14. ASSIGNMENT TOPICS WITH MATERIALS

UNIT-I

1. TYPES OF LATHE OPERATIONS

Lathe Operations:

All the operations performed on a lathe can be divided into two groups:

i. **Standard (or) common operations**: They include facing, plain and step turning, taper turning, knurling, threading, drilling, boring, reaming, chamfering, forming etc.

ii. **Special (or) rare operations**: They include grinding, milling, copying (or) duplicating, relieving, spherical and elliptical turning, spinning, tapping, dieing etc.

Common lathe operations which can be carried out on a lathe are enumerated and briefly discussed as follows:

1. Facing
2. Plain turning
3. Step turning
4. Taper turning
5. Drilling
6. Boring
7. Reaming
8. Undercutting or grooving
9. Threading
10. Knurling
11. Forming

1. **Facing**:

This operation is essential for all works

- “Facing” is an operation of machining the ends of a work piece to produce a flat surface square with the axis.
- It is also used to cut the work to the required length.
- The operation involves feeding the tool perpendicular to the axis of rotation of the work piece.
- A properly ground facing tool is mounted in the tool post. A regular turning tool may also be used for facing a large work piece.

The cutting edge should be set at the same height as the centre of the work piece.
2. Plain turning:

- It is an operation of removing excess material from the surface of the cylindrical work piece.

- In this operation, the work is held either in the chuck or between centers and the longitudinal feed is given to the tool either by hand or power.

2. Types of Lathe:

The fundamental principle of operation of all lathes is same and performs the same function, yet they are classified according to the design, type of drive, arrangement of gears, and purpose. The following are important type of lathes.

1. Speed lathe:

   - It is driven by power and consists of a bed, a headstock, a tailstock and an adjustable slide for supporting the tool.

   - It has no gear box, lead Screw & Carriage. Head stock may have a step-cone pulley arrangement or may be equipped with a variable Speed Motor.

   - Various speeds are obtained by Cone pulley. Since the tool is fed into the work by hand and
cuts are very small, therefore this type of lathe is driven at high speeds usually from 1200 to 3600 rpm.

- Usage: It is mainly used for woodworking, centering, metal spinning, polishing etc.

2. Engine or Center lathe:

- It is a general-purpose lathe and is widely used in workshops.
- The main parts of engine lathe are the bed, headstock, tailstock, carriage, lead screw and feed change gear box.
- It differs from a speed lathe that it has additional mechanism for controlling the spindle speed and for supporting and controlling the feed of fixed cutting tool.
- The cutting tool may be fed both in cross and longitudinal direction with reference to the lathe axis with the help of a carriage.
- The engine lathe, depending upon the design of the headstock for receiving power, may be classified as belt driven lathe, motor driven lathe and geared head lathe.
- In Belt driven lathe, Power from motor is transmitted to spindle by belt drive, In Geared head lathe power from motor is transmitted to spindle by gear drive.
- The speed changes in belt drive are obtained by shifting the belt to different steps of cone pulley.
- In geared-Head lathe the gear ratio (Spindle speed to motor speed) is changed by Speed-Lever.

Usage: It is used for producing cylindrical components. By using the attachments and accessories, other operations such as taper turning, Drilling, milling and grinding may also be performed.

3. Bench lathe:

The bench lathe is so small that it can be mounted on a bench.

- All the types of operation can be performed on this lathe that may be done on an ordinary speed or engine lathe.
This is used for small work usually requiring considerable accuracy such as in the production of gauges, punches and beds for press tools.

4. Tool room lathe:
   - The tool room lathe is similar to an engine lathe and is equipped with all the accessories needed for accurate tool work.
   - It has an individually driven-geread headstock with a wide range of spindle speeds.
   - Since this lathe is used for precision work on tools, gauges, dies, jigs and other small parts, therefore greater skill is needed to operate the lathe.

5. Capstan and turret lathe:
   - The capstan and turret lathes are the modification of engine lathe and is particularly used for mass production of identical parts in a minimum time.
   - These lathes are semiautomatic and are fitted with multi tool holding devices, called capstan and turret heads.
   - The advantage of capstan and turret lathe is that several different types of operation can be performed on a work piece without resetting of the work or tools.

6. Automatic lathe:
   - The automatic lathes are so designed that the tools are automatically fed to the work and withdrawn after all the operations are completed to finish the work.
   - Since the entire operation is automatic, these lathes require little attention of the operator.
   - These lathes are used for mass production of identical parts.

7. Special purpose lathes:
   - The works, which cannot be conveniently accommodated or machined on a standard lathe, the special purpose lathes are used.
   - The gap bed lathe which has a removable section in the bed in front of the headstock to provide a space or gab, is used to swing extra large diameter jobs.

   a) Crankshaft lathe: is especially used for turning crankshafts.
b) Wheel lathe: is which is of large design, is especially used for finishing the journal and for turning the locomotive driving wheels.

c) Axle lathe: is used for turning car axles.

d) Precision Lathe: Precision turning of previously rough-turned work pieces.

e) Facing Lathe: Used to machine the end faces

f) Vertical lathe: It is used for turning and boring very large and heavy rotating parts which cannot be supported on other types of lathes.

3. SPECIFICATION OF MACHINE TOOLS.

A machine tool may have a large number of various features and characteristics. But only some specific salient features are used for specifying a machine tool. All the manufacturers, traders and users must know how are machine tools specified.

The methods of specification of some basic machine tools are as follows:

- **Centre lathe**
  - Maximum diameter and length of the jobs that can be accommodated
  - Power of the main drive (motor)
  - Range of spindle speeds
  - Range of feeds
  - Space occupied by the machine.

- **Shaping machine**
  - Length, breadth and depth of the bed
  - Maximum axial travel of the bed and vertical travel of the bed / tool
  - Maximum length of the stroke (of the ram / tool)
  - Range of number of strokes per minute
  - Range of table feed
  - Power of the main drive
  - Space occupied by the machine

- **Drilling machine (column type)**
  - Maximum drill size (diameter) that can be used
  - Size and taper of the hole in the spindle
  - Range of spindle speeds
  - Range of feeds
  - Power of the main drive
  - Range of the axial travel of the spindle / bed
  - Floor space occupied by the machine

- **Milling machine** (knee type and with arbour)
4. BROAD CLASSIFICATION OF MACHINE TOOLS

Number of types of machine tools gradually increased till mid 20th century and after that started decreasing based on Group Technology. However, machine tools are broadly classified as follows:

- According to direction of major axis:
  - horizontal center lathe, horizontal boring machine etc.
  - vertical – vertical lathe, vertical axis milling machine etc.
  - inclined – special (e.g. for transfer machines).

- According to purpose of use:
  - general purpose – e.g. center lathes, milling machines, drilling machines etc.
  - single purpose – e.g. facing lathe, roll turning lathe etc.
  - special purpose – for mass production.

- According to degree of automation
  - non-automatic – e.g. center lathes, drilling machines etc.
  - semi-automatic – capstan lathe, turret lathe, hobbing machine etc.
  - automatic – e.g., single spindle automatic lathe, swiss type automatic lathe, CNC milling machine etc.

- According to size:
  - heavy duty – e.g., heavy duty lathes (e.g. ≥ 55 kW), boring mills, planning machine, horizontal boring machine etc.
  - medium duty – e.g., lathes – 3.7 ~ 11 kW, column drilling machines, milling machines etc.
  - small duty – e.g., table top lathes, drilling machines, milling machines.
  - micro duty – e.g., micro-drilling machine etc.

- According to precision:
  - ordinary – e.g., automatic lathes
o high precision – e.g., Swiss type automatic lathes

• According to number of spindles:
  o single spindle – center lathes, capstan lathes, milling machines etc.
  o multi-spindle – multispindle (2 to 8) lathes, gang drilling machines etc.

• According to blank type:
  o bar type (lathes)
  o chucking type (lathes)
  o housing type

• According to type of automation:
  o fixed automation – e.g., single spindle and multispindle lathes
  o flexible automation – e.g., CNC milling machine

• According to configuration:
  o stand alone type – most of the conventional machine tools.
  o machining system (more versatile) – e.g., transfer machine, machining center, FMS etc.

UNIT-II
1. DIFFERENT TYPES OF DRILLING MACHINES
   (a) General purpose drilling machines of common use

• Table top small sensitive drilling machine

These small capacity (≤ 0.5 kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size (φ≤ 10 mm) drills. Figure1 typically shows one such machine.

Fig1. Table top sensitive drilling machine
• Pillar drilling machine

These drilling machines, usually called pillar drills, are quite similar to the table top drilling machines but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are grouted on the floor (foundation). Here also, the drill-feed and the work table movement are done manually. Fig.2 typically shows a pillar drill. These low cost drilling machines have tall tubular columns and are generally used for small jobs and light drilling.

![Fig.2 Pillar Drilling machine](image)

• Column drilling machine

These box shaped column type drilling machines as shown in Fig.3 are much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.
Fig.3 Column drilling machine

- **Radial drilling machine**
  This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in Fig.4. The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the drill spindle can be additionally swivelled and / or tilted.

Fig.4 Radial drilling machine

- **CNC column drilling machine**
  In these versatile and flexibly automatic drilling machine having box column type rigid structure the work table movements and spindle rotation are programmed and accomplished by Computer Numerical Control (CNC). These modern sophisticated drilling machines are suitable for piece or batch production of precision jobs.

(b) **General purpose drilling machines with more specific use.**
- **Hand drills**
Unlike the grouted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled as shown in Fig.5. The small and reasonably light hand drills are run by a high speed electric motor. In fire hazardous areas the drill is often rotated by compressed air.

![Fig.5 Hand drill in operation](image)

- **Gang drilling machine**
  In this almost single purpose and more productive machine a number (2 to 6) of spindles with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig. Fig.6 schematically shows a typical gang drilling machine.

![Fig.6 Schematic view of a gang drilling machine](image)

- **Turret (type) drilling machine**
  Turret drilling machines are structurally rigid column type but are more productive like gang drill by having a pentagon or hexagon turret as shown in Fig.7. The turret bearing a number of drills and similar tools is indexed and moved up and down to perform quickly the desired series of operations progressively. These drilling machines are available with varying degree of automation both fixed and flexible type.
Fig. 7 Schematic view of turret type drilling machine

- **Multispindle drilling machine**
  In these high production machine tools a large number of drills work simultaneously on a blank through a jig specially made for the particular job. The entire drilling head works repeatedly using the same jig for batch or lot production of a particular job. Fig. 8 shows a typical multispindle drilling machine. The rotation of the drills are derived from the main spindle and the central gear through a number of planetary gears in mesh with the central gear) and the corresponding flexible shafts. The positions of those parallel shafts holding the drills are adjusted depending upon the locations of the holes to be made on the job. Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length. In some heavy duty multispindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.

Fig. 8 A typical multi spindle drilling machine

- **Micro (or mini) drilling machine**
This type of tiny drilling machine of height within around 200 mm is placed or clamped on a table, as shown in Fig. 9 and operated manually for drilling small holes of around 1 to 3 mm diameter in small workpieces.

![Fig. 9 Photographic view of a micro (or mini) drilling machine](image)

- **Deep hole drilling machine**
  Very deep holes of L/D ratio 6 to even 30, required for rifle barrels, long spindles, oil holes in shafts, bearings, connecting rods etc, are very difficult to make for slenderness of the drills and difficulties in cutting fluid application and chip removal. Such drilling cannot be done in ordinary drilling machines and ordinary drills. It needs machines like deep hole drilling machine such as gun drilling machines with horizontal axis which are provided with
  - high spindle speed
  - high rigidity
  - tool guide
  - pressurized cutting oil for effective cooling, chip removal and lubrication at the drill tip.
  Deep hole drilling machines are available with both hard automation and CNC system.

3. **Explain the working principle and Kinematic System of general purpose drilling machine?**
   Kinematic system in any machine tool is comprised of chain(s) of several mechanisms to enable transform and transmit motion(s) from the power source(s) to the cutting tool and the workpiece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions. Even for the same type of machine tool, say column drilling machine, the designer may take different kinematic structure depending upon productivity, process capability, durability, compactness, overall cost etc. targeted. Fig. 10 schematically shows a typical kinematic system of a very general purpose drilling machine, i.e., a column drilling machine having 12 spindle speeds and 6 feeds. The kinematic system enables the drilling machine the following essential works;
• **Cutting motion:** The cutting motion in drilling machines is attained by rotating the drill at different speeds (r.p.m.). Like centre lathes, milling machines etc, drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions. It is shown in Fig.10 that the drill gets its rotary motion from the motor through the speed gear box (SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be changed to any of the 12 speeds by shifting the cluster gears in the SGB. The direction of rotation of the drill can be changed, if needed, by operating the clutch in the speed reversal mechanism, RM-s shown in the figure.

• **Feed motion:** In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (within a range) depending upon the tool-work materials and other conditions and requirements. Fig.10 visualises that the drill receives its feed motion from the output shaft of the SGB through the feed gear box (FGA), and the clutch. The feed rate can be changed to any of the 6 rates by shifting the gears in the FGB. And the automatic feed direction can be reversed, when required, by operating the speed reversal mechanism, RM-s as shown. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quill. The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

• **Tool work mounting:** The taper shank drills are fitted into the taper hole of the spindle either directly or through taper socket(s). Small straight shank drills are fitted through a drill chuck having taper shank. The workpiece is kept rigidly fixed on the bed (of the table). Small jobs are generally held in vice and large or odd shaped jobs are directly mounted on the bed by clamping tools using the T-slots made in the top and side surfaces of the bed as indicated in Fig.10.
2. APPLICATIONS OF DRILLING MACHINE
Drilling machines of different capacity and configuration are basically used for originating cylindrical holes and occasionally for enlarging the existing holes to full or partial depth. But different types of drills are suitably used for various applications depending upon work material, tool material, depth and diameter of the holes. General purpose drills may be classified as:

- **According to material:**
  - High speed steel – most common
  - Cemented carbides
    - Without or with coating

*Fig. 10 Schematic view of the drives of a drilling machine*
In the form of brazed, clamped or solid

- **According to size**
  - Δ Large twist drills of diameter around 40 mm
  - Δ Microdrills of diameter 25 to 500 μm
  - Δ Medium range (most widely used) diameter ranges between 3 mm to 25 mm.

- **According to number of flutes**
  - Δ Two fluted – most common
  - Δ Single flute – e.g., gun drill (robust)
  - Δ Three or four flutes – called slot drill

- **According to helix angle of the flutes**
  - Δ Usual – 20° to 35° – most common
  - Δ Large helix : 45° to 60° suitable for deep holes and softer work materials
  - Δ Small helix : for harder / stronger materials
  - Δ Zero helix : spade drills for high production drilling micro-drilling and hard work materials.

- **According to length – to – diameter ratio**
  - Δ Deep hole drill, e.g. crank shaft drill, gun drill etc.
  - Δ General type : L/φ = 6 to 10
  - Δ Small length : e.g. centre drill

- **According to shank**
  - Δ Straight shank – small size drill being held in drill chuck
  - Δ Taper shank – medium to large size drills being fitted into the spindle nose directly or through taper sockets

- **According to specific applications**
  - Δ Centre drills (Fig.1) : for small axial hole with 60° taper end to accommodate lathe centre for support

  Δ Step drill and subland drill (Fig.2) : for small holes with two or three steps

![Fig.1 Centre Drill](image_url)
Δ Half round drill, gun drill and crank shaft drill (for making oil holes) – shown in Fig. 3
Δ Ejector drill for high speed drilling of large diameter holes
Δ Taper drill for batch production
Δ Trepanning tool (Fig. 4): for large holes in soft materials

Besides making holes, drilling machines may be used for various other functions using suitable cutting tools.

**Fig. 2** (a) Stepped drill and (b) subland drill

**Fig. 3** Schematic views of (a) half round drill, (b) gun drill and (c) crank shaft drill
The wide range of applications of drilling machines include:

- Origination and/or enlargement of existing straight through or stepped holes of different diameter and depth in wide range of work materials – this is the general or common use of drilling machines.

- Making rectangular section slots by using slot drills having 3 or four flutes and 180° cone angle
- Boring, after drilling, for accuracy and finish or prior to reaming
- Counter boring, countersinking, chamfering or combination using suitable tools as shown in Fig. 5

Fig. 4 Schematic view of a trepanning tool.

Fig. 5 Schematic view of (a) counter boring and (b) countersinking
• Spot facing by flat end tools (Fig.6)
• Tapping for making large through holes and or getting cylindrical solid core.
• Reaming is done, if necessary, after drilling or drilling and boring holes for accuracy and good surface finish. Different types of reamers of standard sizes are available as shown in Fig.7 for different applications.

![Fig.6 Schematic view of spot facing](image)

![Fig.7 Different types of reamers.](image)

• Cutting internal screw threads mounting a tapping attachment in the spindle.

Several other operations can also be done, if desired, in drilling machines by using special tools and attachments.

3. CLASSIFY THE TYPES OF SHAPERS
1. According to the type of mechanism used for giving reciprocating motion to the ram:
   (i) Crank shaper:
   • In this type of shaper, a crank and a slotted lever quick return motion mechanism is used to give reciprocating motion to the ram.
   • The crank arm is adjustable and is arranged inside the body of a bull gear (also called...
crank gear).

(ii) Geared shaper
- In this shaping machine, the ram carries a rack below it, which is driven by a spur gear.
- This type of shaper is not widely used.

(iii) Hydraulic shaper:
- In this type of shaper, a hydraulic system is used to drive the ram.
- This shaper is more efficient than the crank and geared type shapers.

2. According to position and travel of ram:

(i) Horizontal shaper:
- In this shaping machine, the ram moves or reciprocates in a horizontal direction.
- This shaper is mainly used for producing flat surfaces.

(ii) Vertical shaper:
- In this shaper, the ram reciprocates vertically in the downward as well as in upward motion.
- This type of shaping machine is very convenient for machining internal surfaces, keyways, slots or grooves.

(iii) Travelling head shaper:
- A travelling head shaper has a reciprocating ram mounted on a saddle which travels sideways along the bed. The ram carries the tool slide.
- Heavy duty jobs which cannot be held on the standard shaper table are kept stationary on the base travelling head shaper and machined as the ram reciprocates.

3. According to the type of cutting stroke

(i) Push-cut shaper:
- In this shaper, the ram pushes the tool across the work during cutting operation. In other words, forward stroke is the cutting stroke and the backward stroke is an idle stroke.
- This is the most general type of shaper used in common practice.

(ii) Draw-cut shaper:
- In a draw-cut shaper, the ram draws or pulls the tool across the work during cutting operation. In other words, the backward stroke is the cutting stroke and forward stroke is an idle stroke.

4. According to the design of the table:

(i) Standard or plain shaper:
- In this type of shaper, the table has only two movements namely horizontal and vertical, to give the feed.
- It cannot be swiveled or tilted.

(ii) Universal shaper:
- In this shaper, in addition to the above two movements, the table can be swiveled about an horizontal axis parallel to the ram and the upper portion of the table can be
tilted about a horizontal axis perpendicular to the first axis.
- A universal shaper is mostly used in tool room.

4. CRANK AND SLOTTED LINK MECHANISM OF SHAPER

Crank and Slotted Lever Mechanism:

The crank and slotted lever mechanism is shown in below Fig. and its main features are driving gear (bull gear) and slotted link (rocker arm). An electric motor drives the bull gear by means of a pinion through a gear box. A crank pin which is fastened to the bull gear moves a sliding block which is located in a slot of slotted link. One end of slotted link is pivoted at the bottom, and other end is connected to the ram. The up and down movement of slider causes the slotted lever to oscillate about its pivot as the bull gear rotates. Thus the oscillating motion of slotted lever imparts a reciprocating motion to the ram.

Crank and slotted lever mechanism enables the ram to move faster during returning (idle) stroke than during forward (cutting) stroke. The principle of quick return motion is illustrated in below Fig. The cutting stroke is made less rapidly than the return stroke because crank pin produces the working stroke 'DE' during its travel through major arc 'ABC' and through minor arc 'CA' it produces the return stroke. As the speed of rotation of the bull gear is constant, this will causes the return stroke to complete in a shorter time. The ratio between cutting time and return time may be given as,

\[
\frac{\text{Cutting time}}{\text{Return time}} = \frac{\text{Angle subtended by arc ABC}}{\text{Angle subtended by arc CA}}
\]
This ratio is usually 3:2, and slightly changes with length of stroke. The disadvantage with this mechanism is that the quick return effect is diminishes with smaller strokes. Adjustment for length of stroke and position of stroke:

The length of stroke of the ram is depends on the radial distance of crank. As the pin is moved near to the centre, the stroke becomes shorter and if it is moved away from the centre the stroke become longer. Thus the length of stroke can be obtained by adjusting the radial position of crank pin.
UNIT-III

1. TYPES OF MILLING MACHINES
Milling machines can be broadly classified;
(a) According to nature of purposes of use :
   - **general purpose** – most versatile commonly used mainly for piece or small lot production
   - **single purpose** – e.g., thread milling machines, cam milling machines and slitting machine which are generally used for batch or lot production.
   - **Special purpose** – these are used for lot or mass production, e.g., duplicating mills, die sinkers, short thread milling etc.

(b) According to configuration and motion of the work-holding table / bed
   - **Knee type** : typically shown in Fig. In such small and medium duty machines the table with the job/work travels over the bed (guides) in horizontal (X) and transverse (Y) directions and the bed with the table and job on it moves vertically (Z) up and down.

- **Bed type** : Usually of larger size and capacity; the vertical feed is given to the milling head instead of the knee type bed.
Fig. Bed type milling machine

- **Planer type**: These heavy duty large machines, called plano-miller, look like planing machine where the single point tools are replaced by one or a number of milling heads; generally used for machining a number of longitudinal flat surfaces simultaneously, viz., lathe beds, table and bed of planning machine etc.

- **Rotary table type**: Such open or closed ended high production milling machines possess one large rotary work-table and one or two vertical spindles as typically shown in Fig; the positions of the job(s) and the milling head are adjusted according to the size and shape of the job.
(c) According to the orientation of the spindle(s).

- **Plain horizontal knee type**
  
  This non-automatic general purpose milling machine of small to medium size possesses a single horizontal axis milling arbour; the work-table can be linearly fed along three
axes (X,Y, Z) only; these milling machines are most widely used for piece or batch production of jobs of relatively simpler configuration and geometry.

- **Horizontal axis (spindle) and swivelling bed type** These are very similar to the plain horizontal arbour knee type machines but possess one additional swivelling motion of the work-table.
- **Vertical spindle type**
  In this machine, typically shown in Fig, the only spindle is vertical and works using end mill type and face milling cutters; the table may or may not have swivelling features.
- **Universal head milling machine**
  These versatile milling machines, typically shown in Fig, not only possess both horizontal milling arbour and the vertical axis spindle, the latter spindle can be further tilted about one (X) or both the horizontal axes (X and Y) enabling machining jobs of complex shape.
**Fig.** Vertical spindle type milling machine
Fig. (a) & (b) Universal head milling machine

(d) According to mechanisation / automation and production rate
Milling machines are mostly general purpose and used for piece or small lot production. But like other machine tools, some milling machines are also incorporated with certain type and degree of automation or mechanisation to enhance production rate and consistency of product quality. In this respect milling machines can be further classified as follows:

- **Hand mill (milling machine)** - this is the simplest form of milling machine where even the table feed is also given manually as can be seen in Fig.
Planer and rotary table type vertical axis milling machines are not that automated but provide relatively higher production rate.

Tracer controlled copy milling machine, typically shown in Fig, are mechanically or hydraulically operated semi-automatic milling machines used for lot production of cams, dies etc by copying the master piece.

Milling machines for short thread milling may be considered single purpose and automatic machine being used for mass production of small bolts and screws.
Fig. Tracer controlled milling machine

- **Computer Numerical Controlled (CNC) milling machine**
  Replacement of hard or rigid automation by Flexible automation by developing and using CNC has made a great break through since mid seventies in the field of machine tools’ control. The advantageous characteristics of CNC machine tools over conventional ones are:
  - flexibility in automation
  - change-over (product) time, effort and cost are much less
  - less or no jigs and fixtures are needed
  - complex geometry can be easily machined
  - high product quality and its consistency
  - optimum working condition is possible
  - lesser breakdown and maintenance requirement

Fig. typically shows a CNC milling machine. The versatility of CNC milling machine has been further enhanced by developing what is called Machining Centre. Fig.visualises one of such Machining Centres.
2. KINEMATIC SYSTEM OF MILLING MACHINE

The kinematic system comprising of a number of kinematic chains of several mechanisms enables transmission of motions (and power) from the motor to the cutting tool for its rotation at varying speeds and to the work-table for its slow feed motions along X, Y and Z directions. In some milling machines the vertical feed is given to the milling(cutter) head. The more versatile milling machines additionally possess the provisions of rotating the work table and tilting the vertical milling spindle about X and / or Y axes.

Fig. typically shows the kinematic diagram of the most common and widely used milling machine having rotation of the single horizontal spindle or arbour and three feed motions of the work-table in X, Y and Z directions.

1. The milling cutter mounted on the horizontal milling arbour, receives its rotary motion at different speeds from the main motor through the speed gear box which with the help of cluster gears splits the single speed into desirably large number(12, 16, 18, 24 etc) of spindle speeds. Power is transmitted to the speed gear box through Vee-belts and a safety clutch as shown in the diagram. For the feed motions of the workpiece (mounted on the work-table) independently, the cutter speed, rotation of the input shaft of the speed gear box is transmitted to the feed gear box through reduction (of speed) by worm and worm wheels as shown. The cluster gears in the feed gear box enables provide a number of feed rates desirably. The feeds of the job can be given both manually by rotating the respective wheels by hand as well as automatically by engaging the respective clutches. The directions of the longitudinal (X), cross (Y) and vertical (Z) feeds are controlled by appropriately shifting the clutches. The system is so designed that the longitudinal feed can be combined with the
cross feed or vertical feed but cross feed and vertical feed cannot be obtained simultaneously. This is done for safety purpose. A telescopic shaft with universal joints at its ends is incorporated to transmit feed motion from the fixed position of the feed gear box to the bed (and table) which moves up and down requiring change in length and orientation of the shaft. The diagram also depicts that a separate small motor is provided for quick traverse of the bed and table with the help of an over running clutch. During the slow working feeds the rotation is transmitted from the worm and worm wheel to the inner shaft through three equi-spaced rollers which get jammed into the tapering passage. During quick unworking work-traverse, the shaft is directly rotated by that motor on-line without stopping or slowing down the worm. Longer arbours can also be fitted, if needed, by stretching the over-arm. The base of the milling machine is grouted on the concrete floor or foundation.
3. SURFACE GRINDING MACHINES
This machine may be similar to a milling machine used mainly to grind flat surface. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel.
Basically there are four different types of surface grinding machines characterized by the movement of their tables and the orientation of grinding wheel spindles as follows:

- Horizontal spindle and reciprocating table
- Vertical spindle and reciprocating table
- Horizontal spindle and rotary table
- Vertical spindle and rotary table

1. Horizontal spindle reciprocating table grinder

Figure 1 illustrates this machine with various motions required for grinding action. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Fig.2.

![Fig.1: Horizontal spindle reciprocating table surface grinder](image)

![Fig.2: Surface grinding](image)
2 Vertical spindle reciprocating table grinder
This grinding machine with all working motions is shown in Fig.3. The grinding operation is similar to that of face milling on a vertical milling machine. In this machine a cup shaped wheel grinds the workpiece over its full width using end face of the wheel as shown in Fig. 4. This brings more grits in action at the same time and consequently a higher material removal rate may be attained than for grinding with a peripheral wheel.

![Diagram of Vertical Spindle Reciprocating Table Grinder](image)

**Fig.3** Vertical spindle reciprocating table surface grinder

**Fig.4** Surface grinding in Vertical spindle reciprocating table surface grinder

3 Horizontal spindle rotary table grinder
Surface grinding in this machine is shown in Fig5. In principle the operation is same as that for facing on the lathe. This machine has a limitation in accommodation of workpiece and therefore does not have wide spread use. However, by swivelling the worktable, concave or convex or tapered surface can be produced on individual part as illustrated in Fig.6
4 Vertical spindle rotary table grinder

The principle of grinding in this machine is shown in Fig 7. The machine is mostly suitable for small workpieces in large quantities. This primarily production type machine often uses two or more grinding heads thus enabling both roughing and finishing in one rotation of the work table.
5 Creep feed grinding machine:
This machine enables single pass grinding of a surface with a larger down feed but slower table speed than that adopted for multi-pass conventional surface grinding. This machine is characterized by high stiffness, high spindle power, recirculating ball screw drive for table movement and adequate supply of grinding fluid. A further development in this field is the creep feed grinding centre which carries more than one wheel with provision of automatic wheel changing. A number of operations can be performed on the workpiece. It is implied that such machines, in the view of their size and complexity, are automated through CNC.

6 High efficiency deep grinding machine:
The concept of single pass deep grinding at a table speed much higher than what is possible in a creep feed grinder has been technically realized in this machine. This has been made possible mainly through significant increase of wheel speed in this new generation grinding machine.

4. CYLINDRICAL GRINDING MACHINES
This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled. Broadly there are three different types of cylindrical grinding machine as follows:
   1. Plain centre type cylindrical grinder
   2. Universal cylindrical surface grinder
   3. Centreless cylindrical surface grinder

1 Plain centre type cylindrical grinder
Figure 29.8 illustrates schematically this machine and various motions required for grinding action. The machine is similar to a centre lathe in many respects. The workpiece is held between head stock and tailstock centres. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Fig.1
Universal cylindrical surface grinder
Universal cylindrical grinder is similar to a plain cylindrical one except that it is more versatile. In addition to small worktable swivel, this machine provides large swivel of head stock, wheel head slide and wheel head mount on the wheel head slide.
This allows grinding of any taper on the workpiece. Universal grinder is also equipped with an additional head for internal grinding. Schematic illustration of important features of this machine is shown in Fig.3.

3 Special application of cylindrical grinder
Principle of cylindrical grinding is being used for thread grinding with specially formed wheel that matches the thread profile. A single ribbed wheel or a multi ribbed wheel can be used as shown in Fig4.

Roll grinding is a specific case of cylindrical grinding wherein large workpieces such as shafts, spindles and rolls are ground.
Crankshaft or crank pin grinders also resemble cylindrical grinder but are engaged to grind crank pins which are eccentric from the centre line of the shaft as shown in Fig5. The eccentricity is obtained by the use of special chuck.
Cam and camshaft grinders are essentially subsets of cylindrical grinding machine dedicated to finish various profiles on disc cams and cam shafts. The desired contour on the workpiece is generated by varying the distance between wheel and workpiece axes. The cradle carrying the head stock and tail stock is provided with rocking motion derived from the rotation of a master cam that rotates in synchronization with the workpiece. Newer machines however, use CNC in place of master cam to generate cam on the workpiece.

4 External centreless grinder
This grinding machine is a production machine in which outside diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by means of a regulating wheel and ground by the grinding wheel. In through-feed centreless grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece. The regulating wheel is kept slightly inclined to the axis of the grinding wheel and the workpiece is fed longitudinally as shown in Fig.6.

![Fig6: Centreless through feed grinding](image)

Parts with variable diameter can be ground by Centreless infeed grinding as shown in Fig.6(a). The operation is similar to plunge grinding with cylindrical grinder. End feed grinding shown in Fig.6(b) is used for workpiece with tapered surface.
The grinding wheel or the regulating wheel or both require to be correctly profiled to get the required taper on the workpiece.

5 Tool post grinder
A self powered grinding wheel is mounted on the tool post or compound rest to provide the grinding action in a lathe. Rotation to the workpiece is provided by the lathe spindle. The lathe carriage is used to reciprocate the wheel head.
UNIT-IV

1. TYPES OF FITS
When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a fit. A fit may be defined as the degree of tightness and looseness between two mating parts.

The important terms related to the fit are given below:

**Clearance**
In a fit, this is the difference between the sizes of the hole and the shaft, before assembly, when this difference is positive. The clearance may be maximum clearance and minimum clearance. Minimum clearance in the fit is the difference between the maximum size of the hole and the minimum size of the shaft.

**Interference**
It is the difference between the sizes of the hole and the shaft before assembly, when the difference is negative. The interference may be maximum or minimum. Maximum interference is arithmetical difference between the minimum size of the hole and the maximum size of the shaft before assembly. Minimum interference is the difference between the maximum size of the hole and the minimum size of the shaft.

**Transition**
It is between clearance and interference, where the tolerance zones of the holes and shaft overlap.

So, you can see that fits depend upon the actual limits of the hole and or shaft and can be divided into three general classes:

(i) Clearance Fit.

(ii) Interference Fit.

(iii) Transition Fit.

1 Clearance Fit
In clearance fit, an air space or clearance exists between the shaft and hole as shown in Figure 1. Such fits give loose joint. A clearance fit has positive allowance, i.e. there is minimum positive clearance between high limit of the shaft and low limit of the hole.

![Figure 1: Clearance Fit](image-url)

Clearance fit can be sub-classified as follows:

**Loose Fit**
It is used between those mating parts where no precision is required. It provides minimum allowance and is used on loose pulleys, agricultural machineries etc.

**Running Fit**
For a running fit, the dimension of shaft should be smaller enough to maintain a film of oil for lubrication. It is used in bearing pair etc. An allowance 0.025 mm per 25 mm of diameter of boaring may be used.

**Slide Fit or Medium Fit**
It is used on those mating parts where great precision is required. It provides medium allowance and is used in tool slides, slide valve, automobile parts, etc.

**2 Interference Fit**
A negative difference between diameter of the hole and the shaft is called interference. In such cases, the diameter of the shaft is always larger than the hole diameter. In Figure 2. Interference fit has a negative allowance, i.e. interference exists between the high limit of hole and low limit of the shaft.

![Figure 2: Interference Fit](image)

In such a fit, the tolerance zone of the hole is always below that of the shaft. The shaft is assembled by pressure or heat expansion.

The interference fit can be sub-classified as follows:

**Shrink Fit or Heavy Force Fit**
It refers to maximum negative allowance. In assembly of the hole and the shaft, the hole is expanded by heating and then rapidly cooled in its position. It is used in fitting of rims etc.

**Medium Force Fit**
These fits have medium negative allowance. Considerable pressure is required to assemble the hole and the shaft. It is used in car wheels, armature of dynamos etc.

**Tight Fit or Press Fit**
One part can be assembled into the other with a hand hammer or by light pressure. A slight negative allowance exists between two mating parts (more than wringing fit). It gives a semi-permanent fit and is used on a keyed pulley and shaft, rocker arm, etc.

**3 Transition Fit**
It may result in either clearance fit or interference fit depending on the actual value of the individual tolerances of the mating components. Transition fits are a compromise between
clearance and interference fits. They are used for applications where accurate location is important but either a small amount of clearance or interference is permissible. As shown in Figure 3, there is overlapping of tolerance zones of the hole and shaft.

Figure 3: Transition Fit

Transition fit can be sub-classified as follows:

**Push Fit**
It refers to zero allowance and a light pressure (10 cating dowels, pins, etc.) is required in assembling the hole and the shaft. The moving parts show least vibration with this type of fit. It is also known as **snug fit**.

**Force Fit or Shrink Fit**
A force fit is used when the two mating parts are to be rigidly fixed so that one cannot move without the other. It either requires high pressure to force the shaft into the hole or the hole to be expanded by heating. It is used in railway wheels, etc.

**Wringing Fit**
A slight negative allowance exists between two mating parts in wringing fit. It requires pressure to force the shaft into the hole and gives a light assembly. It is used in fixing keys, pins, etc.

2. **SYSTEMS OF TOLERANCES**
The permissible variation in size or dimension is tolerance. Thus, the word tolerance indicates that a worker is not expected to produce the part of the exact size, but definite a small size error is permitted. The difference between the upper limit (high limit) and the lower limit of a dimension represents the margin for variation to workmanship, and is called a tolerance zone (Figure 1). Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service.

There are two ways of writing tolerances

(a) Unilateral tolerance
(b) Bilateral tolerance.
1 Unilateral Tolerance

In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it (Figure 2).

![Figure 1: Tolerance](image1)

**Figure 1: Tolerance**

**Examples of unilateral tolerance are:**

25\(+0.02\), 25\(-0.01\), 25\(-0.02\), 25\(+0.01\), 25\(+0.02\) etc.

Unilateral system is preferred in interchangeable manufacture, especially when precision fits are required, because

(a) it is easy and simple to determine deviations,

(b) another advantage of this system is that „Go” Gauge ends can be standardized as the holes of different tolerance grades have the same lower limit and all the shafts have same upper limit, and

(c) this form of tolerance greatly assists the operator, when machining of mating parts. The operator machines to the upper limit of shaft (lower limit for hole) knowing fully well that he still has some margin left for machining before the parts are rejected.

2 Bilateral Tolerance

In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size, but may not be necessarily equally dispose about it (Figure 3).

![Figure 2: Unilateral Tolerance](image2)
In this system, it is not possible to retain the same fit when tolerance is varied and the basic size of one or both of the mating parts are to be varied. This system is used in mass production when machine setting is done for the basic size.

3. CLASSIFICATION OF THE GAUGES
Gauges are the tools which are used for checking the size, shape and relative positions of various parts but not provided with graduated adjustable members. Gauges are, therefore, understood to be single-size fixed-type measuring tools.

Classifications of Gauges
(a) Based on the standard and limit
   (i) Standard gauges
   (ii) Limit gauges or “go” and “not go” gauges

(b) Based on the consistency in manufacturing and inspection
   (i) Working gauges
   (ii) Inspection gauges
   (iii) Reference or master gauges

(c) Depending on the elements to be checked
   (i) Gauges for checking holes
   (ii) Gauges for checking shafts
   (iii) Gauges for checking tapers
   (iv) Gauges for checking threads

(v) Gauges for checking forms

(d) According to the shape or purpose for which each is used
   (i) Plug
   (ii) Ring
   (iii) Snap
   (iv) Taper
(v) Thread
(vi) Form
(vii) Thickness
(viii) Indicating
(ix) Air-operated

1 Standard Gauges
Standard gauges are made to the nominal size of the part to be tested and have the measuring member equal in size to the mean permissible dimension of the part to be checked. A standard gauge should mate with some snugness.

2 Limit Gauges
These are also called „go” and „no go” gauges. These are made to the limit sizes of the work to be measured. One of the sides or ends of the gauge is made to correspond to maximum and the other end to the minimum permissible size. The function of limit gauges is to determine whether the actual dimensions of the work are within or outside the specified limits. A limit gauge may be either double end or progressive. A double end gauge has the „go” member at one end and „no go” member at the other end. The „go” member must pass into or over an acceptable piece but the „no go” member should not. The progressive gauge has „no go” members next to each other and is applied to a workpiece with one movement. Some gauges are fixed for only one set of limits and are said to be solid gauges. Others are adjustable for various ranges.

4. TYPES OF GAUGES COMMONLY USED IN PRODUCTION WORK
Some of the important gauges which are commonly used in production work have been discussed as follows:

1 Plug Gauges
These gauges are used for checking holes of many different shapes and sizes. There are plug gauges for straight cylindrical holes, tapered, threaded square and splined holes. Figure 1 shows a standard plug gauge used to test the nominal size of a cylindrical hole. Figure 2 shows a double-ended limit plug gauge used to test the limits of size. At one end, it has a plug minimum limit size, the „go” end and; at the other end a plug of maximum limit, the „no go” end. These ends are detachable from the handle so that they may be renewed separately when worn in a progressive limit plug gauge. The „go” and „no go” section of the gauge are on the same end of the handle. Large holes are gauged with annular plug gauges, which are shell-constructed for light weight, and flat plug gauges, made in the form of diametrical sections of cylinders.
2 Ring Gauges
Ring gauges are used to test external diameters. They allow shafts to be checked more accurately since they embrace the whole of their surface. Ring gauges, however, are expensive to manufacture and, therefore, find limited use. Moreover, ring gauges are not suitable for measuring journals in the middle sections of shafts. A common type of standard ring gauge is shown in Figure 1. In a limit ring gauge, the “go” and “no go” ends are identified by an annular groove on the periphery. About 35 mm all gauges are flanged to reduce weight and facilitate handling.

3 Taper Gauges
The most satisfactory method of testing a taper is to use taper gauges. They are also used to gauge the diameter of the taper at some point. Taper gauges are made in both the plug and ring styles and, in general, follow the same standard construction as plug and ring gauges. A taper plug and ring gauge is shown in Figure 3.

When checking a taper hole, the taper plug gauge is inserted into the hole and a slight pressure is exerted against it. If it does not rock in the hole, it indicates that the taper angle is correct. The same procedure is followed in a ring gauge for testing tapered spindle. The taper diameter is tested for the size by noting how far the gauge enters the tapered hole or the tapered spindle enters the gauge. A mark on the gauge shows the correct diameter for the large end of the taper. To test the correctness of the taper two or three chalk or pencil lines are drawn on the gauge about equidistant along a generatrix of the cone. Then the gauge is inserted into the hole and slightly turned. If the lines do not rub off evenly, the taper is incorrect and the setting in the machine must
be adjusted until the lines are rubbed equally all along its length. Instead of making lines on the
gauge, a thin coat of paint (red led, carbon black, Purssian blue, etc.) can be applied.
The accuracy of a taper hole is tested by a taper limit gauge as shown in Figure 4. This has two
check lines „go” and „no go” each at a certain distance from the end of the face. The go portion
corresponds to the minimum and „no go” to the maximum dimension.

![Figure 4: Limit Taper Plug Gauge](image)

4 Snap Gauges
These gauges are used for checking external dimensions. Shafts are mainly checked by snap
gauges. They may be solid and progressive or adjustable or double-ended. The most usual types are
shown in Figure 5.

![Figure 5: Snap Gauges](image)

(a) Solid or non-adjustable caliper or snap gauge with „go” and „no go” each is used for large sizes.
(b) Adjustable caliper or snap gauge used for larger sizes.
This is made with two fixed anvils and two adjustable anvils, one for „go” and another for the „no
go”.
The housing of these gauges has two recesses to receive measuring anvils secured with two screws.
The anvils are set for a specific size, within an available range of adjustment of 3 to 8 mm. The
adjustable gauges can be used for measuring series of shafts of different sizes provided the
diameters are within the available range of the gauge.
(iii) Double-ended solid snap gauge with „go” and „no go” ends is used for smaller sizes.
5 Thread Gauges
Thread gauges are used to check the pitch diameter of the thread. For checking internal threads
(nut, bushes, etc.), plug thread gauges are used, while for checking external threads (screws, bolts,
etc.), ring thread gauges are used. Single-piece thread gauges serve for measuring small diameters.
For large diameters the gauges are made with removable plugs machined with a tang. Standard gauges are made single-piece. Common types of thread gauges are shown in Figure 6.

![Figure 6: Thread Gauge](image)

Standard plug gauges may be made of various kinds:
(a) Plug gauge with only threaded portion.
(b) Threaded portion on one end and plain cylindrical plug on opposite end to give correct “core” diameter.
(c) Thread gauge with core and full diameters.

Limit plug gauges have a long-threaded section on the “go” and a short-threaded section on the “no go” end to correspond to the minimum and maximum limits respectively. Roller rings gauges, similarly have “go” and “no go” ends. They may also be solid and adjustable. Roller Snap gauges are often used in production practice for measuring external threads. They comprise a body, two pairs “go” rollers and two pairs “no go” rollers. Taper thread gauges are used for checking taper threads. The taper-ring thread gauge are made in two varieties – rigid (non-adjustable) and adjustable. The “go” non-adjustable ring gauges are full threaded while the “no go” have truncated thread profile.

6 Form Gauges
Form gauges may be used to check the contour of a profile of workpiece for conformance to certain shape or form specifications.

Template Gauge
It is made from sheet steel. It is also called profile gauge. A profile gauge may contain two outlines that represent the limits within which a profile must lie as shown in Figure 7.

![Figure 7: A Template Gauge](image)

7 Screw Pitch Gauges
Screw pitch gauges serve as an everyday tool used in picking out a required screw and for checking the pitch of the screw threads. They consist of a number of flat blades which are cut out to a given pitch and pivoted in a holder as shown in Figure 8. Each blade is stamped with the pitch or number of thread per inch and the holder bears an identifying number designating the thread it is intended for. The sets are made for metric threads with an angle 60°, for English threads with an angle of 55°. A set for measuring metric threads with 30 blades has pitches from 0.4 to 0.6 mm and for English threads with 16 blades has 4 to 28 threads per inch. In checking a thread for its pitch the closest corresponding gauge blade is selected and applied upon the thread to be tested. Several blades may have to be tried until the correct is found.

8 Radius and Fillet Gauges
The function of these gauges is to check the radius of curvature of convex and concave surfaces over a range from 1 to 25 mm. The gauges are made in sets of thin plates curved to different radius at the ends as shown in Figure 9. Each set consists of 16 convex and 16 concave blades.

9 Feller Gauges
Feller gauges are used for checking clearances between mating surfaces. They are made in form of a set of steel, precision machined blade 0.03 to 1.0 mm thick and 100 mm long. The blades are provided in a holder as shown in Figure 10. Each blade has an indication of its thickness. The Indian standard establishes seven sets of feller gauges : Nos 1, 2, 3, 4, 5, 6, 7, which differ by the number of blades in them and by the range of thickness. Thin blades differ in thickness by 0.01 mm in the 0.03 to 1 mm set, and by 0.05 mm in the 0.1 to 1.0 mm set. To find the size of the clearance, one or two blades are inserted and tried for a fit between the contacting surfaces until blades of suitable thickness are found.
10 Plate and Wire Gauges
The thickness of a sheet metal is checked by means of plate gauges and wire diameters by wire gauges. The plate gauge is shown in Figure 11. It is used to check the thickness of plates from 0.25 to 5.0 mm, and the wire gauge, in Figure 12, is used to check the diameters of wire from 0.1 to 10 mm.

11 Indicating Gauges
Indicating gauges employ a means to magnify how much a dimension deviates, plus or minus, from a given standard to which the gauge has been set. They are intended for measuring errors in geometrical form and size, and for testing surfaces for their true position with respect to one another. Beside this, indicating gauges can be adapted for checking the run out of toothed wheels, pulleys, spindles and various other revolving parts of machines. Indicating gauges can be of a dial or lever type, the former being the most widely used.

12 Air Gauges
Pneumatic or air gauges are used primarily to determine the inside characteristics of a hole by means of compressed air. There are two types of air gauges according to operation: a flow type and a pressure type gauge. The flow type operates on the principle of varying air velocities at constant pressure and the pressure type operates on the principle of air escaping through an orifice.
UNIT-V
1. DIFFERENT ELEMENTS OF SURFACE TEXTURE
The various elements of surface texture can be defined and explained with the help of fig which shows a typical surface highly magnified.

Surface: The surface of a part is confined by the boundary which separates that part from another part, substance or space. Actual surface. This refers to the surface of a part which is actually obtained after a manufacture ring process.
Nominal surface: A nominal surface is a theoretical, geometrically perfect surface which does not exist in practice, but it is an average of the irregularities that are superimposed on it.
Profile: Profile is defined as the contour of any section through a surface. Roughness. As already explained roughness refers to relatively finely spaced micro geometrical irregularities. It is also called as primary texture and constitutes third and fourth order irregularities.
Roughness Height: This is rated as the arithmetical average deviation expressed in micro-meters normal to an imaginary centre line, running through the roughness profile.
Roughness Width: Roughness width is the distance parallel to the normal surface between successive peaks or ridges that constitutes the predominant pattern of the roughness.
Roughness Width cutoff: This is the maximum width of surface irregularities that is included in the measurement of roughness height. This is always greater than roughness width and is rated in centimetres.
Waviness: Waviness consists of those surface irregularities which are of greater spacing than roughness and it occurs in the form of waves. These are also termed as moon geometrical errors and constitute irregularities of first and second order. These are caused due to misalignment of centres, vibrations, machine or work deflections, warping etc.
Effective profile: It is the real center of a surface obtained by using instrument
Laws: Flaws are surface irregularities or imperfections which occur art infrequent intervals and at random intervals. Examples are: scratches, holes, cracks, porosity etc. These may be observed
directly with the aid of penetrating dye or other material which makes them visible for examination and evaluation.

**Surface Texture:** Repetitive or random deviations from the nominal. Surface which forms the pattern on the surface. Surface texture includes roughness, waviness, lays and flaws.

**Lay:** It is the direction of predominant surface pattern produced by tool marks or scratches. It is determined by the method of production used. Symbols used to indicate the direction of lay are given below:

- \[ \parallel \] = Lay parallel to the boundary line of the nominal surface that is, lay parallel to the line representing surface to which the symbol is applied e.g., parallel shaping, end view of turning and O.D grinding.
- \[ \perp \] = Lay perpendicular to the boundary line of the nominal surface, that is lay perpendicular to the line representing surface to which the symbol is applied, e.g., end view of shaping, longitudinal view of turning and O.D. grinding.
- \[ \times \] = Lay angular in both directions to the line representing the surface to which symbol is applied, e.g. traversed end mill, side wheel grinding.
- \[ \circ \] = Lay multidirectional e.g. lapping super finishing, honing.
- \[ \rightarrow \] = Lay approximately circular relative to the centre of the surface to which the symbol is applied e.g., facing on a lathe.
- \[ \rightarrow \] = Lay approximately radial relative to the centre of the surface to which the symbol is applied, e.g., surface ground on a turntable, fly cut and indexed on end mill.

**Sampling length:** It is the length of the profile necessary for the evaluation of the irregularities to be taken into account. It is also known as cut-off length. It is measured in a direction parallelogram general direction of the profile. The sampling length should bear some relation to the type of profile.

2. **EVALUATION OF SURFACE FINISH**

A numerical assessment of surface finish can be carried out in a number of ways. These numerical values are obtained with respect to a datum. In practice, the following three methods of evaluating primary texture (roughness) of a surface are used:
(1) Peak to valley height method
(2) The average roughness
(3) Form factor or bearing curve.

(1) **Peak to valley height method:**
This method is largely used in Germany and Russia. It measures the maximum depth of the surface irregularities over a given sample length, and largest value of the depth is accepted as a measure of roughness. The drawback of this method is that it may read the same \( h_{max} \) for two largely different texture. The value obtained would not give a representative assessment of the surface.

![Peak to Valley height](image)

To, overcomes this PV (Peak to Valley) height is defined as the distance between a pair of lines running parallel to the general ‘lay’ of the trace positioned so that the length lying within the peaks at, the top is 5% of the trace length, and that within the valleys at the bottom is 10% of the trace length. This is represented graphically in Fig.

(2) **The average roughness:** For assessment off average roughness the following three statistical criteria are used:
(a) **C.L.A Method:** In this method, the surface roughness is measured as the average deviation from the nominal surface.

![C.L.A](image)

Centre Line Average or Arithmetic Average is defined as the average values of the ordinates from the mean line, regardless of the arithmetic signs of the ordinates

\[
C.L.A \text{ Value} = \frac{h_1 + h_2 + h_3 + \ldots + h_n}{n} \quad \ldots(i)
\]

Also

\[
C.L.A. = \frac{A_1 + A_2 + A_3 + \ldots + A_n}{L} = \frac{\Sigma A}{L} \quad \ldots(ii)
\]
The calculation of C.L.A value using equation (ii) is facilitated by the planimeter. CLA value measure is preferred to RMS value measure because its value can be easily determined by measuring. The areas with planimeter or graph or can be readily determined in electrical instruments by integrating the movement of the styles and displaying the result as an average.

(b) R.M.S. Method: In this method also, the roughness is measured as the average deviation from the nominal surface. Root mean square value measured is based on the least squares.

R.M.S value is defined as the square root of the arithmetic mean of the values of the squares of the ordinates of the surface measured from a mean line. It is obtained by setting many equidistant ordinates on the mean line (y1, y2, y3, ... ) and then taking the root of the mean of the squared ordinates.

Let us assume that the sample length ‘L’ is divided into ‘n’ equal parts and y1, y2, y3, ... are the heights of the ordinates erected at those points.

Then,

\[
\text{RMS average} = \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + ... + y_n^2}{n}}
\]

\[
y_{rms} = \left( \frac{1}{L} \int_0^L y^2 \, dL \right)^{1/2}
\]

(c) Ten Point Height Method: In this method, the average difference between the five highest peaks and five lowest valleys of surface texture within the sampling length, measured from a line parallel to the mean line and not crossing the profile is used to denote the amount of surface roughness.

Mathematically,

\[
R_2 = \text{ten point height of irregularities}
\]

\[
= \frac{1}{5} \left[ (R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10}) \right]
\]

This method is relatively simple method of analysis and measures the total depth of surface irregularities within the sampling length. But it does not give sufficient information about the surface, as no account is taken of frequency of the irregularities and the profile shape. It is used when it is desired to control the cost of finishing for checking the rough machining.
(3) Form factor and Bearing Curves: There are certain characteristics which may be used to evaluate surface texture.

**Form Factor:** The load carrying area of every surface is often much less than might be thought. This is shown by reference to form factor. The form factor is obtained by measuring the area of material above the arbitrarily chosen base line in the section and the area of the enveloping rectangle. Then,

\[
\text{Degree of fullness (K)} = \frac{\text{Area of metal}}{\text{Area of enveloping rectangle}}
\]

\[
\text{Degree of emptiness} = (K_p) = 1 - K
\]

**Bearing Area Curve:** The bearing area curve is also called as Abbot's bearing curve. This is determined by adding the lengths a, b, c etc. at depths x, y, z etc. below the reference line and indicates the percentage bearing area which becomes available as the crest area worn away. Fig. indicates the method of determining the bearing curve.

3. MEASUREMENT OF SURFACE FINISH SURFACES TEXTURE:

The methods used for ensuring the surface finish can be classified broadly into two groups.

1. Inspection by comparison.
2. Direct instrument measurement

**1. Inspection by comparison methods.** In these methods, the surface texture is assessed by observation of the surface. These are the methods of qualitative analysis of the surface texture. The texture, e of the surface W be tested is compared with that of a specimen of known roughness value and \`finished by similar machining processes. Though these methods are rapid, the results are not reliable because they can be misleading if comparison is not made with\`the surface produced by similar techniques. The various methods available for comparison are:

(i) Visual Inspection
(ii) Touch Inspection
(iii) Scratch Inspection
(iv) Microscopic Inspection
(v) Surface photographs
(vi) Micro-Interferometer
(vii) Wallace surface Dynamometer
(viii) Reflected Light Intensity.

(i) Visual Inspection: In this method the surface is inspected by naked eye. This method is always likely to be misleading particularly when surfaces with high degree of finish are inspected. It is therefore limited to rougher surfaces.

(ii) Touch Inspection: This method can simply assess which surface is more rough, it cannot give the degree of surface roughness. Secondly, the minute flaws can't be detected. In this method, the finger tip is moved along the surface at a speed of about 25 mm per second and the irregularities as small as 0.0125 mm can be detected. In modified method a tennis ball is rubbed over the surface and surface roughness is judged thereby.

(iii) Scratch Inspection: In this method a softer material like lead, babbit, or plastic is rubbed over the surface to be inspected. The impression of the scratches on the surface produced is then visualized.

(iv) Microscopic Inspection: This is probably the best method for examining the surface texture by comparison. But since, only a small surface can be inspected at a time several readings are required to get an average value. In this method, a master finished surface is placed under the microscope and compared with the surface under inspection. Alternatively, a straight edge is placed on the surface to be inspected and a beam of light projected at about 600 to the work. Thus the shadow is cast into the surface, the scratches are magnified and the surface irregularities can be studied.

(v) Surface photographs: In this method magnified photographs of the surface are taken with different types of illumination to reveal the irregularities.

If the vertical illumination is used then defects like irregularities and scratches appear as dark spots and flat portion of the surface appears as bright area. In case of 'oblique illumination, reverse is the case. Photographs with different illumination are compared and the result is assessed.

(vi) Micro Interferometer: In this method, an optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light. Interference bands are studied through a microscope. The scratches in the surface appear as interference lines extending from the dark bands into the bright bands. The depth of the defect is measured in terms of the fraction of the interference bands.

(vii) Wallace Surface Dynamometer: It is a sort of friction meter. It consists of a pendulum in which the testing shoes are damped to a bearing surface and a predetermined spring pressure can be applied. The pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested. If the surface is smooth, then there will be less friction and pendulum swings for a longer period. Thus, the time of swing is a direct measure of surface texture.

(viii) Reflected Light Intensity: In this method a beam of light of known quantity is projected upon the surface. This light is reflected in several directions as beams of lesser intensity and the change in light intensity in different directions is measured by a photocell. The measured intensity changes
are already calibrated by means of reading taken from surface of known roughness by some other suitable method.

2. Direct Instrument Measurement:
These are the methods of quantitative analysis. These methods enable to determine the numerical value of the surface finish of any surface by using instruments of stylus probe type operating on electrical principles. In these instruments the output has to be amplified and the amplified output is used to operate recording or indicating instrument.

Principle, constructive and operation of stylus Probe type surface texture measuring instruments:
If a finely pointed Probe or stylus be moved over the surface of a work piece, the vertical movement of the stylus caused due to the irregularities in the surface texture can be used to assess the surface finish of the work piece.

Stylus which is a fine point made of diamond or any such hard material is drawn over the surface to be tested. The movements of the stylus are used to modulate a high frequency carrier current or to generate a voltage signal. The output is then amplified by suitable means and used to operate a recording or indicating instrument.

Stylus type instruments generally consist of the following units:
(i) Skid or shoe
(ii) Finely pointed stylus or probe
(iii) An amplifying device for magnifying the stylus movement and indicator
(iv) Recording device to produce a trace and ~
(v) Means for analyzing the trace.

Advantages:
The main advantage of such instruments is that the electrical signal available can be processed to obtain any desired roughness parameter or can be recorded for display or subsequent analysis. Therefore, the stylus type instruments are widely used for surface texture measurements inspite of the following disadvantages.

Disadvantages:
(i) These instruments are bulky and complex.
(ii) They are relatively fragile.
(iii) Initial cost is high.
(iv) Measurements are limited to a section of a surface.
(v) Needs skilled operators for measurements.
(vi) Distance between stylus and skid and the shape of the skid introduce errors in measurement for wavy surfaces.

The stylus probe instruments currently in use for surface finish measurement.
(a) Profilometer
(b) The Tomlinson surface meter.
(c) The Taylor Hobson Talysurf
(d) Profilograph.

(b) Profilometer:

Profilometer is an indicating and recording instrument used to measure roughness in microns. The principle of the instrument is similar to gramophone pick up. It consists of two principal units: a tracer and an amplifier. Tracer is a finely pointed stylus. It is mounted in the pick up unit which consists of an induction coil located in the field of a permanent magnet. When the tracer is moved across the surface to be tested, it is displaced vertically up and down due to the surface irregularities. This causes the induction coil to move in the field of the permanent magnet and induces a voltage. The induced voltage is amplified and recorded.

This instrument is best suited for measuring surface finish of deep bores.

(b) The Tomlinson surface meter:
The Tomlinson surface meter is a comparatively cheap and reliable instrument. It was originally designed by Dr. Tomlinson.
It consists of a diamond probe (stylus) held by spring pressure against the surface of a lapped steel cylinder and is attached to the body of the instrument by a leaf spring. The lapped cylinder is supported on one side by the probe and on the either side by fixed rollers. A light spring steel arm is attached to the lapped cylinder. It carries at its tip a diamond scriber which rests against a smoked glass. The motions of the stylus in all the directions except the vertical one are prevented by the forces exerted by the two springs.

For measuring surface finish the body of the instrument is moved across the surface by screw rotated by asynchronous motor. The vertical movement of the probe caused by surface irregularities makes the horizontal lapped cylinder to roll. This causes the movement of the arm attached to the lapped cylinder. A magnified vertical movement of the diamond scriber on smoked glass is obtained by the movement of the arm. This vertical movement of the scriber together with horizontal movement produces a trace on the smoked glass plate. This trace is further magnified at X 50 or X 100 by an optical projector for examination.

(c) The Taylor Hobson Talysurf:
Taylor-Hobson Talysurf is a stylus and skid type of instrument working on carrier modulating principle. Its response is more rapid and accurate as compared to Tomlinson Surface Meter. The measuring head of this instrument consists of a sharply pointed diamond stylus of about 0.002 mm tip radius and skid or shoe which is drawn across the surface by means of a motorized driving unit. In this instrument the stylus is made to trace the profile of the surface irregularities, and the oscillatory movement of the stylus is converted into changes in electric current by the arrangement as shown in Fig.
The arm carrying the stylus forms an armature which pivots about the centre piece of E-shaped stamping. On two legs of (outer pole pieces) the E-shaped stamping there are coils carrying an a.c. current. These two coils with other two resistances form an oscillator. As the armature is pivoted about the central leg, any movement of the stylus causes the air gap to vary and thus the amplitude of the original a.c. current flowing in the coils is modulated. The output of the bridge thus consists of modulation only as shown in Fig. This is further demodulated so that the current now is directly proportional to the vertical displacement of the stylus only.

(d) Profilograph:

(i) Profilograph: The principle of Working of a tracer type profilograph is shown in Fig. The work to be tested is placed on the table of the instrument. The work and the table are traversed with the help of a lead screw.

The stylus which is pivoted to a mirror moves over the tested surface. Oscillations of the tracer point are transmitted to the mirror. A light source sends a beam of light through lens and a precision slit to the oscillating mirror. The reflected beam is directed to a revolving drum, upon which a sensitised film is arranged. This drum is rotated through two bevel gears from the same lead screw that moves the table of the instrument. A profilogram will be obtained from the sensitised film that may be sub-sequently analysed to determine the value of the surface roughness.
4. DIFFERENT ORDERS OF GEOMETRICAL IRREGULARITIES

As we know that the material machined by chip removal process can't be finished perfectly due to some departures from ideal conditions as specified by the designer. Due to conditions not being ideal, the surface produced will have some irregularities; these geometrical irregularities can be classified into four categories.

First Order: The irregularities caused by inaccuracies in the machine tool itself are called as first order irregularities. These include:
1. Irregularities caused due to lack of straightness of guide ways on which the tool most moves.
2. Surface regularities arising due to deformation of work under the action of cutting forces, and
3. Due to the weight of the material itself.

Second Order: The irregularities caused due to vibrations of any kind are called second order irregularities.

Third Order: Even if the machine were perfect and completely free from vibrations some irregularities are caused by machining itself due to the characteristics of the process.

Fourth Order: The fourth order irregularities include those arising from the rupture of the material during the separation of the chip.

Irregularities on the surface of the part:

The irregularities on the surface of the part produced can also be grouped into two categories:
(i) Roughness or primary texture, (ii) Waviness or secondary texture.

i) Roughness (Primary texture):
The surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting element on the material i.e., cutting tool shape, tool feed rate or by some other disturbances such as friction, wear or corrosion.
These include irregularities of third and fourth order and constitute the micro-geometrical errors. The ratio \( l_r / h_r \) denoting the micro-errors is less than 50, where \( l_r = \) length along the surface and \( h_r = \) deviation of surface from the ideal one.

**ii) Waviness (Secondary texture):**
The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centres, non-linear feed motion, deformation of work under the action of cutting forces, vibrations of any kind etc.

These errors include irregularities of first and second order and constitute the macro-geometrical errors. The ratio of \( l_w / h_w \) denoting the macro-errors is more than 50. Where, \( l_w = \) length along the surface and \( h_w = \) deviation of surface from ideal one.
UNIT-I

Two marks questions with answers

1. What is metal cutting?
Metal cutting: The process in which a thin layer of excess metal (chip) is removed by a wedge-shaped single-point or multipoint cutting tool with defined geometry from a work piece, through a process of extensive plastic deformation.

2. Define Machine Tool?
Machine Tool - definition: A machine tool is a non-portable power operated and reasonably valued device or system of devices in which energy is expended to produce jobs of desired size, shape and surface finish by removing excess material from the preformed blanks in the form of chips with the help of cutting tools moved past the work surface(s).

3. What is Machining?
Definition of Machining: Machining is an essential process of finishing by which jobs are produced to the desired dimensions and surface finish by gradually removing the excess material from the preformed blank in the form of chips with the help of cutting tool(s) moved past the work surface(s).

4. Classify Machine tools?
Machine Tools classification.
1. Machine Tools for Cylindrical work: Work piece is rotated about an axis, (or) alternatively the work may be at rest and the tool is rotated as well as traversed.
Ex: Lathe, Boring Machines, Cylindrical Surface Grinding machines..Etc
2. Machine Tools for Flat surface work:
Ex: Planning, Shaping, Slotting..Etc

5. What are the effects of BUE formation?

Effects of BUE formation:
Formation of BUE causes several harmful effects, such as:

- It unfavorably changes the rake angle at the tool tip causing increase in cutting forces and power consumption.
- Repeated formation and dislodgement of the BUE causes fluctuation in cutting forces and thus induces vibration which is harmful for the tool, job and the machine tool.
- Surface finish gets deteriorated.
- May reduce tool life by accelerating tool-wear at its rake surface by adhesion and flaking occasionally, formation of thin flat type stable BUE may reduce tool wear at the rake face.

Three marks questions with answers

1. Explain briefly mechanics of chip formation.

Machining is a semi-finishing or finishing process essentially done to impart required or stipulated dimensional and form accuracy and surface finish to enable the product to
- fulfill its basic functional requirements
- provide better or improved performance
- render long service life.

Machining is a process of gradual removal of excess material from the preformed blanks in the form of chips.

The form of the chips is an important index of machining because it directly or indirectly indicates:

- Nature and behavior of the work material under machining condition
- Specific energy requirement (amount of energy required to remove unit volume of work material) in machining work
• Nature and degree of interaction at the chip-tool interfaces. The form of machined chips depends mainly upon:
  • Work material
  • Material and geometry of the cutting tool
  • Levels of cutting velocity and feed and also to some extent on depth of cut
  • Machining environment or cutting fluid that affects temperature and friction at the chip-tool and work-tool interfaces. Knowledge of basic mechanism(s) of chip formation helps to understand the characteristics of chips and to attain favorable chip forms.

2. Explain the geometry of single point tool
Geometry of single point turning tools Both material and geometry of the cutting tools play very important roles on their performances in achieving effectiveness, efficiency and overall economy of machining. Cutting tools may be classified according to the number of major cutting edges (points) involved as follows:
  • Single point: e.g., turning tools, shaping, planning and slotting tools and boring tools
  • Double (two) point: e.g., drills • Multipoint (more than two): e.g., milling cutters, broaching tools, hobs, gear shaping cutters etc.

3. Describe basic elements of machining.
Basic elements of Machining: The basic elements of machining are work piece, tool and chip. For any cutting action, it is necessary to have relative motion between tool and work piece. Unwanted material is removed from work piece by the cutting action of the tool. The type of chips formed is greatly affected by the work piece material, geometry of cutting tool and method of cutting. The chip formed can be continuous, discontinuous or segmental and continuous chips with built up edge. Ductile material, High cutting speeds and large rake angle produce continuous chips. Mild steel and copper are considered most desirable metals for producing continuous chips. Brittle material (cast iron and bronze), low cutting speeds and small rake angles are the main reasons for producing discontinuous chips. Continuous chips with built up edge are mainly produced due to high local temperature, high pressure while cutting ductile material.

4. Explain ideal properties of cutting tool materials
Basic properties that cutting must possess are:
  • Tool material must be at least 30 to 50% harder than the work piece material.
Tool material must have high hot hardness temperature. 
- High toughness 
- High wear resistance 
- High thermal conductivity 
- Lower coefficient of friction 
- Easiness in fabrication and cheap 

Different elements used in cutting tool materials and their properties are:

<table>
<thead>
<tr>
<th>Element</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten</td>
<td>Increases hot hardness, Hard carbides formed, Abrasion resistance</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Increases hot hardness, Hard carbides formed, Improving resistance</td>
</tr>
<tr>
<td>Chromium</td>
<td>Depth hardenability during heat treat, hard carbides are formed, Improving abrasion resistance, some corrosion resistance</td>
</tr>
<tr>
<td>Vanadium</td>
<td>combines with carbon for wear resistance, retards grain growth for better toughness</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Increases hot hardness, toughness</td>
</tr>
<tr>
<td>Carbon</td>
<td>Hardening element forms carbides</td>
</tr>
</tbody>
</table>

Different cutting tool materials used for cutting operations in practice are high carbon steel, high speed steel, non-ferrous cast alloys, cemented carbides, ceramics and sintered oxides, ceremets, diamond, cubic boron nitride, UCON and sialon.

5. Draw a neat sketch of Lathe and mention different parts on it.
Fig: Lathe

**Principle parts of a lathe:**

Lathe major parts are

1. Bed
2. Headstock
3. Tail stock.
5. Feed mechanism.

**Five marks questions with answers**

1. What is the Need and purpose of chip-breaking?

Need and purpose of chip-breaking

- The chips produced during machining, specially while employing higher speeds in machining of high tensile strength materials need to be effectively controlled.
- This requirement is more pronounced if carbide tipped tools are being used for machining, because in that case higher speeds will be used and, therefore, due to high temperatures the resulting chip will be continuous, of blue colour and take the shape of a coil.
- Such a chip, if not broken into parts and removed from the surroundings of the metal cutting area, is likely to adversely effect the machining results in one or more of the following ways:
  - It may adversely effect the tool life by spoiling the cutting edge, creating crater and raising temperature.
  - Its presence may lead to a poor surface finish on the work piece.
If the chip gets curled around the rotating work piece and/or the cutting tool, it may be hazardous to the machine operator.

- If a large and continuous coil is allowed to be formed, it may engage the entire machine and even the workplace. It is quite dangerous.
- Very large coils offer a lot of difficulty in their removal.

Such difficulties are, however, not encountered while machining materials like brass and cast iron, because in their machining continuous chips of the above type are not produced. But, in case of continuous chips some means must be used to overcome the difficulties and adverse effects mentioned above. For this purpose the chip breakers are used. These chip breakers break the produced chips into small pieces. The work hardening of the material of the chip makes the work of the chip breakers easy. Chip breaking is done in proper way also for the additional purpose of improving machinability by reducing the chip-tool contact area, cutting forces and crater wear of the cutting tool.

The following types of chip breakers are commonly used:

1. Groove type: It consists of grinding a groove on the face of the tool, behind the cutting edge, leaving a small land near the tip, as shown in Fig.

2. Step type: It consists of grinding a step on the face of the tool, adjacent to the cutting edge, as shown in Fig.

3. Secondary rake type: It consists of providing a secondary rake on the tool through grinding, together with a small step, as shown in Fig.
4. Clamp type: This type of chip breaker is very common with the carbide tipped tools. The chip breaker is a thin and small plate which is either brazed to or held mechanically on the tool face, as shown in fig:

5. 

2. List different types of Lathe Operations? Explain any two.

**Lathe Operations:**

All the operations performed on a lathe can be divided into two groups:

iii. **Standard**(or) **common operations:** They include facing, plain and step turning, Taper turning, knurling, threading, drilling, boring, reaming, Chamfering, forming Etc

iv. **Special** (or) **rare operations:** They include grinding, milling, copying (or) duplicating, relieving, spherical and elliptical turning, spinning, tapping, dieing Etc.

Common lathe operations which can be carried out on a lathe are enumerated and briefly discussed as follows

1. Facing
2. Plain turning
3. Step turning
4. Taper turning
5. Drilling
6. Boring
7. Reaming
8. Undercutting or grooving
9. Threading
10. Knurling
11. Forming
1. **Facing:**

   This operation is essential for all works

   - “Facing” is an operation of machining the ends of a work piece to produce a flat surface square with the axis.
   - It is also used to cut the work to the required length.
   - The operation involves feeding the tool perpendicular to the axis of rotation of the work piece
   - A properly ground facing tool is mounted in the tool post. A regular turning tool may also be used for facing a large work piece.

   The cutting edge should be set at the same height as the centre of the work piece.

   ![Facing Diagram](image)

   **Fig: Facing**

2. **Plain turning:**

   - It is an operation of removing excess material from the surface of the cylindrical work piece.

   - In this operation, the work is held either in the chuck or between centers and the longitudinal feed is given to the tool either by hand or power.

   ![Plain Turning Diagram](image)

   **Fig: Plain Turning**

3. **Write the differences between Capstan Lathe and Turret Lathe**

   **The differences between Capstan Lathe and Turret Lathe:**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Aspects</th>
<th>Turret lathe</th>
<th>Capstan lathe</th>
</tr>
</thead>
</table>

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   S.SATHISH
   Assistant Professor
<table>
<thead>
<tr>
<th></th>
<th>Turret position</th>
<th>Feeding of tools</th>
<th>Extent of rigidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Turret (head) is mounted directly on the saddle.</td>
<td>For feeding the tools entire saddle is moved.</td>
<td>Very high rigidity because all the cutting forces are transferred to the lathe bed.</td>
</tr>
<tr>
<td>2.</td>
<td>Turret is mounted on an auxiliary slide, which moves on the guide ways provided on the saddle.</td>
<td>The saddle is fixed at a convenient distance from the work and the tools are fed by moving the slide.</td>
<td>Because of the overhung of the slide or ram, the tool support unit is subjected to bending and deflection, resulting in vibrations.</td>
</tr>
<tr>
<td>3.</td>
<td>Capability to handle jobs</td>
<td>Can handle heavier jobs involving heavy cutting forces and severe cutting conditions.</td>
<td>Since this type of lathe cannot withstand heavy cutting loads, therefore its use is confined to relatively lighter and smaller jobs and precision work.</td>
</tr>
<tr>
<td>4.</td>
<td>Maximum bar size that can be handled</td>
<td>Up to 200 mm diameter.</td>
<td>Up to 60 mm diameter.</td>
</tr>
<tr>
<td>5.</td>
<td>Tool travel</td>
<td>Almost full length of the bed (since the turret saddle directly rides over the bed).</td>
<td>Limited tool travel (since the tool feeding is done by the traverse of the slide).</td>
</tr>
<tr>
<td>6.</td>
<td>Rate of tool feeding</td>
<td>Relatively slower and as such provides more fatigue to the operator's hands.</td>
<td>The tool traverse is faster and offers less fatigue to the operator's hands.</td>
</tr>
<tr>
<td>7.</td>
<td>Type of carriage</td>
<td>Reach-over type or side-hung type.</td>
<td>Usually equipped with the reach-over type only since it is employed for relatively smaller jobs and therefore, does not require a large swing over bed moreover this type of carriage provides better rigidity.</td>
</tr>
</tbody>
</table>

S.SATHISH
Assistant Professor
9. Other provisions

Heavier designs are usually provided with pneumatic or hydraulic chucks to ensure a firmer grip over heavy jobs. Provision for cross feeding of the hexagonal turret (in some designs) to enable cross feeding of turret head tools.

These lathes do not have such provisions.

4. Explain about work holding devices used in Lathe

**WORK HOLDING DEVICES:**

The work holding devices must be capable of:

(i) Locating the work relative to the spindle axis
(ii) Rotating the work at required speed without slip
(iii) Giving additional support to long work pieces
(iv) Holding the work firmly so as to prevent the deflection of work by the cutting force.

The following work holding devices are commonly used on engine lathe.

1. Chucks
   (a) 3-jaw chuck
   (b) 4-jaw chuck
   (c) Combination chuck
   (d) Magnetic chuck
   (e) Collet chuck

2. Centres
   (a) Live centre
   (b) Dead centre

3. Drive (catch) plate

4. Face plate

5. Angle plate.

6. Carriers (lathe dogs)

7. Mandrels

8. Rests (steadies)
   (a) Steady rest (fixed rest)
(b) Follower rest

**Chucks**

(i) 3-jaw chuck

![Fig: jaw chuck](image)

- In 3-Jaw universal chuck (or) self centering chuck all the jaws move together in equal amounts to clamp the work. i.e the job is automatically centered and reduce the time of set-up.
- The jaws are not reversible, and separate internal is soon lost due to wear. The chuck is used for holding cylindrical (or) hexagonal work.
- This chuck is unsuitable for irregular shaped work pieces which demands the use of four jaws chuck

![Fig: jaw chuck](image)

5. Explain the different Types of lathe?

**Types of lathe:**

The fundamental principle of operation of all lathes is same and performs the same function, yet they are classified according to the design, type of drive, arrangement of gears, and purpose. The following are important type of lathes.
1. Speed lathe:

- It is driven by power and consists of a bed, a headstock, a tailstock and an adjustable slide for supporting the tool.
- It has no gear box, lead Screw& Carriage. Head stock may have a step-cone pulley arrangement or may be equipped with a variable Speed Motor.
- Various speeds are obtained by Cone pulley. Since the tool is fed into the work by hand and cuts are very small, therefore this type of lathe is driven at high speeds usually from 1200 to 3600 rpm.
- Usage: It is mainly used for woodworking, centering, metal spinning, polishing etc.

2. Engine or Center lathe:

- It is a general-purpose lathe and is widely used in workshops.
- The main parts of engine lathe are the bed, headstock, tailstock, carriage, lead screw and feed change gear box.
- It differs from a speed lathe that it has additional mechanism for controlling the spindle speed and for supporting and controlling the feed of fixed cutting tool.
- The cutting tool may be fed both in cross and longitudinal direction with reference to the lathe axis with the help of a carriage.
- The engine lathe, depending upon the design of the head stock for receiving power, may be classified as belt driven lathe, motor driven lathe and geared head lathe.
- In Belt driven lathe, Power from motor is transmitted to spindle by belt drive, In Geared head lathe power from motor is transmitted to spindle by gear drive.
- The speed changes in belt drive are obtained by shifting the belt to different steps of cone pulley.
- In geared-Head lathe the gear ratio (Spindle speed to motor speed) is changed by Speed-Lever.

Usage: It is used for producing cylindrical components. By using the attachments and accessories, other operations such as taper turning, Drilling, milling and grinding may also be performed.
3. Bench lathe:
The bench lathe is so small that it can be mounted on a bench.

- All the types of operation can be performed on this lathe that may be done on an ordinary speed or engine lathe.
- This is used for small work usually requiring considerable accuracy such as in the production of gauges, punches and beds for press tools.

4. Tool room lathe:

- The tool room lathe is similar to an engine lathe and is equipped with all the accessories needed for accurate tool work.
- It has an individually driven-geared headstock with a wide range of spindle speeds.
- Since this lathe is used for precision work on tools, gauges, dies, jigs and other small parts, therefore greater skill is needed to operate the lathe.

5. Capstan and turret lathe:

- The capstan and turret lathes are the modification of engine lathe and is particularly used for mass production of identical parts in a minimum time.
- These lathes are semiautomatic and are fitted with multi tool holding devices, called capstan and turret heads.
- The advantage of capstan and turret lathe is that several different types of operation can be performed on a work piece without resetting of the work or tools.

6. Automatic lathe:

- The automatic lathes are so designed that the tools are automatically fed to the work and withdrawn after all the operations are completed to finish the work.
- Since the entire operation is automatic, these lathes require little attention of the operator.
- These lathes are used for mass production of identical parts.

7. Special purpose lathes:
The works, which cannot be conveniently accommodated or machined on a standard lathe, the special purpose lathes are used.

The gap bed lathe which has a removable section in the bed in front of the headstock tom provide a space or gab, is used to swing extra large diameter jobs.

a) Crankshaft lathe: is especially used for turning crankshafts.

b) Wheel lathe: is which is of large design, is especially used for finishing the journal and for turning the locomotive driving wheels.

c) Axle lathe: is used for turning car axles.

d) Precision Lathe: Precision turning of previously rough-turned work pieces.

e) Facing Lathe: Used to machine the end faces

f) Vertical lathe: It is used for turning and boring very large and heavy rotating parts which cannot be supported on other types of lathes.

Multiple choice questions with answers
1. In which operation, motion of job is rotary and motion of cutting tool is forward translating?
   a) turning  
   b) planning  
   c) milling  
   d) all of the mentioned

2. Which type of job motion is there in drilling operation?
   a) rotary  
   b) translating  
   c) fixed  
   d) none of the mentioned

3. In which type of operation, motion of cutting tool is translating?
   a) drilling and milling  
   b) milling and turning  
   c) boring and drilling  
   d) turning and planning

4. In which type of operation, motion of cutting tool is rotary as well as translating?
   a) planning  
   b) milling
c) drilling
  d) turning

5. In drilling motion of job is rotary.
a) true
b) false

6. Motion of cutting tool is rotary in milling machine.
a) true
b) false

7. Which type of cutting tools have wide application on lathes?
a) single point
b) multi point
c) both single point and multi point
d) none of the mentioned

8. Which of the following is the example of multi point cutting tool?
a) milling cutter
b) broaching tool
c) both milling cutter and broaching tool
d) none of the mentioned

9. In how many groups, cutting tools can be divided?
a) 2
b) 3
c) 4
d) none of the mentioned

10. Motion of job is forward rotary in broaching operation.
a) true
b) false

**KEY:**
1 – (a) 2 – (c) 3 – (c) 4 – (c) 5 – (b) 6 – (b) 7 – (a) 8 – (c) 9 – (a) 10 – (b)

**Fill in the blanks questions with answers**

1. In which operation, motion of job is rotary and motion of cutting tool is forward translating________

2) Which type of chips form while machining of brittle materials………
3) The angle between side cutting edge and end cutting edge is called as ……

4) The cutting tool removes the metal from work piece in the form of ………

5) In the metal cutting process, when the compression limit of the metal in front of the cutting tool has been exceeded then it is separated from workpiece and flows ………

6) Continuous chips are formed during metal cutting operation due to ………

7) The surface of the single point cutting tool on which the chips formed in cutting operation slide is called as ………

8) Tool life in orthogonal cutting is………..

9) Calculate the power required for machining of a workpiece on lathe having efficiency of 85% on full load, when tangential force required is 1200 N and cutting speed 195 m/min ……..

10) In metal cutting operation, maximum heat (i.e. 80-85%) is generated in ……

KEY:

UNIT-II
Two marks questions with answers

1. Define boring?
Introduction Boring is a process of producing circular internal profiles on a hole made by drilling or another process. It uses single point cutting tool called a boring bar. In boring, the boring bar can be rotated, or the work part can be rotated. Machine tools which rotate the boring bar against a stationary work piece are called boring machines (also boring mills). Boring can be accomplished on a turning machine with a stationary boring bar positioned in the tool post and rotating work piece held in the lathe chuck as illustrated in the figure. In this section, we will consider only boring on boring machines.
2. List out the Applications of Slotting machine?
Slotting machines are very similar to shaping machines in respect of machining principle, tool-work motions and general applications. However, relative to shaping machine, slotting machines are characterized by:

- Vertical tool reciprocation with down stroke acting
- Longer stroke length
- Less strong and rigid
- An additional rotary feed motion of the work table
- Used mostly for machining internal surfaces

The usual and possible machining applications of slotting machines are:

- Internal flat surfaces
- Enlargement and / or finishing non-circular holes bounded by a number of flat surfaces as shown in Fig.(a)
- Blind geometrical holes like hexagonal socket as shown in Fig.(b)
- Internal grooves and slots of rectangular and curved sections.
- Internal keyways and splines, straight tooth of internal spur gears, internal curved surface of circular section, internal oil grooves etc. which are not possible in shaping machines.
However, it has to be borne in mind that productivity and process capability of slotting machines are very poor and hence used mostly for piece production required by maintenance and repair in small industries. Scope of use of slotting machine for production has been further reduced by more and regular use of broaching machines.

3. What is the working principle of Planing machine?

The simple kinematic system of the planing machine enables transmission and transformation of rotation of the main motor into reciprocating motion of the large work table and the slow transverse feed motions (horizontal and vertical) of the tools. The reciprocation of the table, which imparts cutting motion to the job, is attained by rack-pinion mechanism. The rack is fitted with the table at its bottom surface and the pinion is fitted on the output shaft of the speed gear box which not only enables change in the number of stroke per minute but also quick return of the table. The blocks holding the cutting tools are moved horizontally along the rail by screw-nut system and the rail is again moved up and down by another screw-nut pair as indicated in Fig.
4. Draw the kinematic diagram of shaping machine and mention parts?

Fig. Kinematic diagram of a shaping machine.

5. What are the Basic purposes of use of drilling machines?
Drilling machines are generally or mainly used to originate through or blind straight cylindrical holes in solid rigid bodies and/or enlarge (coaxially) existing (premachined) holes:
- of different diameter ranging from about 1 mm to 40 mm
- of varying length depending upon the requirement and the diameter of the drill
- in different materials excepting very hard or very soft materials like rubber, polythene etc.

Three marks questions with answers
1. Explain with a neat sketch the construction and working principle of radial drilling machine?
Principle parts of drilling machine:
The different parts of a radial drilling machine are as follows:
1. Base  
2. Column  
3. Radial arm  
4. Drill Head  
5. Spindle speed and Feed mechanism
Fig: Radial Drilling Machine

Radial drilling machine.

1) **Base**: The base is of heavy casting made up of cast iron. It supports the column and other parts of machine In certain cases, T-slots are provided on top surface for clamping the work directly so that it will serve the function of table.

2) **Column**: It is a cylindrical casting mounted directly to the base. It supports the table, spindle head, motor and the driving mechanism. And also supports radial arm which can slide vertically up and down.

3) **Radial arm**: Radial arm is mounted horizontally on column. It is provided with accurate guide ways on which drill head slides. The radial arm slides up and down, and also swung around the column.

4) **Drill Head**: It is mounted on the radial arm. It may be slide along the arm to locate the drill spindle with respect to work. After proper adjustment of spindle the drill head is locked on radial arm. It is provided with mechanism to drive the drill at required speeds and feeds.

5) **Spindle speed and feed mechanism**: The drill spindle is driven by a motor fitted directly over the drill head. Through the gearbox multiple speeds and feeds can be obtained.
2. Explain Classification of Boring Machines?

Classification of Boring Machines: They can broadly be classified into the following three types.
- Horizontal Boring Machines
- Vertical Boring Machines
- Jig Boring Machine

1. Horizontal Boring Machines:

![Diagram of Horizontal Boring Machines]

**Fig:** Horizontal Boring Machines

1) In Horizontal boring machine the spindle is arranged horizontally. These machines are designed such that the workpiece is stationary and the tool revolves.

2) These machines are designed such that the workpiece is stationary and the tool revolves.

3) The primary cutting motion is the rotation of spindle and the feed motion is imparted to either tool work depending upon the type of machining being done.

4) The table for holding the workpiece may be adjusted and fed in two coordinate (longitudinally and transversely) directions. The head carrying the spindle may be adjusted upward and downward on the heavy column along the end support. The spindle can be rotated and also can be fed in either direction parallel to its axis.
5) Horizontal boring machines are designed to machine relatively large and heavy work pieces.

6) The operations that can be performed on this machine are boring, drilling, counter boring, threading and milling.

3. Describe the main parts of Slotter?
The different parts of a slotting machine are
6. Ram and tool head assembly 7. Ram drive mechanism 8. Feed mechanism

**Feed mechanism:** In a slotter, the feed is given to by the table. A slotting machine table may have three types of feed movement
1. Longitudinal 2. Cross 3. Circular
   - If the table is fed perpendicular to the column toward or away from its face, the feed movement is termed as longitudinal.
   - If the table is fed parallel to the face of the column the feed movement is termed as cross.
   - If the table is rotated on a vertical axis, the feed movement is termed as circular.

4. What are the main parts of Drilling machine?
Figure shows general configuration of drilling machine, column drill in particular. The salient parts are

- Column with base: it is the basic structure to hold the other parts
- Drilling head: this box type structure accommodates the power drive and the speed and feed gear boxes.
- Spindle: holds the drill and transmits rotation and axial translation to the tool for providing cutting motion and feed motion – both to the drill.

Drilling machines are available in varying size and configuration such as pillar drill, column drill, radial drill, micro-drill etc. but in working principle all are more or less the same.

Drilling machines are used:
- Mainly for drilling (originating or enlarging cylindrical holes)
- Occasionally for boring, counter boring, counter sinking etc.
- Also for cutting internal threads in parts like nuts using suitable attachment.
5. Explain different operations performed on a shaper.

**Shaper operations:**
A shaper is a machine tool primarily designed to generate a flat surface by a single point cutting tool. The different operations which a shaper can perform are as follows:
1. Machining of horizontal surfaces
2. Machining of vertical surfaces
3. Machining of angular surfaces
4. Machining of curved surfaces
5. Machining of irregular surfaces
6. Machining of slots, grooves, and keyways etc.

![Diagram of Shaper Mechanism]

**Crank and Slotted Lever Mechanism:**

The crank and slotted lever mechanism is shown in below Fig. and its main features are driving gear (bull gear) and slotted link (rocker arm). An electric motor drives the bull gear by means of a pinion through a gear box. A crank pin which is fastened to the bull gear moves a
sliding block which is located in a slot of slotted link. One end of slotted link is pivoted at the bottom, and other end is connected to the ram. The up and down movement of slider causes the slotted lever to oscillate about its pivot as the bull gear rotates. Thus the oscillating motion of slotted lever imparts a reciprocating motion to the ram.

Crank and slotted lever mechanism enables the ram to move faster during returning (idle) stroke than during forward (cutting) stroke. The principle of quick return motion is illustrated in below Fig. The cutting stroke is made less rapidly than the return stroke because crank pin produces the working stroke 'DE' during its travel through major arc 'ABC' and through minor arc 'CA' it produces the return stroke. As the speed of rotation of the bull gear is constant, this will causes the return stroke to complete in a shorter time. The ratio between cutting time and return time may be given as,

\[
\frac{\text{Cutting time}}{\text{Return time}} = \frac{\text{Angle subtended by arc ABC}}{\text{Angle subtended by arc CA}}
\]
This ratio is usually 3:2, and slightly changes with length of stroke. The disadvantage with this mechanism is that the quick return effect is diminishes with smaller strokes. Adjustment for length of stroke and position of stroke:
The length of stroke of the ram is depends on the radial distance of crank. As the pin is moved near to the centre, the stroke becomes shorter and if it is moved away from the centre the stroke become longer. Thus the length of stroke can be obtained by adjusting the radial position of crank pin.

2. Explain different types of drilling machines?

(a) General purpose drilling machines of common use

- Table top small sensitive drilling machine

These small capacity ($\leq 0.5$ kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size ($\phi \leq 10$ mm) drills. Figure1 typically shows one such machine.
Fig 1. Table top sensitive drilling machine

• **Pillar drilling machine**

These drilling machines, usually called pillar drills, are quite similar to the table top drilling machines but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are grouted on the floor (foundation). Here also, the drill-feed and the work table movement are done manually. Fig.2 typically shows a pillar drill. These low cost drilling machines have tall tubular columns and are generally used for small jobs and light drilling.

Fig 2. Pillar Drilling machine

• **Column drilling machine**

These box shaped column type drilling machines as shown in Fig.3 are much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.
**Radial drilling machine**
This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in Fig.4. The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the drill spindle can be additionally swivelled and / or tilted.

**CNC column drilling machine**
In these versatile and flexibly automatic drilling machine having box column type rigid structure the work table movements and spindle rotation are programmed and accomplished by Computer Numerical Control (CNC). These modern sophisticated drilling machines are suitable for piece or batch production of precision jobs.

(b) **General purpose drilling machines with more specific use.**
• **Hand drills**
Unlike the grouted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled as shown in Fig. 5. The small and reasonably light hand drills are run by a high speed electric motor. In fire hazardous areas the drill is often rotated by compressed air.

**Fig. 5 Hand drill in operation**

- **Gang drilling machine**
  In this almost single purpose and more productive machine a number (2 to 6) of spindles with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig. Fig. 6 schematically shows a typical gang drilling machine.

**Fig. 6 Schematic view of a gang drilling machine**

- **Turret (type) drilling machine**
  Turret drilling machines are structurally rigid column type but are more productive like gang drill by having a pentagon or hexagon turret as shown in Fig. 7. The turret bearing a number of drills and similar tools is indexed and moved up and down to perform quickly the desired series of operations progressively. These drilling machines are available with varying degree of automation both fixed and flexible type.
In these high production machine tools a large number of drills work simultaneously on a blank through a jig specially made for the particular job. The entire drilling head works repeatedly using the same jig for batch or lot production of a particular job. Fig.8 shows a typical multispindle drilling machine. The rotation of the drills are derived from the main spindle and the central gear through a number of planetary gears in mesh with the central gear) and the corresponding flexible shafts. The positions of those parallel shafts holding the drills are adjusted depending upon the locations of the holes to be made on the job. Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length. In some heavy duty multispindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.

**Multispindle drilling machine**

**Micro (or mini) drilling machine**
This type of tiny drilling machine of height within around 200 mm is placed or clamped on a table, as shown in Fig.9 and operated manually for drilling small holes of around 1 to 3 mm diameter in small workpieces.

![Photographic view of a micro (or mini) drilling machine](image)

**Fig.9 Photographic view of a micro (or mini) drilling machine**

- **Deep hole drilling machine**

  Very deep holes of L/D ratio 6 to even 30, required for rifle barrels, long spindles, oil holes in shafts, bearings, connecting rods etc, are very difficult to make for slenderness of the drills and difficulties in cutting fluid application and chip removal. Such drilling cannot be done in ordinary drilling machines and b ordinary drills. It needs machines like deep hole drilling machine such as gun drilling machines with horizontal axis which are provided with
  - high spindle speed
  - high rigidity
  - tool guide
  - pressurized cutting oil for effective cooling, chip removal and lubrication at the drill tip.

  Deep hole drilling machines are available with both hard automation and CNC system.

3. **Explain the working principle and Kinematic System of general purpose drilling machine?**

   Kinematic system in any machine tool is comprised of chain(s) of several mechanisms to enable transform and transmit motion(s) from the power source(s) to the cutting tool and the workpiece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions. Even for the same type of machine tool, say column drilling machine, the designer may take different kinematic structure depending upon productivity, process capability, durability, compactness, overall cost etc targeted. Fig.10 schematically shows a typical kinematic system of a very general purpose drilling machine, i.e., a column drilling machine having 12 spindle speeds and 6 feeds. The kinematic system enables the drilling machine the following essential works;

   - **Cutting motion:** The cutting motion in drilling machines is attained by rotating the drill at different speeds (r.p.m.). Like centre lathes, milling machines etc, drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool
material, drill diameter, machining and machine tool conditions. It is shown in Fig.10 that the drill gets its rotary motion from the motor through the speed gear box (SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be changed to any of the 12 speeds by shifting the cluster gears in the SGB. The direction of rotation of the drill can be changed, if needed, by operating the clutch in the speed reversal mechanism, RM-s shown in the figure.

• **Feed motion:** In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (within a range) depending upon the tool-work materials and other conditions and requirements. Fig.10 visualises that the drill receives its feed motion from the output shaft of the SGB through the feed gear box (FGA), and the clutch. The feed rate can be changed to any of the 6 rates by shifting the gears in the FGB. And the automatic feed direction can be reversed, when required, by operating the speed reversal mechanism, RM-s as shown. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quill. The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

• **Tool work mounting:** The taper shank drills are fitted into the taper hole of the spindle either directly or through taper socket(s). Small straight shank drills are fitted through a drill chuck having taper shank. The workpiece is kept rigidly fixed on the bed (of the table). Small jobs are generally held in vice and large or odd shaped jobs are directly mounted on the bed by clamping tools using the T-slots made in the top and side surfaces of the bed as indicated in Fig.10.
4. Discuss various Applications of drilling machines?
Drilling machines of different capacity and configuration are basically used for originating cylindrical holes and occasionally for enlarging the existing holes to full or partial depth. But different types of drills are suitably used for various applications depending upon work material, tool material, depth and diameter of the holes.

General purpose drills may be classified as:

- **According to material**:
  - High speed steel – most common
- Cemented carbides
  - Without or with coating
  - In the form of brazed, clamped or solid

- **According to size**
  - Large twist drills of diameter around 40 mm
  - Microdrills of diameter 25 to 500 μm
  - Medium range (most widely used) diameter ranges between 3 mm to 25 mm.

- **According to number of flutes**
  - Two fluted – most common
  - Single flute – e.g., gun drill (robust)
  - Three or four flutes – called slot drill

- **According to helix angle of the flutes**
  - Usual – 20° to 35° – most common
  - Large helix : 45° to 60° suitable for deep holes and softer work materials
  - Small helix : for harder / stronger materials
  - Zero helix : spade drills for high production drilling micro-drilling and hard work materials.

- **According to length – to – diameter ratio**
  - Deep hole drill; e.g. crank shaft drill, gun drill etc.
  - General type : L/φ ≥ 6 to 10
  - Small length : e.g. centre drill

- **According to shank**
  - Straight shank – small size drill being held in drill chuck
  - Taper shank – medium to large size drills being fitted into the spindle nose directly or through taper sockets

- **According to specific applications**
  - Centre drills (Fig.11) : for small axial hole with 60° taper end to accommodate lathe centre for support
  - Step drill and subland drill (Fig.12) : for small holes with two or three steps

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Fig.11 Centre Drill
Fig.12 (a) Stepped drill and (b) subland drill

- Half round drill, gun drill and crank shaft drill (for making oil holes) – shown in Fig.13
- Ejector drill for high speed drilling of large diameter holes
- Taper drill for batch production
- Trepansing tool (Fig.14) : for large holes in soft materials

Besides making holes, drilling machines may be used for various other functions using suitable cutting tools.
Fig. 13 Schematic views of (a) half round drill, (b) gun drill and (c) crank shaft drill
The wide range of applications of drilling machines include:

- Origination and/or enlargement of existing straight through or stepped holes of different diameter and depth in wide range of work materials – this is the general or common use of drilling machines.
- Making rectangular section slots by using slot drills having 3 or four flutes and 180° cone angle
- Boring, after drilling, for accuracy and finish or prior to reaming
- Counter boring, countersinking, chamfering or combination using suitable tools as shown in Fig.15

![Fig.15 Schematic view of (a) counter boring and (b) countersinking](image)

- Spot facing by flat end tools (Fig.16)
- Trepanning for making large through holes and or getting cylindrical solid core
- Reaming is done, if necessary, after drilling or drilling and boring holes for accuracy and good surface finish. Different types of reamers of standard sizes are available as shown in Fig.17 for different applications.

![Fig.16 Schematic view of spot facing](image)
Fig. 17 Different types of reamers.

- Cutting internal screw threads mounting a tapping attachment in the spindle.

Several other operations can also be done, if desired, in drilling machines by using special tools and attachments.

5. Classify the types of Shapers?

1. According to the type of mechanism used for giving reciprocating motion to the ram:
   (i) Crank shaper:
       • In this type of shaper, a crank and a slotted lever quick return motion mechanism is used to give reciprocating motion to the ram.
       • The crank arm is adjustable and is arranged inside the body of a bull gear (also called crank gear).
   (ii) Geared shaper
       • In this shaping machine, the ram carries a rack below it, which is driven by a spur gear.
       • This type of shaper is not widely used.
   (iii) Hydraulic shaper:
       • In this type of shaper, a hydraulic system is used to drive the ram.
       • This shaper is more efficient than the crank and geared type shapers.

2. According to position and travel of ram:
   (i) Horizontal shaper:
       • In this shaping machine, the ram moves or reciprocates in a horizontal direction.
       • This shaper is mainly used for producing flat surfaces.
   (ii) Vertical shaper:
       • In this shaper, the ram reciprocates vertically in the downward as well as in upward motion.
       • This type of shaping machine is very convenient for machining internal surfaces,
keyways, slots or grooves.

(iii) Travelling head shaper:
- A travelling head shaper has a reciprocating ram mounted on a saddle which travels sideways along the bed. The ram carries the tool slide.
- Heavy duty jobs which cannot be held on the standard shaper table, are kept stationary on the base travelling head shaper and machined as the ram reciprocates.

3. According to the type of cutting stroke
   (i) Push-cut shaper:
   - In this shaper, the ram pushes the tool across the work during cutting operation. In other words, forward stroke is the cutting stroke and the backward stroke is an idle stroke.
   - This is the most general type of shaper used in common practice.
   (ii) Draw-cut shaper:
   - In a draw-cut shaper, the ram draws or pulls the tool across the work during cutting operation. In other words, the backward stroke is the cutting stroke and forward stroke is an idle stroke.

4. According to the design of the table:
   (i) Standard or plain shaper:
   - In this type of shaper, the table has only two movements namely horizontal and vertical, to give the feed.
   - It cannot be swiveled or tilted.
   (ii) Universal shaper:
   - In this shaper, in addition to the above two movements, the table can be swiveled about an horizontal axis parallel to the ram and the upper portion of the table can be tilted about a horizontal axis perpendicular to the first axis.
   - A universal shaper is mostly used in tool room.

Multiple choice questions with answers

1. Reciprocation of the cutting tool in shaping machines is accomplished by
   a. Rack pinion mechanism
   b. Crank and connecting rod mechanism
   c. Cam and cam follower mechanism
   d. Oscillating lever mechanism

2. Internal keyway in gears can be cut in
a. Shaping machine  
b. Planing machine  
c. Slotting machine  
d. None of the above

3. The job reciprocates in 
   a. Shaping machine  
b. Planing machine  
c. Slotting machine  
d. All of the above

4. The T-slots in the table of planing machines are cut in  
   a. Shaping machine  
b. Planing machine  
c. Slotting machine  
d. None of the above

5. Flat surface can be produced in  
   a. Shaping machine only  
b. Planing machine only  
c. Slotting machine only  
d. All of the above

6. Large number of cutting tools can be simultaneously used in  
   a. Shaping machine  
b. Planing machine  
c. Slotting machine  
d. None of the above

7. Heavy cuts can be given during machining in  
   a. Shaping machine  
b. Planing machine  
c. Slotting machine  
d. None of the above

8. Slotting machines are used to cut internal gear teeth for  
   a. Batch production  
b. Lot production  
c. Mass production  
d. None of the above

9. The work-table can rotate in  
   a. Shaping machine  
b. Planing machine  
c. Slotting machine  
d. None of the above
10. Length of the stroke can be varied in
   a. Shaping machine
   b. Planing machine
   c. Slotting machine
   d. All of the above

Answers:

1 d   2 c   3 b   4 b   5 d
6 b   7 b   8 a   9 c   10 b

Fill in the blank questions with answers

1. Shaping can be performed more effectively by ______ milling machine.
2. Surfacing can be performed more effectively by ______ milling machine.
3. Boring can be performed more effectively by ______ milling machine.
4. Slotting can be performed more effectively by ______ milling machine.
5. To produce more accurate holes, which……..operation should be performed third?
6. To produce more accurate holes, which……..operation should be performed second?
7. Which……..process is carried out to provide seating for head of screw?
8. Which……..operation is performed to provide recess for bolt heads or nuts?
9. Which……..operation is carried out to make the hole dimensionally more accurate?
10. Taping process employs……operating conditions

KEY:
UNIT-III

Two marks questions with answers

1. What is the working principle of milling machine?

Milling is defined as a machining process for removing excess material from a work piece by feeding the work against a rotating multipoint cutting tool. The rotating cutting tool called the milling cutter is having the shape of a solid of revolution with cutting teeth arranged either on the periphery or on end face or on the both.

Working principle of Milling:
The work is rigidly clamped on the table of the machine (or) held between centres, and revolving multi teeth cutter mounted either on a spindle (or) an arbor. The cutter revolves at higher speed and the work fed slowly past the cutter. The work can be fed in vertical, longitudinal (or) cross direction. As the work advances, the cutter teeth remove the metal from the work surface to produce the desired shape.

2. What are the different types of Milling Machine?

TYPES OF MILLING MACHINES:
The broad classification of these machines can be done as follows
1. Column and knee type milling machines.
2. Fixed bed type or manufacturing type milling machines.
3. Planer type milling machines.
4. Production milling machines.
5. Special purpose machines

3. What are the different Classifications of milling cutter?
Milling cutters are broadly classified as,

(a) **Profile sharpened cutters** – where the geometry of the machined surfaces are not related with the tool shape, viz;
   i. Slab or plain milling cutter : — straight or helical fluted
   ii. side milling cutters – single side or both sided type
   iii. slotting cutter
   iv. slitting or parting tools
   v. end milling cutters – with straight or taper shank
   vi. face milling cutters

(b) **Form relieved cutters** – where the job profile becomes the replica of the tool-form, e.g., viz;
   i. Form cutters
   ii. gear (teeth) milling cutters
   iii. spline shaft cutters
   iv. tool form cutters
   v. T-slot cutters
   vi. Thread milling cutter

4. What are the different uses of Milling Machine?

Milling machines of various type are widely used for the following purposes using proper cutting tools called milling cutters :

- Flat surface in vertical, horizontal and inclined planes
- Making slots or ribs of various sections
- Slitting or parting
- Often producing surfaces of revolution
- Making helical grooves like flutes of the drills
- Long thread milling on large lead screws, power screws, worms etc and short thread milling for small size fastening screws, bolts etc.
- 2-D contouring like cam profiles, clutches etc and 3-D contouring like die or mould cavities
- Cutting teeth in piece or batch production of spur gears, straight toothed bevel gears, worm wheels, sprockets, clutches etc.
- Producing some salient features like grooves, flutes, gushing and profiles in various cutting tools, e.g., drills, taps, reamers, hobs, gear shaping cutters etc.

5. What are the Special applications of cylindrical grinder?

Principle of cylindrical grinding is being used for thread grinding with specially formed wheel that matches the thread profile. A single ribbed wheel or a multi ribbed wheel can be used as shown in Fig.
Roll grinding is a specific case of cylindrical grinding wherein large workpieces such as shafts, spindles and rolls are ground. Crankshaft or crank pin grinders also resemble cylindrical grinders but are engaged to grind crank pins which are eccentric from the centre line of the shaft as shown in Fig. The eccentricity is obtained by the use of special chuck.

Cam and camshaft grinders are essentially subsets of cylindrical grinding machine dedicated to finish various profiles on disc cams and cam shafts. The desired contour on the workpiece is generated by varying the distance between wheel and workpiece axes. The cradle carrying the head stock and tail stock is provided with rocking motion derived from the rotation of a master cam that rotates in synchronization with the workpiece. Newer machines however, use CNC in place of master cam to generate cam on the workpiece.

Three marks questions with answers

1. Explain the different types of Internal grinding machines?

This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled. Broadly there are three different types of internal grinding machine as follows:
   1. Chucking type internal grinder
   2. Planetary internal grinder
   3. Centreless internal grinder
1 Chucking type internal grinder

Figure illustrates schematically this machine and various motions required for grinding action. The workpiece is usually mounted in a chuck. A magnetic face plate can also be used. A small grinding wheel performs the necessary grinding with its peripheral surface. Both transverse and plunge grinding can be carried out in this machine as shown in Fig.

Fig. Internal Centre less Grinding  Fig. Internal (a) Traverse Grinding (b) Plunge Grinding

2. Planetary internal grinder

Planetary internal grinder is used where the workpiece is of irregular shape and cannot be rotated conveniently as shown in Fig. In this machine the workpiece does not rotate. Instead, the grinding wheel orbits the axis of the hole in the workpiece.

Fig. Internal grinding in planetary grinder

3 Centreless internal grinder
This machine is used for grinding cylindrical and tapered holes in cylindrical parts (e.g. cylindrical liners, various bushings etc). The workpiece is rotated between supporting roll, pressure roll and regulating wheel and is ground by the grinding wheel as illustrated in Fig.

![Internal centreless grinding](image)

**Fig. Internal centreless grinding**

2. **Explain, Tool and cutter grinder machine?**

Tool grinding may be divided into two subgroups: tool manufacturing and tool resharpening. There are many types of tool and cutter grinding machine to meet these requirements. Simple single point tools are occasionally sharpened by hand on bench or pedestal grinder. However, tools and cutters with complex geometry like milling cutter, drills, reamers and hobs require sophisticated grinding machine commonly known as universal tool and cutter grinder. Present trend is to use tool and cutter grinder equipped with CNC to grind tool angles, concentricity, cutting edges and dimensional size with high precision.

![Pictorial view of a tool and cutter grinder](image)

**Fig. Pictorial view of a tool and cutter grinder**
3. Explain, External centreless grinder?
This grinding machine is a production machine in which outside diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by means of a regulating wheel and ground by the grinding wheel.
In through-feed centreless grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece. The regulating wheel is kept slightly inclined to the axis of the grinding wheel and the workpiece is fed longitudinally as shown in Fig.

![Diagram of Centreless through feed grinding]

**Fig:** Centreless through feed grinding

4. Explain, Creep feed grinding machine?
This machine enables single pass grinding of a surface with a larger down feed but slower table speed than that adopted for multi-pass conventional surface grinding. This machine is characterized by high stiffness, high spindle power, recirculating ball screw drive for table movement and adequate supply of grinding fluid. A further development in this field is the creep feed grinding centre which carries more than one wheel with provision of automatic wheel changing. A number of operations can be performed on the workpiece. It is implied that such machines, in the view of their size and complexity, are automated through CNC.

5. Explain, Vertical spindle rotary table grinder?
The principle of grinding in this machine is shown in Fig. The machine is mostly suitable for small work pieces in large quantities. This primarily production type machine often uses two or more grinding heads thus enabling both roughing and finishing in one rotation of the work table.
Five marks of questions with answers

1. What are the different Classifications of milling machines?
Milling machines can be broadly classified;
(a) According to nature of purposes of use:
   - **general purpose** – most versatile commonly used mainly for piece or small lot production
   - **single purpose** – e.g., thread milling machines, cam milling machines and slitting machine which are generally used for batch or lot production.
   - **Special purpose** – these are used for lot or mass production, e.g., duplicating mills, die sinkers, short thread milling etc.

(b) According to configuration and motion of the work-holding table / bed
   - **Knee type**: typically shown in Fig. In such small and medium duty machines the table with the job/work travels over the bed (guides) in horizontal (X) and transverse (Y) directions and the bed with the table and job on it moves vertically (Z) up and down.
- **Bed type**: Usually of larger size and capacity; the vertical feed is given to the milling head instead of the knee type bed.

- **Planer type**: These heavy duty large machines, called plano-miller, look like planing machine where the single point tools are replaced by one or a number of milling heads; generally used for machining a number of longitudinal flat surfaces simultaneously, viz., lathe beds, table and bed of planning machine etc.
- **Rotary table type**: Such open or closed ended high production milling machines possess one large rotary work-table and one or two vertical spindles as typically shown in Fig; the positions of the job(s) and the milling head are adjusted according to the size and shape of the job.

![Fig. Planar type milling machine](image1)

![Fig. Rotary table type milling machine](image2)
(c) According to the orientation of the spindle(s).
  - **Plain horizontal knee type**
    This non-automatic general purpose milling machine of small to medium size possesses a single horizontal axis milling arbour; the work-table can be linearly fed along three axes (X, Y, Z) only; these milling machines are most widely used for piece or batch production of jobs of relatively simpler configuration and geometry.

Fig. Plain horizontal knee type milling machine

- **Horizontal axis (spindle) and swivelling bed type** These are very similar to the plain horizontal arbour knee type machines but possess one additional swivelling motion of the work-table.
- **Vertical spindle type**
  In this machine, typically shown in Fig, the only spindle is vertical and works using end mill type and face milling cutters; the table may or may not have swivelling features.
- **Universal head milling machine**
  These versatile milling machines, typically shown in Fig, not only possess both horizontal milling arbour and the vertical axis spindle, the latter spindle can be further...
tilted about one (X) or both the horizontal axes (X and Y) enabling machining jobs of complex shape.

**Fig.** Vertical spindle type milling machine
Milling machines are mostly general purpose and used for piece or small lot production. But like other machine tools, some milling machines are also incorporated with certain type and degree of automation or mechanisation to enhance production rate and consistency of product quality. In this respect milling machines can be further classified as follows:

- **Hand mill (milling machine)** - this is the simplest form of milling machine where even the table feed is also given manually as can be seen in Fig.
Planer and rotary table type vertical axis milling machines are not that automated but provide relatively higher production rate.

Tracer controlled copy milling machine, typically shown in Fig, are mechanically or hydraulically operated semi-automatic milling machines used for lot production of cams, dies etc by copying the master piece.

Milling machines for short thread milling may be considered single purpose and automatic machine being used for mass production of small bolts and screws.
Tracer controlled milling machine

**Computer Numerical Controlled (CNC) milling machine**
Replacement of hard or rigid automation by Flexible automation by developing and using CNC has made a great break through since mid seventies in the field of machine tools’ control. The advantageous characteristics of CNC machine tools over conventional ones are:

- flexibility in automation
- change-over (product) time, effort and cost are much less
- less or no jigs and fixtures are needed
- complex geometry can be easily machined
- high product quality and its consistency
- optimum working condition is possible
- lesser breakdown and maintenance requirement

Fig. typically shows a CNC milling machine. The versatility of CNC milling machine has been further enhanced by developing what is called Machining Centre. Fig. visualises one of such Machining Centres.
2. Explain the Kinematic system of milling machine?
The kinematic system comprising of a number of kinematic chains of several mechanisms enables transmission of motions (and power) from the motor to the cutting tool for its rotation at varying speeds and to the work-table for its slow feed motions along X, Y and Z directions. In some milling machines the vertical feed is given to the milling(cutter) head. The more versatile milling machines additionally possess the provisions of rotating the work table and tilting the vertical milling spindle about X and / or Y axes.

Fig. typically shows the kinematic diagram of the most common and widely used milling machine having rotation of the single horizontal spindle or arbour and three feed motions of the work-table in X, Y and Z directions.

2. The milling cutter mounted on the horizontal milling arbour, receives its rotary motion at different speeds from the main motor through the speed gear box which with the help of cluster gears splits the single speed into desirably large number(12, 16, 18, 24 etc) of spindle speeds. Power is transmitted to the speed gear box through Vee-belts and a safety clutch as shown in the diagram. For the feed motions of the workpiece (mounted on the work-table) independently, the cutter speed, rotation of the input shaft of the speed gear box is transmitted to the feed gear box through reduction (of speed) by worm and worm wheels as shown. The cluster gears in the feed gear box enables provide a number of feed rates desirably. The feeds of the job can be given both manually by rotating the respective wheels by hand as well as automatically by engaging the respective clutches. The directions of the longitudinal (X), cross (Y) and vertical (Z) feeds are controlled by appropriately shifting the clutches. The system is so designed that the longitudinal feed can be combined with the cross feed or vertical feed but cross feed and vertical feed cannot be obtained.
simultaneously. This is done for safety purpose. A telescopic shaft with universal joints at its ends is incorporated to transmit feed motion from the fixed position of the feed gear box to the bed (and table) which moves up and down requiring change in length and orientation of the shaft. The diagram also depicts that a separate small motor is provided for quick traverse of the bed and table with the help of an over running clutch. During the slow working feeds the rotation is transmitted from the worm and worm wheel to the inner shaft through three equi-spaced rollers which get jammed into the tapering passage. During quick unworking work-traverse, the shaft is directly rotated by that motor on-line without stopping or slowing down the worm. Longer arbours can also be fitted, if needed, by stretching the over-arm. The base of the milling machine is grouted on the concrete floor or foundation.
3. Explain in detail, Surface grinding machine?
This machine may be similar to a milling machine used mainly to grind flat surface. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel.

Fig. Kinematic diagram of a milling machine
Basically there are four different types of surface grinding machines characterized by the movement of their tables and the orientation of grinding wheel spindles as follows:

- Horizontal spindle and reciprocating table
- Vertical spindle and reciprocating table
- Horizontal spindle and rotary table
- Vertical spindle and rotary table

1. **Horizontal spindle reciprocating table grinder**

Figure 1 illustrates this machine with various motions required for grinding action. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Fig.2

![Fig.1: Horizontal spindle reciprocating table surface grinder](image)

**Fig.2** Surface grinding (a) traverse grinding (b) plunge grinding

A: rotation of grinding wheel  
B: reciprocation of worktable  
C: transverse feed  
D: down feed
2 Vertical spindle reciprocating table grinder
This grinding machine with all working motions is shown in Fig.3. The grinding operation is similar to that of face milling on a vertical milling machine. In this machine a cup shaped wheel grinds the workpiece over its full width using end face of the wheel as shown in Fig. 4. This brings more grits in action at the same time and consequently a higher material removal rate may be attained than for grinding with a peripheral wheel.

3 Horizontal spindle rotary table grinder
Surface grinding in this machine is shown in Fig5. In principle the operation is same as that for facing on the lathe. This machine has a limitation in accommodation of workpiece and therefore does not have wide spread use. However, by swivelling the worktable, concave or convex or tapered surface can be produced on individual part as illustrated in Fig.6
Fig. Surface Grinding in Horizontal spindle rotary table grinder

Fig.6 Grinding of a tapered surface in horizontal spindle rotary table surface grinder

4 Vertical spindle rotary table grinder
The principle of grinding in this machine is shown in Fig7. The machine is mostly suitable for small workpieces in large quantities. This primarily production type machine often uses two or more grinding heads thus enabling both roughing and finishing in one rotation of the work table.
5 Creep feed grinding machine:
This machine enables single pass grinding of a surface with a larger down feed but slower table speed than that adopted for multi-pass conventional surface grinding. This machine is characterized by high stiffness, high spindle power, recirculating ball screw drive for table movement and adequate supply of grinding fluid. A further development in this field is the creep feed grinding centre which carries more than one wheel with provision of automatic wheel changing. A number of operations can be performed on the workpiece. It is implied that such machines, in the view of their size and complexity, are automated through CNC.

6 High efficiency deep grinding machine:
The concept of single pass deep grinding at a table speed much higher than what is possible in a creep feed grinder has been technically realized in this machine. This has been made possible mainly through significant increase of wheel speed in this new generation grinding machine.

4. Explain different types of Cylindrical grinding machine?
This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled. Broadly there are three different types of cylindrical grinding machine as follows:
1. Plain centre type cylindrical grinder
2. Universal cylindrical surface grinder
3. Centreless cylindrical surface grinder

1 Plain centre type cylindrical grinder
Figure 29.8 illustrates schematically this machine and various motions required for grinding action. The machine is similar to a centre lathe in many respects. The workpiece is held between head stock and tailstock centres. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Fig.1
Fig. 1 Plain centre type cylindrical grinder

Fig. 2 Universal cylindrical surface grinder

Universal cylindrical grinder is similar to a plain cylindrical one except that it is more versatile. In addition to small worktable swivel, this machine provides large swivel of head stock, wheel head slide and wheel head mount on the wheel head slide.
This allows grinding of any taper on the workpiece. Universal grinder is also equipped with an additional head for internal grinding. Schematic illustration of important features of this machine is shown in Fig. 3.

3 Special application of cylindrical grinder
Principle of cylindrical grinding is being used for thread grinding with specially formed wheel that matches the thread profile. A single ribbed wheel or a multi ribbed wheel can be used as shown in Fig. 4.

Roll grinding is a specific case of cylindrical grinding wherein large workpieces such as shafts, spindles and rolls are ground.
Crankshaft or crank pin grinders also resemble cylindrical grinder but are engaged to grind crank pins which are eccentric from the centre line of the shaft as shown in Fig. 5. The eccentricity is obtained by the use of special chuck.
Cam and camshaft grinders are essentially subsets of cylindrical grinding machine dedicated to finish various profiles on disc cams and cam shafts. The desired contour on the workpiece is generated by varying the distance between wheel and workpiece axes. The cradle carrying the head stock and tail stock is provided with rocking motion derived from the rotation of a master cam that rotates in synchronization with the workpiece. Newer machines however, use CNC in place of master cam to generate cam on the workpiece.

4 External centreless grinder
This grinding machine is a production machine in which outside diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by means of a regulating wheel and ground by the grinding wheel.

In through-feed centreless grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece. The regulating wheel is kept slightly inclined to the axis of the grinding wheel and the workpiece is fed longitudinally as shown in Fig.6.

![Fig6: Centreless through feed grinding](image)

Parts with variable diameter can be ground by Centreless infeed grinding as shown in Fig.6(a). The operation is similar to plunge grinding with cylindrical grinder.

End feed grinding shown in Fig.6(b) is used for workpiece with tapered surface.
The grinding wheel or the regulating wheel or both require to be correctly profiled to get the required taper on the workpiece.

5 Tool post grinder
A self powered grinding wheel is mounted on the tool post or compound rest to provide the grinding action in a lathe. Rotation to the workpiece is provided by the lathe spindle. The lathe carriage is used to reciprocate the wheel head.

5 Explain Lapping Process?
Lapping is regarded as the oldest method of obtaining a fine finish. Lapping is basically an abrasive process in which loose abrasives function as cutting points finding momentary support from the laps. Figure 1 schematically represents the lapping process. Material removal in lapping usually ranges from .003 to .03 mm but many reach 0.08 to 0.1 mm in certain cases.

Characteristics of lapping process:
- Use of loose abrasive between lap and the workpiece
- Usually lap and workpiece are not positively driven but are guided in contact with each other
- Relative motion between the lap and the work should change continuously so that path of the abrasive grains of the lap is not repeated on the workpiece.
Fig. 1 Scheme of lapping process

Cast iron is the mostly used lap material. However, soft steel, copper, brass, hardwood as well as hardened steel and glass are also used.

Abrasives of lapping:
- Al2O3 and SiC, grain size 5–100μm
- Cr2O3, grain size 1–2 μm
- B4C3, grain size 5-60 μm
- Diamond, grain size 0.5–5 V

Vehicle materials for lapping
- Machine oil
- Rape oil
- grease Technical parameters affecting lapping processes are:
  - unit pressure
  - the grain size of abrasive
  - concentration of abrasive in the vehicle
  - lapping speed

Lapping is performed either manually or by machine. Hand lapping is done with abrasive powder as lapping medium, whereas machine lapping is done either with abrasive powder or with bonded abrasive wheel.

1 Hand lapping
Hand lapping of flat surface is carried out by rubbing the component over accurately finished flat surface of master lap usually made of a thick soft close-grained cast iron block. Abrading action is accomplished by very fine abrasive powder held in a vehicle. Manual lapping requires high personal skill because the lapping pressure and speed have to be controlled manually.

Laps in the form of ring made of closed grain cast iron are used for manual lapping of external cylindrical surface. The bore of the ring is very close to size of the workpiece however, precision adjustment in size is possible with the use of a set screw as illustrated in Fig2(a). To increase range of working, a single holder with interchangeable ring laps can also be used. Ring lapping is
recommended for finishing plug gauges and machine spindles requiring high precision. External threads can be also lapped following this technique. In this case the lap is in the form of a bush having internal thread.

Solid or adjustable laps, which are ground straight and round, are used for lapping holes. For manual lapping, the lap is made to rotate either in a lathe or honing machine, while the workpiece is reciprocated over it by hand. Large size laps are made of cast iron, while those of small size are made of steel or brass. This process finds extensive use in finishing ring gauges.

2 Lapping Machine

Machine lapping is meant for economic lapping of batch qualities. In machine lapping, where high accuracy is demanded, metal laps and abrasive powder held in suitable vehicles are used. Bonded abrasives in the form wheel are chosen for commercial lapping. Machine lapping can also employ abrasive paper or abrasive cloth as the lapping medium. Production lapping of both flat and cylindrical surfaces are illustrated in Fig.3 (a) and (b). In this case cast iron plate with loose abrasive carried in a vehicle can be used. Alternatively, bonded abrasive plates may also be used. Centreless roll lapping uses two cast iron rolls, one of which serves as the lapping roller twice in diameter than the other one known as the regulating roller. During lapping the abrasive compound is applied to the rolls rotating in the same direction while the workpiece is fed across the rolls. This process is suitable for lapping a single piece at a time and mostly used for lapping plug gauges, measuring wires and similar straight or tapered cylindrical parts.
Centreless lapping is carried out in the same principle as that of centreless grinding. The bonded abrasive lapping wheel as well as the regulating wheel are much wider than those used in centreless grinding. This technique is used to produce high roundness accuracy and fine finish, the workpiece requires multi-pass lapping each with progressively finer lapping wheel. This is a high production operation and suitable for small amount of rectification on shape of workpiece. Therefore, parts are to be pre-ground to obtain substantial straightness and roundness. The process finds use in lapping piston rings, shafts and bearing races. Machines used for lapping internal cylindrical surfaces resembles honing machines used with power stroke. These machines in addition to the rotation of the lap also provide reciprocation to the workpiece or to the lap. The lap made usually of cast iron either solid or adjustable type can be conveniently used.

Figure 4 shows that to maximize the MRR (material removal rate) an optimum lapping pressure and abrasive concentration in the vehicle have to be chosen.

The effect of unit pressure on MRR and surface roughness is shown in Fig.5. It is shown in the same figure that unit pressure in the range of $p_1$-$p_2$ gives the best values for MRR and roughness of the lapped surface. The variation in MRR and surface roughness with grain size of abrasive are shown in Fig.6. It appears that grain size corresponding to permissible surface roughness and
maximum MRR may be different. Primary consideration is made on the permissible surface roughness in selecting abrasive grain size.

Fig. 6 Effect of abrasive grain size on surface roughness and MRR

Fig. 7 Effect of lapping time on surface roughness and MRR.

The dependence of MRR, surface roughness and linear loss (L) of workpiece dimension is shown in Fig. 7. Lapping conditions are so chosen that designed surface finish is obtained with the permissible limit of linear loss of workpiece dimension as shown in Fig. 8.

Multiple choice questions with answers

1. Milling machine is a machine tool that removes the metal as the work is fed against a rotating single point cutter.
   a) true
   b) false

2. In milling machine, cutter rotates at high speed and removes metal at very high speed.
   a) true
   b) false

3. Milling machine can hold ______ cutters at a time.
   a) only one
b) only two  
c) only three  
d) none of the mentioned  

4. Which of the following machine is superior to other machines as regards accuracy and better surface finish?  
a) lathe  
b) drill  
c) shaper  
d) milling  

5. Milling machines find wide application in production work.  
a) true  
b) false  

6. Which type of machining can be done by milling machine?  
a) cutting keyways  
b) slots and grooves  
c) gears  
d) all of the mentioned  

7. Which of the following motion does a milling machine has?  
a) vertical motion  
b) crosswise motion  
c) longitudinal motion  
d) all of the mentioned  

8. For milling, the work is fixed on a table which controls the feed against the cutter.  
a) true  
b) false  

9. Generally in workshop, column and knee type milling machine is used.  
a) true  
b) false
10. Milling machine is designed for manufacturing a variety of tool room work.
   a) true
   b) false

KEY:
1. b  2. a  3. d  4. d  5. a  6. d  7. d  8. a  9. a  10. a

Fill in the blanks questions with answers

1. Grain number of grinding wheel is ___ to grain size.
2. What is the correct range for grain number of grinding wheel for coarse grains…
3. What is the correct range for grain number of grinding wheel for medium grains…
4. Which grinding machine will give better result for rough machining…
5. Which symbols range of alphabet represent soft grain in grinding wheel?
6. The broaching machines have……drive for the cutting motion.
7. .................type broaches , being used for non-uniform profile
8. Internal broaching tools are used to…..and……various contours in through holes preformed by casting, forging, rolling, drilling, punching etc.
9. Form cutting can be performed more effectively by ______ milling machine.
10. Surfacing can be performed more effectively by ______ milling machine.

KEY:
1. Inversely proportional  2. 10-24  3. 30-60  4. Coarse grain  5. A – H

UNIT-IV

Two marks of questions with answers

S.SATHISH
Assistant Professor
1. **Define Limit?**
   Limits can be defined as the permissible variation in dimension that is permitted to account for variability.

2. **What is Tolerance?**
   The permissible variation in size or dimension is called tolerance. Thus, the word tolerance indicates that a worker is not expected to produce the part to the exact size, but a definite small size error is permitted. The difference between the upper limit (high limit) and the lower limit of a dimension represents the margin for variation in workmanship, and is called a 'tolerance zone'.
   Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service.

![Tolerance Diagram](image)

For example, a shaft of 25 mm basic size may be written as 25 ± 0.02.
The maximum permissible size (upper limit) = 25.02 mm and the minimum permissible size (2000 limit) = 24.98 mm

Then, Tolerance = Upper limit – Lower limit = 25.02 – 24.98 = 0.04 mm.

3. **What are the different types of Systems of Writing Tolerances?**
   There are two systems of writing tolerances:
   (i) Unilateral system
   (ii) Bilateral system

4. **What are the Advantages of Unilateral Dimensioning System?**
   Advantages of Unilateral Dimensioning System
   1. Unilateral system of dimensioning is the easiest and simplest method to find the deviations.
   2. It can standardize the ‘Go’ gauge ends without any difficulty.
   3. While machining the mating parts, the tolerance under this system facilitates the operator to a higher extent.

5. **What is fit and mention their types?**
   Fit may be defined as a degree of tightness or looseness, between two mating parts to perform a definite function when they are assembled together.
   Types of fits:-
   On the basis of positive, zero and negative values of Clearance, there are three basic types of fits:
   (1) Clearance Fit (2) Transition Fit and, (3) Interference Fit.
Three Marks Questions with Answers

1. Solve the following Problem

For a particular application, an H 7 fit has been selected for the hole and a K 6 fit for the shaft. The tolerance quoted are $+25 \over 0$ for the hole and $+18 \over 12$ for the shaft.

Find the upper limit and lower limit for the hole and also for bush. The basic size of fit is $50 \times 10^{-3}$ m.

Solution

The upper limit for the hole will be $(50.000 + 0.025) \times 10^{-3} = 50.025 \times 10^{-3}$ m.
The lower limit for the hole will be $(50.000 + 0) \times 10^{-3} = 50.000 \times 10^{-3}$ m.
The upper limit for the bush will be $(50.000 + 0.018) \times 10^{-3} = 50.018 \times 10^{-3}$ m.
The lower limit for the bush will be $(50.000 + 0.002) \times 10^{-3} = 50.002 \times 10^{-3}$ m.

2. Solve the following Problem

A dowel pin is required to be inserted in a base. For this application H 7 fit for hole and a p 6 fit for the shaft are chosen. The tolerance quoted are $+25 \over 0$ for the hole and $+42 \over 26$ for the shaft. Find the upper and lower limits of the hole and also dowel pin, and the maximum interference between dowel pin and the hole. The basic size of the fit is $50 \times 10^{-3}$ m.

Solution

The upper limit for the hole will be $(50.000 + 0.025) \times 10^{-3} = 50.025 \times 10^{-3}$ m
The lower limit for the hole will be $(50.000 + 0) \times 10^{-3} = 50 \times 10^{-3}$ m
The upper limit for dowel pin will be $(50.000 + 0.042) \times 10^{-3} = 50.042 \times 10^{-3}$ m
The lower limit for dowel pin will be $(50.000 + 0.026) \times 10^{-3} = 50.026 \times 10^{-3}$ mm
The maximum interference between dowel pin and the hole is $(50.042 - 50.000) \times 10^{-3} = 0.042 \times 10^{-3}$ m = $42 \times 10^{-6}$ m.

3. Explain different systems of fit?

A fit system is the systems of standard allowance to suit specific range of basic size. If these standard allowances are selected properly and assigned in mating parts ensures specific classes of fit.
There are two systems of fit for obtaining clearance, interference or transition fit. These are:

(i) Hole basis system (Figure1)

(ii) Shaft basis system (Figure2)

**Hole Basis System**
In the hole basis system, the size of the hole is kept constant and shaft sizes are varied to obtain various types of fits.
In this system, lower deviation of hole is zero, i.e. the low limit of hole is same as basic size. The high limit of the hole and the two limits of size for the shaft are then varied to give desired type of fit.
The hole basis system is commonly used because it is more convenient to make correct holes of fixed sizes, since the standard drills, taps, reamers and branches etc. are available for producing holes and their sizes are not adjustable. On the other hand, size of the shaft produced by turning, grinding, etc. can be very easily varied.

**Shaft Basis System**
In the shaft basis system, the size of the shaft is kept constant and different fits are obtained by varying the size of the hole. Shaft basis system is used when the ground bars or drawn bars are readily available. These bars do not require further machining and fits are obtained by varying the sizes of the hole.
In this system, the upper deviation (fundamental deviation) of shaft is zero, i.e. the high limit of the shaft is same as basic size and the various fits are obtained by varying the low limit of shaft and both the limits of the hole.

4. **What is the difference between clearance and interference?**
   **Clearance**
   In a fit, this is the difference between the sizes of the hole and the shaft, before assembly, when this difference is positive. The clearance may be maximum clearance and minimum clearance.
Minimum clearance in the fit is the difference between the maximum size of the hole and the minimum size of the shaft.

**Interference**
It is the difference between the sizes of the hole and the shaft before assembly, when the difference is negative. The interference may be maximum or minimum. Maximum interference is arithmetical difference between the minimum size of the hole and the maximum size of the shaft before assembly. Minimum interference is the difference between the maximum size of the hole and the minimum size of the shaft.

5. Solve the following Problem

A shaft of 25 mm basic size is given as 25 ± 0.02 mm. Find the tolerance.

**Solution**

The maximum permissible size (upper limit) = 25.02 mm and the minimum permissible size (lower limit) = 24.98 mm

Then, Tolerance = Upper Limit - Lower Limit
= 25.02 - 24.98
= 0.04 mm = 4 × 10⁻² m

There are two ways of writing tolerances
(a) Unilateral tolerance
(b) Bilateral tolerance.

![Figure: Tolerance]

Five marks questions with answers

1. **Classify different types of fits?**

When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a fit. A fit may be defined as the degree of tightness and looseness between two mating parts.

The important terms related to the fit are given below:

**Clearance**
In a fit, this is the difference between the sizes of the hole and the shaft, before assembly, when this difference is positive. The clearance may be maximum clearance and minimum clearance. Minimum clearance in the fit is the difference between the maximum size of the hole and the minimum size of the shaft.
Interference
It is the difference between the sizes of the hole and the shaft before assembly, when the difference is negative. The interference may be maximum or minimum. Maximum interference is arithmetical difference between the minimum size of the hole and the maximum size of the shaft before assembly. Minimum interference is the difference between the maximum size of the hole and the minimum size of the shaft.

Transition
It is between clearance and interference, where the tolerance zones of the holes and shaft overlap.
So, you can see that fits depend upon the actual limits of the hole and or shaft and can be divided into three general classes:
(i) Clearance Fit.
(ii) Interference Fit.
(iii) Transition Fit.

1 Clearance Fit
In clearance fit, an air space or clearance exists between the shaft and hole as shown in Figure 1. Such fits give loose joint. A clearance fit has positive allowance, i.e. there is minimum positive clearance between high limit of the shaft and low limit of the hole.

![Figure 1: Clearance Fit](image)

Clearance fit can be sub-classified as follows:

Loose Fit
It is used between those mating parts where no precision is required. It provides minimum allowance and is used on loose pulleys, agricultural machineries etc.

Running Fit
For a running fit, the dimension of shaft should be smaller enough to maintain a film of oil for lubrication. It is used in bearing pair etc. An allowance 0.025 mm per 25 mm of diameter of boaring may be used.

Slide Fit or Medium Fit
It is used on those mating parts where great precision is required. It provides medium allowance and is used in tool slides, slide valve, automobile parts, etc.

2 Interference Fit
A negative difference between diameter of the hole and the shaft is called interference. In such cases, the diameter of the shaft is always larger than the hole diameter. In Figure 2. Interference fit
has a negative allowance, i.e. interference exists between the high limit of hole and low limit of the shaft.

![Figure 2: Interference Fit](image)

In such a fit, the tolerance zone of the hole is always below that of the shaft. The shaft is assembled by pressure or heat expansion. The interference fit can be sub-classified as follows:

**Shrink Fit or Heavy Force Fit**
It refers to maximum negative allowance. In assembly of the hole and the shaft, the hole is expanded by heating and then rapidly cooled in its position. It is used in fitting of rims etc.

**Medium Force Fit**
These fits have medium negative allowance. Considerable pressure is required to assemble the hole and the shaft. It is used in car wheels, armature of dynamos etc.

**Tight Fit or Press Fit**
One part can be assembled into the other with a hand hammer or by light pressure. A slight negative allowance exists between two mating parts (more than wringing fit). It gives a semi-permanent fit and is used on a keyed pulley and shaft, rocker arm, etc.

**3 Transition Fit**
It may result in either clearance fit or interference fit depending on the actual value of the individual tolerances of the mating components. Transition fits are a compromise between clearance and interference fits. They are used for applications where accurate location is important but either a small amount of clearance or interference is permissible. As shown in Figure 3, there is overlapping of tolerance zones of the hole and shaft.

![Figure 3: Transition Fit](image)

Transition fit can be sub-classified as follows:

**Push Fit**
It refers to zero allowance and a light pressure (10 cating dowels, pins, etc.) is required in assembling the hole and the shaft. The moving parts show least vibration with this type of fit. It is also known as **snug fit**.

**Force Fit or Shrink Fit**
A force fit is used when the two mating parts are to be rigidly fixed so that one cannot move without the other. It either requires high pressure to force the shaft into the hole or the hole to be expanded by heating. It is used in railway wheels, etc.

**Wringing Fit**
A slight negative allowance exists between two mating parts in wringing fit. It requires pressure to force the shaft into the hole and gives a light assembly. It is used in fixing keys, pins, etc.

2. **What are the different systems of tolerances?**
The permissible variation in size or dimension is tolerance. Thus, the word tolerance indicates that a worker is not expected to produce the part of the exact size, but definite a small size error is permitted. The difference between the upper limit (high limit) and the lower limit of a dimension represents the margin for variation to workmanship, and is called a tolerance zone (Figure 1).

Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service.

There are two ways of writing tolerances

(a) Unilateral tolerance
(b) Bilateral tolerance.

![Figure 1: Tolerance](image)

1. **Unilateral Tolerance**

In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it (Figure 2).
Unilateral system is preferred in interchangeable manufacture, especially when precision fits are required, because
(a) it is easy and simple to determine deviations,
(b) another advantage of this system is that „Go” Gauge ends can be standardized as the holes of different tolerance grades have the same lower limit and all the shafts have same upper limit, and
(c) this form of tolerance greatly assists the operator, when machining of mating parts. The operator machines to the upper limit of shaft (lower limit for hole) knowing fully well that he still has some margin left for machining before the parts are rejected.

2 Bilateral Tolerance
In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size, but may not be necessarily equally dispose about it (Figure 3).

In this system, it is not possible to retain the same fit when tolerance is varied and the basic size of one or both of the mating parts are to be varied. This system is used in mass production when machine setting is done for the basic size.
3. Solve the following problem,
For each of the following hole and shaft assembly, find shaft-tolerance, hole tolerance and state whether the type of fit is

(a) Clearance,

(b) Transition, and

(c) Interference:

(i) Hole: 50 \( \pm 0.25 \text{ mm} \), Shaft: 50 \( \pm 0.05 \text{ mm} \)

(ii) Hole: 30 \( \pm 0.05 \text{ mm} \), Shaft: 30 \( \pm 0.02 \text{ mm} \)

(iii) Hole: 25 \( \pm 0.04 \text{ mm} \), Shaft: 25 \( \pm 0.06 \text{ mm} \)
Solution

(a) Hole: High limit of hole = 50.025 mm
    Low limit of hole = 50.00 mm
    Hole tolerance = 50.025 – 50.00
                   = 0.025 mm = 25 × 10⁻⁶ m

Shaft: High limit of shaft = 50.05 mm
    Low limit of shaft = 50.005 mm
    Shaft tolerance = 50.05 – 50.005
                    = 0.045 mm = 45 × 10⁻⁶ m

If we choose high limit of hole with high limit of shaft then
    Allowance = 50.025 – 50.05
                = – 0.025 (Interference)

Similarly, if we choose low limit of hole and either high limit or low limit
of shaft, it is clear that there will be interference.

Thus, we conclude that the type of fit is **Transition fit**.

(b) Hole: High limit = 30.05 mm
    Low limit = 30.00 mm
    Tolerance = 0.05 mm = 5 × 10⁻³ m

Shaft: High limit = 30 – 0.02 = 29.98 mm
    Low limit = 30 – 0.05 = 29.95 mm
    Tolerance = 29.98 – 29.95 = 0.03 mm = 3 × 10⁻³ m

If we select high limit of hole and high limit of shaft then
    Allowance = 30.05 – 29.98 = 0.07 mm

If we choose low limit of hole and high limit of shaft then
    Allowance = 30.00 – 29.98 = 0.02 mm

Thus, we conclude that the type of fit is **Clearance fit**.
4. What are gauges and classify the gauges based on the purposes for which they are used?
Gauges are the tools which are used for checking the size, shape and relative positions of various parts but not provided with graduated adjustable members. Gauges are, therefore, understood to be single-size fixed-type measuring tools.

Classifications of Gauges
(a) Based on the standard and limit
   (i) Standard gauges

   (ii) Limit gauges or “go” and “not go” gauges

(b) Based on the consistency in manufacturing and inspection
   (i) Working gauges

   (ii) Inspection gauges

   (iii) Reference or master gauges

(c) Depending on the elements to be checked
   (i) Gauges for checking holes

   (ii) Gauges for checking shafts
(iii) Gauges for checking tapers
(iv) Gauges for checking threads
(v) Gauges for checking forms
(d) According to the shape or purpose for which each is used
(i) Plug
(ii) Ring
(iii) Snap
(iv) Taper
(v) Thread
(vi) Form
(vii) Thickness
(viii) Indicating
(ix) Air-operated

1 Standard Gauges
Standard gauges are made to the nominal size of the part to be tested and have the measuring member equal in size to the mean permissible dimension of the part to be checked. A standard gauge should mate with some snugness.

2 Limit Gauges
These are also called “go” and “no go” gauges. These are made to the limit sizes of the work to be measured. One of the sides or ends of the gauge is made to correspond to maximum and the other end to the minimum permissible size. The function of limit gauges is to determine whether the actual dimensions of the work are within or outside the specified limits. A limit gauge may be either double end or progressive. A double end gauge has the “go” member at one end and “no go” member at the other end. The “go” member must pass into or over an acceptable piece but the “no go” member should not. The progressive gauge has “no go” members next to each other and is applied to a workpiece with one movement. Some gauges are fixed for only one set of limits and are said to be solid gauges. Others are adjustable for various ranges.

5. Explain the different types of gauges commonly used in production work?
Some of the important gauges which are commonly used in production work have been discussed as follows:

1 Plug Gauges
These gauges are used for checking holes of many different shapes and sizes. There are plug gauges for straight cylindrical holes, tapered, threaded square and splined holes. Figure1 shows a standard plug gauge used to test the nominal size of a cylindrical hole. Figure 2 shows a double-ended limit plug gauge used to test the limits of size. At one end, it has a plug minimum limit size, the “go” end and; at the other end a plug of maximum limit, the “no go” end. These ends are
detachable from the handle so that they may be renewed separately when worn in a progressive limit plug gauge. The „go” and „no go” section of the gauge are on the same end of the handle. Large holes are gauged with annular plug gauges, which are shell-constructed for light weight, and flat plug gauges, made in the form of diametrical sections of cylinders.

![Figure 1: Standard Ring and Plug Gauges](image1)

![Figure 2: Progressive and Double Ended Limit Plug Gauges](image2)

2 Ring Gauges
Ring gauges are used to test external diameters. They allow shafts to be checked more accurately since they embrace the whole of their surface. Ring gauges, however, are expressive manufacture and, therefore, find limited use. Moreover, ring gauges are not suitable for measuring journals in the middle sections of shafts. A common type of standard ring gauge is shown in Figure 1. In a limit ring gauge, the „go” and „no go” ends are identified by an annular groove on the periphery. About 35 mm all gauges are flanged to reduce weight and facilitate handling.

3 Taper Gauges
The most satisfactory method of testing a taper is to use taper gauges. They are also used to gauge the diameter of the taper at some point. Taper gauges are made in both the plug and ring styles and, in general, follow the same standard construction as plug and ring gauges. A taper plug and ring gauge is shown in Figure 3.

![Figure 3: Taper Plug and Ring Gauge](image3)

When checking a taper hole, the taper plug gauge is inserted into the hole and a slight pressure is exerted against it. If it does not rock in the hole, it indicates that the taper angle is correct. The same procedure is followed in a ring gauge for testing tapered spindle. The taper diameter is tested for the size by noting how far the gauge enters the tapered hole or the tapered spindle enters the gauge. A mark on the gauge show the correct diameter for the large end of the taper.
To test the correctness of the taper two or three chalk or pencil lines are drawn on the gauge about equidistant along a generatrix of the cone. Then the gauge is inserted into the hole and slightly turned. If the lines do not rub off evenly, the taper is incorrect and the setting in the machine must be adjusted until the lines are rubbed equally all along its length. Instead of making lines on the gauge, a thin coat of paint (red led, carbon black, Prussian blue, etc.) can be applied.

The accuracy of a taper hole is tested by a taper limit gauge as shown in Figure 4. This has two check lines „go” and „no go” each at a certain distance from the end of the face. The go portion corresponds to the minimum and „no go” to the maximum dimension.

![Figure 4: Limit Taper Plug Gauge](image)

4 Snap Gauges

These gauges are used for checking external dimensions. Shafts are mainly checked by snap gauges. They may be solid and progressive or adjustable or double-ended. The most usual types are shown in Figure 5.

![Figure 5: Snap Gauges](image)

(a) Solid or non-adjustable caliper or snap gauge with „go” and „no go” each is used for large sizes.

(b) Adjustable caliper or snap gauge used for larger sizes.

This is made with two fixed anvils and two adjustable anvils, one for „go” and another for the „no go”.

The housing of these gauges has two recesses to receive measuring anvils secured with two screws. The anvils are set for a specific size, within an available range of adjustment of 3 to 8 mm. The adjustable gauges can be used for measuring series of shafts of different sizes provided the diameters are within the available range of the gauge.

(iii) Double-ended solid snap gauge with „go” and „no go” ends is used for smaller sizes.

5 Thread Gauges
Thread gauges are used to check the pitch diameter of the thread. For checking internal threads (nut, bushes, etc.), plug thread gauges are used, while for checking external threads (screws, bolts, etc.), ring thread gauges are used. Single-piece thread gauges serve for measuring small diameters. For large diameters the gauges are made with removable plugs machined with a tang. Standard gauges are made single-piece. Common types of thread gauges are shown in Figure 6.

![Figure 6: Thread Gauge](image)

Standard plug gauges may be made of various kinds:
(a) Plug gauge with only threaded portion.
(b) Threaded portion on one end and plain cylindrical plug on opposite end to give correct “core” diameter.
(c) Thread gauge with core and full diameters.

Limit plug gauges have a long-thread section on the “go” and a short-threaded section on the “no go” end to correspond to the minimum and maximum limits respectively.

Roller rings gauges, similarly have “go” and “no go” ends. They may also be solid and adjustable.

Roller Snap gauges are often used in production practice for measuring external threads. They comprise a body, two pairs “go” rollers and two pairs “no go” rollers.

Taper thread gauges are used for checking taper threads. The taper-ring thread gauge are made in two varieties – rigid (non-adjustable) and adjustable. The “go” non-adjustable ring gauges are full threaded while the “no go” have truncated thread profile.

**6 Form Gauges**
Form gauges may be used to check the contour of a profile of workpiece for conformance to certain shape or form specifications.

**Template Gauge**
It is made from sheet steel. It is also called profile gauge. A profile gauge may contain two outlines that represent the limits within which a profile must lie as shown in Figure 7.
7 Screw Pitch Gauges
Screw pitch gauges serve as an everyday tool used in picking out a required screw and for checking the pitch of the screw threads. They consist of a number of flat blades which are cut out to a given pitch and pivoted in a holder as shown in Figure 8. Each blade is stamped with the pitch or number of thread per inch and the holder bears an identifying number designating the thread it is intended for. The sets are made for metric threads with an angle 60°, for English threads with an angle of 55°. A set for measuring metric threads with 30 blades has pitches from 0.4 to 0.6 mm and for English threads with 16 blades has 4 to 28 threads per inch.
In checking a thread for its pitch the closest corresponding gauge blade is selected and applied upon the thread to be tested. Several blades may have to be tried until the correct is found.

8 Radius and Fillet Gauges
The function of these gauges is to check the radius of curvature of convex and concave surfaces over a range from 1 to 25 mm. The gauges are made in sets of thin plates curved to different radius at the ends as shown in Figure 9. Each set consists of 16 convex and 16 concave blades.

9 Feller Gauges
Feller gauges are used for checking clearances between mating surfaces. They are made in form of a set of steel, precision machined blade 0.03 to 1.0 mm thick and 100 mm long. The blades are provided in a holder as shown in Figure 10. Each blade has an indication of its thickness. The Indian standard establishes seven sets of feller gauges: Nos 1, 2, 3, 4, 5, 6, 7, which differ by the number of blades in them and by the range of thickness. Thin blades differ in thickness by 0.01 mm in the 0.03 to 1 mm set, and by 0.05 mm in the 0.1 to 1.0 mm set.
To find the size of the clearance, one or two blades are inserted and tried for a fit between the contacting surfaces until blades of suitable thickness are found.
10 Plate and Wire Gauges
The thickness of a sheet metal is checked by means of plate gauges and wire diameters by wire gauges. The plate gauge is shown in Figure 11. It is used to check the thickness of plates from 0.25 to 5.0 mm, and the wire gauge, in Figure 12, is used to check the diameters of wire from 0.1 to 10 mm.

11 Indicating Gauges
Indicating gauges employ a means to magnify how much a dimension deviates, plus or minus, from a given standard to which the gauge has been set. They are intended for measuring errors in geometrical form and size, and for testing surfaces for their true position with respect to one another. Beside this, indicating gauges can be adapted for checking the run out of toothed wheels, pulleys, spindles and various other revolving parts of machines. Indicating gauges can be of a dial or lever type, the former being the most widely used.

12 Air Gauges
Pneumatic or air gauges are used primarily to determine the inside characteristics of a hole by means of compressed air. There are two types of air gauges according to operation: a flow type and a pressure type gauge. The flow type operates on the principle of varying air velocities at constant pressure and the pressure type operates on the principle of air escaping through an orifice.

Multiple choice Questions with Answers

1. The standard size of a part with reference to which the variations in the limits of size can be determined is known as
a) Normal size  b) Basic size  c) Actual size  d) None of the above

2. The permissible variation in the dimension is referred as,
   a) Limits   b) Basic size  c) Tolerance  d) None of the above

3. The difference between upper limit and lower limit is called as,
   a) Actual size  b) Basic size  c) Tolerance  d) None of the above

4. The prescribe difference between the dimensions of two mating parts is,
   a) Tolerance  b) Allowance  c) Either of the above  d) None of the above

5. The algebraic difference between maximum limits of size and corresponding basic size is known as,
   a) Deviation  b) Tolerance  c) Clearance  d) None of the above

6. In which type of fit, shaft is smaller than hole,
   a) Transition  b) Interference  c) Clearance  d) None of the above

7. For lathe spindle dividing heads, which type of fit is provided,
   a) Slide fit  b) Slack running fit  c) Force fit  d) Easy Slide fit

8. Interference fit consists of,
   a) Push fit  b) Force fit  c) Tight fit  d) Both b&c

9. In which system, the dimension of part is allowed to vary only one side of the basic size,
   a) Shaft basis system  b) Unilateral system  c) Bilateral system  d) Hole basis system

10. A combination square comprises of
   a) Slip gauge  b) Centre head  c) Sine bar  d) Steel plate

**KEY:**
**UNIT-1**

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<th>2.c</th>
<th>3.c</th>
<th>4.b</th>
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<td>7.d</td>
<td>8.d</td>
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<td>10.b</td>
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</tbody>
</table>

S.SATHISH
Assistant Professor
Fill in the blanks questions with answers

1. The permissible variation in the dimension is referred as............
2. The algebraic difference between maximum limits of size and corresponding basic size is known as............
3. In which type of fit, shaft is smaller than hole......
4. For lathe spindle dividing heads............type of fit is provided.
5. Interference fit consists of......
6. In which system, shaft is kept constant and hole sizes are varied.......... 
7. In which system, hole is kept constant and shaft sizes are varied........
8. In which system, the dimension of part is allowed to vary only one side of the basic size...
9. Dial indicators is one of the most commonly used......
10. Angle gauges are made up of........

KEY:

UNIT-4

|--------------|--------------|--------------|-------------------|------------------------|

UNIT-V

Two marks questions with answers

1. What are the various factors affects the surface roughness?

Factors Affecting Surface Roughness:-
The following factors affect the surface roughness:
(1) Vibrations
(2) Material of the work piece
(3) Type of machining.
(4) Rigidity of the system consisting of machine tool, fixture cutting tool and work
(5) Type, form, material and sharpness of cutting tool
(6) Cutting conditions i.e., feed, speed and depth of cut
(7) Type of coolant used.

2. What are the Reasons for Controlling Surface Texture?

Reasons for Controlling Surface Texture:-
(1) To improve the service life of the components
(2) To improve the fatigue resistance
(3) To reduce initial wear of parts
(4) To have a close dimensional tolerance on the parts
(5) To reduce frictional wear
(6) To reduce corrosion by minimizing depth of irregularities
(7) For good appearance
(8) If the surface is not smooth enough, a turning shaft may act like a reamer and the piston rod like a broach.

However, the perfectly smooth surface is not always required; the requirement of surface texture depends upon the specific application of the part.

3. Define surface roughness?

Roughness (Primary texture):
The surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting element son the material i.e., cutting tool shape, tool feed rate or by some other disturbances such as friction, wear or corrosion.

These include irregularities of third and fourth order and constitute the micro-geometrical errors. The ratio \( lr / hr \) denoting the micro-errors is less than 50, where \( Ir = \) length along the surface and \( hr = \) deviation of surface from the ideal one.

4. Define surface waviness?

Waviness (Secondary texture):
The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centres, non-linear feed motion, deformation of work under the action of cutting forces, vibrations of any kind etc.
These errors include irregularities of first and second order and constitute the macro-geometrical errors. The ratio of $I_w / h_w$ denoting the macro-errors is more than 50. Where, $I_w = \text{length along the surface and } k_w = \text{deviation of surface from ideal one.}$

5. List out various methods for Evaluation of Surface Finish?

**Evaluation of Surface Finish:**
A numerical assessment of surface finish can be carried out in a number of ways. These numerical values are obtained with respect to a datum. In practice, the following three methods of evaluating primary texture (roughness) of a surface are used:
(1) Peak to valley height method
(2) The average roughness
(3) Form factor or bearing curve.

**3 marks questions with answers**

1. **What are the different roughness symbols used in the industry?**
The roughness symbols indicate the practice followed in the industry.

<table>
<thead>
<tr>
<th>Roughness Values ($R_z \mu m$)</th>
<th>Roughness Grade Number</th>
<th>IS Roughness Symbol</th>
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<tr>
<td>90</td>
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</tr>
<tr>
<td>0.025</td>
<td>N1</td>
<td>VVV</td>
</tr>
</tbody>
</table>

2. **State how surface finish is designated on drawings?**
The surface roughness is represented as shown in figure:
3. What are the different ISI Symbols for Indication of surface Finish?
The surface roughness is represented in figure. If the matching method is milling, sampling length is 2.5 mm, direction of lay is parallel to the surface, machining allowance is 3 mm and the representative will be as shown in figure,

**Representation of Surface Roughness:**
(i) The limits of surface roughness can be represented as,

\[ R_{a_{1.6}}^{8.0} \text{ or } R_{a}^{8.0-16.0} \]

(ii) The surface roughness and sampling length can be represented as,

\[ R_{a}^{8.0}(2.5) \]

Here surface sampling length is 2.5 mm p

(iii) The surface roughness and lay can be stated as,

\[ R_{a}^{1.6} \text{ lay Circular} \]

However, in most cases, one single piece of information is sufficient which is indicated as follows,

The I.S.O has recommended as series of preferred roughness values and corresponding roughness grade numbers to be used when specifying surface roughness on drawings.
4. Solve the following problem?

**Problem 10.** Calculate the C.L.A. value of a surface for the following data:
The sampling length is 0.8 mm, the graph is drawn to a vertical magnification of 15,000 and horizontal magnification of 100 and the areas above and below the datum line are 160, 90, 180, 50 mm² and 95, 65, 170, 150 mm² respectively.

**Sol.** 
\[
\text{C.L.A.} = \frac{\sum A}{L} \times \frac{1}{\text{vertical scale}} \times \frac{1}{\text{horizontal scale}} \\
= \frac{160 \times 95 + 90 + 65 + 180 + 170 + 50 + 150}{0.8} \times 15000 \times 100 \\
= 0.8 \, \mu\text{m}.
\]

5. Solve the following problem?

**Problem 11.** In the measurement of surface roughness, heights of 20 successive peaks and valleys measured from a datum are as follows:
45, 25, 40, 25, 35, 16, 40, 22, 25, 34, 25, 40, 20, 36, 28, 18, 20, 25, 30, 38
If these measurements were made over a length of 20 mm, determine the C.L.A and RMS values of the surface.

**Sol.**
\[
\text{C.L.A. value} = \frac{45 + 25 + 40 + 25 + 35 + 16 + 40 + 22 + 25 + 34 + 25 + 40 + 20 + 36 + 28 + 18 + 20 + 25 + 30 + 38}{20} \\
= 29.35
\]
\[
\text{RMS Value} = \sqrt{\frac{45^2 + 25^2 + 40^2 + 25^2 + 35^2 + 16^2 + 40^2 + 22^2 + 25^2 + 34^2 + 25^2 + 40^2 + 20^2 + 36^2 + 28^2 + 18^2 + 20^2 + 25^2 + 30^2 + 38^2}{20}} \\
= 930.96
\]
Five marks questions with answers

1. Explain different elements of surface texture?

The various elements of surface texture can be defined and explained with the help of fig which shows a typical surface highly magnified.

Surface: The surface of a part is confined by the boundary which separates that part from another part, substance or space. Actual surface. This refers to the surface of a part which is actually obtained after a manufacture ring process.

Nominal surface: A nominal surface is a theoretical, geometrically perfect surface which does not exist in practice, but it is an average of the irregularities that are superimposed on it.

Profile: Profile is defined as the contour of any section through a surface. Roughness. As already explained roughness refers to relatively finely spaced micro geometrical irregularities. It is also called as primary texture and constitutes third and fourth order irregularities.

Roughness Height: This is rated as the arithmetical average deviation expressed in micro-meters normal to an imaginary centre line, running through the roughness profile.

Roughness Width: Roughness width is the distance parallel to the normal surface between successive peaks or ridges that constitutes the predominant pattern of the roughness.

Roughness Width cutoff: This is the maximum width of surface irregularities that is included in the measurement of roughness height. This is always greater than roughness width and is rated in centimetres.

Waviness: Waviness consists of those surface irregularities which are of greater spacing than roughness and it occurs in the form of waves. These are also termed as moon geometrical errors.
and constitute irregularities of first and second order. These are caused due to misalignment of centres, vibrations, machine or work deflections, warping etc.

**Effective profile:** It is the real centre of a surface obtained by using instrument

**Laws:** Flaws are surface irregularities or imperfections which occur at infrequent intervals and at random intervals. Examples are: scratches, holes, cracks, porosity etc. These may be observed directly with the aid of penetrating dye or other material which makes them visible for examination and evaluation.

**Surface Texture:** Repetitive or random deviations from the nominal. Surface which forms the pattern on the surface. Surface texture includes roughness, waviness, lays and flaws.

![Diagram of Types of Lay](image)

**Lay:** It is the direction of predominant surface pattern produced by tool marks or scratches. It is determined by the method of production used. Symbols used to indicate the direction of lay are given below:

| | = Lay parallel to the boundary line of the nominal surface that is, lay parallel to the line representing surface to which the symbol is applied e.g., parallel shaping, end view of turning and O.D grinding.

| = Lay perpendicular to the boundary line of the nominal surface, that is lay perpendicular to the line representing surface to which the symbol is applied, e.g., end view of shaping, longitudinal view of turning and O.D. grinding.

X = Lay angular in both directions to the line representing the surface to which symbol is applied, e.g. traversed end mill, side wheel grinding.

M = Lay multidirectional e.g. lapping super finishing, honing.

C = Lay approximately circular relative to the centre of the surface to which the symbol is applied e.g., facing on a lathe.

R = Lay approximately radial relative to the centre of the surface to which the symbol is applied, e.g., surface ground on a turntable, fly cut and indexed on end mill.

**Sampling length:** It is the length of the profile necessary for the evaluation of the irregularities to be taken into account. It is also known as cut-off length. It is measured in a direction parallelogram general direction of the profile. The sampling length should bear some relation to the type of profile.
2. Explain different evaluation methods of surface finish?

**Evaluation of Surface Finish:**
A numerical assessment of surface finish can be carried out in a number of ways. These numerical values are obtained with respect to a datum. In practice, the following three methods of evaluating primary texture (roughness) of a surface are used:

1. Peak to valley height method
2. The average roughness
3. Form factor or bearing curve.

**(1) Peak to valley height method:**
This method is largely used in Germany and Russia. It measures the maximum depth of the surface irregularities over a given sample length, and largest value of the depth is accepted as a measure of roughness. The drawback of this method is that it may read the same \( h_{max} \) for two largely different texture. The value obtained would not give a representative assessment of the surface.

![Peak to Valley height](image)

To overcome this PV (Peak to Valley) height is defined as the distance between a pair of lines running parallel to the general lay of the trace positioned so that the length lying within the peaks at the top is 5% of the trace length, and that within the valleys at the bottom is 10% of the trace length. This is represented graphically in Fig.

**(2) The average roughness:** For assessment of average roughness the following three statistical criteria are used:

(a) **C.L.A Method:** In this method, the surface roughness is measured as the average deviation from the nominal surface.

![Centre Line Average](image)

Centre Line Average or Arithmetic Average is defined as the average values of the ordinates from the mean line, regardless of the arithmetic signs of the ordinates.
The calculation of C.L.A value using equation (ii) is facilitated by the planimeter. CLA value measure is preferred to RMS value measure because its value can be easily determined by measuring. The areas with planimeter or graph or can be readily determined in electrical instruments by integrating the movement of the styles and displaying the result as an average.

(b) R.M.S. Method: In this method also, the roughness is measured as the average deviation from the nominal surface. Root mean square value measured is based on the least squares.

R.M.S value is defined as the square root of the arithmetic mean of the values of the squares of the ordinates of the surface measured from a mean line. It is obtained by setting many equidistant ordinates on the mean line (y1, y2, y3,...) and then taking the root of the mean of the squared ordinates.

Let us assume that the sample length \( L \) is divided into \( n \) equal parts and \( y_1, y_2, y_3, ... \) are the heights of the ordinates erected at those points.

Then,

\[
RMS\ average = \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + ... + y_n^2}{n}}
\]

(c) Ten Point Height Method: In this method, the average difference between the five highest peaks and five lowest valleys of surface texture within the sampling length, measured from a line parallel to the mean line and not crossing the profile is used to denote the amount of surface roughness.

Mathematically,

\[
R_2 = ten\ point\ height\ of\ irregularities
= \frac{1}{5} \left[ (R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10}) \right]
\]

This method is relatively simple method of analysis and measures the total depth of surface irregularities within the sampling length. But it does not give sufficient information about the
surface, as no account is taken of frequency of the irregularities and the profile shape. It is used when it is desired to control the cost of finishing for checking the rough machining.

(3) **Form factor and Bearing Curves:** There are certain characteristic which may be used to evaluate surface texture.

**Form Factor:** The load carrying area of every surface is often much less than might be thought. This is shown by reference to form factor. The form factor is obtained by measuring the area of material above the arbitrarily chosen base line in the section and the area of the enveloping rectangle. Then,

\[
\text{Degree of fullness (K)} = \frac{\text{Area of metal}}{\text{Area of enveloping rectangle}}
\]

\[
\text{Degree of emptiness} = (K_p) = 1 - K
\]

**Bearing Area Curve:** The bearing area curve is also called as Abbot's bearing curve. This is determined by adding the lengths a, b, c etc. at depths x, y, z etc. below the reference, line and indicates the percentage bearing area which becomes available as the crest area worn away. Fig. indicates the method of determining the bearing curve.

3. Explain the different methods used for ensuring the surface finish?
Measurement of surface finish surfaces texture:
The methods used for ensuring the surface finish can be classified broadly into two groups.

1. Inspection by comparison.
2. Direct instrument measurement

1. **Inspection by comparison methods.** In these methods, the surface texture is assessed by observation of the surface. These are the methods of qualitative analysis of the surface texture. The texture of the surface to be tested is compared with that of a specimen of known roughness value and finished by similar machining processes. Though these methods are rapid, the results are not reliable because they can be misleading if comparison is not made with the surface produced by similar techniques. The various methods available for comparison are:
   (i) Visual Inspection
   (ii) Touch Inspection
   (iii) Scratch Inspection
   (iv) Microscopic Inspection
   (v) Surface photographs
   (vi) Micro-Interferometer
   (vii) Wallace surface Dynamometer
   (viii) Reflected Light Intensity.

(i) **Visual Inspection:** In this method the surface is inspected by naked eye. This method is always likely to be misleading particularly when surfaces with high degree of finish are inspected. It is therefore limited to rougher surfaces.

(ii) **Touch Inspection:** This method can simply assess which surface is more rough, it cannot give the degree of surface roughness. Secondly, the minute flaws can't be detected. In this method, the finger tip is moved along the surface at a speed of about 25 mm per second and the irregularities as small as 0.0125 mm can be detected. In modified method a tennis ball is rubbed over the surface and surface roughness is judged thereby.

(iii) **Scratch Inspection:** In this method a softer material like lead, babbit, or plastic is rubbed over the surface to be inspected. The impression of the scratches on the surface produced is then visualized.

(iv) **Microscopic Inspection:** This is probably the best method for examining the surface texture by comparison. But since, only a small surface can be inspected at a time several readings are required to get an average value. In this method, a master finished surface is placed under the microscope and compared with the surface under inspection. Alternatively, a straight edge is placed on the surface to be inspected and a beam of light projected at about 600 to the work. Thus the shadow is cast into the surface, the scratches are magnified and the surface irregularities can be studied.

(v) **Surface photographs:** In this method magnified photographs of the surface are taken with different types of illumination to reveal the irregularities. If the vertical illumination is used then defects like irregularities and scratches appear as dark spots and flat portion of the surface appears as bright area. In case of 'oblique illumination, reverse is the case. Photographs with different illumination are compared and the result is assessed.

(vi) **Micro Interferometer:** In this method, an optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light. Interference bands are studied through a microscope. The scratches in the surface appear as interference lines extending from the dark bands
into the bright bands. The depth of the defect is measured in terms of the fraction of the interference bands.

**(vii) Wallace Surface Dynamometer:** It is a sort of friction meter. It consists of a pendulum in which the testing shoes are damped to a bearing surface and a predetermined spring pressure can be applied. The pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested. If the surface is smooth, then there will be less friction and pendulum swings for a longer period. Thus, the time of swing is a direct measure of surface texture.

**(viii) Reflected Light Intensity:** In this method a beam of light of known quantity is projected upon the surface. This light is reflected in several directions as beams of lesser intensity and the change in light intensity in different directions is measured by a photocell. The measured intensity changes are already calibrated by means of reading taken from surface of known roughness by some other suitable method.

**2. Direct Instrument Measurement:**
These are the methods of quantitative analysis. These methods enable to determine the numerical value of the surface finish of any surface by using instruments of stylus probe type operating on electrical principles. In these instruments the output has to be amplified and the amplified output is used to operate recording or indicating instrument.

**Principle, constructive and operation of stylus Probe type surface texture measuring instruments:**
If a finely pointed Probe or stylus be moved over the surface of a work piece, the vertical movement of the stylus caused due to the irregularities in the surface texture can be used to assess the surface finish of the work piece.

![Stylus Diagram](image)

Stylus which is a fine point made of diamond or any such hard material is drawn over the surface to be tested. The movements of the stylus are used to modulate a high frequency carrier current or to generate a voltage signal. The output is then amplified by suitable means and used to operate a recording or indicating instrument.

Stylus type instruments generally consist of the following units:
(i) Skid or shoe
(ii) Finely pointed stylus or probe
(iii) An amplifying device for magnifying the stylus movement and indicator
(iv) Recording device to produce a trace and ~
(v) Means for analyzing the trace.

**Advantages:**
The main advantage of such instruments is that the electrical signal available can be processed to obtain any desired roughness parameter or can be recorded for display or subsequent analysis. Therefore, the stylus type instruments are widely used for surface texture measurements inspite of the following disadvantages.
Disadvantages:
(i) These instruments are bulky and complex.
(ii) They are relatively fragile.
(iii) Initial cost is high.
(iv) Measurements are limited to a section of a surface.
(v) Needs skilled operators for measurements.
(vi) Distance between stylus and skid and the shape of the skid introduce errors in measurement for wavy surfaces.

The stylus probe instruments currently in use for surface finish measurement.
(a) Profilometer
(b) The Tomlinson surface meter.
(c) The Taylor Hobson Talysurf
(d) Profilograph.

(c) Profilometer:

![Diagram of Profilometer]

Profilometer is an indicating and recording instrument used to measure roughness in microns. The principle of the instrument is similar to gramophone pick up. It consists of two principal units: a tracer and an amplifier. Tracer is a finely pointed stylus. It is mounted in the pick up unit which consists of an induction coil located in the field of a permanent magnet. When the tracer is moved across the surface to be tested, it is displaced vertically up and down due to the surface irregularities. This causes the induction coil to move in the field of the permanent magnet and induces a voltage. The induced voltage is amplified and recorded. This instrument is best suited for measuring surface finish of deep bores.

(b) The Tomlinson surface meter:
The Tomlinson surface meter is a comparatively cheap and reliable instrument. It was originally designed by Dr. Tomlinson.
It consists of a diamond probe (stylus) held by spring pressure against the surface of a lapped steel cylinder and is attached to the body of the instrument by a leaf spring. The lapped cylinder is supported on one side by the probe and on the either side by fixed rollers. A light spring steel arm is attached to the lapped cylinder. It carries at its tip a diamond scriber which rests against a smoked glass. The motions of the stylus in all the directions except the vertical one are prevented by the forces exerted by the two springs.

For measuring surface finish the body of the instrument is moved across the surface by screw rotated by asynchronous motor. The vertical movement of the probe caused by surface irregularities makes the horizontal lapped cylinder to roll. This causes the movement of the arm attached to the lapped cylinder. A magnified vertical movement of the diamond scriber on smoked glass is obtained by the movement of the arm. This vertical movement of the scriber together with horizontal movement produces a trace on the smoked glass plate. This trace is further magnified at X 50 or X 100 by an optical projector for examination.

(c) The Taylor Hobson Talysurf:
Taylor-Hobson Talysurf is a stylus and skid type of instrument working on carrier modulating principle. Its response is more rapid and accurate as compared to Tomlinson Surface Meter. The measuring head of this instrument consists of a sharply pointed diamond stylus of about 0.002 mm tip radius and skid or shoe which is drawn across the surface by means of a motorized driving unit. In this instrument the stylus is made to trace the profile of the surface irregularities, and the oscillatory movement of the stylus is converted into changes in electric current by the arrangement as shown in Fig.
The arm carrying the stylus forms an armature which pivots about the centre piece of E-shaped stamping. On two legs of (outer pole pieces) the E-shaped stamping there are coils carrying an a.c. current. These two coils with other two resistances form an oscillator. As the armature is pivoted about the central leg, any movement of the stylus causes the air gap to vary and thus the amplitude of the original a.c. current flowing in the coils is modulated. The output of the bridge thus consists of modulation only as shown in Fig. This is further demodulated so that the current now is directly proportional to the vertical displacement of the stylus only.

(d) Profilograph:
(i) Profilograph: The principle of Working of a tracer type profilograph is shown in Fig. The work to be tested is placed on the table of the instrument. The work and the table are traversed with the help of a lead screw.

The stylus which is pivoted to a mirror moves over the tested surface. Oscillations of the tracer point are transmitted to the mirror. A light source sends a beam of light through lens and a precision slit to the oscillating mirror. The reflected beam is directed to a revolving drum, upon which a sensitised film is arranged. This drum is rotated through two bevel gears from the same lead screw that moves the table of the instrument. A profilogram will be obtained from the sensitised film that may be sub-sequently analysed to determine the value of the surface roughness.
4. Explain different Orders of Geometrical Irregularities?
As we know that the material machined by chip removal process can't be finished perfectly due to some departures from ideal conditions as specified by the designer. Due to conditions not being ideal, the surface produced will have some irregularities; these geometrical irregularities can be classified into four categories.

First Order: The irregularities caused by inaccuracies in the machine tool itself are called as first order irregularities. These include:
1. Irregularities caused due to lack of straightness of guide ways on which the tool most moves.
2. Surface regularities arising due to deformation of work under the action of cutting forces, and
3. Due to the weight of the material itself.

Second Order: The irregularities caused due to vibrations of any kind are called second order irregularities.

Third Order: Even if the machine were perfect and completely free from vibrations some irregularities are caused by machining itself due to the characteristics of the process.

Fourth Order: The fourth order irregularities include those arising from the rupture of the material during the separation of the chip.

Irregularities on the surface of the part:
The irregularities on the surface of the part produced can also be grouped into two categories:
(i) Roughness or primary texture, (ii) Waviness or secondary texture.

i) Roughness (Primary texture):
The surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting element on the material i.e., cutting tool shape, tool feed rate or by some other disturbances such as friction, wear or corrosion.

These include irregularities of third and fourth order and constitute the micro-geometrical errors. The ratio \( \frac{Ir}{hr} \) denoting the micro-errors is less than 50, where \( Ir \) = length along the surface and \( hr \) = deviation of surface from the ideal one.
ii) Waviness (Secondary texture):
The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centres, non-linear feed motion, deformation of work under the action of cutting forces, vibrations of any kind etc.

These errors include irregularities of first and second order and constitute the macro-geometrical errors. The ratio of \( I_w / h_w \) denoting the macro-errors is more than 50. Where, \( I_w \) = length along the surface and \( k_w \) = deviation of surface from ideal one.

5. What are the different alignment test are performed on lathe machine?

1. Quality of slide ways:
To test the quality of the slide ways it is necessary to mount the dial indicator on a good datum surface. Then the plunger is moved along the longitudinal direction of the slide ways which provides an indication of the undulations present on the surface of the slide ways.

2. Accuracy of the spindle:
These tests are related to the true running of the spindle and the centre located in the spindle along with the alignment, parallelism and perpendicularity of the spindle with the other axes of the concerned machine tool.

True running of the centre: The live centre may be loaded into the lathe spindle and a dial indicator mounted as shown in fig. This test is required only for machines where the work piece is held between centres. The readings of the dial indicator are taken while rotating the spindle through full rotation.
**True running of the spindle:** the taper shank of the test mandrel of about 300 mm length is mounted into the spindle as shown in fig. The plunger of the dial indicator rests on the cylindrical surface of the mandrel. The spindle is rotated slowly and the readings of the dial indicator are noted. The deviation should normally be less than 0.01mm. The test is to be repeated with the dial indicator positioned close to the spindle bore as well as at the extreme end of the test mandrel.

**Squreeness of the face:** this test is used to measure the squreeness of the shoulder face with reference to the spindle axis. The plunger of the dial indicator rests on the extreme radial position of the shoulder face and the reading is taken. It is repeated by slowly rotating the spindle till the dial indicator comes to a point that is diametrically opposite to the reading taken earlier.

3. **Alignment tests:**

*Parallelism and perpendicularity:* Parallelism and perpendicularity between two axes or two surfaces is normally measured in two planes, horizontal and vertical. For this purpose the test mandrel is mounted in the spindle as shown in fig. with dial indicator mounted on the saddle or carriage. The plunger of the dial indicator touches the mandrel surface as shown in fig. the saddle is moved for a specified distance and the dial reading noted. The test is repeated in the horizontal direction as well.
Parallelism between the outside diameter of the tail stock sleeve and the slide ways as shown in fig.

Parallelism between the line of centres and the slide ways shown in fig.

Multiple choice questions with answers

1) What does effective profile mean, while defining a surface texture?
   a. Work piece having repetitive irregularities
   b. Roughness can be measured in this imaginary profile
   c. Real contour of a surface
   d. All of the above

2) Which among the following causes first order surface irregularity?
   a. Lack of straightness
   b. Lack of rigidity
   c. Feed and speed
   d. Vibrations

3) Which among the following is a type of direct measuring instrument of roughness?
   a. Micro interferometer
   b. Wallace surface dynamometer
   c. Profilometer
   d. None of the above

4) Which principle does Taylor-Hobson-Talysurf tester work on?
a. Capacitive demodulating principle
b. Intensity modulating principle
c. Inductive modulating principle
d. Carrier modulating principle

5) Which of the following methods is unreliable to evaluate the surface finish?

a. Electrical stylus profilometer  
b. Wallace surface dynamometer  
c. Profilograph  
d. Tomlinson surface tester

6) Which of the following statements is true?

a. Photocell is used to measure light intensity  
b. Planimeter is used to measure surface roughness  
c. According to Indian Standard 696 roughness value is to be measured in millimeter  
d. All statements are true

7) What is ten point height method?

a. It is the average sum of ten highest points measured within sampling length  
b. It is the average difference of five highest points and five deepest valleys measured within sampling length  
c. It is the sum of ten highest points divided by sum of ten deepest valleys measured within sampling length  
d. It is the average sum of five highest points and five deepest valleys measured within sampling length

8) Which method is calculated considering geometric average of ordinates?

a. Centre line average method  
b. Peak to valley height method  
c. Root mean square method  
d. All of the above

9) Calculate CLA value of roughness for a graph, having 100 horizontal magnification and 10000 vertical magnification for a sampling length of 1.2 mm. The areas above the datum line are 100 mm², 120 mm², 140 mm², 40 mm² and below the datum line are 80 mm², 40 mm², 150 mm², 90 mm².

a. 0.6333 micron  
b. 6.333 micron  
c. 0.912 micron  
d. 0.079 micron
10) The surface finish is improved by the increase in

A. cutting speed
B. nose radius
C. true rake angle
D. all of these

KEY:  1.c  2.a  3.c  4.d  5.b  6.a  7.b  8.c  9.a  10.d

Fill in the blanks with answers

1. Waviness is also called ..........................
2. Roughness is also called ..........................
3. The first order irregularities caused by ..................
4. The secondary order irregularities caused by ..........
5. The third order irregularities caused by ...............
6. The fourth order irregularities caused due ..........
7. M = Symbol used to indicate ...............lay
8. Sampling length is also known as .......... 
9. Peak to valley height method is largely used in ...... 
10. C.L.A stands for ...........

KEY:
1. Secondary texture 
2. Primary texture 
3. Inaccuracies in the machine tool 
4. Due to vibrations 
5. Due to the characteristics of the process. 
6. The rupture of the material 
7. Multidirectional 
8. Cut-off length 
9. Germany and Russia 
10. Centre Line Average.
17. Beyond the syllabus topics with material

5.1.1 Classification of NC machine tools

5.1.2 Components of a NC machine tool

*The components of a traditional NC machine tool are:*

*Program of instructions* The program of instruction, often called part program is the detailed set of directions for producing a component by the NC machine. Each line of instruction is a mixture of alphabetic codes and numeric data and is punched in a input media (usually paper tape) in a specified format. This program is translated into electrical signals to drive various motors to operate the machine to carry out the required operations.

*Tape punch* Usually it is a paper tape of 1 inch width. Paper-Mylar, Aluminium Mylar or plastics are also used as tape materials. Paper tapes are cheap and popular but cannot last long. It is treated to resist oil and water. Mylar tapes are expensive but durable. These are still used by machine manufacturers to store information as executive tapes. Punching machine (Flexo writers) of various types is used to key in program instructions to tapes. Presently tapes are prepared by micro computers by eying in the information from the manuscript. The end of NC tapes was the result of two competing developments, CNC and DNC.

*Tape readers* A tape reader reads the hole pattern on the tape and converts the patterns to a corresponding electrical signal.

*Machine controller* It receives the electrical signals from tape reader or an operating panel and causes NC machine to respond. It contains a decoder/encoder, an interpolator and facilities to execute auxiliary functions which are machine dependent. The decoder/encoder receives the data and stores them in two separate memory locations. One for the part geometry data and the other for the process data.

For cutting complex surfaces, the interpolator breaks down these curves into small individual increments for each controlled motion of machine tools. Controller also interfaces various machine units like drive motors, transducers and other control functions of the machine tools.

*NC machine* It responds to the electrical signals from the controller. Accordingly the machine executes various slide motions and spindle rotations to manufacture a part.

*The major advantages of NC over conventional methods of machine control are as follows:*

- Higher precision: NC machine tools are capable of machining at very close tolerances, in some operations as small as 0.005 mm.
- Machining of complex three-dimensional shapes: this is discussed in Section 6.2 in connection with the problem of milling of complex shapes.
- Better quality: NC systems are capable of maintaining constant working conditions for all parts.
Higher productivity: NC machine tools reduce drastically the non machining time. Adjusting the machine tool for a different product is as easy as changing the computer program and tool turret with the new set of cutting tools required for the particular part.

Multi-operational machining: some NC machines, for example machine centers, are capable of accomplishing a very high number of machining operations thus reducing significantly the number of machine tools in the workshops.

Low operator qualification: the role of the operation of a NC machine is simply to upload the work piece and to download the finished part. In some cases, industrial robots are employed for material handling, thus eliminating the human operator.

Types of NC systems

*Machine controls are divided into three groups:*

- Traditional numerical control (NC).
- Computer numerical control (CNC).
- Distributed numerical control (DNC).

CNC refers to a system that has a local computer to store all required numerical data. While CNC was used to enhance tapes for a while, they eventually allowed the use of other storage media, magnetic tapes and hard disks. The advantages of CNC systems include but are not limited to the possibility to store and execute a number of large programs (especially if a three or more dimensional machining of complex shapes is considered), to allow editing of programs, to execute cycles of machining commands, etc.

The development of CNC over many years, along with the development of local area networking, has evolved in the modern concept of DNC. Distributed numerical control is similar to CNC, except a remote computer is used to control a number of machines. An off-site mainframe host computer holds programs for all parts to be produced in the DNC facility. Programs are downloaded from the mainframe computer, and then the local controller feeds instructions to the hardwired NC machine. The recent developments use a central computer which communicates with local CNC computers (also called Direct Numerical Control).

Controlled axes

NC system can be classified on the number of directions of motion they are capable to control simultaneously on a machine tool. Each free body has six degree of freedom, three positive or negative translations along x, y, and z-axis, and three rotations clockwise or counter clockwise about these axes. Commercial NC system are capable of controlling simultaneously two, two and half, three, four and five degrees of freedom, or axes. The NC systems which control three linear translations (3-axis systems), or three linear translations and one rotation of the worktable (4-axis systems) are the most common.
Although the directions of axes for a particular machine tool are generally agreed as shown in the figure, the coordinate system origin is individual for each part to be machined and has to be decided in the very beginning of the process of CNC part programming.

**Point-to-point vs. continuous systems**

*The two major types of NC systems are (see the figure):*

- Point-to-point (PTP) system.
- Contouring system.

PTP is a NC system, which controls only the position of the components. In this system, the path of the component motion relative to the work piece is not controlled. The travelling between different positions is performed at the traverse speed allowable for the machine tool and following the shortest way.

Contouring NC systems are capable of controlling not only the positions but also the component motion, i.e., the travelling velocity and the programmed path between the desired positions:

Schematics of point-to-point (Left) and contouring (Right) NC systems.

**CNC**

The abbreviation CNC stands for computer numerical control, and refers specifically to a computer "controller" that reads G-code instructions and drives a machine tool, a powered mechanical
device typically used to fabricate components by the selective removal of material. CNC does numerically directed interpolation of a cutting tool in the work envelope of a machine. The operating parameters of the CNC can be altered via a software load program.

CNC was preceded by NC (Numerically Controlled) machines, which were hard wired and their operating parameters could not be changed. NC was developed in the late 1940s and early 1950s by John T. Parsons in collaboration with the MIT Servomechanisms Laboratory. The first CNC systems used NC style hardware, and the computer was used for the tool compensation calculations and sometimes for editing.

Punched tape continued to be used as a medium for transferring G-codes into the controller for many decades after 1950, until it was replaced by RS232 cables, floppy disks, and now is commonly tied directly into plant networks. The files containing the G-codes to be interpreted by the controller are usually saved under the .NC extension. Most shops have their own saving format that matches their ISO certification requirements.

The introduction of CNC machines dramatically changed the manufacturing industry. Curves are as easy to cut as straight lines, complex 3-D structures are relatively easy to produce, and the number of machining steps that required human action has been dramatically reduced.

With the increased automation of manufacturing processes with CNC machining, considerable improvements in consistency and quality have been achieved with no strain on the operator. CNC automation reduced the frequency of errors and provided CNC operators with time to perform additional tasks. CNC automation also allows for more flexibility in the way parts are held in the manufacturing process and the time required changing the machine to produce different components.

**History of CNC**

1949 - US Air Force asks MIT to develop a "numerically controlled" machine.
1952 - Prototype NC machine demonstrated (punched tape input).
1980 - CNC machines (computer used to link directly to controller).
1990 - DNC: external computer “drip feeds” control programmer to machine tool controller.

**Motivation and uses**

- To manufacture complex curved geometries in 2D or 3D was extremely expensive by mechanical means (which usually would require complex jigs to control the cutter motions).
- Machining components with repeatable accuracy.
- Unmanned machining operations.

**Advantages of CNC**
- Easier to program.
- Easy storage of existing programs.
- Easy to change a program.
- Avoids human errors.
- NC machines are safer to operate.
- Complex geometry is produced as cheaply as simple ones.
- Usually generates closer tolerances than manual machines.

**CNC terminology**

BLU: basic length unit - smallest programmable move of each axis.

Controller: (Machine Control Unit, MCU) - Electronic and computerized interface between operator and m/c.

Controller components:
- Data Processing Unit (DPU).
- Control-Loops Unit (CLU).

**Data Processing Unit:**
- Input device [RS-232 port/ Tape Reader/ Punched Tape Read r].
- Data Reading Circuits and Parity Checking Circuits.
- Decoders to distribute data to the axes controllers.

**Control Loops Unit:**
- Interpolator to supply machine-motion commands between data points.
- Position control loop hardware for ch axis of motion.

**Types of CNC machines**

Based on Motion Type: Point-to-Point or Continuous path.
Based on Control Loops: Open loop or Close loop.
Based on Power Supply: Electric or Hydraulic or Pneumatic.
Based on Positioning System: Incremental or Absolute.