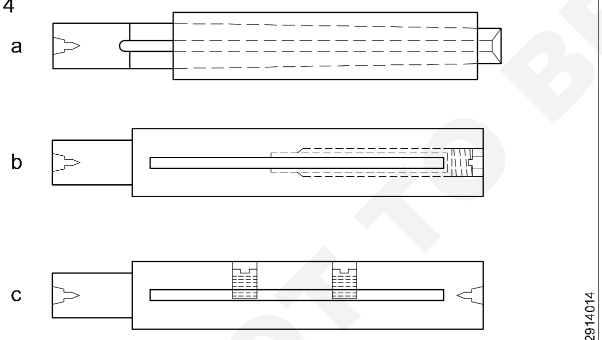
The plate is charges with the abrasive material or compound suitable for the work. Too much abrasive should not be used as it causes excessive wear of the lap without doing any additional work. While lapping ever charging contact between the lap and the work must be used so that lap wear and stock removal is uniform. Manual lapping is a skilled job as the proper lapping speed to be used and the pressure depends upon the judgement and feel of the operator.

Internal Laps: There are a number of ways of making internal laps, three of which are shown in Fig 4 The lap at Fig 4a is made by pouring lead around a tapered mandrel which has a lengthwise groove. The lead in the groove acts as a key. After turning lead to size, it is split along one side.

The lap at Fig 4b may be made of copper, brass of cast iron. In it a tap size hole is drilled about half the length and then a smaller hole for a short distance farther. The hole is tapped a few threads and fitted with a pointed screw.

The adjustable lap at Fig 4c may made of copper or brass. It is split practically its full length and may have one or more screws.

Fig 4



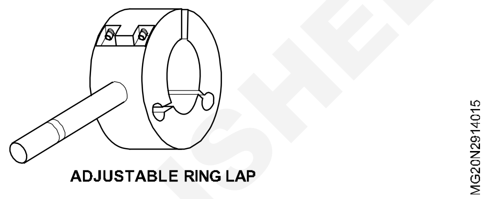
INTERNAL LAPS

Charging of the lap is done by sprinkling some lapping powder on a flat plate and then rolling the lap over powder. Work-piece is fitted on the lap, mounted between the centres and run at a slow speed (150-200 r.p.m)with a lathe dog. Work piece is run back and forth along the entire length of the lap. It is then removed, rinsed in varsol for removing the abrasive and then the hole sized gauged.

Lap should always be kept moist. Loose abrasive is not added to the lap. It necessary, the lap is re-charged and adjusted.

External laps: These are used to finish the outside of cylindrical workpieces. They are usually made of close-grain cost iron. They may be of several forms, one of which is shown in Fig 5 It has several cuts partially through besides the complete slit. The provision of closing screws and opening screws enable precision adjustments to be easily maintained. It is necessary that the bore is smooth, straight and close to the size of work. The lap should be slightly shorter in length than that of the work. It is difficult to handle long laps as it is to be adjusted tightly on the work and reciprocated rapidly. When reciprocated. The lap should over-run the work about 1/3 rd the length of the lap. The lap should always be kept moist.

Fig 5

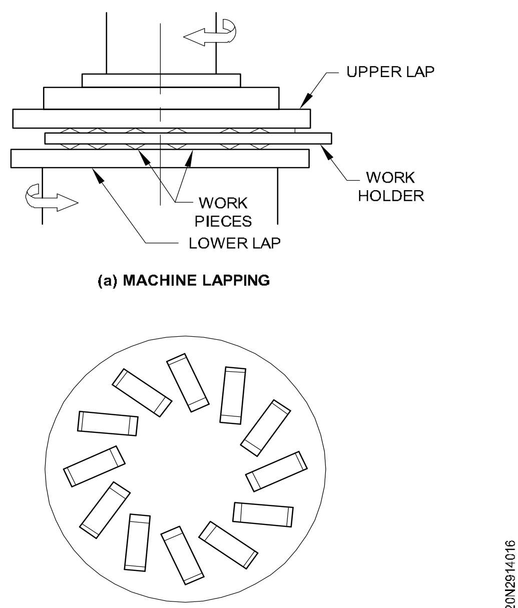


ADJUSTABLE RING LAP

Machine lapping: It is used to obtain extreme accuracy of dimension, improved geometric accuracy and improved surface quality. The lap is usually similar to that used in hand lapping and the abrasive in suspension is applied.

Machine shown in (Fig 6a) has two laps rotating in opposite directions; the workpieces between the laps in a holder. The workpieces must have random motion over the laps and should only be lightly constrained in the work holder The work holder is given as eccentric motion as it rotates with 12 work pieces (Fig 6b) lapped at a time, the pressure of the upper lap is equalised and more over an under sized work piece doesn't affect the lapping action on the remainder.

Fig 6



(a) MACHINE LAPPING

(b) DISTRIBUTION OF WORK - PIECE IN MACHINE LAPPING

Grinding, Faults and their Corrections

Objectives: At the end of this lesson you shall be able to
- **state the problems, causes and correction of common grinding faults**
- **state the problems, causes and correction of grinding faults based on operation**
- **state the problems, causes and correction of wheel breakage.**

	Problem	Causes	Correction
Chatter vibration	Regularly spaced marks	Vibration	Rebalance motor and wheel.
	Wide, regularly spaced marks	Vibration from belt Pulley loose or out of balance	Replace belt. Eliminate looseness. Balance pulley.
	Long, regularly spaced marks	Wheel out of balance Wheel face out of round.	Wheel face out of round True wheel before balancing
	Short, close, evenly spaced marks	Spindle bearings loose	Adjust spindle bearings. Warm up grinding machine to reach appropriate temperature. Check thrust bearing.
	Slightly longer and more widely spaced marks	Wheel spindle run - out or out of round	Replace wheel spindle.
	Long, widely spaced marks	Drive gear backlash	Replace gears. Introduce V belt drive. Check lubricated condition.
	Regular or irregular marks	Faulty thrust bearing	Replace thrust bearing.
	Narrow, regularly spaced marks	Spindle pulley loose	Tighten spindle pulley.
	Longish, widely spaced discolored	Glazed or loaded wheel marks, distributed evenly	Use coarser grit, softer grade or more open structure wheel.
	Chatter marks	Incorrect wheel dressing	Redress wheel face with sharp diamond dresser. Mount diamond dresser rigidly in holder.
	Irregular marks	Work center holes out of round or not in line. Steady rests improperly adjusted.	Check work center holes for roundness and alignment. Check workpiece for fit to centers. Check lubricated condition between work center holes and centers. Adjust steady rests.
	Marks synchronized with floor vibration	Vibration from floor	For large machines, build additional foundation separated from floor. For normal machines, try adjusting anchor bolts. Try changing machine location. Mount machine on some vibration insulting material.
	Mottle marks	Glazed wheel	Balance and redress wheel. Remove grease or oil spots from wheel face.
	Deep, narrow regular marks	Wheel too coarse	Use finer grit wheel.

	Problem	Possible causes	Suggested correction
Scratching feed marks		Shedding	Use harder acting wheels.
			Use more friable abrasive grains.
		Incorrect dressing	Redress wheel face with sharp diamond dresser.
			After dressing, clean wheel surface with stiff - bristled brush.
		Contamination by coarse grits or foreign matters	Dress or replace wheel.
	Deep isolated scratches	Flanges loose	Insert blotters between wheel surface and flanges and tighten screws evenly.
		Organic wheel deteriorated	Do not use solution - type coolant. Prevent rise in coolant temperature with cooling system during summer.
			Limit maximum pH (alkalinity) to 9.
Loading Glazing Shedding		Head and tailstock out of alignment	Check head and tailstock, and table ways.
	Large wheel wear	Wheel to soft	Reduce work speed, wheel traverse rate and wheel infeed rate.
	Grinding marks on workpiece		Increase wheel speed, wheel diameter, and wheel thickness.
	Workpiece tapered shedding		Take lighter dressing cuts and reduce diamond traverse rate.
	Poor cutting ability	Wheel too hard	Increase work speed, wheel traverse rate and wheel infeed rate rate.
	wheel glazing		Reduce wheel speed, wheel diameter, and wheel thickness.
	wheel loading		Redress wheel face frequently with sharp diamond dresser.
	burned work chatter marks		Use coarse grit, or softer grade wheel.
	Loading	Wheel specification unsuitable	Use coarser grit, softer grade, or more open structure wheel.
		Incorrect wheel dressing	Use sharp diamond dresser.
		Poor coolant quality	Increase diamond traverse rate and then clean wheel surface.
		Faulty grinding operation	Change coolant or use high detergent type.
			Grind under conditions which provide softer wheel acts.
	Glazing	Wheel specification unsuitable	Use coarser grit, softer grade, or more open structure wheel.
			Use more friable abrasive grains.
		Incorrect wheel dressing	Use sharp diamond dresser.
			Increase diamond traverse rate.
			Take heavier dressing cuts.

	Poor quality/quantity coolant	Increase lubricity of coolant. In addition to improving coolant supply method, supply
Irregular scratches	Dirty coolant Dust or other particles	Clean and check coolant circulating system, in particular, filter, tank, and inside guard. Check dust collector for proper functioning and improve work environment.
Draughts board pattern	Faulty grinding operation	Do not excessively force wheel onto workpiece. Make wheel act softer. Supply large and equal volume of coolant to grinding point.
Grain marks	Wheel too soft Wheel to coarse	Use finer grit or harder grade wheel.
	Incorrect wheel dressing	Dress the wheel with lighter cuts and slow diamond traverse rate. Replace diamond dresser.
Fine spirals		Reduce traverse feed at even rate and take lighter dressing cuts. Mount diamond dresser rigidly at angle of 15 degrees against wheel rotation. Make final dressing in opposite direction to initial runs. Round off wheel edges.
	Faulty grinding operation	Prevent wheel edge from digging in workpiece. Grind workpiece under light load which provides low grinding force, and use additional steady rests so that it cannot be inclined by grinding force. Reduce table speed or change some speed per pass.
	Faulty grinding operation	Prevent wheel edge from digging in workpiece. Grind workpiece under light load which provides low grinding force, and use additional steady rests so that it cannot be inclined by grinding force. Reduce table speed or change some speed per pass.
Spiral feed marks	Contact with wheel edge	Round off wheel edges.
	Wrong grit size	Use finer grit for rough finishing and relatively - coarse grit for finishing. Reduce wheel infeed rate and traverse rate gradually to allow wheel to completely spark out.
	Incorrect wheel dressing	Take lighter dressing cuts and reduce diamond traverse rate. Large and equal volume of coolant to grinding point.

	Faulty grinding operation	Grind under conditions which provide softer wheel acts.
Burnt and cracked work	Wheel specification unsuitable	Use softer grade, or more open structure wheel .
	Poor coolant quality, quantity and distribution.	Increase lubricity of coolant. (Oil or water - soluble coolant is better for use.) Supply large and equal volume of coolant to grinding point. Improve coolant supply method and direct coolant effectively at grinding points. (Ex.installation of high - pressure coolant system).
	Faulty grinding operation	Reduce wheel infeed rate and increase wheel traverse rate.
	Inadequate heat treatment of workpiece	Increase tempering temperature and remove any remaining unstable structure from workpiece.
	Incorrect work centers work not high enough above center (centerless grinding)	Drill work center holes correctly. Regrind and lap work center holes. Lubricate centers and work center holes sufficiently. Readjust work blade. (Centerless grinding)
Out of round work	Poor wheel dressing	Adjust dressing tool so that the circumference of the wheel touches the circumference of the work.
	Work out of balance	Rebalance workpiece.
	Faulty grinding operation	Do not allow wheel to separate from work edge Reduce wheel infeed rate. Reduce wheel speed and wheel diameter.
	Wheel specification unsuitable	Use softer grade wheel.
Out of Cylindricity	Wheel specification unsuitable	For plunge grinding, ensure that wheel width is larger than work width. Use harder grade wheel.
	Incorrect wheel dressing	Adjust dressing tool so that the circumference of the wheel touches the circumference of the work.
	Faulty grinding operation	Check steady rest position. Feed table more smoothly. Do not allow wheel to separate from work on both edges.

	Work thermally - expanded	Supply plant of coolant. Re - examine coolant supply method. (Ex. Installation of high - pressure coolant system.) Workpiece not flat or parallel (thin workpiece)
Work piece not flat or parallel (thin workpiece)	Faulty grinding operation	Insert suitably -thick metal flat between magnetic chucks and workpiece to reduce magnetic force of chuck.
	Wheel specification unsuitable	Use softer grade, or coarser grit wheel. Dress more frequently.
	Poor coolant quality, quantity, and distribution	Increase lubricity of coolant. (oil or water - soluble coolant is better for use) Supply large and equal volume of coolant to grinding point. Improve coolant supply method and direct coolant effectively at grinding points. (Ex. Installation of high - pressure coolant system.)
Listed by grinding operation		
Cylindrical grinding		
Chatter marks	Incorrect wheel dressing	Redress wheel face with sharp diamond dresser. Mount diamond dresser rigidly in holder.
Short, close, evenly spaced marks	Spindle bearings loose	Reduce wheel speed. Re - adjust and tight spindle bearings. Give sufficient time for spindle bearings to warm up. (Warm up grinding machine to stablize bearing temperature.) Tighten thrust bearing.
Slightly longer and more widely spaced marks	Wheel spindle run - out or out of round	Replace spindle if it is twisted or warped, or out of round.
Regularly spaced marks	Vibration	Rebalance wheel. Rebalance motor and wheel spindle. Check fit between flanges and wheel spindle.
Short, regularly	Spindle pulley loose	Tighten spindle pulley.

spaced marks		
Wide, regularly spaced marks	Vibration from flat belt	Flat belts to have a uniform thickness and width. All sections to have same pliability.
Pulley loose or out of balance	Rebush or lap to suite spindle Balance carefully	
Regular, widely spaced disclosed chatter marks	Wheel specification unsuitable	Use coarser grit, softer grade, or more open structure wheel. (More likely to be caused by glazed or loaded wheel)
Long, regularly spaced marks	Wheel out of balance	True wheel before rebalancing. Rotate wheel to spin out excess coolant.
Wheel face out of round	True wheel before and after balancing. True wheel perimeter and sides.	
Long, regularly spaced marks	Wheel out of balance	True wheel before rebalancing. Rotate wheel to spin out excess coolant.
Wheel face out of round	True wheel before and after balancing. True wheel perimeter and sides.	
Long, widely spaced chatter marks	Drive gear backlash	Replace old and worn - out gear. Introduce V - belt drive.
	Check lubricated condition.	
Regular or irregular marks	Faulty thrust bearing	Replace thrust bearing.
Even and regularly or irregularly space marks irregular chatter marks	Belt joint (belt lacing) Center holes out of round or not in line	Use endless belt. Check workpiece for fit to centers. Lubricated centers and work center holes.
Rests improperly adjusted	Adjust rests to fit to workpiece.	
Deep, narrow, regular scratches	Wheel specification unsuitable	Use finer grit wheel.
Wide, irregular scratches	Wheel specification unsuitable	Use harder grade wheel.
Mottle marks	Faulty wheel face	Balance and redress wheel. (Wheel glazing)
	Belt fluttering	Replace belt.

Irregular marks	Dust setting on machine	Keep air and shop clean. Install dust collectors.
	Incorrect wheel dressing	Dress wheel face with sharp diamond dresser. After dressing, flush wheel face with coolant to clean.
	Chemical action of cutting fluid	If too strong alkaline coolant was used for organic bond, reduce soda content, or change coolant.
Deep irregular scratches	Flanges loose	Re - tighten flanges.
Irregular marks of various lengths	Dirty coolant	Provide efficient filter. Clean out tank more frequently.
Grain marks	Wheel specification unsuitable	Use finer grit or harder grade wheel.
	Incorrect wheel dressing	Dress wheel with lighter cuts and slow diamond traverse rate.
	Incorrect grinding conditions	Commence grinding using high work speed and wheel traverse rate to remove previous wheel marks, finish with high work speed and slow traverse, and allow wheel to completely spark out.
Fine spirals	Incorrect wheel dressing	Replace diamond dresser. Dress wheel with lighter cuts and slow diamond traverse rate. Mount diamond dresser rigidly in holder. Make final dressing in opposite direction of initial runs. Set diamond dresser downwards at angle of 15 degrees against wheel rotation. Round off both wheel edges.
	Faulty grinding operation	Avoid having only one of wheel edges in contact. Reduce wheel infeed rate. Reduce wheel traverse rate per revolution of workpiece. Arrange additional steady rests.
Uneven traverse	Table traverse	Eliminate looseness.
Lines	Mechanism worn	Replace all worn parts.
	Run - out	Check centers for run - out.

Spiral pattern on workpiece whose lead corresponds to traverse	Incorrect wheel dressing	Mount diamond dresser tool to ensure that the point of diamond contact is that of wheel contact on the workpiece. Set diamond dresser download at angle of 15 degrees against wheel rotation. Round off both edges of wheel.
Poor cutting ability wheel glazing wheel loading burned work chattering marks	Grade too hard	Increase work speed and wheel traverse rate. Increase wheel infeed rate. Reduce wheel speed, outside diameter, and thickness. Redress wheel face with sharp diamond dresser. Use softer grade and / or coarser grit wheel.
Grinding marks on workpiece large wheel wear workpiece tapered	Grade too soft	Reduce work speed and wheel traverse rate. Reduce wheel infeed rate. Increase wheel speed, outside diameter, and thickness. Take lighter dressing cuts and reduce diamond traverse rate. Do not allow wheel to separate from workpiece when table reciprocates.
Metal rigidly fixed on the abrasive particles or lodged in wheel pores	Wheel specification unsuitable	Use coarser grit and/or more open structure wheel. Use more friable abrasives.
	Incorrect wheel dressing.	Dress wheel face with sharp diamond dresser. Increase diamond traverse rate. After dressing, flush wheel face with coolant to clean.
	Poor coolant quality/quantity	Supply plenty of cleaner coolant.
	Faulty grinding operation	Reduce work speed and wheel traverse rate. Increase wheel speed, outside diameter, and thickness. Supply plenty of coolant.
Shiny appearance	Wheel specification unsuitable	Use softer grade and/or coarser grit wheel. Use more friable abrasives.
	Incorrect wheel dressing	Dress wheel face with sharp diamond dresser.
	Incorrect quality coolant	Increase diamond traverse rate. Take heavier dressing cuts.

	Faulty grinding operation	Reduce oil level - increase amount of coolant. Increase work speed and wheel traverse rate. Reduce wheel speed, outside diameter, and thickness. Increase wheel infeed rate.
Out - of - round work	Uneven pressure on driving dog	Provide cushion between drive pin and driving dog.
	See causes and suggested correction for out - of - round work listed in common grinding faults.	
Out of cylindricity	Faulty machine or setting	Repair or replace worn parts. Adjust both head and tailstock.
	See causes and suggested correction for out of cylindricity listed in common grinding faults.	
Discolored workpiece	Faulty machine or setting	Adjust drive to avoid belt slippage.
	See causes and suggested correction for burnt and cracked work listed in common grinding faults.	
Chatter marks	Wheel specification unsuitable	Use coarser grit or softer grade wheel Balance wheel.
	Faulty grinding operation	Reduce wheel infeed rate or workpiece through feed.
	Incorrect wheel dressing	Increase diamond traverse rate.
	Faulty machine or setting	Adjust spindle bearings, drives and other parts to eliminate looseness. Lower work blade in relation to centerlines of two wheels.

		Reduce blade grade. (An angle of approximately 30 degrees is good for general run of work.)
General lines/ scratches	Faulty machine or setting	Grind work blade to eliminate dirt (chips and abrasives) and wear from it.
	Wheel specification unsuitable	Use harder grade wheel.
	Dirty coolant	Use clean coolant with greater lubricity.
Spirals with irregular brightness	Faulty machine or setting	Remove dirt or oil from work blade.
	Incorrect wheel dressing	Dress regulating wheel at the same angle as dressing grinding wheel (in order to prevent bent caused by uneven grinding force).
		Dress wheel to ensure that it has slight gradient upward to exit side.
Spirals	Incorrect wheel dressing	Dress wheel so it stops grinding ½ from exit edge.
		Round off both edges of wheel.
	Guides improperly adjusted	Set guides parallel to wheel face by using lining bar of approximately equal diameter to workpiece.
	Out - of - round work	Wheel specification unsuitable Use softer grade wheel.
		Balance and redress wheel.
		Redress regulating wheel as well.
	Faulty grinding operation	Make first cut light at high traverse rate to attain maximum straight effect.
		Then use heavier cuts and finish with a light cut.
	Poor quality/quantity coolant	Supply plenty of clean coolant.
	Incorrect workpiece center height	Isodiametric shape (triangular or pentagon)
		Raise work center in relation to wheel centerlines.
		Polygonal (flower - petal) shape lower work center in relation to wheel centerlines.
Out of cylindricity	Improper regulating wheel	Concave workpiece Increase angle of regulating wheel housing.
		Barrel - shape workpiece decrease angle of regulating wheel housing.
	Guides improperly adjusted	Set entrance and exit guides parallel to wheel face.

Internal grinding		
Out - of - round work	Faulty grinding operation	Adjust work chuck
	Incorrect wheel dressing	Redress wheel face with sharp diamond dresser.
Out of cylindricity	Wheel specification unsuitable	Increase quill rigidity (by changing quill material for example.) If it is caused by shedding, use harder grade wheel. If wheel acts too hard, use softer grade wheel.
	Faulty grinding operation	Increase wheel width to size larger than workpiece width so that wheel edges on both sides will not affect grinding. Adjust wheel head angle and infeed rate
	Incorrect wheel dressing	Redress wheel face with sharp diamond dresser.
	Faulty grinding operation	Increase work speed.
	See causes and suggested correction for burnt and cracked work listed in common grinding faults.	
Wheel breakage		
General breakage	Incorrect wheel mounting on flanges	Wheels to be good sliding fit on wheel spindle when mounted onto flanges. (If too tight to slide on, wheel will be broken within 3 minutes of starting operation).
Radial break in 3 or more pieces	Incorrect grinding work faulty grinding operation	Do not use wheel at speeds exceeding maximum operating speed marked on wheel or inspection sheet. Prevent overheating caused by excessive infeed. Prevent overheating caused by insufficient coolant. Perform ring test on wheel before mounting wheel onto flanges.
Radial break in 3 or more pieces	Incorrect wheel mounting on flanges	Do not tighten wheel with uneven pressure. Flanges and wheel to be free from foreign particles in between. Be sure to use blotters.
Radial break in 2 or more pieces	Faulty grinding operation	Avoid excessive force on wheel sides if wheel is allowed to grind on sides.

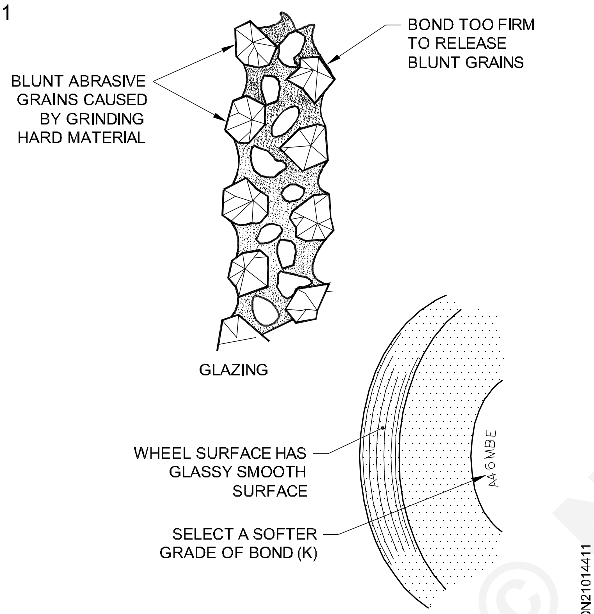
Glazing and loading

Objectives : At the end of this lesson you shall be able to
- **differentiate between glazing and loading of a grinding wheel**
- **state the effects of a glazed and loaded wheel while grinding**
- **state the causes and remedies for glazing**
- **state the causes and remedies for loading.**

Glazing

When the surface of a grinding wheel develops a smooth and shining appearance, it is said to be glazed. (Fig 1) This indicates the abrasive particles on the wheel face are not sharp. These are worked down to bond level.

Fig 1



GLAZED WHEEL

Loading

When soft materials like aluminium, copper, lead, etc. are ground the metal particles get clogged between the abrasive particles. This condition is called loading. (Fig 2)

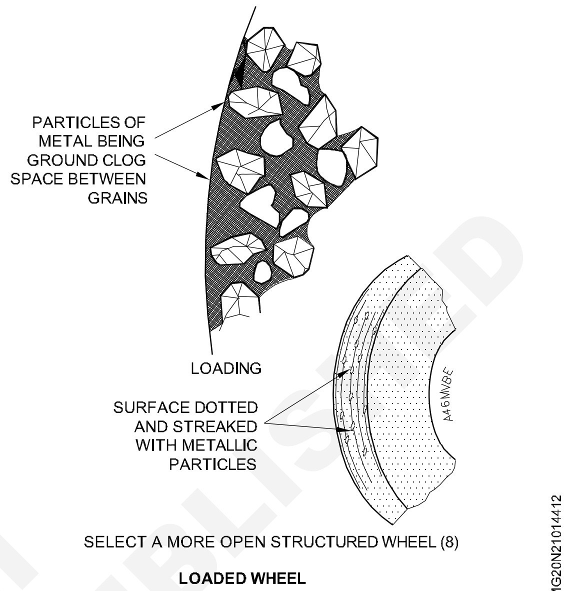
The effects of a glazed or a loaded grinding wheel are almost the same. They are:

- excessive cutting pressure between wheel and work
- more heat generation
- burning of the ground surface
- poor surface finish
- inaccuracies in the size and shape of the workpiece
- wheel breakage (sometimes).

A dull or glazed wheel should be dressed for the following reasons.

To reduce heat generated between the work surfaces and the grinding wheel.

Fig 2



LOADED WHEEL

To reduce the strain on the grinding wheel and the machine.

To improve the surface finish and accuracy of the work.

To increase the rate of metal removal.

Causes and remedies of glazing

Wrong selection of grade and size

> **Wrong selection of grinding wheel means hard grade wheel in place of soft wheel and fine grain size in place of medium grain size.**

Select a grinding wheel of the right grade and size.

High wheel speed

Set the wheel to the recommended speed.

Feed too fine

Set the feed rate correctly.

Dirty coolant

Change the coolant.

A glazed or a loaded grinding wheel can be reused after removing the glazed or loaded particles from the grinding wheel face.

Grinding Wheel Dressing and Truing

Objectives: At the end of this lesson you shall be able to
- **state three important purposes of dressing a grinding wheel**
- **differentiate between dressing and truing**
- **state the three types of wheel dressers and their uses.**

Dressing is an operation to change the cutting action of a wheel or to recondition is grinding surface. Grinding wheels should be dressed and trued regularly to improve:

- work production
- wheel performance
- grinding economy

Dressing (Fig 1)

Dressing refers to the removing of clogs and blunt abrasive grains from the surface of the grinding wheel. Dressing exposes the cutting edges which restore the correct cutting action of the wheel. Dressing is done on a glazed or loaded wheel to recondition it.

Truing

Truing refers to the shaping of the wheel to make it run concentric with the axis. When a new grinding wheel is mounted, it must be trued before use to remove the run out.

Truing is done on the wheel is out of shape due to long use. Sometimes a wheel is also trued to change the shape of the grinding wheel face for a specific grinding operation like form grinding. (Fig 2)

Fig 1

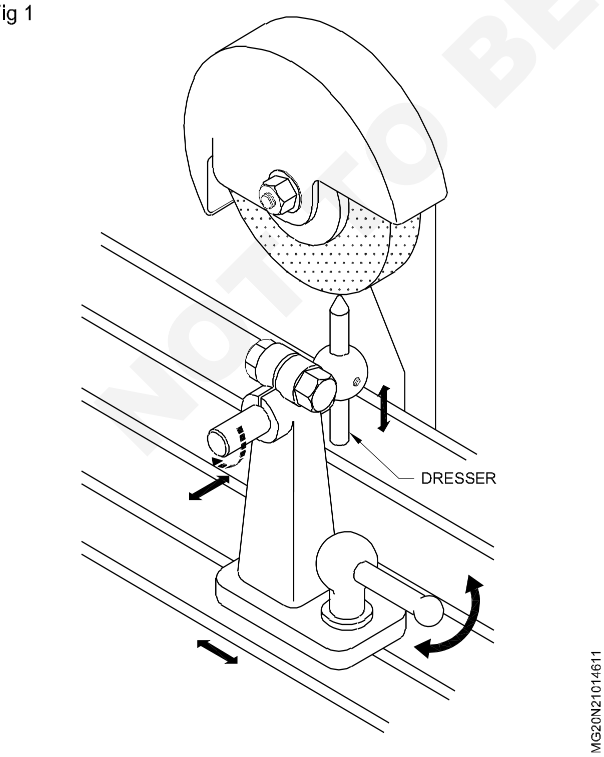
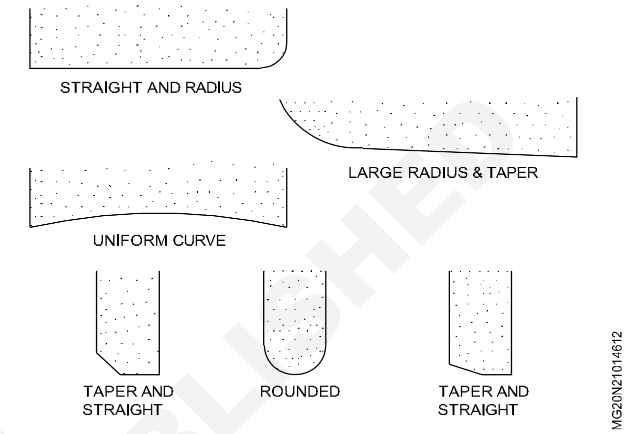


Fig 2



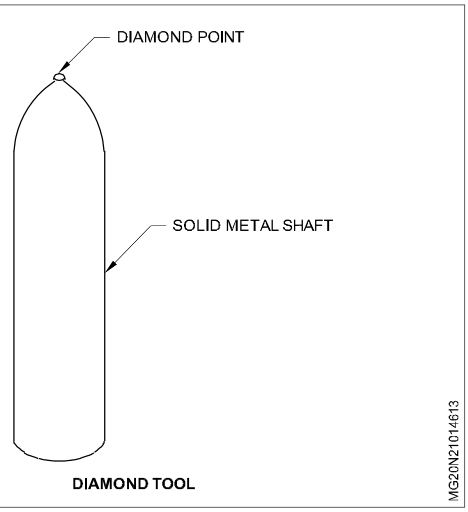
In most of the cases both dressing and truing are done at the same time.

There are three basic types of wheel dressers. They are:

- diamond
- steel
- abrasive

Diamond dressers (Fig 3)

Fig 3



A diamond dressing tool has a hard diamond point mounted in a metal shank. The shank is fitted in a tool holder for location on the grinding machine to perform dressing.

Diamond dressers are most effective for dressing precision grinding wheels.

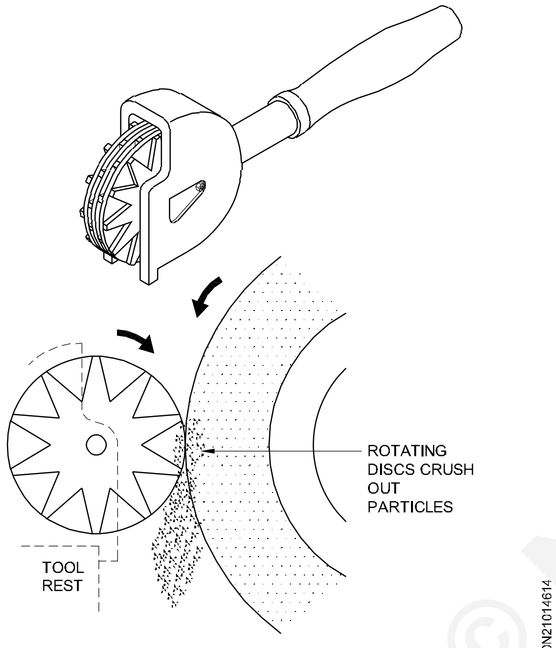
A low feed of a diamond dresser can glaze the wheel. They are specified by their weight in carats. Usually 0.5 carat to 1 carat diamonds are used for dressing up to 200mm dia. wheels.

Steel dressing tools (Fig 4)

Steel dressers for dressing a grinding wheel have rotary cutting surfaces made from hard steel.

They are held in place against the grinding wheel by hand and moved across the face of the grinding wheel to do the dressing. A tool rest or other rigid support must be used during this operation.

Fig 4



CUTTING ACTION OF A STEEL DRESSING TOOL

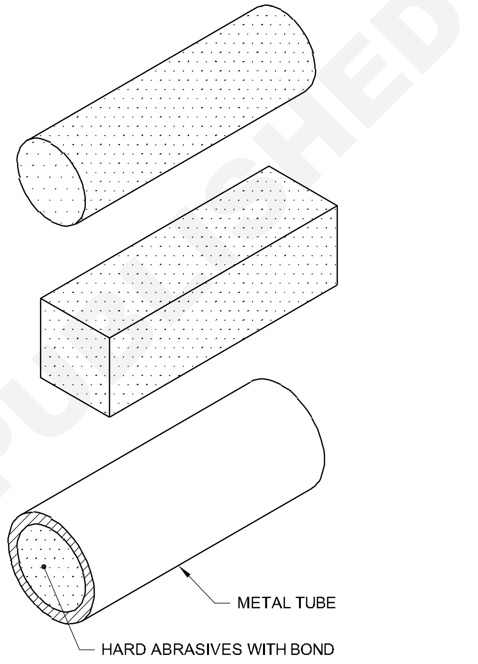
The main types of steel dresser are:

- star and disc dresser (used for coarse grained wheel)
- corrugated disc dresser (used for smooth finish)
- lock disc dresser (used for medium roughing wheel)
- solid cylinder dresser (used for instead of a diamond dress)

When only light dressing is required abrasive sticks can be used. There are abrasive materials made in the form of square or round sticks or put in metal tubes for convenient handling.

This type of dressers is more convenient in tool and cutter grinders where frequent dressing and truing is necessary.

Fig 5



Advantage of balancing, inspection, care and storage of grinding wheel

Objectives: At the end of this lesson you shall be able to
- **state the advantages of balancing**
- **brief the method of wheel inspection, storage and care of grinding wheel**
- **state the safety point while handling the grinding wheel.**

Advantages of balancing

- Power consumption of the machine is not excessive.
- Wear on bearing is minimum.
- Tendency to produce defective work is reduced.
- Chances of wheel breaking is reduced.
- Better accuracy & surface finish of workpiece is obtained.
- Sources of danger to the operator is minimised.
- Vibration of machine spindle is reduced.

Wheel breakage

- Before putting to use, wheel should be examined by tapping to make sure that it is sound. Following main points should be considered to prevent breakage of wheels.
- Use correct wheel speed. Do not overspeed it.
- While mounting, make sure that correct blotters are used and flanges provide even pressure.
- Use appropriate coolant in sufficient quantity to prevent overheating.
- Do not use excessive pressure on work.

- Avoid wheel getting jammed on work.
- Prevent blows on wheel.
- Do not force wheel on arbor.
- Take necessary safety precautions governing use of grinding wheels.

Wheel storage: Grinding wheels should be properly stored on edge or piled flat as per recommendations of the manufacturers, they should be kept in a dry place

and should not be subjected to extreme temperature. Racks in which wheels are stored should be such that once the wheels are placed there, they have no tendency to roll off say as a result of a sudden shock.

Saucer and cup wheels which are less than 150 mm in diameter may be stored on edge or flatwise cup wheels more than 150 mm in diameter and all cylindrical wheels are stacked flatwise. Tapered cup wheels are stacked with the backside up.

All rubber and elastic wheels more than 6 mm thick are stacked on their edges. Rubber and elastic wheels which are 6 mm or less in thickness are stacked flat and on a plane surface that will not warp. The best way to store wheels 50 mm or less in diameter is in properly labelled boxes or drawers.

Safety: The operation of all high speed machinery is hazardous. It applies to grinding machine as the grinding wheel rotates at a high peripheral speed (upto 50 metres/sec and even higher).

Causes of accidents in the operation of grinding machines can be traced to one of the following four sources:

- the wheel
- the machine
- the mounting
- the method of protection.

The chief hazard is the breakage of grinding wheels. In addition to what has been stated earlier regarding prevention of wheel breakage, following measures are important for safety:

- Balance the wheel properly and also test it for its strength.
- Adjust the bearings of the spindle properly.
- Use the proper wheel guards of the required strength.
- Wear safety goggles even if wheel has a glass shield.
- See that clothing doesn't come in contact with the moving wheel or work.
- Run the new wheel at full operating speed at least for one minute before applying work.
- Do not force the work against a cold wheel, but apply gradually.
- True the wheels properly which have become out of round.

Wheel inspection

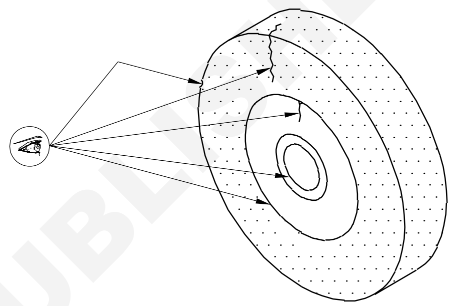
The wheel selected may have been damaged during transport or storage and must be carefully inspected before use.

Visual inspection (Fig 1)

Look for

- Broken or chipped edges.
- Cracks
- Damaged mounting bushing
- Damaged paper washers.

Fig 1



Testing for cracks (Fig 2)

Test a small wheel for cracks by the following method

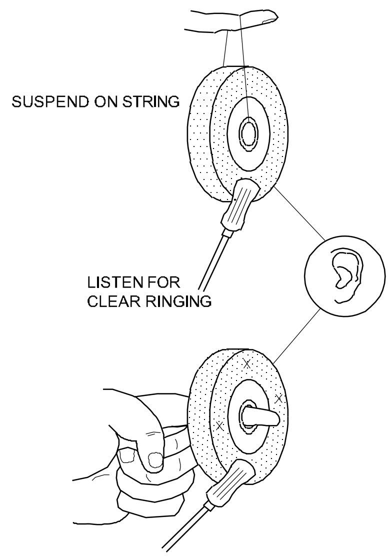
- Suspend the wheel on a piece of string or support it with one finger through the bushing.
- Allow the wheel to hang free.
- Tap the wheel with a non-metallic object such as a small wooden mallet or tool handle.
  - A clear ringing sound indicates that the wheel is not cracked.
  - A dull sound means that the wheel is cracked and must not be used.

Warning

Discard any wheel that:
- **Shows any sign of damage.**
- **Does not ring clearly when struck.**

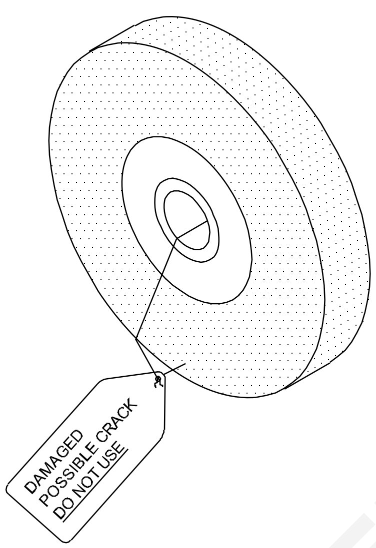
If you are in doubt, do not use the wheel. Clearly mark it and seek advice from your supervisor. (Fig 3)

Fig 2



TESTING A SMALL WHEEL

Fig 3



REJECT AND TAG FAULTY WHEELS

Importance of technical english terms used in industry

Objectives : At the end of this lesson you shall be able to
- **describe work organisation**
- **name the aspects of organisation of work**
- **state the common technical terms used in industry.**

Work organisation

Work organisation is to arrange and distribute the work between the work teams in such a way that the best use is made of the available labour, materials, tools and equipment.

- to order the operations and activities of the work should follow each other.
- to decide the various work teams.
- to instruct and communicate correctly in order to avoid misunderstandings.

Organisation of work

The organisation the organisation of work includes many aspects, such as:

- Pace of work (speed of an assembly line, quotas).
- Work load.
- Number of people performing a job (staffing levels).
- Hours and days on the job.
- Length and number of rest breaks and days away from work.
- Layout of the work.
- Skill mix of those workers on the job.
- Assignment of tasks and responsibilities and
- Training for the tasks being performed.

Some common terms technically used in industry are as follows:

- Lean production
- Continuous improvement
- Just-in-time production
- Work teams
- Total productive maintenance
- Total quality management
- Outsourcing/ contracting out

Lean production

An overall approach to work organisation that focuses on elimination of any "waste" in the production/service delivery process. It often includes the following elements: "continuous improvement", "just-in-time production" and work teams.

Continuous improvement

A process for continually increasing productivity and efficiency, often relying on information provided by employee involvement groups or teams. Generally involves standardizing the work process and eliminating micro-breaks or any "wasted" time spent not producing/ serving.

Just-in-time production

Limiting or eliminating inventories, including work-in-progress inventories, using single piece production techniques often linked with efforts to eliminate "waste" in the production process, including any activity that does not add value to the product.

Work teams

Work teams operate within a production or service delivery process, taking responsibility for completing whole segments of work product. Another type of team meets separately from the production process to "harvest" the knowledge of the workforce and generate develop and implement ideas on how to improve quality, production and efficiency.

Total productive maintenance

Designed to eliminate all nonstandard, non-planned maintenance with the goal of eliminating unscheduled disruptions, simplifying (de-skilling) maintenance procedures and reducing the need for "just-in-case" maintenance employees.

Total quality management

This is aimed towards zero defect or elimination of poor quality in production. The quality concept of assuming the best quality from inception to implementation throughout the production process.

Outsourcing/ Contracting out

Transfer of work formerly done by employees to outside organisations. In many workplaces undergoing restructuring, worker knowledge about the productive/ service process is gathered through "employee involvement" and then used by management to "lean out" and standardize the work process, thereby reducing reliance on worker skill and creativity. This restructuring has resulted in job loss for some underperformed, while increasing the work load and work pace for those who remain on the job. The result of these changes in work organisation is that it is no longer just machines that are wearingout it is the workers themselves.

Different types of documentation as per industrial needs

Objectives : At the end of this lesson you shall be able to
- **state the purpose of documentation**
- **list the different types of documentation**
- **explain the documents format - batch processing, BOM, cycle time, productivity report, manufacturing inspection report.**

Documentation

Documentation and records are used throughout the manufacturing process as well as supporting processes (quality control) must meet the basic requirements. Documentation is a set of documents provided on paper, or online, or on digital or analog media, such as audio tape or CDs. Examples are user guides, white papers, online help, quick reference guides.

The stages of recording the documents is to:

- prepare, review, update and approve documents.
- identify changes and current revision status of documents.
- use of applicable documents available at points of use with the control documents of external origin
- identify and distribute relevant versions to be identifiable and remain legible.
- prevent unintended use of obsolete documents and archiving.

The different types of documentation as per industrial needs includes

- Process charts
- Bill of materials (BOM)
- Production cycle time format
- Productivity reports
- Manufacturing stage inspection report
- Job cards format
- Work activity log
- Batch production record format
- Estimation of work
- Maintenance log format

Process chart

A process chart is a graphical representation of the activities performed during manufacturing or servicing jobs. Graphical representation of the sequence of operations (workflow) constituting a process, from raw materials to finished product.

Process charts are used for examining the process in detail to identify areas of possible improvements.

The different types of process charts they are:

- Operation process chart
- Flow process chart (man/ material/ equipment type)
- Operator chart (also called two handed process chart)
- Multiple activity chart
- Simo chart

The following symbol set derived from Gilbreth's original work as the standard for process charts.(Table 1)

TABLE 1

Symbol	Letter	Description	Examples
O	O	Operation	Saw cut, paint, solder, package
→	M	Transport	Conveyor / Fork lift / OTR truck
☐	I	Inspection	Visual/dimension
D	D	Delay	WIP/Hold/ Queue
∇	S	Storage	Warehouse/tracked storage location

The application of symbols on a flow process chart is shown below

Flow process chart(Machines)

Industry : ______________________________

Product : ______________________________

Summary

Function	Present		Proposed	
	*	Time	*	Time
Operation				
Inspection				
Transport				
Delays				
Storage				

Details	○→□ D▽	Qty	Time (in mins)	Analysis	Actions recommended
Raw material from stores	○→□ D ▽				
To cutting machine	○→□ D ▽				
Cutting of material to size	○→□ D ▽				
Filling, Finishing	○→□ D ▽				
To inspection for finished size	○→□ D ▽				
To stores (Finished job)	○→□ D ▽				

Batch record forms

The documents used and prepared by the manufacturing department provide step-by-step instructions for production-related tasks and activities, besides including areas on the batch record itself for documenting such tasks.

Batch production record is prepared for each batch should include information on the production and control of each batch. The batch production record should confirm that it is the correct with standard operating procedure.

These records should be numbered with a unique batch or identification number and dated and signed when issued.

The batch number should be immediately recorded in data processing system. The record should include date of allocation, product identity and size of batch.

Documentation of completion of each significant step in the batch production records (batch production and control records) should include :

- Dates and, when appropriate time
- Major equipment used machinery and specific batch numbers of raw materials, reprocessed materials used during manufacturing.
- Critical process parameters records.
- Trial product or sample (if required).
- Signatures of staff for sequence of operation.
- Laboratory test results and line inspection notes.
- Achieved production against target.
- Packaging and label (if any) details.

Batch processing record : (Sample format - 1)

The format 1 used in documentation of batch processing record has the description of the job, necessarily mentioned with part number and name of the part.

A predetermined batch quantity with batch number allotted and identified with batch record number is documentation. The product reference is made with purchase order number.

The product reference is made with purchase order number.

The production process is descriptively written about the sequence of operation to be carried out on the product.

The manufacturer organization name, period of manufacture preferably the year with starting date of manufacture and end date of manufacturer and number of pages of document according to batch quantity processed, and total number of pages of document, inclusive of inserted pages and manufacturing facilities is provided with.

The batch processing record is signed with date mentioning name of person responsible and their designation.

The remarks if any on the process should be also mentioned then and there.

BATCH PROCESSING RECORD - FORMAT - 1

Batch Processing Record	
Description of job	Batch no. :
Part no. :	Batch quantity :
Name of part :	Batch record no. :
	Purchase order no. :
Description of process :	
Manufacturing Organisation :	

Period of manufacture (Year - Qtr):	Start date of manufacture:	End date of manufacture:
Number of pages according to batch:	Inserted pages:	Manufacturing facilities:
Total number of pages		
1. Operator / Technician	Date	Name and signature
2. Production in-charge:	Date	Name and signature
3. Section manager	Date	Name and signature
4. Plant in-charge:	Date	Name and signature
5. Production in-charge:	Date	Name and signature
Remarks (if any)		

Bill of materials (BOM) format - 2

The list of parts involved in manufacturing of an assembly hierarchially is given in this format.

The format shown is as per bureau of Indian Standards IS:11666-1985 as example for Engineering Component drawings.

The BOM in the form of tabular columns has the component marked with item number, and its name is given under description and number of is mentioned under quantity, with reference drawing ie., sub assembly/part drawing number.

The material designation as per code of practice or standards is mentioned, and any other specific notes are given under remarks column.

The BOM is placed on the manufacturing drawing containing with assembly and parts in standard sheet sizes of engineering drawing.

BILL OF MATERIAL (BOM) - FORMAT - 2
as per IS: 11666-1985

S.No	Item No.	Description	Quantity	Reference dwg no.	Material as per standard	Remark

Cycle time

Cycle time is the total time from the beginning to the end of the process. Cycle time includes process time, during which a raw material worked with to bring it closer to required form output, and delay time, during which the workpiece waiting for next operation.

The time taken to perform one operation repeatedly measured from "Start to Start" the starting point of one product's processing in a specified machine or operation until the start of another similar product's processing in the same machine or process. Cycle time is commonly categorized into same machine/process.

Machine cycle time

The processing time of the machine working on a part.

Auto cycle time

The time a machine runs un-aided (automatically) without manual intervention.

Overall cycle time

The complete time it takes to produce a single unit. This term is generally used when speaking of a single machine or process.

Total cycle time

This includes all machines, processes, and classes of cycle time through which a product must pass to become a finished product. This is not lead time, but it does help in determining it.

Production cycle time (Format - 3)

This format 3 should contain mentioning the organization name department / section name. The process which is being observed for analysing the cycle time is mentioned with line in charge name and the date/time of the operations, with operator name is indicated.

The time observation on each operation, sequence noted in the column, and lowest repeatable is also mentioned for each operation. The times observation for machine cycle time is also noted, with any notes be recorded in respective operations in sequence.

PRODUCTION CYCLE TIME - FORMAT - 3

Organisation Name: Department / Section :	Process:	Line Incharge:	Date/Time:

Operator :										Machine Cycle Time	Notes
Operator Sequence	Observed Times								Lowest Repeatable		

Productivity report

Productivity report to measure and review the efficiency of a person, machine, factory, system, etc., in converting inputs into useful outputs. Productivity report is computed by dividing average output per period by the total costs incurred or resources (capital, energy, material, personnel) consumed in that period.

The base document daily production report which reveals the actual output against the target plan and on investment cost incurred as mentioned above decides the cost efficiency.

Daily production report (Format 4)

The output of production is shown in the format, referring the job order no quantity, material and size, every process involved, to produce a component, quality control, packing should contain the details of planned quantity and produced quantity is recorded in the document. This is the base details for arriving the productivity report. The incurred cost is worked out considering infrastructure, raw materials and facilities.

DAILY PRODUCTION REPORT - FORMAT- 4

	Daily Production Report						**Organisation Name:**					
Date:	**Department:** **Section:**											
	Process - I		Process-II		Process-III		Process-IV		Quality Control		Packing	
	Planned	Completed	Planned	Completed	Planned	Completed	Planned	Completed	Planned	Completed	Planned	Completed
Job Order No. Quantity Material & Size												
Job Order No. Quantity Material & Size												
Job Order No. Quantity Material & Size												
Job Order No. Quantity Material & Size												
Job Order No. Quantity Material & Size												

Signature of section Incharge

Manufacturing stage inspection report (Format 5)

The format 5 is to monitor the production in various stages for which manufacturing stage inspection conducted for documentation to review the productivity. The format gives the details of product being inspected showing the details of customer reference by purchase order (PO) number and date, job order number and date, process involved in manufacture of product, the quality submitted for inspection. The accepted and rejected quality recorded with inspection record review date and the inspection person signature who conducted the stage inspection is recorded date wise for mentioned /specified period with start and end dates.

MANUFACTURING STAGE INSPECTION REPORT - FORMAT - 5

Organisation Name :

Status: From Date ..../..../..... To Date .../.../.....

Date	Product ID/ Code	Customer	P.O No. & Date	Job Order No.	J.O Date	Process	Qty	Accepted	Rejected	Inspection Record No.	Inspection conducted by

Documentations - 2

Objectives : At the end of this lesson you shall be able to
- **state the purpose of job card and its format details**
- **explain work activity log format details**
- **state the details of batch production format.**

Job card

A job card is a document showing the details of a job to be performed in a production shop. It is used to authorize and instruct the work team to take up the production work.

Job card format - 1

Job card has the details of commencing the job, customer name, work order no, document number, reference number and date.

The details which have to be recorded about the product line description showing the operations each into recording of start time and total time of operation. The location time recorded is to track if any delay/ reasons and necessary actions if taken with remarks.

If the product has to be completed with any of the further operations in sequence, this card will travel along with job for next workstations for further operations if any to complete the requirement of job, and recorded till finishing of the job.

JOB CARD - FORMAT-1

Job Card						Doc No.	
						Rev No.	
						Date	
Order Starting Date							
Customer							
Work Order No.							
Details							
S.No.	Date	Production Line Description	Time (Minutes)			Location Time	Remarks
			Start Time	End Time	Total Time		

Work activity log format - 2

This document is to record the activity/operations performed by the operator from time to time (format) shows time duration as one hour (For whole day shift). The operator has to record every hour, activity description, equipment/ machinery/instrument used to perform the job.

Any remarks may noted by the operator to complete this record.

WORK ACTIVITY LOG - FORMAT-2

Organisation Name:

Department:

Section:

Employee Name:

Supervisor Name:

Date:

Start / Stop	Operations performed	Equipment / Machinery/ Instruments used	Remarks
8.00 to 9.00 a.m.			
9.00 to 10.00 a.m.			
10.00 to 11.00 a.m.			
11.00 to 12.00 noon			
12.00 to 1.00 p.m.			
1.00 to 2.00 p.m.			
2.00 to 3.00 p.m.			
3.00 to 4.00 p.m.			
4.00 to 5.00 p.m.			
5.00 to 6.00 p.m.			

Batch production record format - 3

This document is for recording the details of production covering the processing steps with documented page number with deviation against each in short description.

This document is to be prepared under heading description of job part number, batch number, name of the part. The processing steps number serially for each process with sequential operations in logical order with documented page number. The description of deviation are noted against each operations in sequence gives the detail of batch production record for every part.

BATCH PRODUCTION RECORD - FORMAT-3

Batch Production Record in accordance with batch processing record

Manufacturing Organisation Name: ______________________

Description of job: ______________________

Name of part: __________________________

Batch No.: ___________________________

The following deviations have appeared (continued)

No. process step	Name of processing step	Documented page no.	Short description of deviation
1	Raw material preparation: Operation 1: Descaling Operation 2: Degreasing Operation 3: Wire brushing		1. ____________ 2. ____________ 3. ____________ 4. ____________
2	Sizing of material: Operation 1: Shearing Operation 2: Deburring		1. ____________ 2. ____________ 3. ____________

Estimation and maintenance records

Objectives : At the end of this lesson you shall be able to
- **state the purpose of estimation**
- **explain the details of formats for estimation sheet**
- **explain the details of formats for maintenance log, history sheet of machinery and equipment and checklist for preventive maintenance.**

Estimation is the method of calculating the various quantities and the expenditure to be incurred on a particular job or process.

In case the funds available are less than the estimated cost the work is done in part or by reducing it or specifications are altered,

The following essential details are required for preparing an estimate.

Drawings like plan, elevation and sections of important parts.

Detailed specifications about workmanship & properties of materials, etc.

Standard schedule of rates of the current year.

Estimating is the process of preparing an approximation of quantities which is a value used as input data and it is derived from the best information available.

An estimate that turns out to be incorrect will be an overestimate if the estimate exceeded the actual result, and an underestimate if the estimate fell short of the actual result.

A cost estimate contains approximate cost of a product process or operation. The cost estimate has a single total value and it is inclusive of identifiable component values.

ESTIMATION SHEET - FORMAT-4

Part Name: Base plate Assembly: Shearing machine Assembly No.: MA2WOAO1	Part No.: 1 Material: Fe310.0 Stock size: 305 x 227 x 20	Insert Part Drawing

Operation No.	Operation description	Machine	Estimated time	Rate / piece per hr.	Tools
01	Setting and aligning job on table	Milling	10 min		
02	Mount arbor and cutter	Milling	10 min		
03	Set speed and feed	Milling	2 min		
04	Align cutter in position	Milling	2 min		
05	Mill four sides	Milling	50 min		
06	Mark 45° angle corner	-	8 min		vernier bevel protractor vernier height gauge
07	Set and clamp the job	-	10 min		
08	Mill 45° on opposite sides	-	10 min		
09	Set clamp on other sides	-	20 min		
10	Mill 45° on other sides	-	20 min		
11	Deburr and mark drill position	-	10 min		
12	Set and align for drilling	Drilling	10 min		
13	Mount drill chuck and drill	Drilling	03 min		
14	Set drill rpm	Drilling	02 min		
15	Drill pilot and holes	Drilling	30 min		
16	Counter bore holes	Drilling	15 min		
17	Place job on magnetic chuck on surface grinder	Surface grinder	03 min		
18	Grind the surface as per drawing	Surface grinder	10 min		
19	Deburr sharp edges	-	02 min		Abrasive stick

Maintenance log - Format 5

This format is made with details of maintenance activities performed machine wise,

MAINTENANCE LOG - FORMAT - 5

Organisation Name :				
Department:				
Section:				
Name of the machine:				
S.No	**Date**	**Nature of fault**	**Details of rectification done**	**Signature of in-charge**

History sheet of machinery equipment - Format 6

The document recorded with historical data about the machinery and equipment, contains all details about supplier address, order no., date of receipt, installed and placed, Date of commissioning and machine dimensions, weight, cost, particulars of drive motor, spare parts details, belt specification, lubrication details, major repair/ overhauls done with dates recorded then and there for analysing the functional and frequency of breakdown etc.,

MACHINERY AND EQUIPMENT RECORD FORMAT - 6

Organisation Name :	
Department:	
Section:	
History sheet of machinery & Equipment	
Description of equipment	
Manufacturer's address	
Supplier's address	
Order No. and date	
Date on which received	
Date on which installed and place	
Size : Length x Width x Height	
Weight	
Cost	
Motor particular	Watts/ H.P./ r.p.m: phase: Volts:
Bearings/ spares/ record	
Belt specification	
Lubrication details	
Major repairs and overhauls carried out with dates	

Checklist for preventive maintenance inspection - Format 7

The very essential document required to observe, the functional aspects of each parts, defects and the remedial measures taken is recorded.

This format enables to program the frequency of maintenance schedules so as to minimise frequent breakdown of machinery/ equipments.

PREVENTIVE MAINTENANCE RECORD - FORMAT 7

Organisation Name :				
Department :				
Section :				
Name of the Machine :				
Machine Number :				
Model No & Make :				
Check list for machine inspection				
Inspect the following items and tick in the appropriate column and list the remedial measures for the defective items.				
Items to be checked	**Good working**	**Satisfactory**	**Defective**	**Remedial measures**
Level of the machine				
Belt/chain and its tension				
Bearing condition (Look, feel, Listen noise)				
Driving clutch and brake				
Exposed gears				
Working in all the speeds				
Working in all feeds				
Lubrication and its system				
Carriage & its travel				
Cross-slide & its movement				
Compound slide & its travel				
Tailstock's parallel movement				
Electrical controls				
Safety guards				

Inspected by :

Signature :

Name :

Date : Signature of in-charge

Introduction to CNC technology

Objectives: At the end of this lesson you shall be able to
- **define NC & CNC**
- **name the different components of CNC machine**
- **explain configuration of a CNC system**
- **state the functions of CNC machine.**

Numerical control system

Controlling of machine tool by means of a prepared program is known as **numerical control or NC.**

Definitions

- Numerical control can be defined as a form of programmable automation in which the process is controlled by numbers, letters, and symbols.
- Electronics Industries Association (EIA) defines numerical control as a system in which actions are controlled by the direct insertion of numerical data at some point.

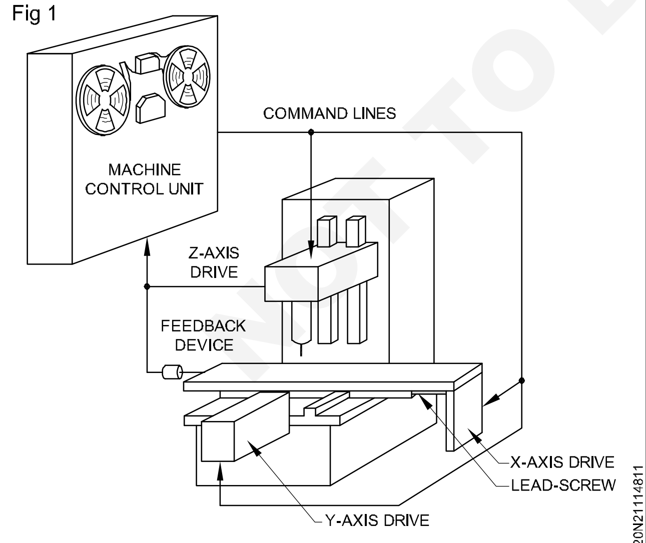
This alphanumeric datas (numbers, alphabets and some special characters) form a program of instructions to complete a particular job. The program consists of instructions such as type of tool to be used, spindle speed rate, feed rate, various movements, and the path to be followed, etc.

The input information for controlling the machine tool motions is provided through punched tapes or magnetic tapes in a coded language.

General working principle of NC system

The general configuration of NC system is shown in Fig 1.

Fig 1



NUMERICAL CONTROL SYSTEM

In NC system the numerical data which is required for producing a part is maintained on a punched tape and is called the part program. The part program is arranged in the form of blocks of information. The block contains the numerical data required to produce one segment of workpiece.

Dimensional information such as length, width, radius, etc., are taken from the engineering drawing. Dimensions are given separately for each axis of motion (X,Y and Z). The other parameters such as cutting speed, feed, spindle direction, coolant ON and OFF, etc., are programmed according to the required tolerance and surface finish.

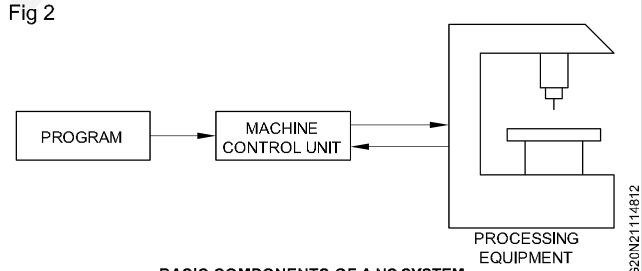
Basic elements (or components) of a NC system

The basic components of NC system are as follows

- Program of instructions
- Machine control unit (MCU)
- Machine tool or processing unit.

The relationship between the three components is depicted in Fig 2

Fig 2



BASIC COMPONENTS OF A NC SYSTEM

Program of instructions

The program of instructions is the detailed step - by - step commands that direct the actions of the processing equipment.

In machine tool applications, the program of instructions is called a part program, and the person who prepares the program is called a part programmer.

The program of instructions are fed to the machine through some type of input medium that can be interpreted by the controller unit. The various forms of input media are punched tape, and magnetic tape, direct entry or manual data input (MDI).

Machine Control Unit (MCU)

The MCU consists of the electronics hardware system that reads and interprets the program of instructions and convert it into mechanical actions of the machine tool.

The MCU includes the following :

Tape reader: It is an electro mechanical device used for winding and reading the punched tape.

Data buffer: It is used to store the input instructions in logical blocks of information.

Signal output channels: They are connected to the servomotors and these channels carry instructions from the controller unit to the machine tool.

Feedback channels: They send the feedback from the machine tools to the controller, to ensure the degree of execution of instructions.

Sequence controls: This controls coordinate the activities like reading into the buffer from the tape, sending signals to the machine tool, etc.

Control panel: It contains the dials and switches by which the machine operator runs the NC system

Machine tool or processing equipment

The machine tool performs the useful work. It consists of the workable and spindle as well as the motors and controls necessary to drive them.

The machine tool is capable of performing different machining operations, automatic workpiece positioning and automatic tool changing.

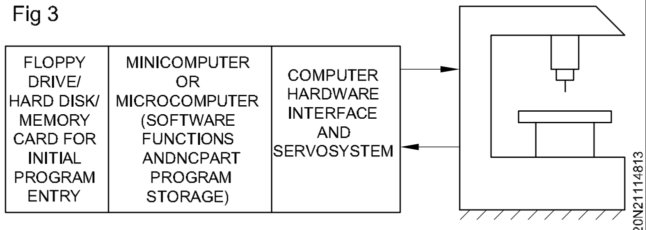
In CNC, a mini - computer is used to control machine tool functions from stored in information's or punched tape input or computer terminal input.

Therefore CNC system replaces some or all of the hardwork functions previously performed by MCU with a dedicated computer i.e., a computer assigned to control a single NC machine.

The external appearance of CNC is similar to that of a NC machine. Part programs are entered once into the CNC by punched tape or magnetic tape but the modifications in it is done by the computer itself. Thus the tape reader is used only for original loading of part program and data. Also CNC offers additional flexibility and computational capability over NC.

Configuration of CNC system (Fig 3)

Fig 3



CONFIGURATION OF CNC SYSTEM

Depicts the general configuration of a CNC system.

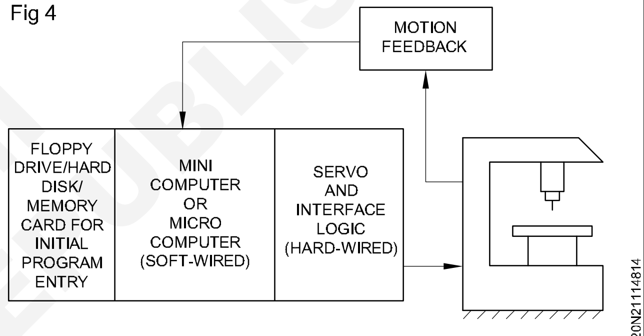
Functions of CNC

The principal functions of CNC are

- Machine tool control
- In process compensation
- Improved programming and operating features , and
- Diagnostics

Machine tool control (Fig 4)

Fig 4



STRAIGHT CNC

Machine tools control is the primary function of CNC. It converts the part program instructions into machine tool actions.

The conversion is achieved by using the following circuits:

i) Hard - wired circuits (servo systems and interface logic), and

ii) Soft - wired circuits (minicomputers)

Hard - wired circuits perform some control functions such as feed rate generation and circular interpolation, better than that of soft - wired circuits. But soft - wired circuits have additional flexibility and computational capability.

Direct numerical control

Objectives: At the end of this lesson you shall be able to
- **state the components of DNC system**
- **identify the types MCU.**

Direct numerical control

DNC

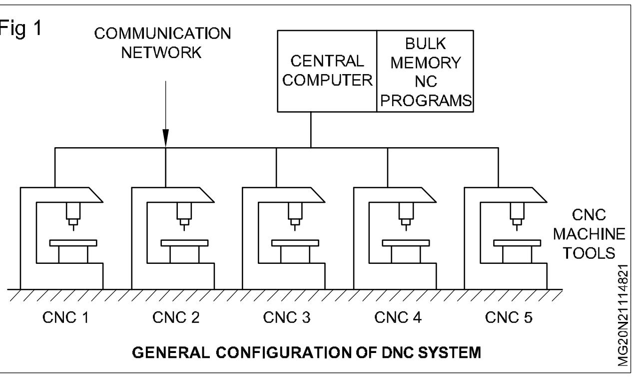
The recent advanced industrial revolution after NC and CNC lead to the development of Direct Numeric Control (DNC) system.

It is named as DNC since part programs are directly entered into the computer without using the punched tapes.

In DNC one large computer is used to control number of separate machine tools.

In DNC system the processing and post processing of part program is performed in a computer. This enables the programmer to modify and edit the part program easily.

Fig 1



GENERAL CONFIGURATION OF DNC SYSTEM

Definition: Direct numerical control system is defined as a manufacturing system in which a number of machine tools are controlled by a computer through direct connection and in real time.

Components of DNC

The general configuration of the basic DNC system is shown in Fig 1. It consists of four basic components.

- Central computer
- Bulk memory
- Telecommunication lines, and
- Machine tools

Central computer: Central computer is the main components of DNC system. It is used to serve the following purposes while machining.

• Providing instructions to each machine tools from bulk memory on demand.

• Data collection and processing from the machine tool.

This two way information flow occurs in real time i.e., Each machine's request for instruction and receiving the information's from machine tools are satisfied instantaneously and respond to them accordingly.

Bulk memory: Bulk memory is used to store the NC part programs.

Telecommunication lines: Telecommunication lines are used for connecting the machine control unit (MCU) with the central computer.

Machine tools: Machine tool is used for performing different machining operations, automatic workpiece positioning and automatic tool changing. It consists of workable, spindle, motors and control devices necessary to drive them.

Personal computers in the MCU

Now a days most of the industries use personal computers (PCs) for the following purposes

- PC is used as a separate front - end interface for the MCU.
- PC contains the motion control board and other hardware required to operate the machine tool. Here the CNC control board fits into a standard slot of the PC.

Advantages of using PCs in MCU

Flexibility to execute a variety of user software in addition to and simultaneously controlling the machine tool operation.

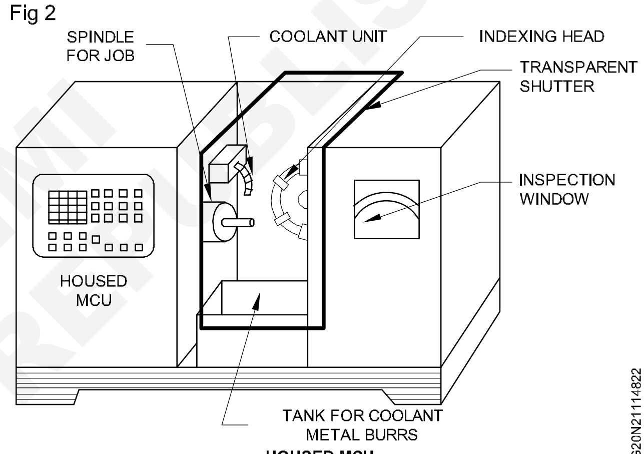
The user software may include programs for shop - floor control, statistical process control, solid modeling, cutting tool management, and other computer - aided manufacturing software.

Types of MCU

There are three different types of MCUs available. They are

- Housed MCU
- Swing around MCU
- Stand alone MCU

Fig 2



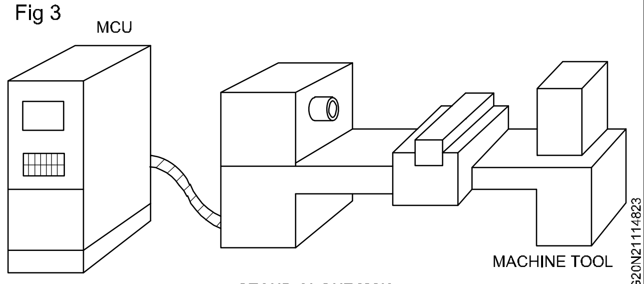
HOUSED MCU

Housed MCU: This MCU itself is mounted on the machine tool or may be built in the casing of the machine shown in Fig 2.

Swing around MCU: This MCU is directly mounted on the machine which can swing around. It can be adjusted as per requirement of the operator's position. This arrangement requires large working space around the machine.

Stand alone MCU: This MCU is enclosed in a separate cabinet which is installed at some remote or same place near to the machine, as shown in Fig 3.

Fig 3



STAND ALONE MCU

Key and switches of operator console

Objective: At the end of this lesson you shall be able to
- **state the purpose of keys and switches of operator console.**

The machine panel also includes many conditional switches that control how the machine behaves during automatic operation. Features like single block, dry run, and optional stop are among those controlled by these conditional switches (more on these features a little later). Buttons and switches found on the control panel. (Fig 1)

As mentioned, many of the same keys found on a typical personal computer are also found on the CNC machine's control panel. Following are the most important functions along with a brief description of their use.

Fig 1

CNC - MACHINE - CONTROL PANEL

Power buttons: To avoid surges, most CNC machines have at least two different power buttons, one for power to the control and another for power to the machine tool itself. The control panel power button must be pressed first, and activates the control screen and control panel. Once the control is ON, then the machine power can be turned ON. Machine power is usually labelled as hydraulic on or machine ready.

Display screen control Keys: You can think of these keys as like the channel selector on a television set. They allow the operator to select which function of the display screen he or she wants to view.

Position button: This selector button allows the operator to look at the machine's position display. In this mode, the display screen shows pertinent information about where the machine is currently positioned.

Program button: This display screen selector button allows the operator to monitor the active program in the control's memory. This key is pressed when editing CNC programs and when monitoring programs in automatic operation.

Offset button: This display screen selector button allows the user to display and manipulate the tool offsets. Along with the cursor control buttons, the operator can use this button to find and change offsets in memory.

Letter keys: This keypad allows alphabetical character entry. Some CNC control panels allow only those alpha keys (N, G, X, and so on) needed for CNC programming on the keyboard. On others, the full character set (A through Z) is available.

Number keys: These keys allow numeric entry. Normally located close to the letter keypad, most CNC controls have number keys positioned in much the same way as on the keypad of an electronic calculator.

The input key: This key is pressed to actually enter data. Examples of when this key is pressed include entering offsets and setting parameters.

Cursor control keys: The display screen of the CNC control will often show a prompt cursor that indicates the current entry position.

Program editing keys: There are many times when a program stored in the control's memory must be altered. The most common example is during the verification of a new program. These keys allow program entry and modification.

Reset button: On most controls, this button usually serves three basic functions.

- First, while editing CNC programs, this key will return the cursor to the beginning of the program.
- Second, this key will clear the look-ahead buffer and stop execution of the program. Cause several commands to be skipped. The control will pick up and continue running, but severe problems could arise due to the missing commands. When in automatic.
- Third, when in alarm state, this key will cancel the alarm once the problem has been solved.

Mode switch

The mode switch is the heart of any CNC machine tool. It should be the very first switch an operator checks prior to performing any function on the machine.

Cycle button: This button is used to activate the program currently in the control memory, causing the machine to go into automatic cycle.

Feed hold: This button allows the operator to halt axis motion temporarily. The cycle start button can be used to reactivate the cycle. Note that all other functions of the machine (coolant, spindle, etc.) will continue to operate. Think of this button as your first panic button. If you are verifying a program, you should always have a finger on this button. If you suspect any mishap, press feed hold, then check for mistakes. If a problem is found, you will take the program out of cycle (by pressing the reset key), fix the problem, and start over. If a mistake is not found and you wish to continue, you can do so by pressing cycle start.

Feed rate over ride: This multiple position switch allows the operator to change the programmed feed rate during cutting commands (G01, G02, G03, etc.). Notice we said feed rate. Under normal conditions, this switch has no control over rapid motion. The feed rate over ride switch is usually segmented in 10 percent increments that range from 0 percent through 200 percent.

Rapid traverse over ride: This switch is used to slow the rapid motion rate. It can come in two different forms. In one form, it is a simple ON/OFF switch. When on, all rapid motion is slowed to 25 percent of the normal rapid rate. In its second and more useful form, rapid override is a four.

Emergency stop: This button will turn power OFF to the machine tool. Usually, power to the control remains.

Conditional switches: These ON/OFF switches control how the machine behaves during automatic and manual operation. They can be toggle switches, locking push buttons, or even set through the display screen and keyboard. Position switch and can be adjusted to 5 percent, 25 percent, 50 percent, and 100 percent of the normal rapid rate.

Dry Run: This conditional switch is most used with the verification of new programs. When this switch is ON, it gives the operator control of the motion rate at which the machine will traverse. This is extremely helpful during rapid motions.

Single block: This conditional switch can be used to force the control to execute one command of the program at a time. When turned ON, the control will stop at the completion of each command. To execute the next command, the operator must push the cycle start button.

Machine lock: This conditional switch keeps all axes of the machine from moving. Many other functions of the machine will continue to operate. For example, the turret will still index, the spindle will still run, coolant will still come on, etc. But axis motion will not occur. Machine lock can be used during automatic operation and manual operation.

Optional block skip (also called block delete)**:** This conditional switch works in conjunction with slash codes (/) in the program. If the control reads a slash code at the beginning of any CNC command in the program, it will look to the position of the optional block skip switch. If the switch is ON, the control will ignore the command in which the slash code is included. If the optional block skip switch is off, the control will execute the command.

Optional stop: This conditional switch works in conjunction with an M01 code in the program. When the control reads an M01 and the optional stop switch is ON, the control will halt the execution of the program. The operator must press the cycle start button to reactivate the program. If the optional stop switch is OFF, the control will ignore the M01 and continue executing the program.

Manual controls: The machine panel for all CNC machining centers will also include several buttons and switches related to manual control of the machine tool's functions. These buttons and switches vary dramatically from one builder to the next.

Common manual functions include spindle control, coolant control, manual tool change control, and control of axis movements.

Advantages of CNC

Objective: At the end of this lesson you shall be able to
- **state the advantages of CNC.**

The greatest development in metal cutting industry is the development of numerically controlled machines. These have many more advantages than the conventional machines. And the computerised numerical controlled machines have more advantages over NC machines.

Advantages of CNC

The advantages of CNC over conventional NC are

- Greater flexibility to add new control options.
- An improvement in the possibilities for correcting errors in part programming.
- Tape and tape reader are used only once resulting improved reliability.
- Use of both metric or imperial system.
- Graphic tool path display is available.
- Reduced inspection and rejection of parts.
- Higher repeatability and accuracy.
- Reduced manufacturing lead time.
- In process adjustment of speed and feed.
- CNC provides a total manufacturing system.

Classification of CNC systems

Objectives: At the end of this lesson you shall be able to
- **list out the classification of CNC systems**
- **distinguish between open loop control and closed loop control systems.**

Classification of CNC systems

The CNC systems are broadly classified as given below

Based on feedback control

- Open loop system
- Closed loop system

- Semi - closed loop system

Based on motion control

- Positional system
- Paraxial system, and
- Continuous path (or contouring) system

Based on power drive

- Hydraulic system
- Electric system, and
- Pneumatic system.

Based on circuit technology

- Analog system, and
- Digital system

Based on positioning system

- Absolute positioning system, and
- Incremental positioning system.

Based on axis identification

- 2 - axis system
- 3 - axis system
- 4 - axis system
- 5 - axis system

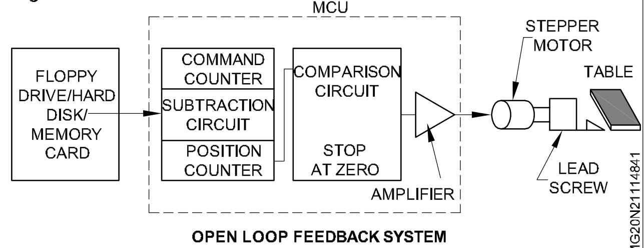
Open loop control system

A control system in which the output value is not checked against the desired input value is known as open - loop control system.

In other words, if there is no feedback device to compare the actual position of tool slide with the desired one, then it is known as open loop control system.

The open loop control system is illustrated in Fig 1.

Fig 1



OPEN LOOP FEEDBACK SYSTEM

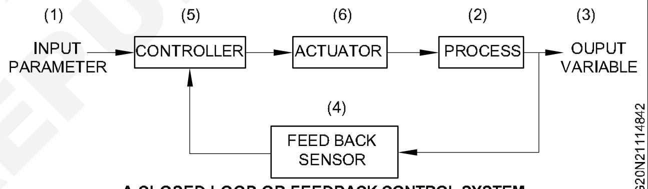
Closed loop control system

A closed loop control system, also known as feedback control system, is one in which the output variable is compared with an input parameter. If there is any difference between the input and output, the difference is used to drive the output into agreement with the input.

In other words, if there is a feedback device to compare and correct the actual position of tool slide with the desired one, it is known as closed loop control system.

The closed loop control system is illustrated in Fig 2.

Fig 2



A CLOSED LOOP OR FEEDBACK CONTROL SYSTEM

Designation of axes

Objectives: At the end of this lesson you shall be able to

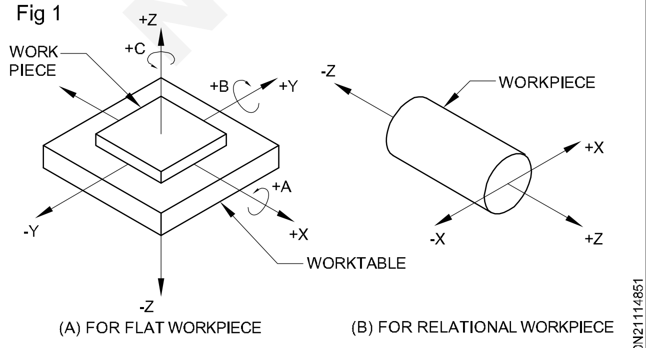
- **identify the designation of axes of CNC machine**
- **explain the purpose of jog mode and MDA mode.**

Z - axis

The Z - axis motion is along the spindle axis or parallel to the spindle axis. In the case of machine without a spindle such as shapers and planers, the Z - axis is perpendicular to the work holding surface. (Figs 1 to 5).

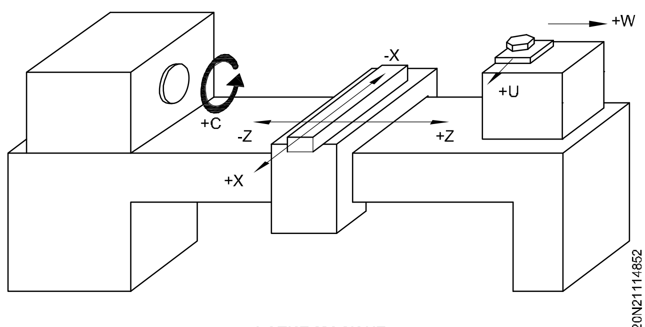
For machines such as milling, drilling and lathe, the cutting tools move in the negative Z direction to move a tool into the work piece. The positive Z motion increases the clearance between the tool holder and work piece surface. (Figs 2 - 5).

Fig 1



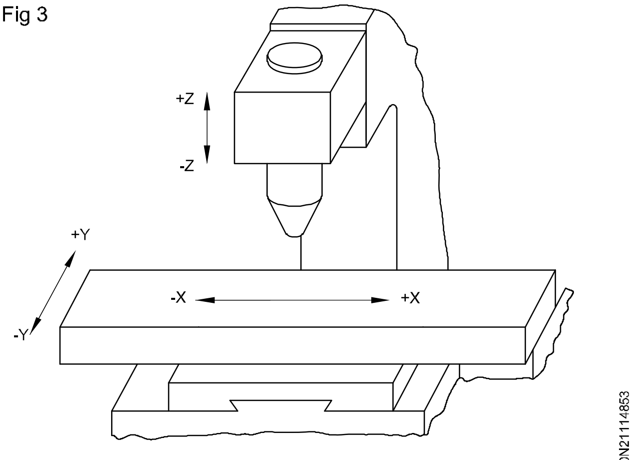
DESIGNATION OF AXES

Fig 2



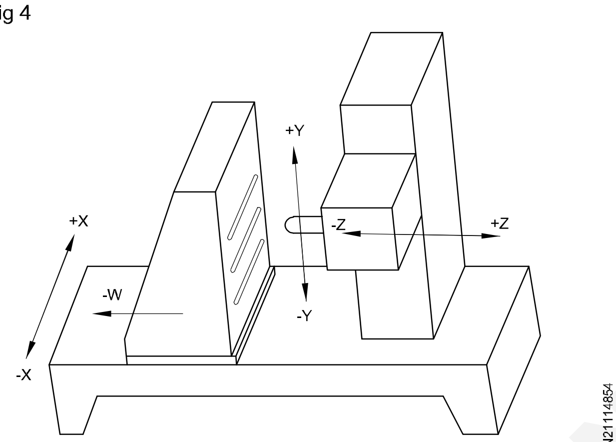
LATHE MACHINE

Fig 3



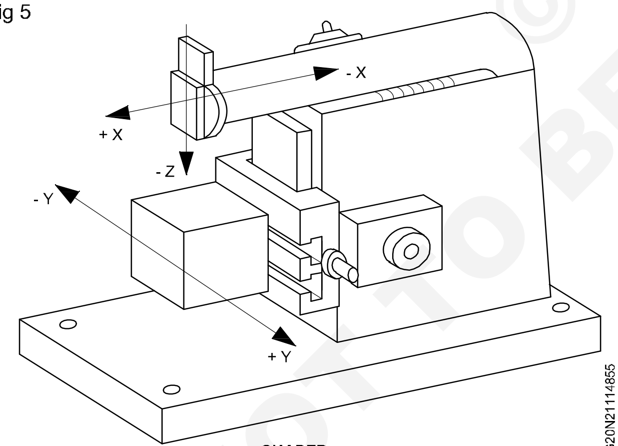
VERTICAL MILLING MACHINE

Fig 4



HORIZONTAL BORING MACHINE

Fig 5



SHAPER

When there are several spindles and slide ways, the spindle perpendicular to the work holding surface may be chosen as the principal spindle. The primary Z motion is then related to the primary spindle. The tool motions of other spindles or slides, designated as U, V, W and P,Q, R respectively. (Fig 2)

X - axis

The principle motion direction of cutting tool or the work piece is designated as X - axis. It is perpendicular to the Z - axis and should be horizontal and parallel to the work holding surface when possible.

When looking from the principle spindle to the column, the positive (+) X is the right. For turning machines, it is radial and parallel to the cross slide.

Y - axis

It is perpendicular to both X and Y - axes, and the direction is identified by the right hand cartesian coordinate system.

CNC Machine jog mode

CNC machine jog mode is one of the most used CNC mode. Jog mode is mostly used to travel the CNC machine carriage (or CNC machine slide) such as CNC machine's axis movement e.g. X - axis Z - axis. These axis movement can be via axis specific keys or through the CNC machine hand wheel.

CNC machine MDI mode or MDA mode

The CNC machine MDI (Manual Data Input) mode or MDA (Manual Data Automatic) mode can be called a semi automatic mode. The CNC MDI or MDA mode is mostly used to index tools, or to execute one block of CNC code (on some models of CNC such as sinumeric 840D you can execute multi block CNC program in MDA mode). The CNC M - codes can be executed in MDI or MDA mode. You can even rotate the CNC machine spindle to a specific RPM in MDI or MDA mode.

CNC machine single block mode

The CNC program consists of CNC program blocks. The CNC program blocks are numbered such as N10, N20, N30 and so on. In CNC machine single block mode when you press the cycle start button on the CNC machine control panel only one block of the CNC program will be executed and the machine slide or CNC machine carriage will stop or you might say that the CNC machine cutting tool feed will be at hold but remember that this does not mean that CNC machine fully stops, only CNC machine axis movement will be at hold and all the other functions like coolent will continue to flow and the spindle will continue to rotate. In short the CNC machine single block mode will not affect the machine spindle rotation but it will only hold the tool feed after the CNC program block is executed. And if you press the cycle start button again the next program block of the CNC program will be executed and the machine will again be at hold after that block completion.

CNC machine auto mode or automatic mode

You will rarely see in a production shop CNC machine out of CNC machine auto mode. The most used mode on a CNC machine (on some controls like sinumeric 840D the machine control panel has a setting key which when switched OFF the machine will only be in auto mode and you can't change the modes). In CNC machine auto mode when you press the cycle start button ON the machine control panel the whole CNC program will be executed. To run the CNC machine in auto mode there are some conditions on some CNC machine such as the CNC machine safety guard door must be closed.

Co-ordinate systems

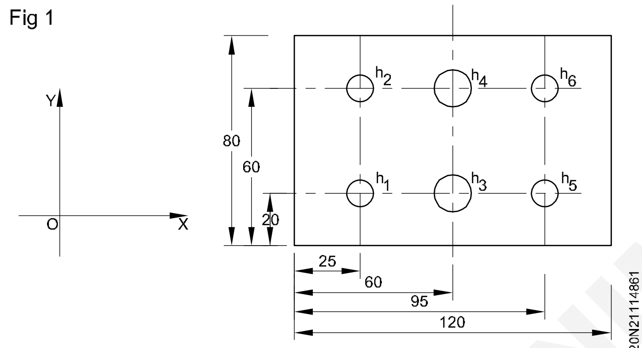
Objectives : At the end of this lesson you shall be able to
- **state the types of co-ordinate system**
- **distinguish between absolute and incremental co-ordinate systems.**

Co - ordinate systems

Absolute co - ordinate system

The system, in which all the measurements are taken from a fixed origin with co - ordinates X=0, Y=0 and Z=0 is known as absolute co - ordinate system. This origin serves as a datum position from which all the distances are measured parallel to each axis of the system. It is fixed by the user before starting the operation. This origin can have different locations on different machines. Often the origin is a point on the work table surface fixed in advance or a point on mounting fixture if it is used. This system can be well understood by the Fig 1.

Fig 1



ABSOLUTE CO-ORDINATE SYSTEM WITH FIXED ORIGIN

The origin '0' can be defined in two ways, depending upon the easiness of part programmer, for calculating the distances and co - ordinates.

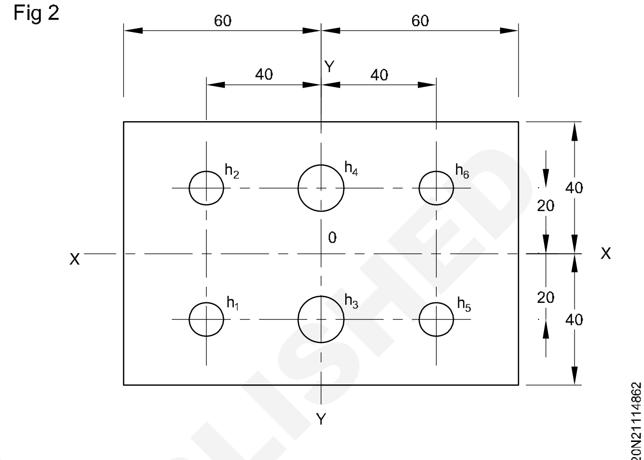
Fixed origin : Which is always fixed at the lower left hand corner of the work table so that all the measurements are positive w.r.t. origin. Fig 1 illustrates this type of origin.

Floating origin : The symmetrical parts can have the origin at their centre and the distances can be measured as positive or negative, depending upon the direction of location with reference to origin. In this case, the origin can also be made at a point from where it is easy to calculate all the distances such as a pre - drilled hole or any other suitable point on the job. In giving Fig 2 it is taken at the centre point of the work piece as '0' point.

The location of origin '0' is stored in MCU memory and the control system can be returned to it by simply pressing "zero reset" button on the panel.

An important feature of absolute coordinates is, that all the dimensions are independent of each other, as each time the table returns to its 'last position' which is 'origin 0', so if an interrupt is made by tool breakage or manual interference causing machine to stop, then the problem is removed and as soon as the machine is switched 'ON', it automatically reaches at 'Origin 0' i.e. which is its 'Last position' also and it does not affect any other dimension further. Thus, making it convenient and easy for an operator to proceed further. These systems are used in point - to - point applications.

Fig 2



ABSOLUTE CO-ORDINATE SYSTEM WITH FLOATING ORIGIN

Incremental co - ordinate system

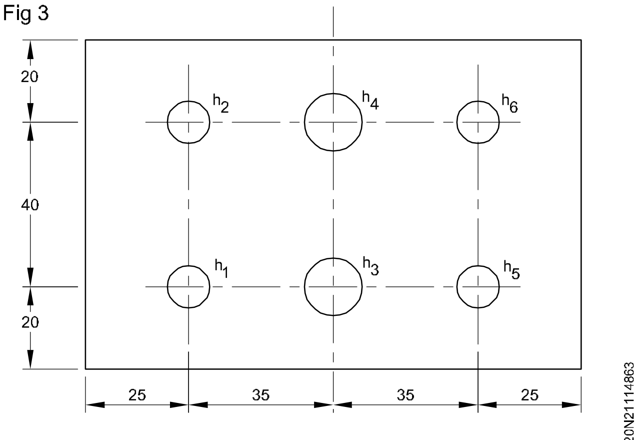
An incremental system is one, in which all measurements for the next position are calculated in the form of increments of distance from the point at which the slide was resting previously. The incremental system, hence, needs no predetermined datum point. Most of the NC lathes, follow an incremental co - ordinate system. The co - ordinates of the work - piece in previous example can be calculated as shown in Fig 3.

The co - ordinates of all the six holes calculated by both of the systems is as shown in the table 1.

TABLE 1

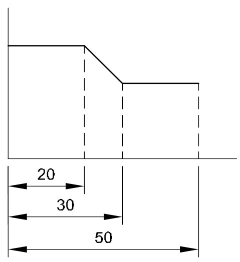
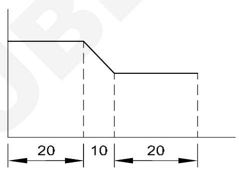
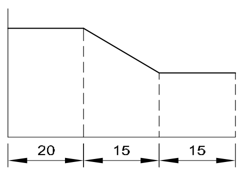
Hole	Absolute system		Incremental system
	Fixed origin (Fig 1)	Floating origin (Fig 2)	(Fig 3)
h1	25,20	-40, -20	25,20
h2	25,60	-40, 20	0,40
h3	60,20	0, -20	35,-40
h4	60,60	0, 20	0,40
h5	85,20	40, -20	35,-40
h6	85,60	40, 20	0,40

Fig 3



INCREMENTAL CO-ORDINATE SYSTEM

Comparison of absolute and incremental coordinate systems

S.No.	Absolute	Incremental
1	If a dimension is changed, then the program is easy to change even during the operation as all the measurements are independent of each other e.g. in case of fig. given below, the dimension '30' can be changed to '35' without any other change. 	Program editing is very difficult as all the dimensions depend upon the previous dimension. For example, as in figure given if dimension '10' is to be changed to the value '15', then the next dimension '20' is also to be changed to '15'.  (A) WITHOUT CHANGE  (B) WITH CHANGE
2	They need some what complicated and costly circuit for their realisation.	Less expensive and simple in construction.
3	There is no restriction that when the program can be changed. Because the system returns to 'zero position' after each operation, the sys tem can be stopped at any point, changed and again started.	In incremental, all the dimensions are to be entered once and if they are to be changed, then the machine is to be stopped and again needs to be started from the first operation, because it is not possible for an operator to bring it back to the previous position within 0.01 mm accuracy.
4	Can be directly translated from drawings, as most of the engineering drawings are made in this pattern.	In this system the dimensions need to be converted into 'incremental' form.
5	Overall error detection is difficult because it is to be detected separately for each operation.	Overall error detection is easy, as at the end of all operations, again the starting point has to be reached i.e. sum total of all the movements (+ve and -ve) should be zero. If it reaches the starting point, it ensures that there is no error.
6	Slower operation as it has to reach 'zero origin' each time.	Faster as compared to absolute.

Part programming

Objectives: At the end of this lesson you shall be able to
- **define the part programming**
- **state the purpose of preparatory (G codes) & Miscellanious functions (M codes)**
- **develop the part programming.**

Part programming

Definition wise "the part program is a sequence of instructions which describe the work which has to be done on a part, in the form required by a computer under the control of an NC computer program".

Actually, part programming for NC production consists of the collection of all data required to produce the part, the calculation of the tool path etc. in a standard format. The methods of part programming can be of two types depending upon the two techniques employed to produce a punched tape

- Manual part programming
- Computer aided part programming.

Manual part programming

In manual part programming, the data required for machining, is written in a standard format known as program manuscripts. Each horizontal line in a manuscript represents a 'block' of information.

Computer aided part programming

If the component requires a great deal of machining such as in case of milling machines or contouring applications, calculation of cutter paths requires more calculations and sometimes if a machining centre is used then selecting different tool for drilling, tapping, boring and milling makes all this part programming more tedious and time consuming. More mistakes are also likely to occur. Thus, we use general purpose computer as an add, to reduce labour involved in part programming. Also one of the high level language such as APT (Automatically Progrmmed Tools), ADAPT, SPLIT, 2CL, romance, auto stop is used for writing a computer programme.

Procedure for developing manual part program

The part programming requires an NC programmer to consider some fundamental elements before the actual programming steps of a part takes place. The elements to be considered are as follows.

- Types of dimensioning system
- Axis designation
- NC words
- Standard G and M Codes
- Tape programming format
- Machine tool zero point setting

Type of dimensioning

After deciding what NC machines is best suitable and available for the application, we determine what type of dimensioning system the machine uses i.e., whether an absolute or incremental dimensional system. (Explained in previous chapter).

Axis designation

Another consideration is designation the axis of the machine tool. In most cases the programmer already known this fundamental element when he select the NC machine tool for his job. The most important factor in axis designation is the location and position of the spindle.

The part programmer also determines how many axes are available on machine tool i.e. X,Y, Z, a, b or c and so on. Also whether machine tool has a continuous path and point to point control system.

NC words

In order to understand the language of NC information processing the following definitions should be understood.

A 'bit' is the basic unit of information represented by either the absence or the presence of a hole punched on the tape. Bit is an abbreviation of "Binary digit", which can be '0' or '1'.

A code or character is the series of combination of '1' s and '0' s. It represents a number of an alphabet or any symbol.

An NC word is a unit of information, such as a dimension (e.g. X01000 or Y10025) or feed rate (e.g. F1000 and so on.

A block is a collection of complete group of NC words representing a single NC instruction (e.g. N1G01 X100 Z100 F100). An end of block (EOB) symbol is used to separate the blocks.

Block number/sequence number (N words)

Each block of the program has a sequence number which is used to identify the sequence of a block of data in it which is in ascending numerical order. This enables the operator to know which sequence of block is being preformed practically by the tool. It consists of a character 'N' followed by a three digit number raising from '0' to '999'.

Preparatory functions (G - words)

The preparatory function is used to initiate the control commands, typically involving a cutter motion i.e. it prepares the MCU to be ready to perform a specific operation and interpret, the data which follows the way of this function. It is represented by the character 'G' followed by a two digit number i.e. '00 to 99'. These codes are explained and listed separately.

Dimension words (X,Y and Z words)

These dimension words are also known as 'co - ordinates'. Which give the position of the tool motion. These words can be of two types.

Linear dimension words

- X,Y,Z for primary or main motion.
- U, V, W for secondary motion parallel to X, Y, Z axes respectively.
- p, q, r for another third type motion parallel to X, Y, Z axes respectively.

Angular dimension words

- a, b, c for angular motion around X,Y, Z axes respectively.
- I,J, K in case of thread cutting is for position of arc centre, thread lead parallel to X, Y, Z axes.

These words are represented by an alphabet representing the axes followed by five or six digits depending upon the input resolution given.

Feed rate word (F - word)

It is used to program the proper feed rate, to be given in mm/min or mm/rev as determined by the prior 'G' code selection G94 and G95 respectively.

It is represented by 'F' followed by three digit number e.g. F100 represents a feed rate of 100 mm/min.

Spindle speed/cutting speed word (S - word)

It specifies the cutting speed of the process or the rpm of spindle. It is also represented by 'S' followed by the three digit number. If the speed is given in metre per min. Then the speed is converted in rpm rounded to two digit accuracy, e.g. S - 800 represents the 800 rpm of spindle.

Tool selection word (T - word)

It consists of 'T' followed by max five digits in the coded number. Different numbers are used for each cutting tools. When the T number is read from the tape, the appropriate tool is automatically selected by ATC (Automatic Tool Changer). Hence this word is used only for machines with ATC or programmable tool turret. e.g. T01, T02, T03..........represents the tool selection word.

Miscellanious words (M - words)

It consists of character M followed by two digit number representing an auxiliary function such as turning ON/OFF spindle, coolant ON/OFF.

End Of Block (EOB)

It identifies the end of instruction block.

G and M codes (G - codes)

This is the preparatory function word, consists of the address character G followed by a two digit code number, known as G - code. This comes after the sequence number word and a tab code. There are two types of G - codes model and non - model. Model codes remain active until cancelled by a contradictory and code of same class. e.g. G70 is a model code which defines that the dimensional units are metric. It will remain active until cancelled by G - 71, which tells that the dimensional units are in inches now. Non - model G codes are active only in the block in which they are programmed. G04 is non- model code.

Introduction to CNC Grinding

Objectives: At the end of this lesson you shall be able to
- **define CNC grinding**
- **define characteristics and structural feature of CNC grinding.**

The CNC grinding machine is a type of machine tool that uses a grinding tool to grind the surface or a workpiece. (Fig 1)

Fig 1

Most grinding machines utilize high-speed rotating grinding wheels, while some employ other abrasives like oilstones, abrasive belts, and free abrasives. Honing machines, superfinishing machines, belt grinding machines, grinding machines, and polishing machines are also used for grinding purposes.

In addition, CNC grinding machines include various types such as CNC surface grinders, CNC centerless grinders, CNC internal and external cylindrical grinders, CNC vertical universal grinders, CNC coordinate grinders, and CNC forming grinders.

Table of Contents

Introduction

CNC machines are the result of combining information technology and mechanical manufacturing technology, representing the current technical level and development trend of modern basic machinery.

In China, the CNC machine tool industry has experienced rapid growth with nearly a hundred CNC machine tool manufacturers. By the year 2000, the number of CNC machine tools had reached 1,000, of which 100 were at an international level in the early 1990s.

The average time between failures of CNC machine tools and CNC systems is 10,000 hours, with an annual output of 20,000 units. Many popular CNC machine tool products are manufactured in China.

Processing range

Grinding machines are capable of processing a wide range of materials, including harder materials like hardened steel and hard alloys, as well as brittle materials like glass and granite.

Grinding machines are commonly used for achieving high precision and surface roughness in grinding operations. They can also be used for highly efficient grinding tasks, such as in the case of strong grinding.

See also Types of chemical Processing Explained

History of grinding machine

In the 1830s, the United Kingdom, Germany, and the United States developed grinding machines with natural abrasive wheels in order to adapt to the hardening of parts such as watches, bicycles, sewing machines, and firearms. These machines were created by adding grinding heads to existing machine tools like lathes and planers. They were simple in structure, low in rigidity, and prone to vibrations during grinding, requiring operators to have high skill levels to produce precise workpieces.

In 1876, the Brown-Sharp Company of the United States showcased the first grinding machine with the basic characteristics of modern machines, a universal cylindrical grinding machine, at the Paris Exposition. This machine featured a reciprocating table that increased machine rigidity, an internal grinding accessory, and workpiece headstock and tailstock.

In 1883, the company developed a surface grinder with a grinding head mounted on a column and a reciprocating table. The development of artificial abrasives and hydraulic transmissions around 1900 greatly promoted the advancement of grinding machines. Various types of grinding machines were introduced with the development of modern industry, particularly the automotive industry.

In the early 20th century, planetary inner grinding machines, crankshaft grinding machines, camshaft grinding machines, and piston ring grinding machines with electromagnetic chucks were developed. In 1908, automatic measuring devices were added to grinding machines. By around 1920, centerless grinders, double-face grinders, roll grinders, guide grinders, honing machines, and superfinishing machines were in use.

In the 1950s, a high-precision cylindrical grinding machine that could be used for mirror grinding was developed. At the end of the 1960s, high-speed grinders with a line speed of 60- 80 m/s and large depth-cutting and slow-feed grinding surface grinders appeared. In the 1970s, digital control and adaptive control of microprocessors were widely applied to grinding machines.

See also Spherical Roller Bearing Explained

Characteristics

Suitable for processing complex shaped parts.

Implements computer control to eliminate human error.

Enables accuracy compensation and optimization control through computer software.

Machining centers, turning centers, grinding centers, and electric machining centers have tool magazine and tool change functions, reducing the number of clamping and improving machining accuracy.

Increases the flexibility of machining equipment.

Flexible processing is suitable not only for multi-variety, medium and small batch production, but also for mass production. It can also alternately process two or more different parts.

The addition of the function of automatically changing the workpiece enables unattended operation at night.

The Flexible Manufacturing System (FMS) comprises several CNC machine tools (machining centers) and provides a more flexible automated manufacturing system, including machining, assembly, and inspection.

Structural features

1 Spindle Components

The grinding wheel typically operates at a line speed of 30-60 m/s, while the CBN grinding wheel can reach up to 150-200 m/s. The highest spindle speed is 15,000 r/min.

The spindle unit is a critical component of the grinding machine. For high-speed and high- precision unit systems, it should possess good rigidity, high rotational precision, low temperature rise, good vibration resistance, low power consumption, long lifespan, and moderate cost.

The bearings of the grinding wheel spindle unit often utilize high-precision dynamic elastic bearings, hydrostatic bearings, hydrodynamic bearings, and message compression bearings.

Electric spindle unit components are increasingly utilized in high-speed and ultra-high-speed grinding machines.

2 Feeding Unit

The feed unit consists of a servo drive unit, a moving member, and a position monitoring unit.

The feed unit is essential to maintaining the normal operation of the grinding wheel and is a crucial indicator for evaluating the performance of the grinding machine.

The feed unit must be flexible in operation, high in resolution, high in positioning accuracy, and fast in dynamic response. It requires both a large acceleration and sufficient driving force.

The common approach for the feed unit is the combination of the AC and DC servo motor and the dynamic screw feed system, or the direct drive of the linear servo motor.

The transmission chain of the two solutions is short, primarily to reduce mechanical transmission errors.

Both solutions rely on the concept of speed regulation and commutation.

3 Components

The grinding wheel frame, head frame, tail frame, work table, bed body, and column are the fundamental components of the CNC grinding machine. The design and manufacturing technology are the foundation for ensuring the quality of the grinding machine.

4 Auxiliary Units

Auxiliary units include a workpiece quick clamping device, high-efficiency grinding fluid supply system, safety protection device, spindle and grinding wheel dynamic balance system, and chip handling system.

Personal and CNC Machine Safety

Objectives: At the end of this lesson you shall be able to
- **follow personal safety in CNC workshop**
- **maintain safety of CNC machine.**

Do's

- A well trained operator should operate the Machine.
- Only one operator should operate the machine at a time.
- Check the lubrication oil and Hydraulic oil level before starting the machine.
- Ensure doors are closed before switching ON the Machine.
- Keep less speed while operating in JOG mode, especially when the tool is near the chuck/Job.
- Operator should ensure the machine zero point while starting the machine.
- Operator should check the work offset for every required set tool and the same to be entered in the program.
- Special care should be taken while changing the tool.
- Check the programme for correction before operating.
- Learn all G codes, and M codes, of the control installed in your machine .
- Learn all offset, Reference points pertaining to your machine.
- Learn the basic maintenance schedule for your machine as per Autonomous maintenance.
- Ensure that the stabilizer is ON before starting.

Don'ts

- Do not operate machine without the working knowledge of the machine.
- Do not operate the machine when covers are removed.
- Do not insert any bar or tool holder in the spindle while rotation.
- Do not open the control panel, without switching OFF power.
- Do not operate the machine without trying in simulation.
- Do not attend electrical fault, without removing the main fuse carriers

CNC Technology basics

Objectives: At the end of this lesson you shall be able to
- **describe the fundamentals of NC controls**
- **state the present status of CNC technology**
- **state the different between conventional lathe and CNC lathe**
- **state the specification of CNC lathe**
- **state the advantages and disadvantages of CNC.**

When the computer was invented, the inventor himself must not have dreamt of the use of computers in various fields of life which is drastically changing the entire scenario of the Universe. It is now an integral part of our day to day life. There is lot of research going on with the help of computers in the field of factory automation. The declining cost of computers coupled with the invention of Multi task high speed micro processors, really made an industrial revolution and there seems to be no end for this. A distinct trend can be observed in industries which include an increase in the use of Computer controlled Machine tools, the application of new manufacturing systems, such as laser beam machines and appearance of new generation of industrial robots in the production line, the manufacturing management through MRP I, MRP II & MRP III etc.(Material Resource Planning)

Evolution of automation

Automatically controlled factory is nothing more than the latest development in the industrial revolution that began in Europe two centuries ago and progressed through the following stages:

- Mechanisation started in 1870 at the beginning of industrial revolution with simple production machines.
- In 18th Century fixed automatic mechanism and transfer lines came into existence for faster output and shorter production time.
- Simple automatic control machines and copying machines were invented in the later part of the 18th century. After 1950 the industrial automation was started. In this second phase of the industrial automation/revolution, workers, instead of physically performing all the task are placed in the control of the machines.

Progressive change after 1950 is as follows

- The introduction of numerical control (NC) in 1952 opened a new era in automation.
- The extension of NC was Computerised Numerical Control (CNC) machine tools in which computer (Micro Processor) is included as an integral part of the control system.
- Commercial Industrial robot was manufactured in 1961 along with CNC systems. The use of these robots, are well utilised only after 1970's.
- The next logical extension is a fully automated factory which employs a flexible manufacturing system (FMS) and Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) techniques.
- The latest of the above is Computer Integrated Manufacturing (CIM) which includes battery of CNC machines, with flexible modules for manufacturing tool head changers, automatic material handling system like AGV's (Automated Guided Vehicle) etc with minimum number of operating personnels.

Fundamentals of NC controls

NC equipment has been defined by Electronics Industries Association (EIA) as "A system in which actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret at some portion of the data".

In a typical NC system the part program is prepared on a punched tape. The part programme is arranged in blocks of information needed for processing a segment of work piece, the segment of length, speed, etc.

Advantage of NC machine are

- Complex shapes can be machined easily
- Accuracy and repeatability is achieved.
- High production rate
- Reduced component rejection
- Less operator skill and involvement

There are many disadvantages of NC system:

- If tape is spoiled the entire programme of manufacturing will be affected
- Editing of the program in tape is not very easy.
- Manual loading of tape is a laborious job.
- Instruction are read, block by block and carried out which is slow when compared to CNC machine tools:
- If the punch reader is not reading the program properly then the entire production is lost.

Computer numerical control

A dedicated micro processor or mini computer on the machine control makes the computer numerical control. CNC machines are very popular coupled with lots of other advantages:

Advantages

- Accuracy and repeatability is very high
- Reduced scrap and rework
- Reduced inspection time
- Ease of inter changeability of machined parts
- Reduced space
- Reduced material handling
- Less paper work
- Less lead time
- Less inventory
- Easy editing of programme
- Complicated shapes and contours are easily manufactured with quality assurance and better production management.
- Better utilisation of machines.
- Reduced tooling
- Reduced operator skill
- Jig not used but with minimum fixtures
- Reduced floor space
- Higher level of integration such as DNC, FMS, CAD/CAM, CIM etc.,

Disadvantages of CNC machines

- High cost of machine
- High cost of training needs
- High Maintenance cost

Major advantages of CNC machines are

- Higher production
- High quality production

These are achieved through:

Higher production

A Keeping idle time as minimum as possible

B Keeping machining time to a minimum

A Keeping idle time as minimum

1	Loading/unloading	:	Through quick work holding and work handling system like pallets, robots etc.
2	Tool Change time	:	Kept as minimum by ATC, quick change tool turret etc. (max.time is less than 8 sec.)
3	Movement of slide	:	Rapid movement is easily achieved through best servo feedback motors

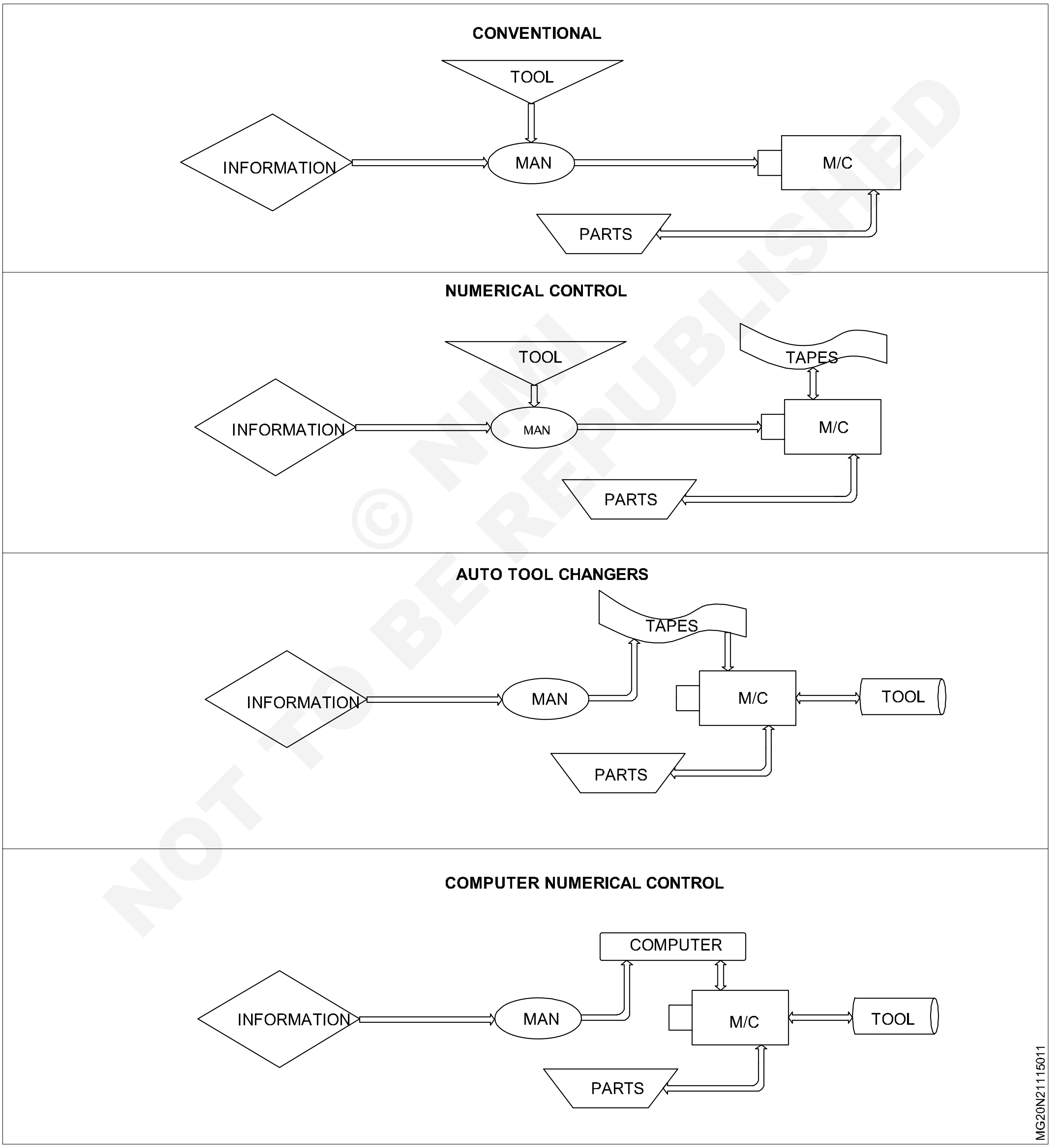
4 Changing of cutting conditions : Step less Speed, feed etc are changed easily through programming instruction.

5 In process control : Self diagnosing and gauging through measuring probes the parts and tools are available as an in-process control.

B Keeping machining time to minimum

Higher metal removal rate through

- Proper cutting tools
- Rigid machine spindle
- Higher spindle power
- Higher feed power
- Rigid structure
- Multi spindle
- Multi turrets etc.



Higher quality is achieved

- Servo mechanism	- For correction of feed through motors
- Curvic coupling	- For quick indexing
- Linear motion guides	- For heavy load movement of slides.
- Linear ball screw	- For accurate friction free backlash free movement
- Encoders and tacho generator	- For accurate positioning and velocity error correction etc.

Applications of CNC

In automobile, aircraft and general engineering industry, CNC machines are common sight now a days. CNC is used to control almost all types of machines and some of the commonly used machines are listed below:

- CNC lathes
- CNC Milling/drilling machine
- CNC turning centres.
- CNC Turn mill centre
- CNC Machine centre, Multi machining centre
- CNC Tool and cutter grinding.
- CNC Grinding machine, surface, cylindrical etc.
- CNC boring and jig boring machines etc.
- CNC EDM, Wire cut EDM etc.
- CNC Gear hobbing, gear shaping, gear grinding etc.
- CNC Electron beam welding
- CNC Laser/plasma/arc welding machine etc
- CNC Co-ordinate measuring machines
- CNC Nibbling press, press brakes, turret

Present status CNC technology

Now a days, CNC controllers with system like Sinumeric, Fanuc, Friera, Allen Brandly, Mazak etc come with graphic display of tool, paths, along with other software's have considerably reduce the manual part programming of three dimensional jobs.

User defined parametric programming, Standard Cycles like stock removal, drilling milling pattern etc are now a day's standard component of the Systems.

Some latest controls are having "DOS" front end with CAD/CAM facility in which one can design a component and get the computer assisted part programmes (CAPP) and proving the component on the machine control itself without wasting much time and money. Modern machine tools have multi spindle with a spindle speed of 75000 rpm; Cutting feed rate of 5000 mm/min, and rapid traverse of 20000 mm/min. Use of multi various sensing elements with adaptive controls, remote diagnostics system makes the machine more versatile and free from accidents.

The silent and salient use of computers in factory automation and in factory management will boost the quality and quantity in production, which in turn will definitely change the lifestyle of the people in future.

Advantages of CNC machines over conventional lathes

- Less manual work.
- Semi skilled operator can operate the machine.
- Greater accuracy.
- More flexibility.
- Alteration in dimension is easier through programme.
- Simulation is possible with that we can verify the dimensions of the component.
- Production rate is more.
- Profitability is high.
- Repeatability is very high compared to conventional lathe.
- One operator can operate more than one machine.
- Lesser production cost.
- Reduced part inventory.
- Reduced floor space requirements.
- Improved manufacturing control.
- Complicated parts shape can be easily machined.
- More number of tools are made available

Difference between conventional and CNC lathes

	Conventional lathe	CNC
1	Involves more manual work	Less manual work
2	Skilled labour needed	Basic Skill is enough
3	Less accuracy	More accuracy
4	Less flexible	More flexible
5	No part programming	Part programming required
6	Any alteration is difficult	Re-programming for dimensional changes made easier manually
7	For every component machining is done with great care.	Once the programme is done, the computer takes care
8	Simulation or trial run not possible	Simulation or trial run possible and correction may be done if required.
9	Less production rate	More production rate
10	Repeatability is not possible	Rate of repeatability is high
11	Individual operator required for each machine	One operator can operate more than one machine

Disadvantages of CNC machines

- Higher investment cost.
- Higher maintenance cost.
- Training of CNC operator involves more cost.
- Semi skilled or unskilled operator cannot do programming in CNC.
- Cost of spare parts and tool cost are high.
- Suitable for mass production only.

CNC Machine accuracy and repeatablity

Objectives: At the end of this lesson you shall be able to
- **define CNC machine accuracy**
- **define CNC machine repeatablity**
- **state about CNC machine accuracy and repeatablity measured**

CNC Machine Accuracy

The CNC machine's accuracy is defined as its closeness to the intended value in other words, accuracy is the degree to which the system's reported measurements match up with reality. If there is a negligible difference between the two measurements, we can confidently say their accuracy is high, it's another name for the correlation between two variables.

To better understand, consider the example below. When you visit a shop that offers CNC machining services, they will likely claim about the precision of their CNC machine tools. If the tool's instruments are set up to cut a metal piece that is 50 mm in length, it is implied that the item will be cut precisely. If the measuring device is as precise as the provider claims, the result will be precisely 50 mm.

Many factors affect the quality of CNC-machined parts, including toolpath programming, tool selection, part design, mechanical skills, and clamping tactics. Elements of landing gear in high-performance aircraft and laser surgery robotic arms are two examples of critical-path components that must always work as intended

CNC Machine Repeatability

Repeatability is the degree to which the outcome differs when repeated attempts are made to achieve the same goal, such as visiting the same spot, measuring the same quantity, or bonding the same number of wafers in succession under the same conditions. Repetition of failed procedures is a common source of errors.

The following steps can improve repeatability

- Measurement and correction
- The process of tracing and correcting for deviations using a control system. Examples of this error include backlash and changes in screw pitch throughout the flight.
- 20% of Machine Operators

Factors Affecting CNC Machine Accuracy and Repeatability (Fig 1)

Many factors influence the accuracy and repeatability of CNC machines:

Fig 1

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- **The Machine's Construction**

  It should be able to do the most forceful machining tasks that your application calls for without causing the parts that hold it up to bend too much.

- **The Feedback System**

  An axis's linear scale provides a direct readout of its relocating component's location. They are not as dependent on the accuracy of the axis system components (ballscrews, way systems, and couplers) as rotary encoders.

- **Machine Tool Calibration**

  The pitch error and backlash compensations on a machine are initially calibrated by the machine builders. However, the end users of the machine must repeat these calibrations at predetermined intervals throughout the machine's lifetime. In order to ensure that the machine continues to function accurately.

- **Environment**

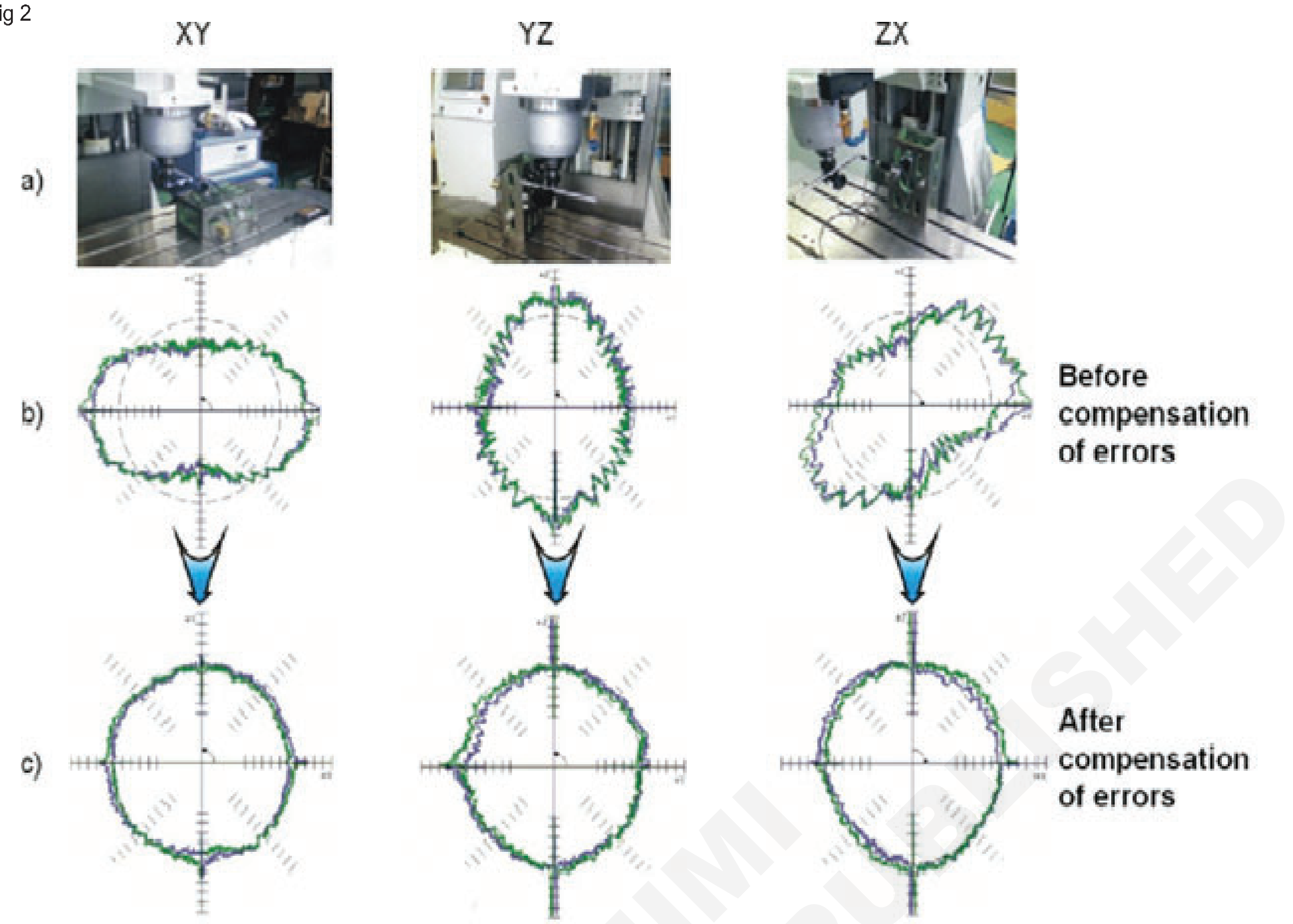
  The temperature and humidity of the area where machine tools will be used need to be kept consistent.

Main Cause Of Errors In Machining Accuracy and Repeatability (Fig 2a, 2b & 2c)

- **Spindle Rotation Error**

  Spindle rotation error is the degree to which the actual axis of rotation deviates from its typical rotation axis at any given time. The coaxiality error of various segments of the main shaft journal, errors in the bearing, misalignment of the bearings, and main shaft deflection are the primary contributors to the radial rotation error of the drive shaft.

Fig 2



- **Guide Rail Error**

  The guide rail serves as a standard for both the movement of the machine tool and the determination of the relative positions of its various parts. Additional contributors to guide rail error include uneven wear and poor installation quality.

- **Transmission Chain Error**

  A transmission error is a difference in position between the starting and finishing transmission elements. The mistakes made during CNC manufacturing and assembly of each link in the transmission chain are the main contributors to transmission errors.

- **Geometric Error of the Tool**

  In any tool's cutting process, wear causes the workpiece's size and shape to change. The geometric accuracy of CNC machine tools is affected by external forces and heat generated during machining. The machine tool's geometric distortion causes geometric errors. According to research, internal and external factors cause CNC machine tool geometric errors. Geometric errors in a machine tool are referred to as "internal factors" when they are caused by the machine's own design.

  External factors include environmental geometric errors and CNC thermal deformation. Some examples are when the tool or CNC part expands and changes shape because of heat during the cutting process. Both of these lead to geometric errors that negatively impact CNC machining. All CNC-machined components have excellent precision and machining accuracy.

- **Positioning Error**

  There are two different kinds of mistakes that can happen when a workpiece is being CNC machined on a machine tool. One is the positioning pair error that occurs inaccurately in CNC manufacturing. The second is the amount by which the finished CNC-processed piece deviates from its planned orientation in terms of perpendicularity, symmetry, positioning, etc.

  When it comes to the precision of CNC machine tools, positioning is crucial. In an open-loop system, position accuracy is significantly impacted. In a closed-loop servo system, it primarily depends on the precision of the CNC-machined components. The main factor influencing positioning accuracy is the machine tool's feed system.

Relationship Between Accuracy and Repeatability

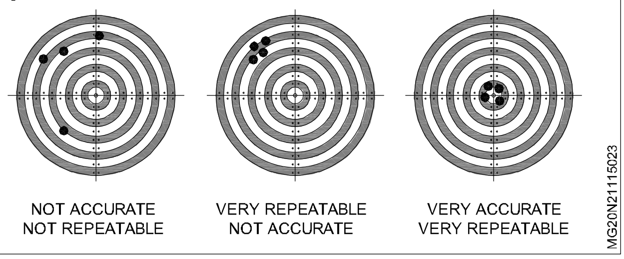
Even though accuracy is "what the buyer pays for," it is still important to understand the repeatability of the system's individual parts and how they interact with one another.

The graphs that follow show this limiting relationship.

In the picture, the points show how many times someone tried to move toward the starting point

- **Low Repeatability and Low Accuracy (Fig 3) :** The data points in the first graph are all over the place with respect to the x-axis origin. The accuracy and repeatability are both poor

Fig 3



- **Low Accuracy and High Repeatability:** The second graph displays results clustered closely together but away from the graph's origin. Accuracy is poor, but repeatability is excellent. But when a result is this consistent, it is possible to figure out what went wrong and fix it or make up for it.
- **High Repeatability and High Accuracy:** As a result of this adjusting process, a third-form graph frequently emerges.

Once the results are so close to the true position, the only way to make them more accurate is to make them easier to repeat. So, the lowest level of accuracy is repeatability.

CNC Machine Accuracy and Repeatability Measured

There are many methods for assessing the accuracy and repeatability of a CNC machine, but the most common is the use of a Coordinate Measuring Machine. The machine uses several sensors to take readings from all over the workpiece. After collecting data with the CMM, this information is downloaded and analyzed to determine how precise and reliable the instrument is.

There are other ways to measure the accuracy and repeatability of a CNC machine, but they are not used as often. One way is by using an optical comparator, which displays an image of the workpiece on a screen. The operator then checks the image to see if there are any differences by comparing it to a master template. Laser interferometry is another way to measure small changes in the distance between two objects.

It's crucial to understand that the repeatability and accuracy of a CNC machine are two different things. While repeatability refers to how consistently the machine produces the same cuts, accuracy refers to how close it is to make perfect cuts. Some machines are accurate but not repeatable. The most reliable machines consistently deliver precise results.

CNC lathe machine elements and their functions

Objectives : At the end of this lesson you shall be to
- **state CNC lathe Basic elements & functions**
- **bed, chuck, tail stock, turret, ball screw and LM guide way**
- **coolant system, hydraulic system**
- **controls of motor switches.**

Basic elements (or components) of a NC system

The basic components of NC system are as follows

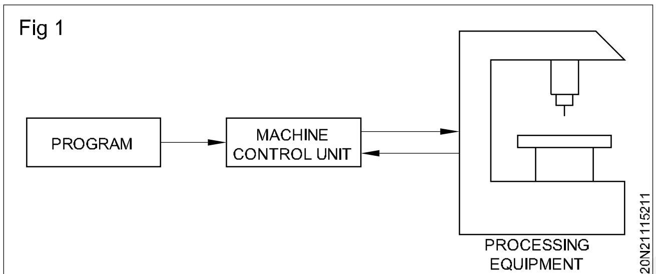
1 Program of instructions.

2 Machine control unit (MCU)

3 Machine tool or processing unit

The relationship between the three components is shown in Fig 1.

Fig 1



BASIC COMPONENTS OF A NC SYSTEM

Program of instructions

- The program of instructions is the detailed step-by-step commands that direct the actions of the processing equipment.
- In machine tool applications, the program of instructions is called a part program, and the person who prepares the program is called a part programmer.
- The program of instructions are fed to the machine through some type of input medium that can be interpreted by the controller unit. The various forms of input media are punched tape, and magnetic tape, direct entry or manual data input (MDI).

Machine Control Unit (MCU)

- The MCU consists of the electronics hardware system that reads and interprets the program of instructions and convert it into mechanical actions of the machine tool.
- The MCU includes the following:

  a **Tape reader:** It is an electro mechanical device used for winding and reading the punched tape.

  b **Data buffer:** It is used to store the input instructions in logical blocks of information.

  c **Signal output channels:** They are connected to the servo motors and these channels carry instructions from the controller unit to the machine tool.

  d **Feedback channels:** They send the feedback from the machine tools to the controller, to ensure the degree of execution of instructions.

  e **Sequence controls:** This controls coordinate the activities like reading into the buffer from the tape, sending signals to the machine tool, etc.

  f **Control panel:** It contains the dials and switches by which machine operator runs the NC system.

- In, the following two alternative controller designs are developed.

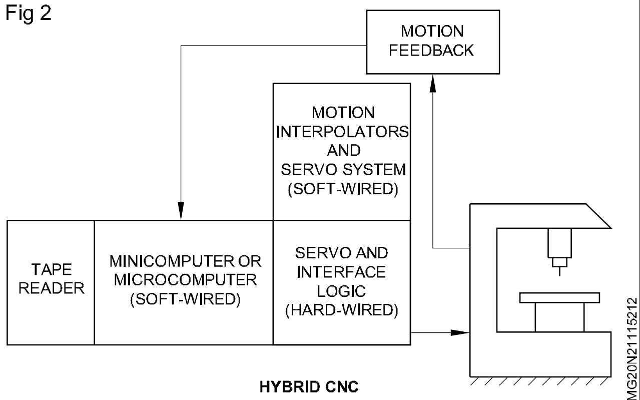
  1 Hybrid CNC, and

  2 Straight CNC

1 Hybrid CNC

In this type of CNC, the controller uses both the soft-wired computer and hard-wired logic circuits(servo systems and interface logic).The hard-wired components perform those function such as feed rate generation and circular interpolation, which they do best .The computer performs the remaining control functions and other duties not associated with a conventional hard-wired controller. The hybrid CNC system is shown in Fig 2.

Fig 2



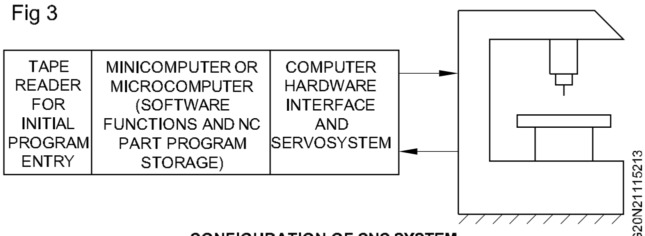
HYBRID CNC

- In CNC, a mini computer is used to control machine tool functions from stored in information or punched tape input or computer terminal input.
- Therefore CNC system replaces some or all of the hard work function previously performed by MCU with a dedicated computer i.e., a computer assigned to control a single NC machine.

Configuration of CNC system

Fig 3 shows the general configuration of a CNC system.

Fig 3



CONFIGURATION OF CNC SYSTEM

Functions of CNC

The principal functions of CNC are,

1 Machine tool control

2 In-process compensation

3 Improved programming and operating features, and

4 Diagnostics.

Machine tool control

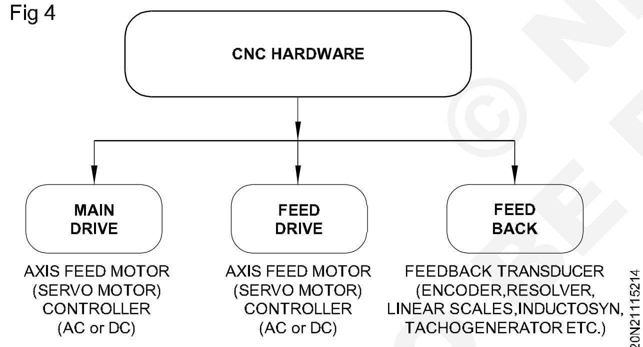
- Machine tool control is the primary function of CNC. It converts the part program instructions into machine tool actions.

- The conversion is achieved by using the following circuits:

  i Hard-wired circuits (servo systems and interface logic), and (Fig 4).

  ii Soft-wired circuits (mini-computers).

Fig 4



CNC MACHINE TOOL HARDWARE

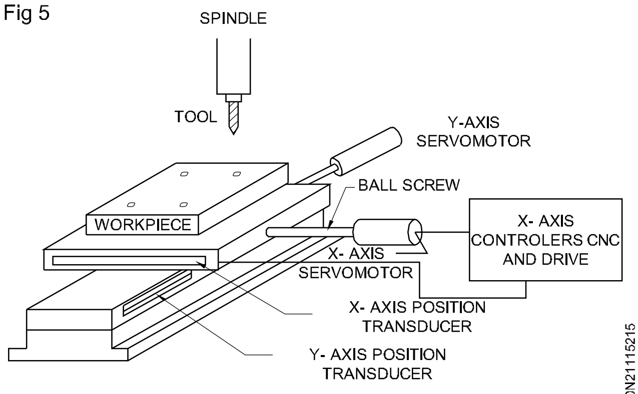
- Hard-wired circuits perform some control functions such as feed rate generation and circular interpolation, better than that of soft-wired circuits. But soft-wired circuits have additional flexibility and computational capability.

In such cases most of the geometric computations will be locally performed by the geometry processors. The geometry processor invokes area clearance and motion control sub programs, that clearance and motion control sub programs that generate actual tool paths and servo control motion.

Fundamental aspects of machine control(Fig 5 & 6)

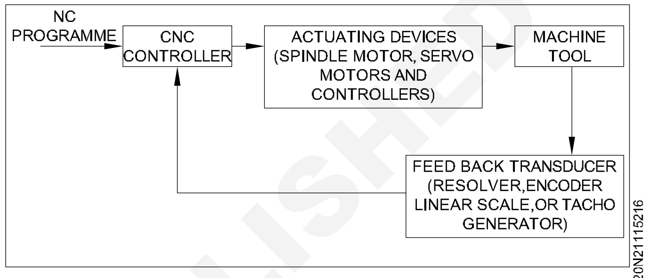
The primary objective of CNC is automatic control of machine tool operation. The CNC machines are, in general, programmed to accomplish three major objectives:

Fig 5



BLOCK DIAGRAM OF A CNC MACHINE TOOL

Fig 6



BLOCK DIAGRAM OF A CNC SYSTEM

1 **Positioning:** Position of a tool (e.g. a metal cutting tool or inspection probe) is controlled in 2 or 3 or more axes, through simultaneous control of the slides of the machine tool.

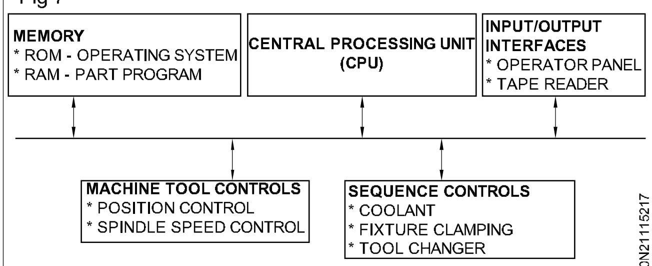
2 **Motion:** The relative velocity of the tool with respect to the work piece is to be controlled, in both spindle drive and positioning drive.

3 **Switching Function:** Miscellaneous function of the machine tools like direction of rotation of spindle, coolant flow etc. are to be controlled.

Depending on the nature of the positioning and motion, the CNC control schemes can be classified into two groups

Machine control unit for CNC (Fig 7)

Fig 7



MACHINE CONTROL UNIT FOR CNC

The MCU is the hardware that distinguishes CNC from conventional NC. The MCU consists of the following components and sub system.

1 Central processing unit.

2 Memory

3 Input/output interface

4 Controls for machine tool axes and spindle speed

5 Programmable logic controller

These sub systems are inter connected by means of a system bus.

Data required for manual part program

The following are the data required for manual part programming.

1 Specification of coordinate system

2 Specification of axes

3 Specification of machines

4 Specification of reference points in machines and work-pieces.

5 Specification of tools

6 Method of holding work pieces

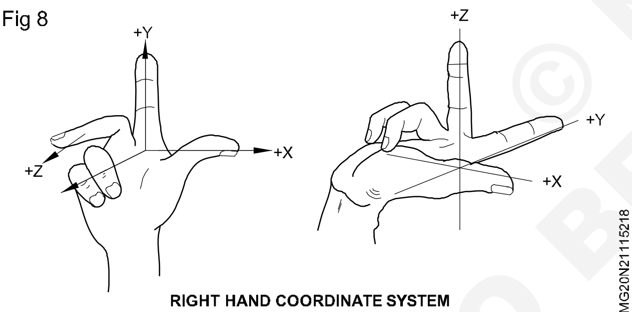
7 Data tables and block containing cutting process parameters such as speed, feed, depth of cut, etc.

8 Sequence of operation.

NC coordinates system (Fig 8)

All the NC machine tools make use of Cartesian coordinate system for the sake of simplicity. The guiding coordinate system followed for designating the axes is the well known right hand coordinate system.

Fig 8



RIGHT HAND COORDINATE SYSTEM

Designation of axes

First axes to be identified is the z axis .This is then followed by x and y axes respectively.

Part programming for turning centers

Diameter programming

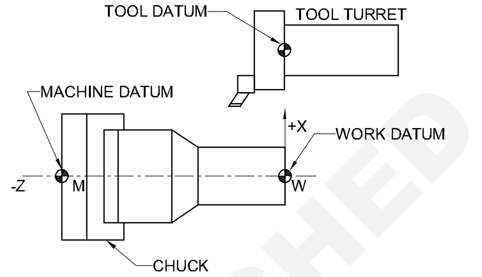
The dimensioning of a turned component is generally specified by its diameters. However, in turning operation, the tool should approach the work piece in radial direction for machining. Hence, for the sake of simplicity, most of the turning centers are provided with diameter programming facility.

This means that all the movements of the tool along X-axis should be doubled to represent the diameter rather than radial movement. The selection of radius or diameter programming depends upon the system variable set during the integration of controller with the machine tool.

Axes system (Fig 9)

In turning centers, the spindle axis is designated as Z. The radial axis perpendicular to the z-axis and away toward the principal tool post is termed as x-axis .The machine datum or home position may be the intersection of spindle axis and clamping plane. At the start, the controller display will show the axis position with respect to home The work piece datum is fixed by the programmer on the work piece for the convenience of part programming. The difference between the tool tip position and the turret datum is termed as offset.

Fig 9



AXES SYSTEM USED IN TURNING CENTERS

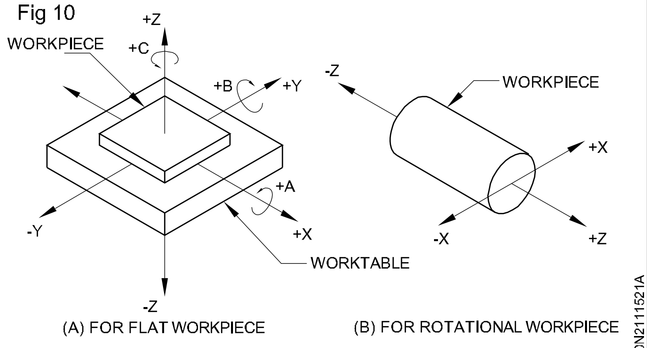
Z-axis

The z-axis motion is along the spindle axis or parallel to the spindle axis. In the case of machine without a spindle such as shapers and planers, the z-axis is perpendicular to the work holding surface.

For machines such as milling, drilling and lathe, the cutting tools move in the negative z direction to move a tool into the work piece. The positive z motion increases the clearance between the tool holder and work piece surface.

When there are several spindles and slide ways, the spindle perpendicular to the work holding surface may be chosen as the principal spindle. The primary z motion is then related to the primary spindle. The tool motions of other spindles or slides, designated as U, V, W and P, Q, R respectively.(Fig 10)

Fig 10



DESIGNATION OF AXES

X-axis

The principal motion direction of cutting tool or the work piece is designated as x-axis .It is perpendicular to the z-axis and should be horizontal and parallel to the work holding surface when possible.

Slideways or guideways

Slideways

Generally all the machine tools are provided with parts such as tables, slides, carriages, etc., to carry the work pieces /cutting tools. These parts are sliding on the ways provided on the parts (tables ,slides, carriages, etc) of the machines ,are known as slideways or guideways.

Functions of slideways

The functions of the slideways are as follows:

1 To control the line of action of the carriage/table on which the tool/work piece is held.

2 To absorb the static and dynamic forces.

Types of guideways /slideways

The types of guideways are as follows:

1 Friction guideways,

2 Antifriction or linear motion guideways,

3 Hydrostatic guideways.

Friction guideways

- Friction guideways are widely used in the lathe beds of all the conventional machine tools, due to their low manufacturing cost and good damping capability.
- Friction guideways operate under the condition of sliding friction.

Different shapes of friction guideways

The different shapes of friction guideways commonly used are as follows:

i Flat guideways,

ii Vee guideways,

iii Dovetail guideways, and

iv Cylindrical guideways.

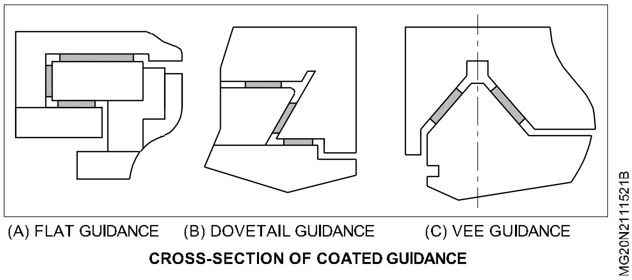
Flat guideways

- Flat guideways, shown in Fig.11 (a), are widely used in the conventional type machine tools for the following reasons.
  - i. Low manufacturing cost, and
  - ii. High load bearing capacity.
- The problem with this guideways is rapid wear rate which may lead to inaccuracies in positioning the tool/ job.

Vee guideways

- Vee or inverted -Vee guideways, shown in Fig.11 (C), are used in the lathe beds of all the conventional type machines tools.
- The advantages with this type of guideways is that the parallel alignment of the guideway with the spindle axis is not affected by wear.

Fig 11



- Since there is a closing action as the upper member settles on the lower and this automatically maintains the parallel alignment. Hence jibs(tapered pieces) which are used to adjust the clearance due to wear between the mating parts is used here.
- Machines use different V-angles to reduce the possibility of uneven wearing of the V slide.
- There is also some provision in the guideways to pre vent the twisting of slide as shown in Fig 12.

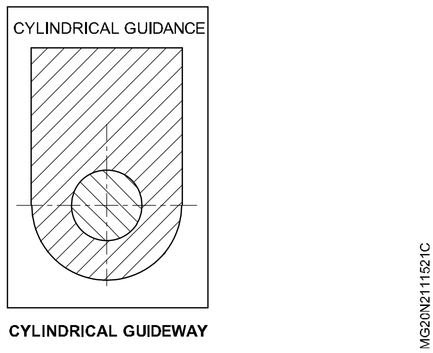
Dovetail guideways

- Dovetail guideways, as shown in Fig 11(B),is the combination of both flat and vee guideways, to get the advantage of both the guideways. These type of guideways are now widely used.

Cylindrical guideways

- In this type of guideways , the bore in the carriage housing provides support all around the guideways as shown in Fig 12. Cylindrical guideways are best suited for short traverse (span length) light loads.

Fig 12



Antifriction guideways

Need for antifriction guideways

- The conventional friction guideways have the following limitations:
  - i Surface to surface contact between the sliding members, which leads to more amount of wear.
  - ii Large amount of friction and heat developed in the sliding parts.
- These limitations will not allow the slider to move at a faster rate demanded by the most of the CNC machines. To overcome this, a number of rolling friction elements are developed. The rolling friction elements are generally called as linear motion or LM devices.

Advantages of using linear motion guideways

LM guideways are used in CNC machine tools of the following reasons

1 To reduce the amount of wear

2 To reduce the friction

3 To reduce the heat generation

4 To improve the heat smoothness

5 Zero stick slip

Types of LM guideways

LM devices are many types. The most commonly used are

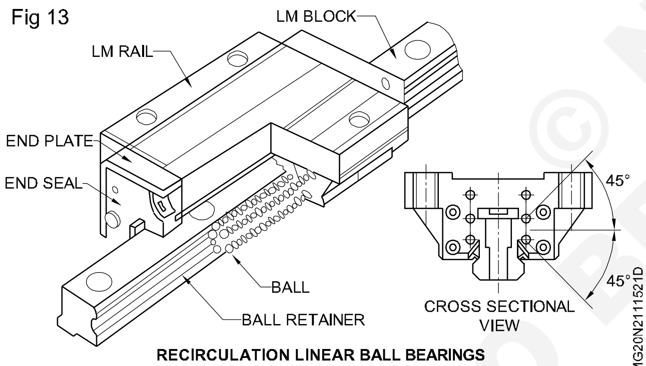
1 Linear bearings with balls and rollers, and

2 Recirculating ball bushings.

Linear bearings with balls and rollers

- A typical linear motion guide using the balls is shown in Fig 13. In this system there are number of recirculating balls are there to provide a rolling motion between the slider and the rail. At the end of the block there are end plates to ensure that the balls are circulating through the rolling tracks. This system provides low friction and high rigidity. Due to this low friction, this system is able to maintain higher accuracy throughout its life.

Fig 13



RECIRCULATION LINEAR BALL BEARINGS

– Instead of balls if rollers are provided then it is called as recirculating linear roller bearings.

Recirculating ball bush

– A linear motion device using a ball bush is shown in Fig 14. Here the balls are arranged in a track inside a bush which can slide along a ground rod to provide the linear motion. Fig 15 illustrates the details of inner construction of ball bushing.

There are two types of ball bushes available. They are

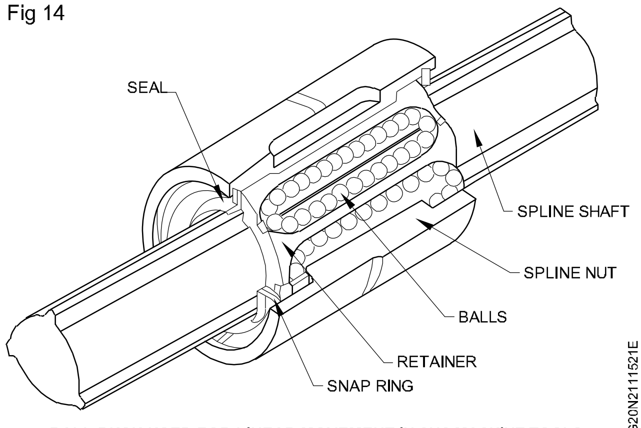
1 Closed type(with or without seal), and

2 Open type (with or without seal).

Hydrostatic guideways

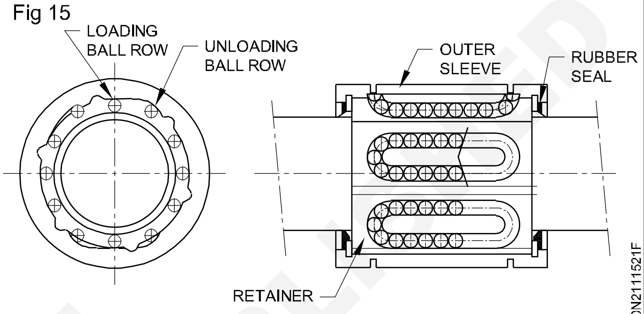
– The guideways in which the surface contact between the sliding parts is separated by a thin layer of fluid (oil or air)is known as hydrostatic guideways.

Fig 14



BALL BUSH USED FOR LINEAR MOVEMENT IN CNC MACHINE TOOLS

Fig 15



DETAILS OF INNER CONSTRUCTION OF BALL BUSHING

– The oil or air is supplied at very pressure thereby reduces the metal to metal contact to a minimum.

Classification of hydrostatic slideways

Hydrostatic slide ways are classified as follows

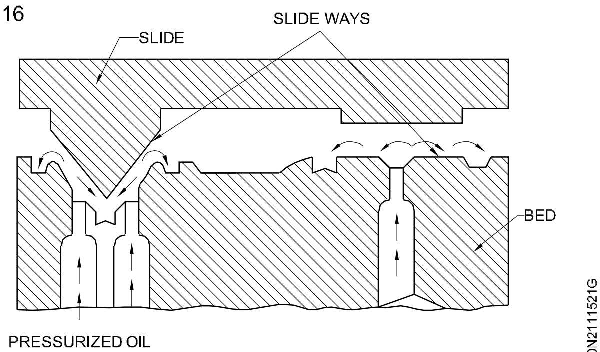
i Oil lubricated slideways, and

ii Air bearing slideways.

Oil lubricated slideways

In oil lubricated type hydrostatic slideways, the surface of the slide is separated from the guideways by a thin film of fluid supplied at very pressure(more than 300 bar).Oil lubricated type hydrostatic slideways is shown in Fig 16.

Fig 16

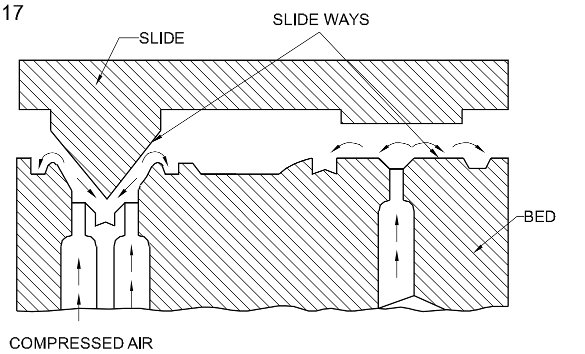


HYDROSTATICALLY LUBRICATED SLIDEWAY

Air bearing slideways

In this type of slideways high pressure air is used instead of oil. The slide is raised on the cushion of compressed air which separates the slide and slideways from the surfaces, as shown in Fig 17.

Fig 17



HYDROSTATICALLY LUBRICATED SLIDEWAY

– The air bearing slideways are best suited for positioning work such as drilling because machining does not take place during the movement of the slide.

Actuation systems

– Actuation systems are used to convert the rotational movement into transverse movement.

Types of actuating mechanism used in CNC

– The two types of actuating mechanisms used for the movement of slides in CNC machines are:

i Screw and nut, and

ii Rack and pinion.

Screw and nut

– The screw and nut system is effectively used for medium traverses light loads. The two types of screw and nut system used in the CNC machine tools are

1 Recirculating ball screws, and

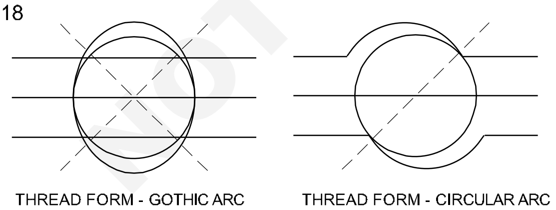
2 Recirculating roller screws.

Recirculating ball screws

– In case recirculating ball screws the nut is replaced by a series of balls. The balls are placed in the space between the screw and nut, results in a highly efficient rolling motion.

- The screw uses two different form of threads 1) Gothic arc, and (2) Circular arc as shown in Fig 18 respectively.

Fig 18



RECIRCULATING BALL SCREWS

- There are two types of screw and nut arrangements commonly used for recirculating the ball to the initial position. They are:

i By using external or internal tube, and

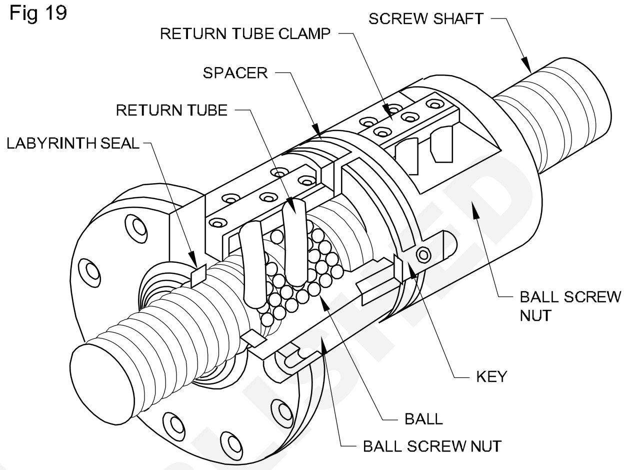
ii By using the deflector.

Recirculating screw and nut arrangement using external and internal type

- This arrangement is shown in Fig.19. Here the balls move along the direction of the slide till it reaches the end portion of the threads.

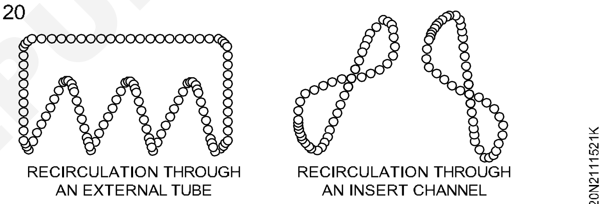
– Once the ball reaches the end of the threads, they are picked up by a return tube (external or internal tube) to the starting position as shown in Fig 20 respectively.

Fig 19



RECIRCULATING BALL SCREW WITH NUT ARRANGEMENT

Fig 20

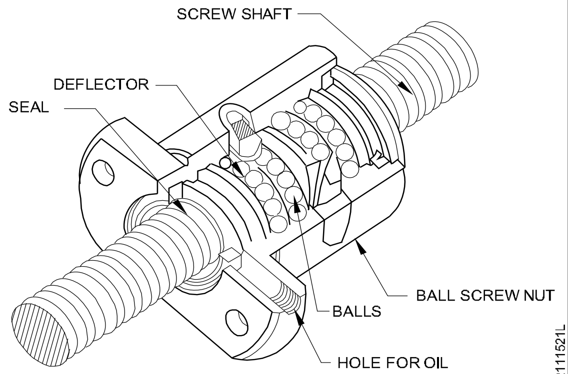


RECIRCULATION

Recirculating screw and nut arrangement using deflector

The another form of bringing the balls to the loading zone is by using the deflector, as shown in Fig 21.

Fig 21



A RECIRCULATING BALL SCREW AND NUT ARRANGEMENT USING DEFLECTOR

Preloading of the recirculating balls

– Further the ball screws are preloaded to eliminate the axial displacement which results in zero backlash. One such method followed for preloading is by fitting two nuts as shown in Fig 22.

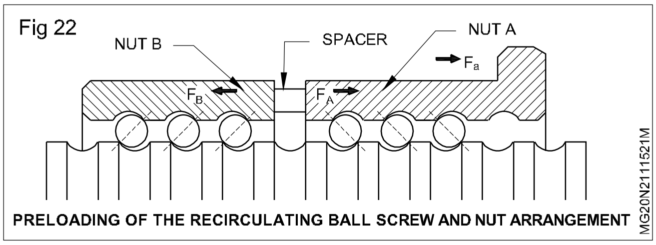


Fig 22
PRELOADING OF THE RECIRCULATING BALL SCREW AND NUT ARRANGEMENT

– The nuts are forced apart or alternatively squeezed together so that the balls in one nut contact one side of the threads in the and the balls in the other nut is in contact with the opposite side of the nut.

Advantages of ball screws over conventional type screws

1 Ball screws have a longer life.

2 Higher accuracy can be maintained.

3 Two frictional resistance hence used for carrying heavier loads at faster rate.

4 Low power requirement for driving.

Recirculating roller screw

The study of recirculating roller screw is beyond our scope.

Spindle drives

Spindle

Spindle is the main part of the machine tool. It receives power from the drive unit and delivers it to the job/work piece.

Function of spindle

The function spindles are as follows

1 To deliver power to the job/tool.

2 To hold the job/tool,

3 To centre the job/tool

Types of spindle drive motors (Fig 23)

– Normally more number of spindle drive motors are available. The following two are widely used:

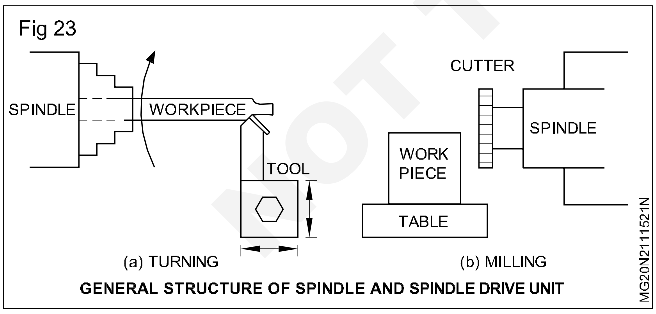


Fig 23
GENERAL STRUCTURE OF SPINDLE AND SPINDLE DRIVE UNIT

1 Separately excited DC shunt motor, and

2 Three phase AC induction motor.

– Normally DC spindle drive motors are used in machine tools. But due to the availability of microprocessor based technology, AC drives are preferred.

Tailstock (Fig 24)

The tailstock holds the free end of long parts which cannot be held in the chuck alone. The quill can be moved in or out through program control on some machines. The body can also be moved through program control on some machines.

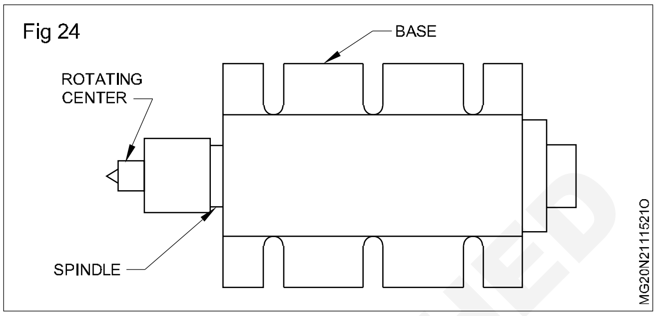


Fig 24

Steady rest (Fig 25)

The steady rest prevents long parts from deflecting when cutting forces are exerted. The steady can be opened and closed through proper arm control on some machines.

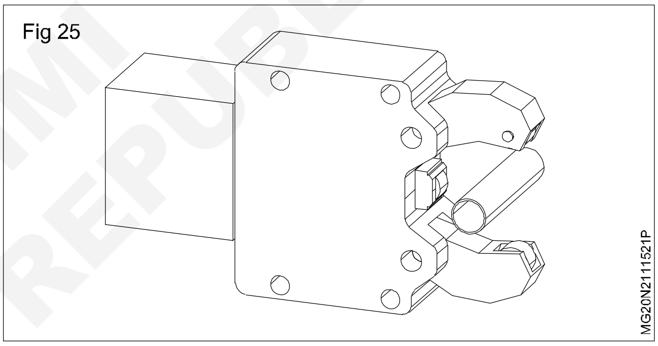


Fig 25

Tool changer

Turret (Fig 26)

The turret typically has 8 or 12 tools mounted, each in its own station. When a tools is selected in the program, the turret rotates about its axis to bring the selected tool into the active position. The indexing time is typically 2 seconds for 180 degree rotation.

Bed (Fig 27)

The bed is the casting which has the guideways for the Z axis. Beds can be flats or slant. A slant bed aids chip disposal, since the chips fall down to the bottom due to gravity.

A conveyor system for removing chips in CNC machine.

It is used to convey material (Chips) from one end to another. Conveyor systems are required in all the fields for moving things.

Fig 26

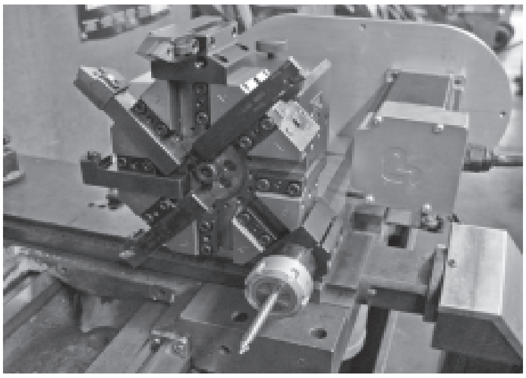
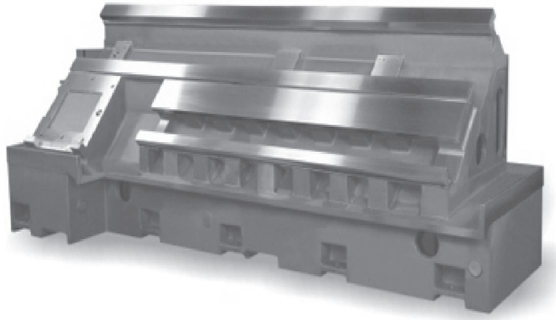


Fig 27



Encoder

Objectives : At the end of this lesson you shall be to
- **state about encoder**
- **state about the use of encode.**

An encoder is a sensing device that provides feedback. Endcoder convert motion to an electrical signal that can be read by some type of control device in a motion control system. It is used in counter or PLC. The encoder sends a feedback signal that can be used to determine position, count, speed or direction. It is found in machinery in all industries.

Emergency stop, machine over travel limit switch

Objective: At the end of this lesson you shall be to
- **explain emergency stop & over travel limit switch.**

Emergency stop buttons are designed in such a manner in which their role is more physical, such as interrupting a power supply to the Machine control system, It is a basic big red pushbuttons fixed on Machine control panel.

Emergency stop pushbutton that has mechanical plastic or metal tabs and grooves internally such that when you push it (interrupting the circuit), it is held in that position until you twist it.

They are designed to be large, hard to miss, and easy to push.

Machine over travel limits

The soft over travel limit alarms typically occur after a power outage, hitting an over travel or crashing a machine. Many times it is an Alarm 500 nth Axis stroke limit + or 501 nth Axis stroke limit on the newer Fanuc controls.

Soft over travel occurs when the axis moves outside of a grid set up in the machine parameters. Whether the machine looses it or the main travel area of the grid shifts by one or two revolutions of the ball screw. Soft over travels are based on home position. So when you set home position on a Fanuc control in another area you are moving the soft over travels.

Hard over travels occur when an axis hits a fixed limit switch to prevent damage to the machine when the home position is set in an improperly place or the machine looses where it was at.

Many times people will notice the problem because they will not be able to zero return the machine The machine will not even make it to the point where is starts to decal. Instead the over travel limit is reached.

Coolant system

Objective: At the end of this lesson you shall be to
- **explain coolant system & hydraulic system of CNC machine.**

Coolant system

Coolant system provided with the machine is designed to supply the coolant through the flexinox to the cutting zone. The coolant flexinox to be positioned such that coolant should flow effectively to the cutting zone.

Since the centrifugal pump is used to discharge the coolant, the system does not call for flow adjustment and pressure setting. Ensure that the pump runs in correct direction & discharges the sufficient amount of collant to the cutting zone.

Check for sufficiency of the coolant in the coolant tank. If the amount of coolant is insufficient, add some over the chip bin.

Some water soluble coolants solidify when the stock solution is put into water of coolant solution. When water soluble coolant is used, use another container to this. The stock solution well before pouring it in to the tank. If the coolant is water soluble a substantial portion of coolant reduction is caused by evaporation of water. If no drg. Radiation of quality is noticed, only adding water may be necessary if not appreciable change in quality.

Hydraulic system of CNC machine

CNC machine is such type of machine where several jobs are executed in compact area and in less time. In such scenario hydraulic system play a big role to exercise several functions hydraulic pressure in CNC machine is developed by hydraulic power pack which is a combination of several hydraulic components.

Pascal's law is the basis of hydraulic drive systems. As the pressure in the system is the same, the force that the fluid gives to the surroundings is therefore equal to pressure X area here the same principle is used a small torque can be transmitted in to a large force.

In basic - 2 axes CNC machine hydraulic system is used for

Chucking work piece /job (Drawbar actuation)

Quil stroke to hold the job between centres

Hydraulic system in CNC is operated by power pack assembly which has

- Oil tank
- Vane pump with required LPM & pressure output (coupled to motor)
- Filters (Inline and return filters)
- Electrical switches
- Pressure regulators.

CNC control system & machining operations and tool path

Objectives : At the end of this lesson you shall be able to
- **explain about feed back system**
- **state the closed loop and open loop control**
- **define the interpolation**
- **state the purpose of interpolation**
- **machining of turning, facing, grooving, threading, drilling, tool path**
- **explain various interlocks used in CNC lathe.**

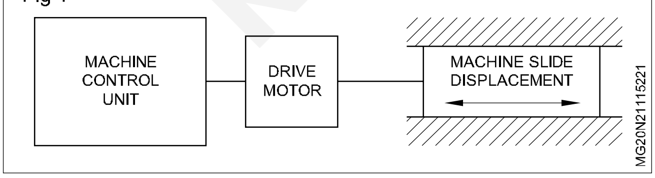
Feed back system

- The feedback system is also referred to as the measuring system.
- It uses position and speed transducers to continously and monitor the position at which the cutting tool is located at any particular instant.
- The MCU uses the difference between reference signals and feedback signals to generate the control signals for correcting position and speed errors. (Fig 1)

Open loop control system (Fig 1)

In an open loop control system (Fig 1) in which there is no arrangement for detecting or comparing the actual position of the cutting tool on the job with the commanded value.

Fig 1



Therefore, this system is not providing any check to see that the commanded position has actually been achieved. There is no feed back of information to the control also. These system are not good where extremely accurate positioning is required.

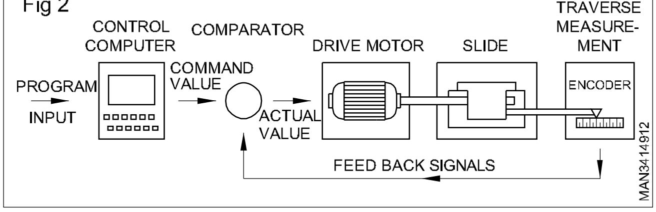
Closed loop control (Fig 2)

Closed loop control (Fig 2) is a term which is used very often when we talk about CNC machines. This term signifies, that the control system has provisions to ensure that the tool reaches the desired position, at the correct feed rate, even if some errors creep in due to unforeseen reasons.

For instance in the previous example 60,000 pulses sent in 2 minutes by the control should cause a tool travel of 60 mm at 30 mm/min, but even if the control sends these may pulses it cannot be ensured that the tool has really travelled exactly 60 mm.

A closed loop control has a device called encoder and this can continuously ascertain the distance actually travelled by the tool and then monitor the same, in the form of feedback signals to the control. The control studies this feedback information and takes corrective action in case any error is detected in the tool position/feed rate.

Fig 2



Interpolation

As the co-ordinates of points on the profile of the job vary continuously, it is necessary to define the path of small segment.

This tedious work is done by the computer by means of "interpolator".

Definition

The methods by which control system calculate the intermediate points and the speed of the motor is known as interpolation.

The parameters supplied may be

1 Radius

2 Start and end point of a curve

3 Radius and centre of a circle

4 Gradient angle for a line.

Types of interpolations

Interpolations are classified as

1 Linear interpolation

2 Circular interpolation

3 Helical interpolation

4 Parabolic interpolation

5 Logarithmic interpolation

6 Exponential interpolation of these the linear and circulate interpolators are commonly employed.

Linear interpolation

In this interpolation, the interpolated points lie on the straight line joining a pair of given points. (Fig 1a)

This is done in two or three dimensions.

The fast of linear interpolator is to supply velocity commands to several axes simultaneously in pps (pulses per second) (Fig 1b)

By changing the frequency of the pulses, the feed can be controlled.

The linear interpolator consists of Digital Differential Analyser (DDA) integrators one for each axis of motion hence each integrator functions separately one for X-axis and the other for Y - axis. (Fig 2a)

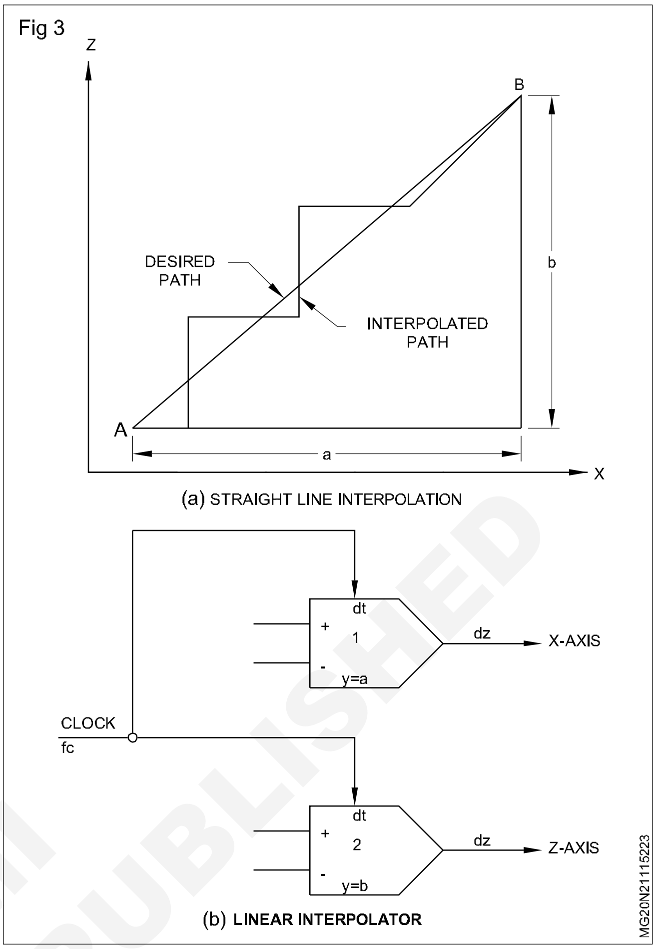
Circular interpolation

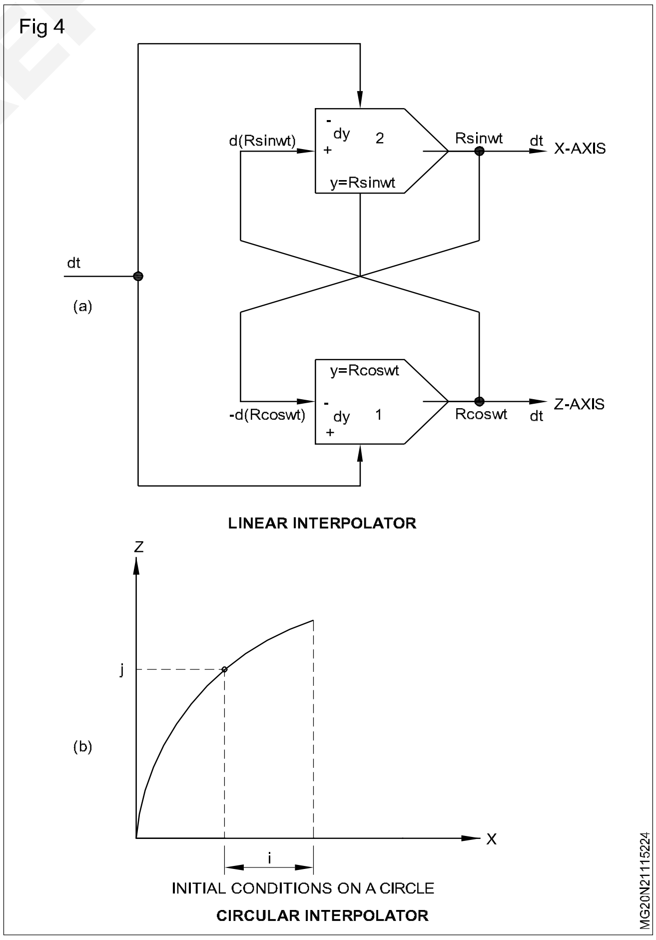
In circular interpolation, the interpolated points lie on a specific circle between a pair of fixed points.

In most cases, the circular interpolation is limited to one quadrant in the machine tool system. (Fig 2b)

The input data should consists of the distances between the initial point and the centre of the circle.

Two Digital Differential Analysers (DDA) are required for circular interpolation.





Advantages of circular interpolation are

Better surface finish

Greater accuracy

Less total machining time

Lower working costs.

Circular interpolation

The circular interpolation

Code G02 (clockwise)

Code G03 (anti - clockwise)

A circular interpolation permits the traversing of the tool with a defined speed along a circular path from the present Start-points to the programmed destination point.

Apart from the destination points co-ordinates, the control unit here also needs statements about the sense of rotation and the centre of the circle. The centre is entered with **I**, J and K with incremental dimensions with the centre points as origin.

The following assignment applies

I for the X - axis

K for the Z - axis

Circular Interpolation with mixed programming

Particularly the incremental statement of the centre of the circle usually represents some difficulties to the operator in practice, since it must often be evaluated using triangle calculations.

This is a prime example of where the mixed co-ordinate programming of the interpolation parameters in absolute dimensions comes in useful.

Straight turning

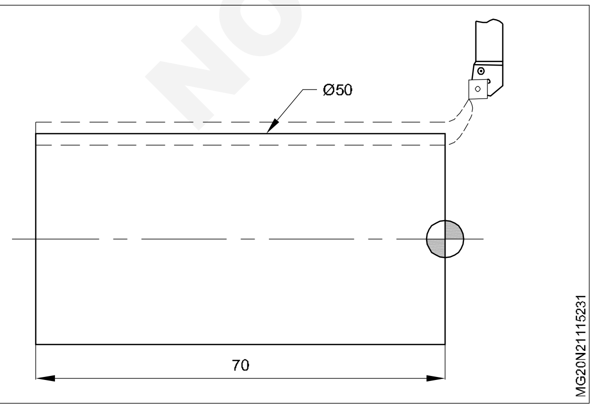
Objective : At the end of this lesson you shall be able to

- **trace the tool path of the given drawing with linear interpolation.**

Straight turning

```
%
O0019 (Fig 1)
N1 ;
G28 U0 W0 ;
G92 S3000 T0100 ;
G96 S200 M03 ;
G00 X55.0 Z0.0 T0101 M08 ;
G01 X0.0 F0.1 ;
G00 X48.0 Z2.0 ;
G01 Z0.0 F0.2;
G01 Z01 Z - 70 F0.1;
G00 X55.0 Z2.0 M09 ;
G28 U0 W0 M05 ;
M30 ;
```

Fig 1



Part program (Fig 2)

```
%
O0018 (Fig 2)
N010 G21;
[BILLET X40 Z60]
N020 G92 S4000;
N030 G99;
N040 G96 S300 M03;
N050 M06 T0101;        (Turning tool)
N060 G00 X40 Z0;
N070 G71 U1 R1;
N080 G71 P090 Q 150 U 0.5 W0. 5 F0 2;
N090 G01 X21 Z0;
N100 G01 X25 Z-2;
N110 G01 X25 Z-36;
N120 G01 X30 Z-36;
N130 G01 X30 Z-46;
N140 G01 X40 Z-50;
N150 G01 X40 Z-60;
N160 G70 P0P0 Q150 F0.1;
N170 M05
N190 G00 X25 Z-32
N 195 G 75 R 0.5;
N 200 G 75 X 22. OZ 36.0 P0.2 Q3 F0. 8;
N 210 M05              (GROOVING CYCLE)
```

N 220 M06 T0303 (Threading tool)

N 230 G00 X25 Z2

G 76 PO 30060 Q 150 R 20; (Thread cutting cycle)

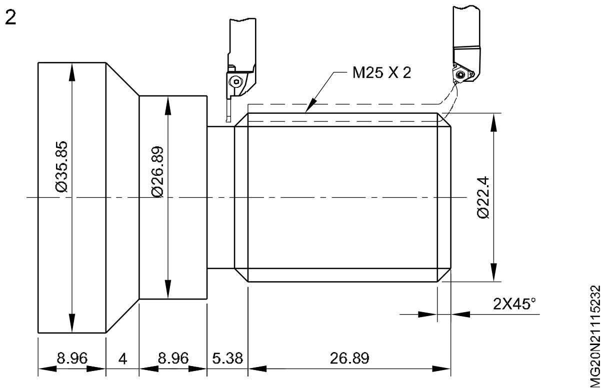
G 76 X 22.4 Z - 31.0 P 1280 Q 300 F2.0;

N250 G28 U0 W0;

N260 M05

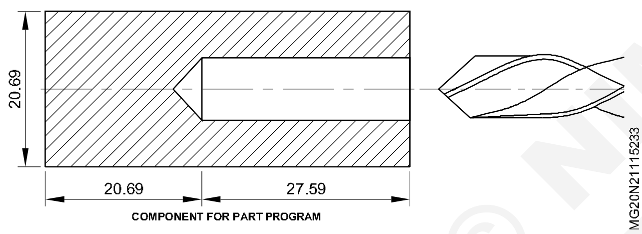
N270 M30

Fig 2



Peck drilling cycle [G74] (Fig 3)

Fig 3



The G74 code is used for peck drilling in Fanuc controller system. We simply position the drill to a safe starting point and then call the drilling cycle. The drill then drills to each incremental peck depth and then retracts to clear the chips. The syntax of G74 code is as follows.

G74 X_Z_K_F_

Where, X = Finish diameter

Z = Finish Z-depth

K = Peck Depth

F = Feed

%

O0012 (Fig 3);

N010 G21 G98;

[BILLET X30 Z70]

N020 G97 S1800 M03;

N030 M06 T0303; (Twist drill ϕ 12 mm)

N040 G00 X0 Z2 M08;

N050 G74 X0 Z-40 K5 F0. 08;

N060 G28 U0 W0;

N070 M09;

N080 M05;

N090 M30;

Interlocks used in CNC Lathe

Interlocks for the axes movement

- Turret should be in clamped condition i.e. input X 0001.1 should be high. Feed rate should be greater than 0 %

Interlocks for turret indexing

- Turret should be in safe zone (X in home position).
- Thermal contact of turret motor i.e. input X 0001.2 should be high (i.e. Turret motor should not be overheated).

Interlocks for spindle function

- Chuck should be clamped I.e. X 0000.2 should be high.
- After giving clockwise / counter clockwise command, CW/CCW push button should be pressed first time, after switching ON the CNC

Lubrication interlocks

- LOW LUB OIL LEVEL CYC. INTR message should not be displayed on the CRT i.e. input X 0000.6 should be HIGH.
- LOW LUB PRESSURE CYC. INTR message should not be displayed when LUB INCH push button Is pressed i.e. input X 0000.7 should be high.

Interlock for starting the auto cycle

- Axes should be referenced (X - reference LED and Z - reference LED should be ON) (only for axis motors with incremental encoders)
- Door should be closed (X 008.7 input should be HIGH) (Optional)
- Chuck should be clamped input X 0000.2 should be high.
- Turret should be clamped input X 0001.1 should be high.
- LUB fault LED should not glow.
- Rapid O/R selector switch and feed O/R selector switch should be selected to required value (it should not be at 0%).
- Program check, machine lock and dry run switches should be in OFF position.

Mains power ON interlock

- Electrical cabinet door should be in the closed condition and "So" RED switch in the electrical should be depressed firmly.