TWO MARKS QUESTIONS WITH ANSWER

DEPARTMENT: MECH   **SEMESTER: IV**

SUBJECT CODE / NAME: ME 6402 / MANUFACTURING TECHNOLOGY – II

UNIT I – THEORY OF METAL CUTTING

Part A

1. **List the various metal removal processes?**   **(AU Apr 2011,Dec12)**
   a. Non cutting process or chipless process.
   b. Cutting process or Chip process
2. **How chip formation occurs in metal cutting?**   **(AU Apr 2011, Dec11)**
   The material of the work piece is stressed beyond its yield point under
   compressive force .This cause the material to deform plastically and
   shear off.
3. **What is tool wear?**   **(AU Apr 2011)**
   During machining the toll is subjected to three important factors such as forces,
   temperature and sliding action due to relative motion between tool and work piece. Due
   to these factors tool will undergo wear.
4. **Mention the cutting fluids?**   **(AU Apr 2012)**
   Two basic types are
   (i) Water based cutting fluids
   (ii) Straight or heat oil based cutting fluids
5. **Draw the nomenclature of cutting tool geometry?**   **(AU Apr 2013,Dec 11)**
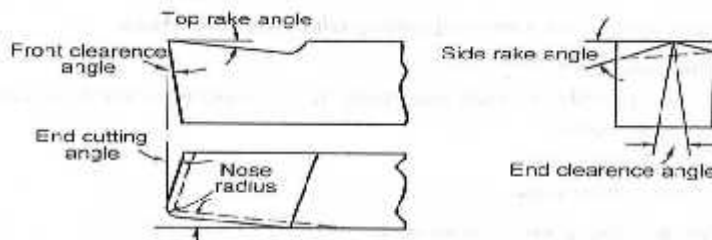
6. **Compare orthogonal and oblique cutting?**   **(AU Dec 2012, Apr 2010)**

Sl. No.	Orthogonal cutting	Oblique cutting
1.	The cutting edge of the tool is perpendicular to the cutting velocity vector.	The cutting edge is inclined at an acute angle with the normal to the cutting velocity vector
2.	The chip flows over the tool face and the direction of chip-flow velocity is normal to the cutting edge.	The chip flows on the tool face making an angle with the normal on the cutting edge.

7. **Define tool life.** (AU Dec 2010) (AU Apr 2013)

Tool life is defined as the time elapsed between two consecutive tool resharpening. During this period the toll serves effectively and efficiently.

8. **What are the objectives and functions of cutting fluids?(AU Dec 2010,Apr 13)**

(i) It is used to cool the cutting tool and work piece

(ii) It improves surface finish

(iii) It protects finished surface from corrosion

(iv) It washes away chips from tool

9. **Briefly explain the effect of rake angle during cutting?** (AU Dec 2010,Apr 09)

Effect of back rack angle:

- For softer material greater angle should be given
- For harder material smaller angle is enough

Effect of Side rack angle:

- Curling of chip depends on this angle.

10. **What are the factors responsible for builtup edge in cutting tools?(AU Dec 2009,Apr 13)**

(i) Low cutting speed

(ii) Small rake angle

(iii)Coarse feed

(iv) Strong adhesion between chip and tool face.

11. **List out the essential characteristics of a cutting fluid. (AU Dec 2009,Apr 12)**

(i) It should have good lubricating properties

(ii)High heat absorbing capacity

(iii) High flash point

(iv) It should be odorless

12. **Name the various cutting tool materials.** (AU Dec 2008,Apr 09).

(i) Carbon tool steel

(ii) High speed steel

(iii) Cemented carbides

(iv) Ceramics

(v) Diamonds

13. **Give two examples of orthogonal cutting.** (AU Dec 2007)

(i) Turning (ii) Facing (iii) Thread cutting (iv) Parting off

14. **What are the four important characteristics of materials used for cutting tools?** (AU Dec 2007)

(i)Hot hardness (ii) Wear resistance (iii High thermal conductivity

(iv) Easy to grind and sharpen (v) Resistance to thermal shock

15. **What is the function of chip breakers?** (AU Dec 2006)

The chip breakers are used to break the chips into small pieces for removal , safety and to prevent both the machine and work damage

16. **Name the factors that contribute to poor surface finish in cutting.(AU Dec 2006)**

(i) Cutting speed

(ii) Feed

(iii) Depth of cut

1. Explain various cutting tool materials?   (AU Apr 2011,Dec 12)

Classification of Tool Materials

The following metals are suitably heat treated wherever required in the manufacture of cutting tools.

    (a) Carbon tool steel.
    (b) High speed steel.
    (c) Cemented carbides.
    (d) Ceramics.
    (e) Diamonds.

1. Carbon tool steels

The composition of typical plain carbon steel used for cutting is as follows

Carbon	-	0.8 to 1.3%
Silicon	-	0.1 to 0.4%
Manganese	-	0.1 to 0.4%

These are suitable for low cutting speeds and used in those applications where the cutting temperature is below 200°C. Such steels have good hardness, strength and toughness when hardened and tempered. It is done to provide a keen cutting edge. It is cheap, easy to forge and simple to harden. Cutting tools such as taps, dies, reamers, hacksaw blades are made by using these materials.

Medium alloy tool steels are similar to carbon tool steel. These are alloy steels alloyed with small quantities of tungsten, molybdenum, chromium and vanadium. It has carbon upto 5%. Chromium and molybdenum are added to increase hardenability of steel whereas tungsten is added to improve wear resistance. Hardness is lost at 350°C.

2. High speed steels (H.S.S.)

This tool steel cuts the metal effectively even at high speeds. It has superior hot hardness and high wear resistance. The cutting speeds can be 2 to 3 times higher than carbon steels. These tools give improved cutting performance and higher metal removal rates. This tool steel maintains its hardness even upto 900°C. The various alloying elements to improve hot hardness and wear resistance are tungsten, chromium, vanadium, cobalt and molybdenum. H.S.S. is widely used for drills, many types of general purpose milling cutters, broaches, taps, turning tools and dies.

The various types of high-speed steels are

    a.   18-4-1 High speed steel
    b.   Molybdenum High speed steel
    c.   Cobalt high speed steel

(i) 18-4-1 High-speed steel:

It contains 18% tungsten, 4% chromium and 1% vanadium. It has about 0.75% carbon. It is commonly used for all purposes. This type of material gives excellent performance over a great range of materials and cutting speeds and retains its hardness upto 600°C. Most of the cutting tools are made of this steel. The various tools such as drill bits, single point cutting tools, milling cutters etc are made from this tool steel.

(ii) Molybdenum high-speed steel:

This steel has 6% Molybdenum, 5% Tungsten, 4% Chromium and 2% Vanadium. It has high toughness and cutting ability.

(iii) Cobalt high-speed steel:

It has the following composition.

Cobalt	-	12%
Tungsten	-	20%

| Chromium | - | 4% |
| Vanadium | - | 2% |

It is also known as *super high-speed steel*. This steel is used for heavy duty and rough cutting tools like planer tools, milling cutters, lathe tools etc.

3. Cemented carbides

Cemented carbides are made by mixing tungsten powder and carbon at high temperature (1500°C) in the ratio of 94 and 6 respectively by weight. This new compound is tungsten carbide. This is combined with cobalt, compacted and sintered in a furnace about 1400°C and can be used at much higher cutting speeds. The composition is 82% tungsten carbide, 10% titanium carbide and 8% Cobalt. They usually take the form of inserts (either braced or clamped form). The clamped inserts can be thrown, after wearing out of all cutting edges takes place. The tool can withstand higher temperature up to 1000°C. Its cutting speed is 6 times higher than the high-speed steel. But, it is brittle and has low resistance to shock. It must be supported very strongly to prevent cracking.

These tool materials are classified into two main types namely

    (a) Straight tungsten carbides
    (b) Alloyed tungsten carbides

Straight tungsten carbides are very strong and more wear resistance. But, rapid cracking takes place while machining steels. To improve resistance to cratering, alloyed tungsten carbides are used with additions of carbides of titanium and molybdenum etc.

Titanium carbide improves the hot hardness and reduces the tendency of chips to weld to the tool. Additions of titanium carbides help to improve resistance to crater wear and make the structure fine grained. For optimum results, both titanium and tantalum carbides are often made. Carbides are used for machining very hard steels and for machining brittle materials like cast iron and bronze.

4. Ceramics

Aluminium oxide and boron nitride powders are mixed together and sintered at 1700°C to form the ingredients of ceramic tools. These materials are very hard with good compressive strength. Ceramic tools are made in tips and clamped on the metal shanks of tools. It can be employed at cutting speeds as high as two to three times those employed with tungsten carbides. But, they are extremely brittle and can't be used where shock and vibrations occur.

A well known variety contains 90% Aluminium Oxide and remaining 10% shared by Chromium Oxide, Magnesium Oxide and Nitrogen Oxide. These ceramics have high compressive strength, longer tool life, greater machining flexibility, superior surface finish. It can withstand the temperature up to 1700°C.

5. Diamonds

Diamond is the hardest cutting material. Poly crystalline diamond is manufactured by sintering under high pressure and temperature. It has low coefficient of friction, high compressive strength and is extremely wear resistant. It is used for machining very hard materials such as glass, plastics, ceramics etc. Due to very high hardness, high compressive and bending strength, the deformation during the process is less. Diamond tools produce very good surface finish at high speeds with good dimensional accuracy. It is very small and best suited for light cuts and finishing operations. It can resist temperature upto 1250°C. The general properties of diamond are

    ❖ It is the hardest substance
    ❖ It has low coefficient of thermal expansion

2. In an orthogonal cutting operation on a workpiece of width 2.5mm, the uncut chip thickness was 0.25mm and degree. It was observed that the chip thickness was 1.25mm.The cutting force was measured to be 900N and the thrust force was found to be 810 N. **(AU Dec 2013,Apr 12)**

(a) Find the shear angle.

(b) If the coefficient of friction between the chip and the tool, was 0.5, what is the machining constant C_m

Given data:

$b = 2.5mm$

$t_1 = 0.25mm$

$\alpha = 0°$

$t_2 = 1.25mm$

$F_z = 900N$

$F_x = 810N$

$\mu = 0.5$

To find:

   (i)   Shear Strength

   (ii) Machining constant

☺ *Solution:*

Chip thickness ratio, $r = \dfrac{t_1}{t_2} = \dfrac{0.25}{1.25} = 0.2$

Shear angle, $\beta = tan^{-1}\left[\dfrac{r\cos\alpha}{1-r\sin\alpha}\right]$

$\qquad = tan^{-1}\left[\dfrac{0.2\cos 0}{1-0.2\sin 0}\right]$

$\beta = 11.31°$

Shear force, $F_s = F_z\cos\beta - F_x\sin\beta$

$\qquad\qquad = 900\cos 11.31 - 810\sin 11.31$

$F_s = 723.66N$

Shear stress or strength,

$\tau_s = \dfrac{F_s}{A_1} = \dfrac{723.66}{2.5\times 0.25}\times \sin 11.31$

$\qquad\qquad\qquad [\because A_1 = bt_1 = 0.25\times 2.5]$

$\tau = 227N/mm^2$ **Ans.**

$\mu = tan\gamma$

$\gamma = tan^{-1}\mu = tan^{-1}(0.5) = 26.56$

Machining constant, $C_m = 2\beta + \gamma - \alpha = 2\times 11.31 + 26.56 - 0$

$C_m = 49.18°$ **Ans.**

Result:

   (i) Shearing strength, $\tau = 227N/mm^2$

   (ii) Machining constant, $C_m = 49.18°$

3. What is a chip Describe the during metal machining with neat sketches.
   **(AU Dec 2010) (AU Apr 2010) (AU Dec 2006)**

   TYPES OF CHIPS
   In a metal cutting operation is carried out in machine shop. Chips are separated from the workpiece to impart the required size and shape to the workpiece. The type of chips edge formed is basically a function of the work material and cutting conditions. The chips that are formed during metal cutting operations can be classified into four types:
   1. Discontinuous or segmental chips
   2. Continuous chips
   3. Continuous chips with built-up edge.
   4. Non homogenous chips
   The above three common types of chips are shown in

(a) Continuous chips   (b) Discontinuous chips   (c) Chips with built-up edge
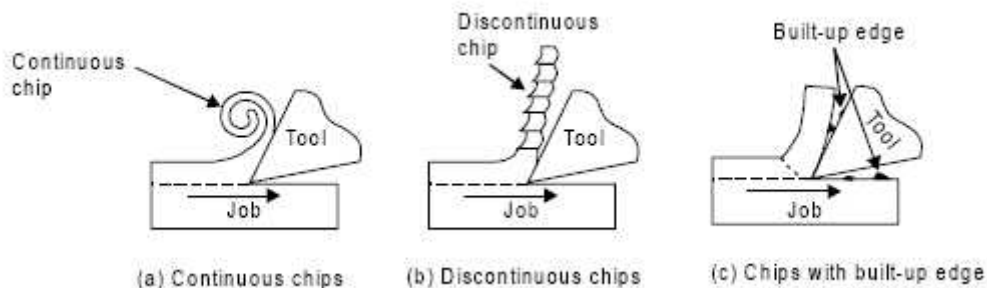
   Continuous chips: It shows continuous chips coming out during machining in machine shop. These types of chips are obtained while machining ductile material such as mild steel and copper. A continuous chip comes from the cutting edge of a cutting tool as a single one piece, and it will remain as one piece unless purposely broken for safety or for convenience in handling. Formation of very lengthy chip is hazardous to the machining process and the machine operators. It may wrap up on the cutting tool, work piece and interrupt in the cutting operation. Thus, it becomes necessary to deform or break long continuous chips into small pieces. It is done by using chip breakers. Chip breaker can be an integral part of the tool design or a separate device.

   Discontinuous chips: It shows discontinuous chips coming out during machining in machine shop. In this type, the chip is produced in the form of small pieces. These types of chips are obtained while machining brittle material like cast iron, brass and bronze. Fairly good surface finish is obtained and tool life is increased with this type of chips.

   Chips With Built up edge: It shows continuous chip with built-up edge. During cutting operation, the temperature rises and as the hot chip passes over s the face of the tool, alloying and welding action may take place due to high pressure, which results in the formation of weak bonds in microstructure and weakened particles might pullout. Owing to high heat and pressure generated, these particles get welded to the cutting tip of the tool and form a false cutting edge. This is known as built-up edge   Non homogenous chips are developed during machining highly hard alloys like titanium which suffers a marked decrease in yield strength with increase in temperature

4. **Mention the functions of Cutting Fluids (AU Dec 2010,Apr 11)**

During any machining or metal cutting process, enough heat is evolved in cutting zone. To remove this heat from cutting zone, soluble oils are used as cutting fluid during machining. Emulsions (also known as soluble oil) cool the work-piece and tool and thus relieved them from overheat. Air circulation is required so as to remove the heat by evaporation. The remaining oil forms a protecting layer over the machined work piece and save it from rust and corrosion. Such coolants decrease adhesion between chip and tool, provides lower friction and wear and a smaller built up edge. They remove chips and hence help in keeping freshly machined surface bright. They also protect the surface from corrosion. They decrease wear and tear of tool and hence increase tool life. They improve machinability and reduce machining forces.

Chemical cutting fluids possess a good flushing action and are non-corrosive and nonclogging. Since they are non-clogging, they are widely used for grinding and sawing. The most efficient method of applying cutting fluids is to use a pump, tray and reservoir, to give a slow continuous stream over the cutting action. Chemical cutting fluids are replacing straight and emulsifiable cutting oils for many applications. If chemical concentrates are mixed in correct proportion with deionized water, chemical cutting fluids provide longer life at less cost than oil base cutting fluids. Other coolants and cutting fluids are cutting wax and kerosene. Cutting fluids may also be used on aluminium, aluminium alloys and brass for machining operations of low severity. It may be used as a coolant and for removing chips when machining cast iron.

Some commonly used machining materials require following cutting fluids:

Steel Soluble oil Straight, Water base mainly grinding

- Aluminium and alloys Paraffin Dry
- Cast iron Dry
- Brass, Copper and Bronze Dry

Functions or Uses of Coolants or Cutting Fluids

The important functions of cutting fluids are given as under.

(*i*) Cutting fluid washes away the chips and hence keeps the cutting region free.

(*ii*) It helps in keeping freshly machined surface bright by giving a protective coating against atmospheric, oxygen and thus protects the finished surface from corrosion.

(*iii*) It decreases wear and tear of cutting tool and hence increases tool life.

 (*iv*) It improves machinability and reduce power requirements

(*v*) It prevents expansion of work pieces.

(*vi*) It cools the tool and work piece and remove the generated heat from the cutting zone.

(*vii*) It decreases adhesion between chip and tool; provide lower friction and wear, and a smaller built-up edge.

MECHANISM OF METAL CUTTING

5. Describe the mechanism of metal cutting?   (AU Dec 2010,Apr 13)
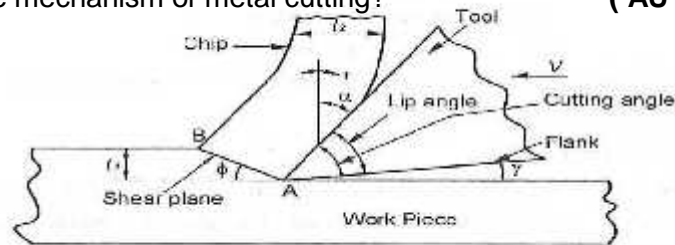
Mechanism of metal cutting

During machining, the cutting tool exerts a compressive force on the work piece. The material of the work piece is stressed beyond its yield point under this compressive force. This causes the material to deform plastically and shear off. The plastic flow takes place in a localized region called *shear plane* as shown in fig. 1.3. This shear plane extends from the cutting obliquely upto the uncut surface ahead of tool. The sheared material begins to flow along the cutting tool face in the form of small pieces called *chips*. The compressive force applied to form the chip is called *cutting force*. When the chip flows over the tool, it will wear off the tool. Due to friction, wearing heat is produced. The heat generated raises the temperature of the work, cutting tool and chip. The temperature rise in cutting tool tends to soften it and causes the loss of keenness in the cutting edge thereby leading to its failure. The cutting force, heat and abrasive wear are the basic features of the metal cutting process.

The following points are worth to be noting:

✦ Shear plane is actually a narrow zone of the order of about 0.025mm.

✦ The cutting edge of the tool is formed by two intersecting surfaces.

✦ The surface along which the chip moves upwards is called *rake surface*.

✦ The surface which is relieved to avoid rubbing with the machined surface is called *flank*.

During cutting process, the following properties of the work piece material are quite important.

(i)   Hardness.

(ii)   Abrasive qualities.

(iii) Toughness.

6. List the various tool materials used in industry. State the optimum temperature of each of the tool materials. **(AU Dec 2010)**

CUTTING TOOL MATERIALS

The various materials are used to remove metal from work piece. The tool must be harder than the material which is to be cut. The selection of cutting tool material will depend upon the following factors:

- ❖ Volume of production
- ❖ Tool design
- ❖ Type of machining process
- ❖ Physical and Chemical properties of work material
- ❖ Rigidity and condition of machine

Properties of Cutting Tool Material

The cutting tool material should possess the following properties.

1. Hot hardness

It is the ability of the cutting tool to withstand high temperature without loosing its cutting edge. The tool must maintain its hardness at high temperature. This hardness is higher than that of work piece. The addition of following materials will improve hot hardness: Chromium, Molybdenum, Tungsten and Vanadium.

2. Wear resistance

It is the ability to resist wear. During machining, friction between work piece and tool cause wear in the tool. If the tool is not having sufficient wear resistance, it will fail quickly. This will lead to poor surface finish. Addition of cobalt increases the wear resistance property of the tool.

3. Toughness

It is the combined property of strength and ductility. The tool material should have sufficient toughness to withstand shock and vibrations. If tool materials have sufficient toughness, the fine cutting edge of the tool does not break or chip, when the tool is suddenly loaded. This property limits the hardness of the tool. High hardness tool will be brittle and weak in tension. Addition of molybdenum and nickel increases toughness.

4. Low friction

The coefficient of friction between tool and the work piece must be low. This will reduce friction, heat developed and tool wear.

5. Cost of tool

Tool material should be economical in production. It should be easy to manufacture the tool from the material.

In addition to the above properties, the tool material should possess the following properties.

- ❖ High thermal conductivity.
- ❖ Resistance to thermal shock.
- ❖ Easy to grind and sharp.

7. The Taylor tool life equation for machining C-40 steel with a HSS cutting tool at a feed of 0.2mm/min and a depth of = C, Where n and C are constants. The following V and T observations have been noted**(AU Dec 2010) (AU Dec 2006)**

V , m/min   25   35
T , min   90   20

Calculate
(1) n and C
(2) Hence recommend the cutting speed for a desired tool life of 60min.

> *(1) n and C,*
>
> Similar to problem 1 in page 1.75.
>
> [n= 0.224 and C= 68.5]
>
> *(2) Hence recommend the cutting speed for a desired tool life of 60 min.*   (8)
>
> $VT^n = C$
>
> At V = 60 min, $60T^{0.224} = 68.5$
>
> $$T = \left(\frac{68.5}{60} \right)^{\frac{1}{0.224}}$$
>
> *= 1 min 48.4sec*

8. State the parameters that influence the life of tool and discuss?**(AU Apr 2010)**

Factors Affecting Tool Life

The life of the cutting tool is affected by the following factors.

(i) Cutting speed.
(ii) Feed and depth of cut
(iii) Tool geometry
(iv) Tool material
(v) Cutting fluid
(vi) Work material
(vii) Rigidity of work, tool and machine.

I. Cutting speed

Cutting speed has greater influence on the tool life. When the cutting speed increases, the cutting temperature will increase. Due to this, hardness of the tool decreases. Hence, the tool flank wears and crater wear occurs. From the above, it is obvious that when cutting speed increases, the tool life will decrease. The tool life will be increased at low cutting speeds.

There is a definite relationship between cutting speed and tool life. This relation is given by *Taylor's formula* as follows:

$$VT^n = C$$

Where,

V = Cutting speed in m/min.

T = Tool life in minutes

n = exponent or index which depends on the tool and work.

= 0.1 to 0.5 for high speed steel tools

= 0.2 to 0.4 for tungsten carbide tools

= 0.4 to 0.6 for Ceramic tools

C = Constant. It is numerically equal to the cutting speed that gives a tool life of one minute.

If the higher cutting speed is permitted by a tool for the same life, we can say that the tool is having better cutting properties and it will be more productive.

For finding tool life, tools are operated to failure at different cutting speeds and the test results are plotted. A typical cutting speed (V) versus Tool life (T) relationship is shown in fig. 1.19.

Fig. 1.19 Tool life Vs Cutting speed

In general, a parabolic decrease in tool life with increased cutting speed is obtained (Refer fig. 1.19.). Such a relationship is plotted as a straight line on log — log graph as shown in fig. 1.19. These plots indicate that as cutting speed increases with decrease in tool life.

Obviously, if a very low cutting speed is used, the tool will loose a long life. If the surface finish of the tool is improved, both the tool life and efficiency of the tool are improved due to the reason that friction between tool and chip is minimized. Roughness of the tools cutting edge could result in a concentration of stresses which may cause surface cracks and chipping of tool.

Generally, the following factors influenced in the cutting speed permitted by a tool.

- ❖ Tool life
- ❖ Properties of material being machined
- ❖ Rate of feed and depth of cut
- ❖ Tool geometry
- ❖ Cutting fluid used
- ❖ Type of machining process
- ❖ Surface finish to be obtained

2. Feed and depth of cut

The life of the cutting tool is influenced by the amount of metal removed by the tool per minute. When we are using fine feed, the area of chip passing over the tool face is greater than that of a coarse feed for a given volume of metal removal. If we offset this advantage in favour of the thick chip, the tool forces to produce thicker chips. Anyway, it is possible to balance two opposing influences to obtain optimum feed rate.

The effect of feed and depth of cut on tool life is given by the formula

$$V = \frac{257}{T^{0.19} \times f^{0.36} \times t^{0.08}} \ m/min$$

Where,

V = Cutting speed

T - Tool life
f - feed in *mm/min*
t - depth of cut in *mm*

This relation is generally applied for machining low carbon steel by a cemented carbide tool. Tool life is decreased with increase in feed and depth of cut.

3. Tool geometry

Large rake angle reduces the tool cross section. Hence, the amount of heat absorbed by the tool is also reduced. This weakens the tool. So, correct rake angle must be used for long tool life. The optimum rake angle for maximum tool life lies between $-5°$ to $+10°$ for turning austenitic steel by a carbide tool. If the relief angle is more, less will be the friction of the tool on the work. But, more relief angle decreases the tool life because of decreased strength. The optimum relief angle is $12°$ to $15°$. Similarly, a higher value of side cutting edge angle gives longer life to tool. The optimum side cutting edge angle lies between $30°$ and $25°$. Increase in nose radius improves the tool life since the stress concentration is less for greater nose radius. The relationship between cutting speed, tool life (T) and nose radius (r) is as follows

$$V T^{0.0937} = 331 \, r^{0.244}$$

The proper end cutting edge angle is provided to improve surface finish, rigidity and equivalent cutting speed. The optimum end cutting edge angle varies from $4°$ to $10°$.

4. Tool material

An ideal tool material is one which removes maximum volume of material at all cutting speeds. Physical and chemical properties of tool material will influence on tool life. For a given cutting speed H.S.S, tool

is more durable than carbon steel tool. But carbide tools have more life than high-speed tool.

5. Cutting fluid

Heat produced during metal cutting is carried away from the tool and work by means of cutting fluid. It reduces friction at chip tool interface and increases tool life.

Cutting fluid which directly controls the amount of heat at the chip tool interface and it is given by the formula.

$$T\theta^{n} = C$$

Where, T - Tool life

θ - Temperature of chip tool interface in °C

n - An index which depends on shape and material of the cutting tool.

6. Work piece material

Tool life also depends on the microstructure of the work piece material. Tool life will be more when machining soft metals than hard metals like cast iron and alloy steel.

7. Rigidity of work, tool and machine

A strongly supported tool on a rigid machine will have more life than tool machining under vibrating machine. Loose work piece will decrease the tool life.

9. What is meant by orthogonal cutting and oblique cutting? **(AU Apr 2010)**

Sl. No.	Orthogonal cutting	Oblique cutting
1.	The cutting edge of the tool is perpendicular to the cutting velocity vector.	The cutting edge is inclined at an acute angle with the normal to the cutting velocity vector.
2.	The chip flows over the tool face and the direction of chip-flow velocity is normal to the cutting edge.	The chip flows on the tool face making an angle with the normal on the cutting edge.
3.	The cutting edge clears the width of the work piece on either end. (e.g. No side flow)	The cutting edge may or may not clear the width of the work piece.
4.	The maximum chip thickness occurs at its middle.	The maximum chip thickness may not occur at the middle.
5.	Tool is perfectly sharp and contacts the chip on rake face only.	Frequently, more than one cutting edges are in action.
6.	Only two components of cutting forces act on the tool. They are mutually perpendicular to each other.	Three components of the cutting forces act on the cutting edge of the tool.
7.	Tool life is less.	Tool life is more.

10. Explain "merchant force circle assumptions.   (AU Apr 2010)

MERCHANT CIRCLE DIAGRAM OF FORCES

The following assumptions have been made by Merchant to workout the force relations.

(i)   The chip may be considered as a separate body held in equilibrium under the action of two equal, opposite and collinear resultant forces. i.e. F and F'

(ii) The chip formation will be continuous without built up edge.

(iii) During cutting process, the cutting velocity remains constant.

(iv) The cutting tool has a sharp cutting edge so that it does not make flank contact to the work piece.

Fig. 1.13. shows a Merchant circle diagram which is convenient to determine the relation between the various forces and angles.
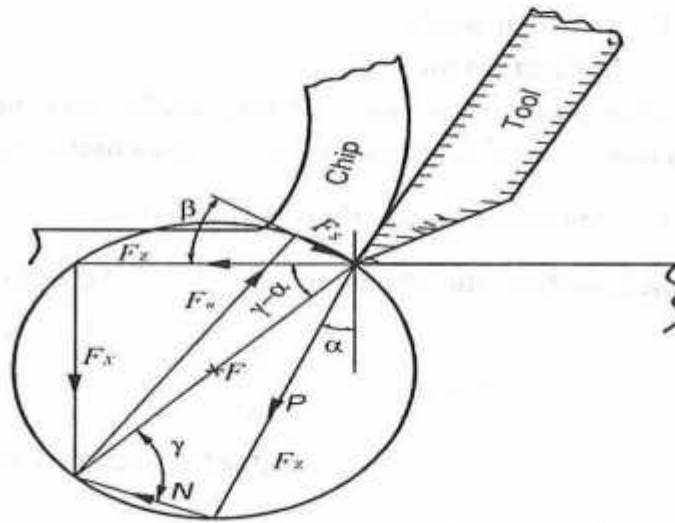
Fig 1.13 Merchant's circle diagram

In this diagram, two force triangles of fig.1.12 have been combined, and F and F' together have been replaced by F. The circle has a diameter equal to F or F' passing through tool point as shown in fig. 1.13

The cutting force F_z and feed force F_x can be determined by using dynamometer. After measuring the F_x and F_z, they can be drawn into suitable scale. The resultant of F_x and F_z is the diameter of the circle i.e. F. The rake angle (α) is measured from the tool, and forces P and N can be determined.

14

The shear angle (β) can be obtained from the relation. Then all the component forces on the chip may be determined from the geometry of fig.1.13.

In the fig.1.13, let

α = Rake angle of tool.

β = Shear angle

γ = Friction angle

When the chip slides over the tool face under pressure, there may be some friction between these two. Therefore, the kinetic coefficient of friction (μ) can be expressed as *Coefficient of friction*, $\mu = \dfrac{P}{N} = tan\,\gamma$

As mentioned earlier, the shear angle (β) can be obtained from the equation,

$$tan\,\beta = \frac{r\cos\alpha}{1-r\sin\alpha}$$

[Refer section 1.6.5. page 1.19]

Chip thickness ratio, $r = \dfrac{t_1}{t_2}$

Where, t_1 and t_2 - Chip thickness before and after cutting respectively.

P - Frictional resistance

$P = F_x \cos\alpha + F_z \sin\alpha$

N - Normal force

$N = F_z \cos\alpha - F_x \sin\alpha.$

F = Resultant force

Resultant force,

$$\boxed{F = \sqrt{F_z^2 + F_x^2}}$$

F_z = Cutting force

Cutting force,

$$\boxed{F_z = F \cos(\gamma - \alpha)}$$

F_s = Shear force

$F_s = F\cos\theta$

Where, $\theta = \beta + \gamma - \alpha$

$$\therefore F = \frac{F_s}{\cos\theta}$$

Substituting F value in F_z equation, we get

$$\therefore F_z = \frac{F_s \cos(\gamma - \alpha)}{\cos\theta}$$

$$F_z = \frac{F_s \cos(\gamma - \alpha)}{\cos(\beta + \gamma - \alpha)} \quad [\because \theta = \beta + \gamma - \alpha]$$

We know that,

$$\boxed{\mu = tan\gamma = \frac{P}{N}}$$

$$= \frac{F_x \cos\alpha + F_z \sin\alpha}{F_z \cos\alpha - F_x \sin\alpha}$$

The coefficient of friction,

$$\boxed{\mu = \frac{F_x + F_z \tan\alpha}{F_z - F_x \tan\alpha}}$$

The relationship for F_s and F_n are as follows

$$\boxed{\begin{array}{l} F_s = F_z\cos\beta - F_x\sin\beta \\ F_n = F_z\sin\beta + F_x\cos\beta \end{array}}$$

11. Explain the geometry of a single point cutting tool with suitable sketches?   **(AU Dec 2009)(AU Dec 2010**

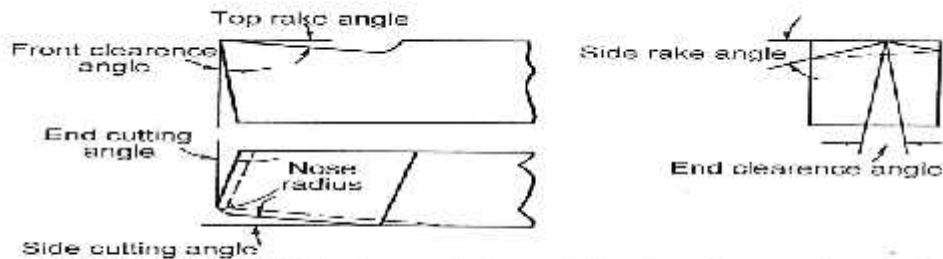### 1.3.1. Nomenclature of Single Point Cutting Tool

Fig. 1.1 Nomenclature of single point cutting tool

Naming the various angles and parts is known as *nomenclature*. The various angles and parts of single point cutting tool are shown in fig. 1.1.

1. Parts of a single point cutting tool

(i) Shank:
The body of the tool which is not grained is called as *shank*.

(ii) Face:
The surface over the chip of the metal slides is known as *face*.

(iii) Flank:
The surface of the tool which is facing the work piece is known as *flank*. In single point cutting tool, generally there are two flanks namely end flank and side flank.

(iv) Base:
It is the bottom surface of the shank. Generally, it is flat in nature.

(v) Nose:
The junction of sides and end cutting edges are called *nose*.

(vi) Cutting edge:
It is the junction of face and flank. It is generally denoted by two types of cutting edges.
1. End cutting edge
2. Side cutting edge

2. Angles of single point cutting tool

(i) Back rake angle:
It is also called *top rake angle*. It is the angle between the face of the tool and the line parallel to the base of the tool. It is the slope given to the face or surface of the tool. This slope is given from the nose along the length of the tool as shown in fig. 1.1. This angle may be positive or negative depending upon the amount of side cutting edge.

(ii) Side rake angle:
It is the slope given to the face or top of the tool. It is the angle between the tool face and the line parallel to the base of the tool as shown in fig.1.1. This slope is given from the nose along the length of the tool. When the angle is positive, slope is given towards the cutting edge and when the angle is negative, slope is given away from the cutting edge.

(iii) Relief angle or Clearance angle:

It is the slope given downwards from the cutting edges. They are divided into two clearance angles as follows:

      a.   Side relief angle.
      b.   End relief angle.

The angle between the side flank and a line perpendicular to the base of the tool is known as *side relief angle*. The purpose of providing this angle is to avoid rubbing when the tool is fed sideway into the job. If the side relief angle is larger, the cutting edge of the tool will break because of insufficient support whereas the side relief angle is very small. The tool cannot be fed into the job but it will rub against the job. So, the tool will be overheated. This will affect the surface finish of the job.

The angle between end flank and a line perpendicular to the base of the tool measured at right angles to the end flank is known as *end relief angle*. This angle prevents the cutting tool from rubbing against the job. If the angle is very larger, it will break due to insufficient support whereas if it is very small, the tool will rub against the job. Due to this, the cutting will not be proper and hence poor surface finish will be obtained. Generally, its value varies from 6° to 10°.

(iv) Cutting edge angles:

There are two cutting edge angles namely side cutting edge angle and end cutting edge angle.

Side cutting edge angle is the angle between the side cutting edge and the side of the tool shank. Otherwise, it is the angle between the side cutting edge and the longitudinal axis of the tool. It avoids the formation of built-up edge, controlling the flow of chip and distributing the cutting force.

End cutting edge angle is the angle between the end cutting edge and a line perpendicular to the tool shank. Otherwise, it is the angle between the face of the tool and a plane perpendicular to the side of the shank. This angle will allow only small section of the end cutting edge to contact the machined surface and prevents vibration and chatter. Normally, this angle varies from 5° to 15°.

(v) Nose radius:

It is the angle between the side cutting edge and the end cutting edge. The line joining of side and end cutting edges by a point leads to high heat concentration. Joining by means of a small radius is a good practice to increase the tool life and to ensure better surface finish on the work piece. Large radii strengthen the tool and hence it is used on cast iron and castings where the cuts are interrupted.

3. Effects of Back rake angle

The size of the angle depends upon the material to be machined. If the material is softer, greater angle should be given whereas the material is harder, smaller angle is enough. i.e., Aluminium requires more back rake angle than cast iron or steel. Back rake angle may be positive, negative or neutral.

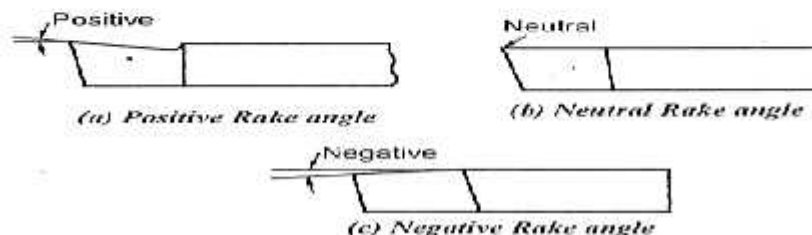(a) Positive Rake angle   (b) Neutral Rake angle

(c) Negative Rake angle

Fig 1.2. (a), (b) and (c) show a tool with positive, neutral and negative back rake angle respectively Higher value of rake angle weakens the cutting edge. A negative rake angle increases the tool force to some extend. These difficulties may be rectified by giving additional support to the cutting edge. Normally, negative rake angles are given to carbide tools.

When will be the positive rake angles used?
    (i) To machine the work hardened materials.
    (ii) To machine low strength ferrous and non-ferrous metals.
    (iii) To turn the long shaft of smaller diameters.
    (iv) To machine the metal having lesser recommended cutting speeds.
    (v) To machine the workpiece using small machine tools with low horsepower.

When will be the negative rake angles used?
    (i) To machine high strength alloys.
    (ii) The machine tools are more rigid.
    (iii) The feed rates are high.
    (iv) To give heavy and interrupted cuts.

4. Effects of side rake angle

During the cutting process, the chip curling or the amount of chip bend depends upon this angle. If the side rake angle is larger, the amount of power required to cut and bend the chip will decrease. Hence, it produces better surface finish.

12. Explain the basic actions of cutting fluids   **(AU Dec 2009 , Apr 10)**

CUTTING FLUIDS

During metal cutting, heat is generated due to plastic deformation of metal, friction of the tool work piece interface. This will increase the temperature of both work piece and the tool. Hence, the hardness of the tool decreases. This leads to tool failure. Cutting fluids are used to carry away the heat produced during machining. At the same time, it reduces the friction between the tool and chip. Cutting fluids usually in the form of a liquid are applied to the chip formation zone to improve the cutting conditions.

i) Cutting fluid cools the cutting tool and work piece. The heat produced during machining is carried away by the fluid. It is done by supplying adequate quantity of cutting fluid. It is necessary to cool the tool to prevent metallurgical damage and to assist in decreasing friction at the tool – chip interface. When the friction is decreased, the tool life will increase and surface finish will also increase. It prevents the work piece from excessive thermal distortion.

ii) It lubricates the cutting tool and thus reduces the coefficient of friction between tool and work. This property reduces the energy or power consumption in removing metal. So, wear on the cutting tool is reduced and hence it increases the tool life.

iii) It improves the surface finish as stated earlier.

18

Properties of Cutting Fluid

A cutting fluid should have the following properties

- ❖ It should have good lubricating properties to reduce frictional forces and to decrease the power consumption.
- ❖ High heat absorbing capacity.
- ❖ It should have a high specific heat, high heat conductivity and high film coefficient.
- ❖ High flash point.
- ❖ It should be odorless
- ❖ It should be non-corrosive to work and tool
- ❖ It should have low viscosity to permit free flow of the liquid
- ❖ It should be harmless to operators and the bearings
- ❖ It should be stable so that it should not get oxidized or decomposed when left in air.
- ❖ It should be transparent so that the cutting action of the tool may be observer. It is especially desirable in precision work.
- ❖ It should not stain or leave residues on the work piece surface.
- ❖ It should be economical to use.

13. Describe an expression for the shear angle in Orthogonal metal cutting .
(AU Dec 2007)

Geometry of Chip Formation

Generally, the outcoming chip thickness is larger than the undeformed metal in work piece. Also metal prior to being cut is much longer than the chip which is removed.
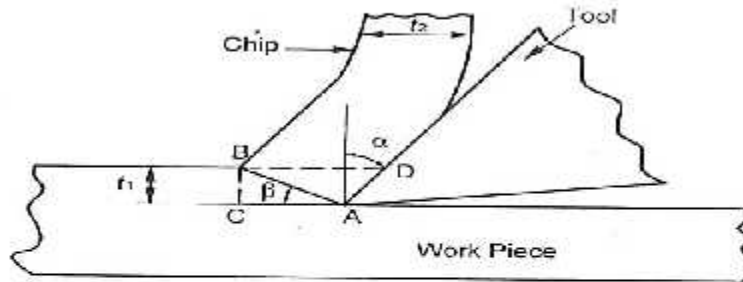
Fig. 1.9 Geometry of chip formation

Let,

t_1 - Chip thickness before cutting.
t_2 - Chip thickness after cutting.

The ratio of chip thickness before cutting to chip thickness after cutting is called *chip thickness ratio*. It is denoted by r.

Chip thickness ratio, $r = \dfrac{t_1}{t_2}$

The chip thickness ratio is always less than one. A ratio 1:2 yields good results.

The reciprocal of chip thickness ratio is called *chip reduction coefficient*. It is denoted by k.

$$k = \frac{1}{r}$$

There is no change in volume when the metal is cut.

Volume of metal to be removed = Volume of chip.

$$t_1 \times b_1 \times l_1 = t_2 \times b_2 \times l_2$$

t_1, b_1 and l_1 - Thickness, width and length of chip before cutting.

t_2, b_2 and l_2 - Thickness, width and length of chip after cutting.

Since, $b_1 = b_2$

$$t_1 \times l_1 = t_2 \times l_2$$

$$\boxed{\frac{t_1}{t_2} = \frac{l_1}{l_2} = r}$$

The chip thickness ratio can be used to measure shear angle (β) as follows.

From right angle triangle ABC

$$AB = \frac{t_1}{\sin\beta} \qquad ---------- \quad (X)$$

From right angle triangle ABD

$$\frac{BD}{AB} = Sin\,(90 - \beta + \alpha) = Cos\,(\beta - \alpha)$$

$$AB = \frac{t_2}{\cos(\beta - \alpha)} \qquad ---------- \quad (Y)$$

Where, α — rake angle.

Equating the equation X and Y

$$\frac{t_1}{\sin\beta} = \frac{t_2}{\cos(\beta - \alpha)}$$

$$\frac{t_1}{t_2} = \frac{\sin\beta}{\cos(\beta - \alpha)}$$

$$r = \frac{\sin\beta}{\cos(\beta - \alpha)}$$

$$r = \frac{\sin\beta}{\cos\beta\cos\alpha + \sin\beta\sin\alpha}$$

$$\frac{r\cos\beta\cos\alpha}{\sin\beta} + \frac{r\sin\beta\sin\alpha}{\sin\beta} = 1$$

$$\frac{r\cos\alpha}{\tan\beta} + r\sin\alpha = 1$$

$$\frac{r\cos\alpha}{\tan\beta} = 1 - r\sin\alpha$$

$$\boxed{tan\beta = \frac{r\cos\alpha}{1 - r\sin\alpha}}$$

From the above relation shear angle,

$$\boxed{\beta = tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right]}$$

14. What are the standard angles of cutting? Illustrate with an example.
(AU Dec 2007)

Angles of single point cutting tool

(i) Back rake angle:

It is also called *top rake angle*. It is the angle between the face of the tool and the line parallel to the base of the tool. It is the slope given to the face or surface of the tool. This slope is given from the nose along the length of the tool as shown in fig. 1.1. This angle may be positive or negative depending upon the amount of side cutting edge.

(ii) Side rake angle:

It is the slope given to the face or top of the tool. It is the angle between the tool face and the line parallel to the base of the tool as shown in fig.1.1. This slope is given from the nose along the length of the tool. When the angle is positive, slope is given towards the cutting edge and when the angle is negative, slope is given away from the cutting edge.

(iii) Relief angle or Clearance angle:

It is the slope given downwards from the cutting edges. They are divided into two clearance angles as follows:

      a. Side relief angle.
      b. End relief angle.

The angle between the side flank and a line perpendicular to the base of the tool is known as *side relief angle*. The purpose of providing this angle is to avoid rubbing when the tool is fed sideway into the job. If the side relief angle is larger, the cutting edge of the tool will break because of insufficient support whereas the side relief angle is very small. The tool cannot be fed into the job but it will rub against the job. So, the tool will be overheated. This will affect the surface finish of the job.

The angle between end flank and a line perpendicular to the base of the tool measured at right angles to the end flank is known as *end relief angle*. This angle prevents the cutting tool from rubbing against the job. If the angle is very larger, it will break due to insufficient support whereas if it is very small, the tool will rub against the job. Due to this, the cutting will not be proper and hence poor surface finish will be obtained. Generally, its value varies from 6° to 10°.

(iv) Cutting edge angles:

There are two cutting edge angles namely side cutting edge angle and end cutting edge angle.

Side cutting edge angle is the angle between the side cutting edge and the side of the tool shank. Otherwise, it is the angle between the side cutting edge and the longitudinal axis of the tool. It avoids the formation

End cutting edge angle is the angle between the end cutting edge and a line perpendicular to the tool shank. Otherwise, it is the angle between the face of the tool and a plane perpendicular to the side of the shank. This angle will allow only small section of the end cutting edge to contact the machined surface and prevents vibration and chatter. Normally, this angle varies from 5° to 15°.

(v) Nose radius:

It is the angle between the side cutting edge and the end cutting edge. The line joining of side and end cutting edges by a point leads to high heat concentration. Joining by means of a small radius is a good practice to increase the tool life and to ensure better surface finish on the work piece. Large radii strengthen the tool and hence it is used on cast iron and castings where the cuts are interrupted.

3. Effects of Back rake angle

The size of the angle depends upon the material to be machined. If the material is softer, greater angle should be given whereas the material is harder, smaller angle is enough. i.e., Aluminium requires more back rake angle than cast iron or steel. Back rake angle may be positive, negative or neutral.

(a) Positive Rake angle   *(b) Neutral Rake angle*

(c) Negative Rake angle

Fig. 1.2. (a), (b) and (c) show a tool with positive, neutral and negative back rake angle respectively. Higher value of rake angle weakens the cutting edge. A negative rake angle increases the tool force to some extend. These difficulties may be rectified by giving additional support to the cutting edge. Normally, negative rake angles are given to carbide tools.

When will be the positive rake angles used?
   (i)   To machine the work hardened materials.
   (ii) To machine low strength ferrous and non-ferrous metals.
   (iii) To turn the long shaft of smaller diameters.
   (iv) To machine the metal having lesser recommended cutting speeds.
   (v)   To machine the workpiece using small machine tools with low horsepower.

When will be the negative rake angles used?
   (i)   To machine high strength alloys.
   (ii) The machine tools are more rigid.
   (iii) The feed rates are high.
   (iv) To give heavy and interrupted cuts.

4. Effects of side rake angle

During the cutting process, the chip curling or the amount of chip bend depends upon this angle. If the side rake angle is larger, the amount of power required to cut and bend the chip will decrease. Hence, it produces better surface finish.

23

Unit II – Centre lathe and Special purpose lathes
Part A

1. **What are the various thread cutting methods? (AU Apr 2011,Dec 12)**

   (1) Reversing the machine.

   (2)Marking the lathe parts

   (3) Using a chasing dial or thread indicator

   (4) Using thread chaser

2. **What is Swiss type automat? (AU Apr 2011)**

   In this type ,the work piece is feed against the tool. The head stock carrying the bar stock moves back and forth for providing the feed movement in the longitudinal direction.

3. **Explain the following parts of lathe? (AU Dec 2010, Apr 12)**

   (a) Lathe bed

   (b) Carriage

   Lathe bed: It is the base of the machine. It carries headstock on its left end and tailstock on its right end.

   Carriage: It is the moving part that slides over the guide ways between headstock and tailstock.

4. **What is an apron? (AU Dec 2010)**

   It is an integral part of several gears, levers and clutches which are mounted with saddle for moving the carriage along with lead screw while thread cutting.

5. **List any four methods by which taper turning is done in a center lathe. (AU Apr 2010) (AU Dec 2009)**

   (i) Form tool method

   (ii) Tailstock set over method

   (iii) Compound rest method

   (iv) Taper turning attachment method

6. **Distinguish between Capstan lathe and Turret lathe. (AU Apr 2010,Apr 13)**

S No	CAPSTAN LATHE	TURRET LATHE
1	Turret head is mounted on a ram which slides over the saddle.	Turret head is directly mounted on saddle .But it slides on the bed
2	Turret movement is limited	Turret moves on the entire length of the bed without any restriction.

7. **Mention four different types of chucks used in a machine shop. (AU Dec 2009)**

    (i) Three jaw chuck (or) self centering chuck

    (ii) Four jaw chuck or independent chuck

    (iii) Magnetic chuck

8. **What is the purpose of a mandrel? How many types of mandrels is there in common use? (AU Dec 2012)**

    Mandrels are used for holding hollow work pieces
    (1) Plain mandrel
    (2) Collar mandrel
    (3) Cone mandrel
    (4) Step mandrel
    (5) Gang mandrel

9. **What are the advantages of using a collect chuck? (AU Dec 2008, Apr 10)**

    (i) Job setting will be easy and quicker
    (ii) Heavy cut can be taken

10. **Why is it essential that the cutting point of the tool should be level with the spindle center while machining taper on a work piece. (AU Dec 2008)**

    It is done to avoid eccentric taper.

11. **What is the difference between a ram type turret lathe and saddle type turret lathe? (AU Dec 2007, Apr 10)**

S No	RAM TYPE TURRET LATHE	SADDLE TYPE TURRET LATHE
1	Turret head can be moved manually.	Turret head cannot be moved manually.
2	The maximum size of 60mm diameter work can be accommodated.	It can accommodate only from 125 to 200mm.

12. **Calculate the power required for cutting a steel rod of 50mm in diameter at 200rpm.**

    Assume cutting force of 160 kg. (AU Dec 2007)

    Power Required = F_C X V

    $$= FC \times \frac{\pi DN}{1000} = (160 \times 9.81) \times \frac{\pi \times 50 \times 200}{1000 \times 60} = 821.8 \text{ kW}$$

13. **What are the advantages of automatic lathes? (AU Dec 2006, Apr 07)**

    (i) Mass production of identical parts.

    (ii) High accuracy is maintained

    (iii) Time of production is minimized.

(iv)   The bar stock is fed automatically.

14. **What are the functions of feed rod and lead screw? (AU Dec 2006)**

    Feed Rod: It is used to guide the carriage in a straight then moves along the bed.

    Lead screw: It is used to move the carriage while thread cutting operation is carried out. It also ensures

    the proper speed of work relative to the tool for thread cutting operation.

15. **Why were power chucks developed? (AU Dec 2006)**

    Power chucks are primarily developed for the application as work holding devides for automatic machines,

    numerical control and CNC machines.

Part **B**

1. Explain the various taper turning methods? **(AU Apr 2011) (AU Dec 2010)**

TAPER TURNING METHODS
(a) Form tool method.
(b) Tailstock set over method.
(c) Compound rest method.
(d) Taper turning attachment method.

Form Tool Method

It is one of the simplest methods to produce short taper. The method is shown in fig. The form tool is ground to the required angle. When the work piece rotates, the tool is fed perpendicular to the lathe axis.
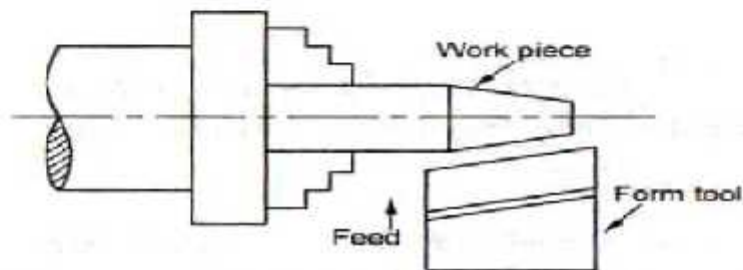
Form tool method

The taper length should be less than the tool cutting edge length. As the entire cutting edge removes metal, it creates lot of vibrations to machine tools and large force is required. It is done in a slow speed.

Tailstock Set over Method

The tailstock set over is calculated by using the formula.

$$\text{Set over, } h = \frac{D-d}{2l} \times L = L\,tan\alpha \qquad [\because \text{angle is small } sin\alpha = tan\alpha]$$

Where, D – Maximum diameter of the work piece
d – Minimum diameter of the work piece
l – Required length on which taper being made
L – Full length of the work piece
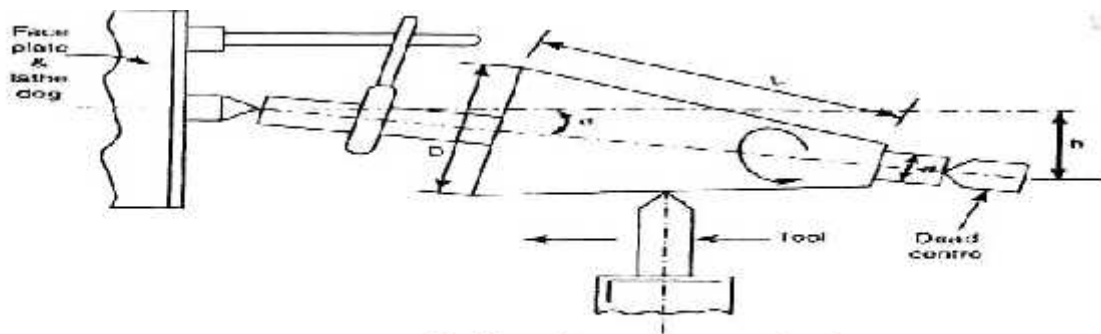
Tailstock set over method

If taper is turned on entire length of the work piece then $l = L$.

$$h = \frac{D - d}{2}$$

This method is employed when the angle of taper is very small (less than 8°). The work piece is held between the live centre and the dead centre. Now, the tailstock is moved cross wise i.e., perpendicular to the lathe axis by turning the set-over screw. This process is called as *tailstock set-over*. Hence, the job is inclined to the required angle. The tool is moved parallel to the lathe axis when the work piece rotates. So, the taper will be turned on the work piece.

Compound Rest Method

This method is used to produce short and steep taper. In this method, work is held in a chuck and is rotated about the lathe axis. The compound rest is swiveled to the required angle and clamped in position.
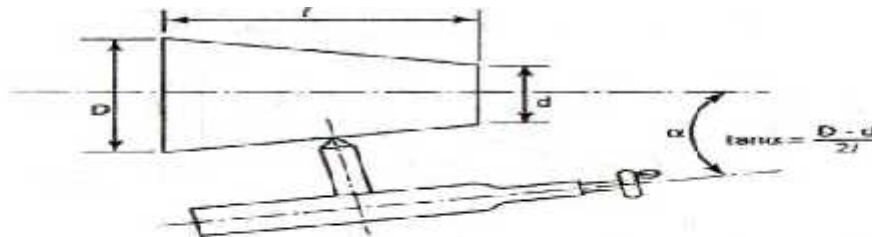
The angle is determined by using the formula, $\tan\alpha = \dfrac{D - d}{2l}$

Then the tool is fed by the compound rest hand wheel. This method is used for producing both internal and external taper. The compound rest can be sweivelled up to 45° on both sides. The tool should be moved by hand.

Taper Turning Attachment Method

A taper turning attachment is attached to the rear end of the bed by using bottom plate or bracket. It has a guide bar which is pivoted as its centre. This guide bar can swing and set at any required angle. It has graduations in degrees. The guide bar can be sweivelled to a maximum of 10° on either side. It has a guide block which connects to the rear end of the cross slide and moves on the guide bar. Before connecting the cross slide, the binder screw is removed such that the cross slide is free from the cross slide screw.

During taper turning, the job is held between centres or in a chuck. The guide bar is turned to a required angle.

The angle is calculated using the formula, $\tan\alpha = \dfrac{D - d}{2l}$
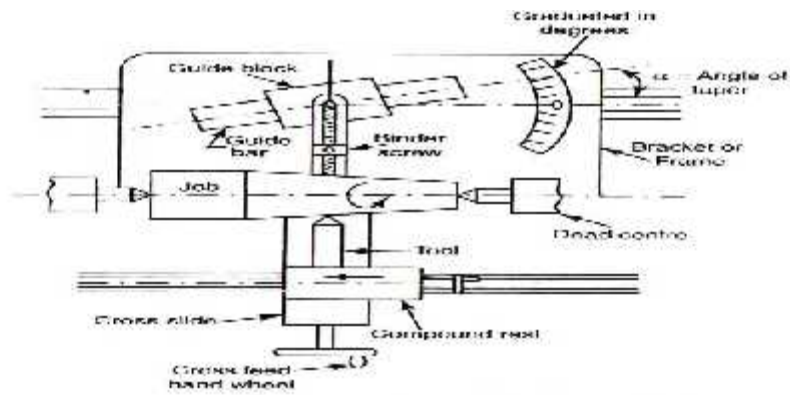
Taper turning attachment method

When the division is given in mm instead of degrees. Then the angular distance (in mm) of the guide bar to be tilted is given by

$$S = \frac{D - d}{2l} \times L_g$$

Where, L_g — Half of the total length of the guide bar.
S — number of divisions in mm

When the longitudinal feed is given, the tool will move at an angular path as the guide block moves at an angle on the guide bar. Compound rest hand wheel is used to give depth of cut. The guide is set at half taper angle. By this method, any type of taper can be turned.

2. Discuss about special attachments of lathe. **(AU Apr 2011)**

SPECIAL ATTACHMENTS

Generally, milling and grinding are performed on lathes by using special attachments.

Milling Attachment

Milling is the process of removing metal by moving the work against rotating cutter.

This rotating cutter is mounted on the tool holder called *arbor*. Milling cutters have multipoint cutting edges. This operation is carried out in two methods depending upon the form of profiles.

1. For cutting grooves or keyways

Here, the work is held on the cross slide and milling cutter is held by a chuck using special attachment. Then the depth of cut is given by a vertical slide provided on the attachment.

2. For cutting multiple grooves and gear wheel

In this case, work is held stationary between centres. The attachment is mounted on the cross slide on the carriage which is driven by separate electric motor. The feeding is given by the carriage and vertical movement is given by the provision made on the attachment. Similarly, a number of grooves are made on the periphery of the work by rotating the work. For cutting gears, a universal dividing head is fitted on the rear end of the headstock spindle to divide the work equally.

Grinding Attachment

Grinding is the operation of removing metal in fine form of chips. It is done by moving the work against a rotating abrasive wheel. This abrasive wheel is known as *grinding wheel*. Both external and internal grinding can be cut by using special attachments on lathe. The wok is held between centres or on a chuck and rotated for grinding external surfaces. For grinding internal surfaces, a work is held on a chuck or faceplate. Then feeding is given by moving the carriage and cross slide is moved for giving depth of cut. Generally, grinding is done on lathes using attachments for finishing workpieces, sharpening a cutting tool and sizing workpieces to close tolerance.

3. Describe the turret indexing mechanism. **(AU Apr 2011, Dec 12)**

GENEVA MECHANISM OR INDEXING MECHANISM

The turret is provided with automatic indexing mechanism. To index the turret by 1/6 of a revolution, the ram is returned to the starting position. Then the next tool comes into position to perform the machining operation.
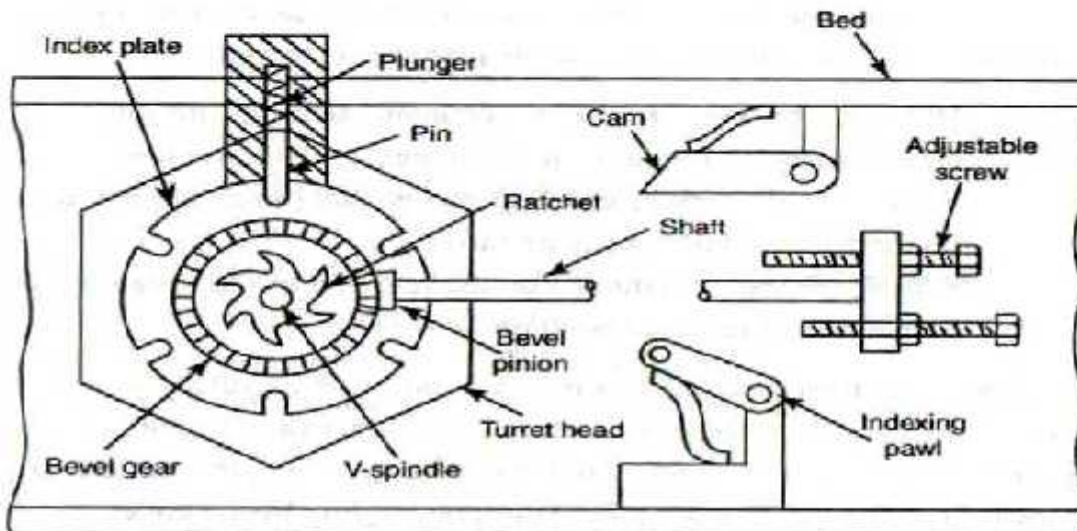

Geneva mechanism or Indexing mechanism

Turret head, an index plate, a bevel gear and ratchet are mounted on the same vertical spindle of the saddle. A spring-actuated plunger is used to lock the index plate which prevents the rotation of turret during machining. When the turret trips the stop, the plunger is released with the help of spring-loaded cam and a pin already fitted with plunger. So, the index plate is free to rotate. Then the indexing pawl is engaged with the ratchet and rotates 1/6 or 60° of revolution. When the turret moves forward, again the plunger locks the index plate.

4. Discuss about the bar feed mechanism .

BAR FEEDING MECHANISM

In turret and capstan lathes, the bar is fed automatically without stopping the lathe which reduces the production time. The bar stock passes through a chuck and hollow spindle of the lathe. The bar is fitted with the bar chuck by setscrews.

The bar chuck rotates in a sleeve along with the bar. The loose sleeve is housed on a sliding bracket which slides over a sliding bar. It is again attached to one end of a chain. A suspended weight is hanging at the other end of the chain to exert a constant force on the bar chuck towards right.
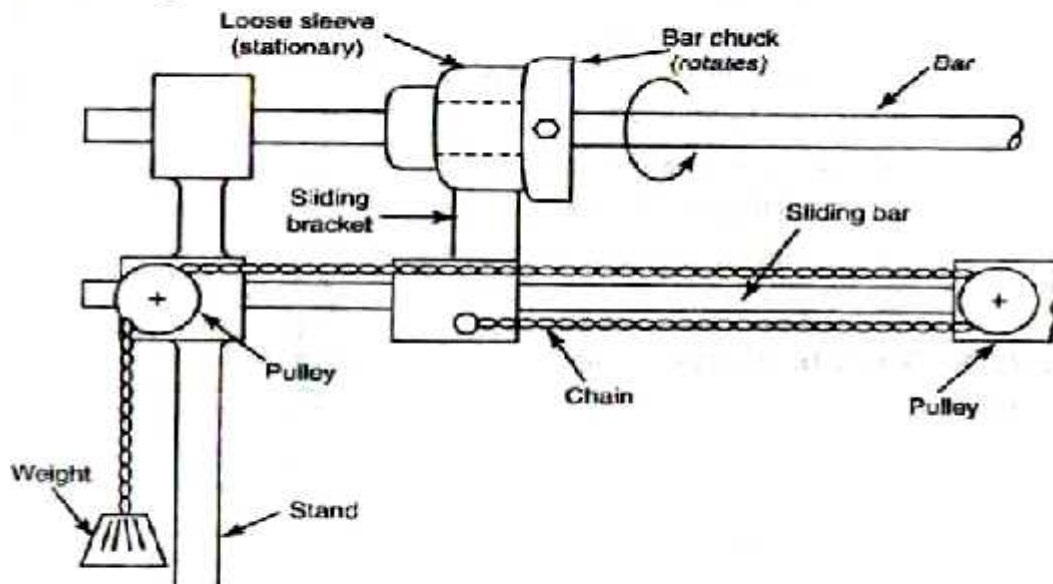
Bar feeding mechanism

When the bar is released by the collet, the force due to weight will feed the work towards right. It continues till the work piece butts against the bar stop held in the turret. Then the collet is closed.

7

5. Describe the holding devices in a lathe. **(AU Dec 2006) (AU Dec 2008)**

WORK HOLDING DEVICES

Some of the standard works holding devices used to hold the work in a lathe are

 (i) Chucks
 (ii) Centres
 (iii) Face plate
 (iv) Angle plate
 (v) Mandrels
 (vi) Steady and Follower rest

Chucks

Chucks are used to hold the work pieces of small length ($l < 4D$) and large diameters. It can also hold irregular shape work pieces. Work pieces which cannot be mounted between centers are mounted in chucks. A chuck is attached to the headstock spindle of the lathe. The work is clamped between the jaws of the chuck and jaws are tightened. The right end of the work piece can be supported by the dead centre if needed. There are three types of chucks.

1. Three jaw or self centering chuck

As the name implies, it has three jaws. When chuck key is turned, all the jaws will move equal distance in radial direction. The chuck has internal mechanism to move the three jaws simultaneously. Hence, work can be centered automatically and quickly.
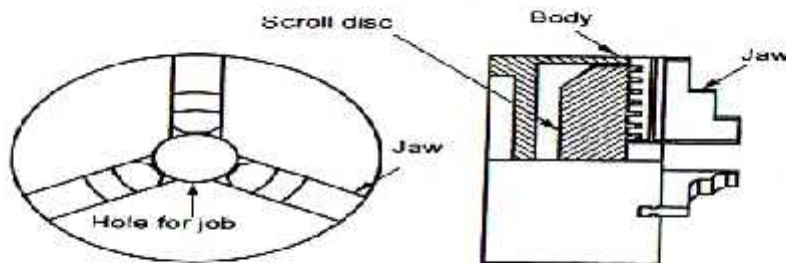
Three jaw chuck

It consists of a circular disc. The disc has a spiral scroll of the front and bevel teeth at its back. Three bevel pinions are fitted with the bevel teeth of disc. By rotating any one of these bevel pinions, the disc rotates. Hence, jaws are meshed with spiral scroll move. This chuck is used for holding round, hexagonal and other regular shaped work piece.

2. Four jaw or Independent Chuck

It has four jaws. Each jaw can be moved independently. These jaws have slots as the backside to mesh with screws. These screws can be screwed in or out of the body. The screws have square hole at the top to receive chuck key. When the chuck key is turned in the slot, the particular jaw only will be moved. Therefore, irregular job can be held in this chuck. The jaws can be reversed for holding large hollow work piece. Concentric circles are inscribed on the face of the chuck for quick centering of work pieces.

Concentric circles

Jaw

Hole for job

Body

Jaw

Four jaw chuck
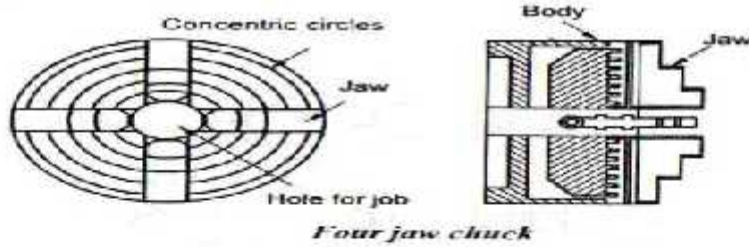
3. Magnetic chuck

Thin jobs can be held by means of magnetic chuck. The chuck gets magnetic power from an electro-magnet. Due to magnetic power, the job is held in position on flat face. The main disadvantage is that the magnetic material only can be held on this chuck.
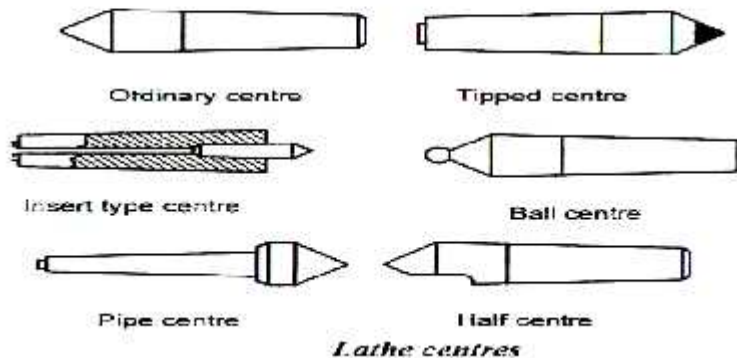
Chuck body

Magnets

Magnetic chuck
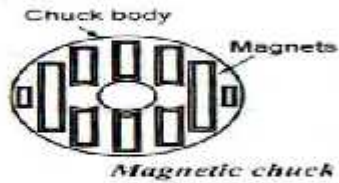
Centres

Generally, long shaft can be held between centres. Catch plate and dog carrier is used to hold the job between centres. Catch plate is in the form of circular disc when is screwed on the spindle nose.
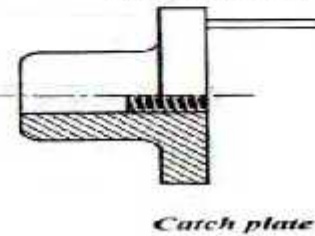
Catch plate

The various dog carriers are shown in fig. These dog carriers are clamped to the job by a screw. The tail of the dog carrier is attached to the catch plate.

Tail

Tail

Lathe dags
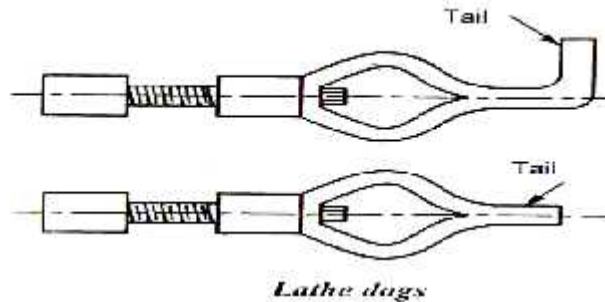
The live centre is inserted in the head stock spindle. The tailstock carries a dead centre. Small holes are drilled on both ends of the job and are supported between centres. The various lathe centres are shown in fig.

Ordinary centre

Tipped centre

Insert type centre

Ball centre

Pipe centre

Half centre

Lathe centres

When the spindle rotates, the work piece will rotate through the catch plate and carrier arrangement shown in fig.   . The live centre will revolve with the work piece and the dead centre will support the right end of the work.
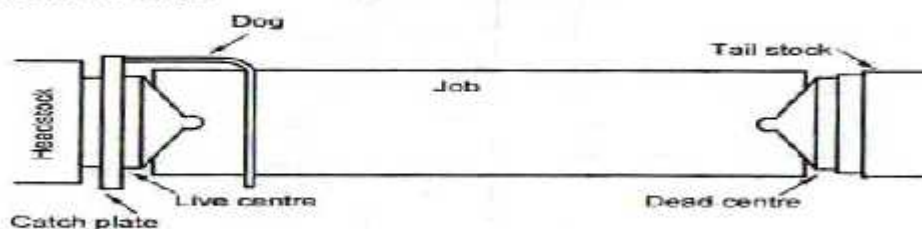
Work held between centres

Faceplate

Faceplate is a circular cast iron disc and has four T-slots and a number of plain radial slots as shown in fig.   . These slots are used for holding work by bolts and clamps. It is highly efficient for holding asymmetrical work or work of complex and irregular shape which is inconvenient to clamp by other means. When the spindle rotates, the faceplate will also be rotated and so the work will rotate.
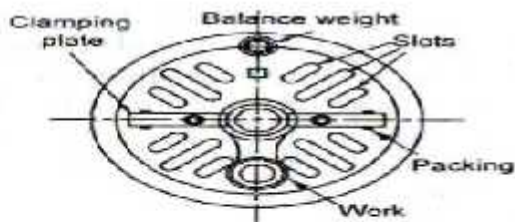
Face plate

Angle Plate

Angle plate is a cast iron block and has two accurately machined faces at right angles to each other.
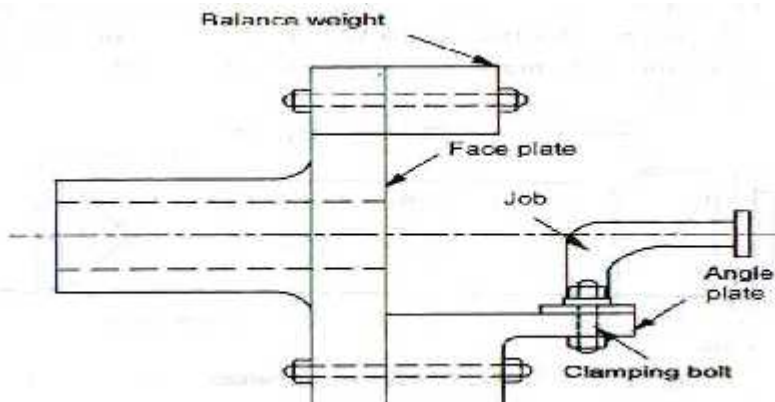
Angle plate

It has holes and slots on both the faces so that its one face may be clamped on a face plate and the work piece is mounted on the other face. When the spindle rotates, the faceplate will also rotate. So, the angle plate and job also will rotate. Usually, counter weights are fitted to balance the weight of the job. The job is fitted eccentrically or fitted in angle plate. The angle plate is used for holding elbow pieces as shown in fig.

Mandrels

Mandrels are used for holding hollow work pieces. The work revolves with the mandrel which is mounted between two centres. There are different types of mandrels used for different types of jobs. These are shown in fig.   . The outside diameter of mandrel should be equal to the inside diameter of job.

10

Various types of mandrels
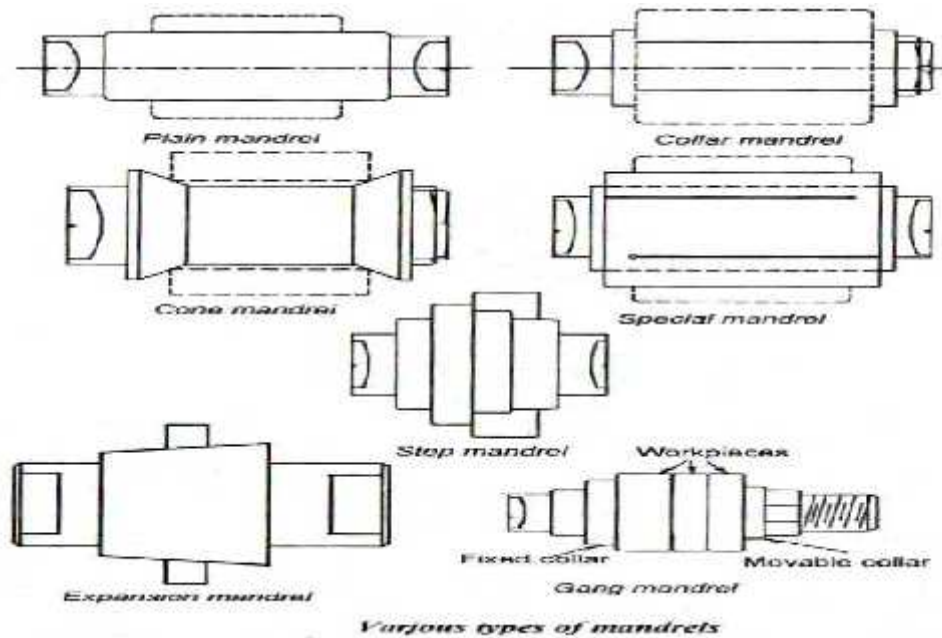
Steady and Follower Rest

Rest is a device which supports long work pieces ($\frac{L}{D}$ >10 or 12) when machined between centres or by a chuck. It is placed in between headstock and tailstock. It prevents vibration and bending of the work piece. There are two types of rests.
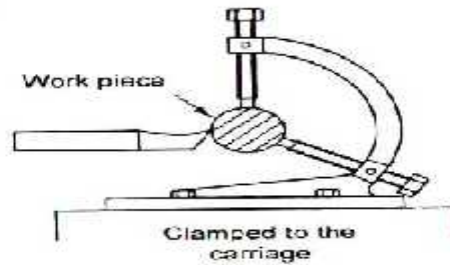
    (a) Steady rest.
    (b) Follower rest.

1. Steady rest

Steady rest

These types of rests are fixed on bed ways of the lathe by clamping the bolts. There is a cast iron base which is used to clamp the rest on the bed. The upper portion of the rest is hinged at one end. This is used to remove the job without disturbing the steady rest. The work piece is supported by three jaws arranged as shown in fig.   The jaws can be separately adjusted radially. For the work to be turned in high velocity, jaws have built up by balls or roller bearings to support it. After setting the jaws over the work piece, the rest is clamped to the lathe led to the required position. Since, the carriage cannot pass it, the job will be turned in two stages by reversing one end after half machining the length. For longer work pieces, two or more steady rests can be used.

2. Follower rest

Follower rest

The rest is mounted on the saddle and moves together with the tool. It has a C type casting and two adjustable jaws to support the work piece shown in fig   The jaws always follow the tool. Therefore, it gives continuous support to the work piece.

6.   Mention the specifications of lathe with a neat sketch. **(AU Dec 2010, Apr 13)**

SPECIFICATION OF A LATHE

The size of the lathe is generally specified as follows:

1. The length of bed.
2. Maximum distance between dead and live centres.
3. Type of bed i.e. straight, semi gap or gap type.
4. The height of centres from the bed.
5. Swing over the bed.
6. Swing over the cross slide.
7. Width of the bed.
8. Spindle bore.
9. Spindle speed.
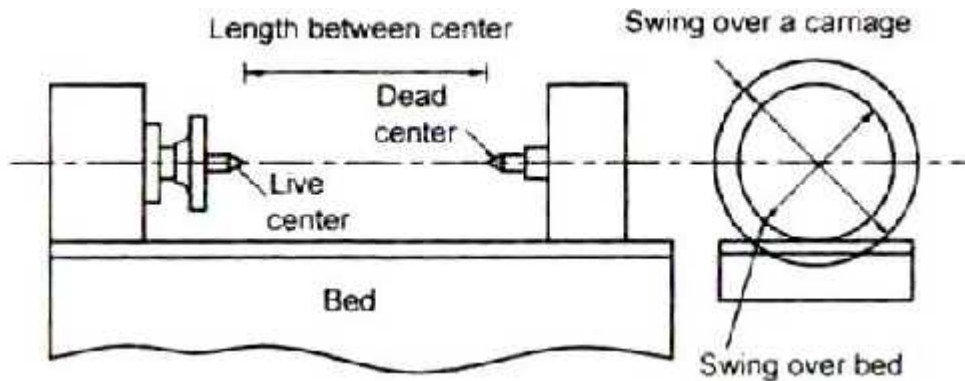
Specification of lathe

10. H.P. of main motor and *rpm*.
11. Number of spindle speeds.
12. Spindle nose diameter.
13. Feeds.
14. Floor space required.

12

Steady and Follower Rest

7.   Draw neat sketches of steady and follower rests and brief their applications. (AU Apr 2010, Dec 09)

when machined between centres or by a chuck. It is placed in between headstock and tailstock. It prevents vibration and bending of the work piece. There are two types of rests.
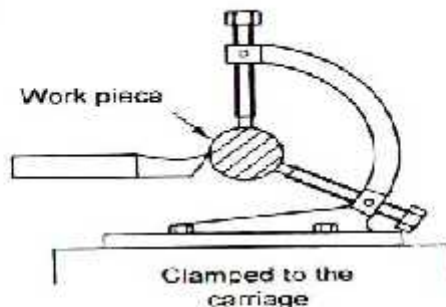
 (a) Steady rest.
 (b) Follower rest.

1. Steady rest

Steady rest

These types of rests are fixed on bed ways of the lathe by clamping the bolts. There is a cast iron base which is used to clamp the rest on the bed. The upper portion of the rest is hinged at one end. This is used to remove the job without disturbing the steady rest. The work piece is supported by three jaws arranged as shown in fig.   The jaws can be separately adjusted radially. For the work to be turned in high velocity, jaws have built up by balls or roller bearings to support it. After setting the jaws over the work piece, the rest is clamped to the lathe led to the required position. Since, the carriage cannot pass it, the job will be turned in two stages by reversing one end after half machining the length. For longer work pieces, two or more steady rests can be used.

2. Follower rest

Follower rest

The rest is mounted on the saddle and moves together with the tool. It has a C type casting and two adjustable jaws to support the work piece shown in fig   The jaws always follow the tool. Therefore, it gives continuous support to the work piece.

8. Describe the constructional features of Swiss Type Screw Cutting Machine

Swiss Type Automatic Lathes (Sliding Head Automatic Lathes)

This type of automatic lathe is suitable for small but long and slender parts like parts of wristwatches. There is a distinct difference between the conventional automatic lathes and Swiss type automatic lathes.In the latter, the work is fed against the tool. The headstock carrying the bar stock moves back and forth for providing the feed movement in the longitudinal direction. Hence, this type of automatic lathe is also called a *sliding head automatic lathe*.

This machine is used for producing long accurate parts of small diameter (2 to 25*mm*). In this, the parts can be machined to an accuracy of 0.005*mm* to 0.0125*mm*.

There may be as many as five cross slides in the case of automatic lathe. However, productivity-wise, the conventional automatic lathes are superior for short work pieces. The advantage of a sliding head automatic lathe is that long slender work pieces can be machined with very good surface finish, accuracy and concentricity in sliding head automatic lathes. Further, the Swiss type automatic lathes are capable of completely machining certain types of parts which may require second and third operations in conventional automatic machines.

shows the Swiss type screw cutting machine.
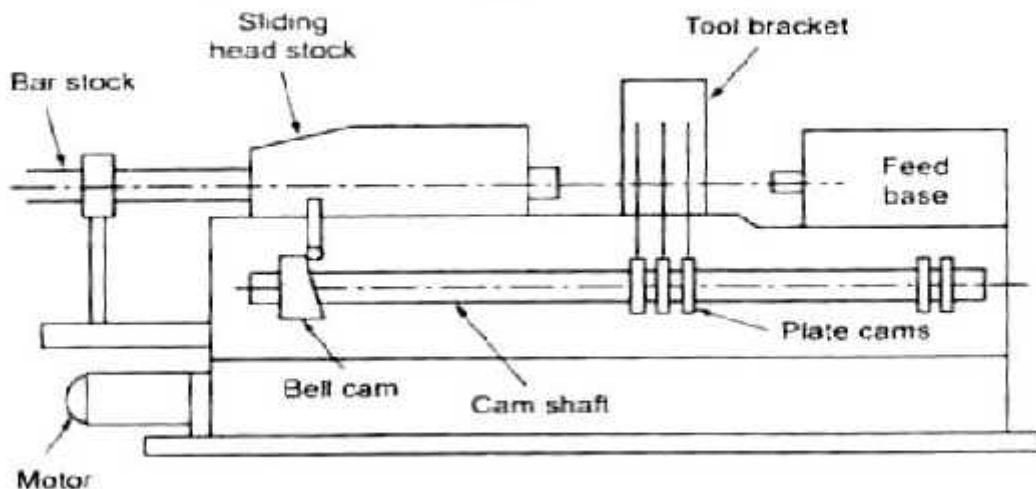
Swiss type screw cutting machine

It consists of four major parts:

1. The sliding headstock through which the bar stock is passed and gripped by a carbide-lined guide bush.
2. The camshaft which controls the bar stock and cutting tool movements.
3. The tool bracket which supports five tool slides and a bush for stock.
4. Auxillary attachments for performing various operations such as knurling, drilling, tapping, screwing, slotting, recessing etc.

9. What is meant by "Tool layout" of a turret lathe? **(AU Dec 2009, Apr 12)**

TOOLING

Simple Tool Layouts

Turret and capstan lathes are mainly used for machining workpieces on a rapid rate. Before starting the production, the following works are carried out

1. Selection of tools.
2. Designing of special tools.
3. Selection of speeds.
4. Selection of feeds.
5. Setting the required length of work piece and tool travel length.

These planning of operation sequence and preparation of turret or capstan are termed as *tool-layout*. The accuracy and cost of product are largely dependent on an efficient tool layout. The tool layout mainly consists of three stages.

1. Planning and scheduling stage: Preparation of operation sheet with order of operation.
2. Detailed sketching of various stages of machining operations in sequence of operations.
3. Sketching the plan showing the various tools into the hexagonal turret face and cross slides with proper sequence.

Step By Step Procedure for Preparing Tool Layout Of Turret And Capstan Lathe In Detail As Below

1. The component to be machined is thoroughly studied and the required total length of the work is calculated.
2. The number of operations involved in the component starting from the right end is roughly listed.

15

3. From the rough list of operations, the proper operation sequence is decided.
4. Various tools according to the sequence of operations are selected.
5. The selected tools are fitted either on hexagonal turret or on cross-slide according to the operation sequence.
6. The proper cutting speeds, feeds and depth of cut for each and every operation are selected.
7. The total time required per piece is determined. The total time includes the following time terms.
   a. Total machining time of each and every operations.
   b. Idle time between successive operations and
   c. Time required for loading and unloading the components.
8. The detailed drawing of the work piece is drawn along with the turret tools and cross-slide tools in position.

The above procedure can be recorded either on a plain paper or on a simplified process planning sheet called *operation sheet or process-layout.*

Before doing the actual layout, the tool designer should be familiar in the field of capstan and turret lathes tools, and operations.

10.   Discuss the main parts of a turret lathe. **(AU Apr 2010, Dec 12)**

SEMI-AUTOMATIC LATHES

In ordinary center lathe, changing and setting of tools take more time. Hence, the rate of production will be low. Ultimately, the cost of production is also increased. So, we are in a position to change center lathe into some special lathes called as *semi-automatic lathes* and *automatic lathes.* In semi-automatic lathes, the required tools are preset. More than one tool can be used at a time to perform the specific task. It reduces tool-changing time, loading and unloading time and increases the rate of production. Hence, these semi-automatic and automatic lathes are used in mass production.

In semi-automatic lathes, all the machining operations are performed automatically. But loading and unloading of job, bringing the tools in correct positions, coolant on or off and selection of spindle speeds are performed manually.

Capstan and Turret lathes are the two types of semi-automatic lathes. The construction and working principle of both the lathes are one and the same. But they differ in applications. The turret lathe is used for heavy jobs whereas the capstan lathe is used for light and small jobs.

IMPORTANT REQUISITES OF CAPSTAN AND TURRET LATHES

The main parts of capstan and turret lathes are
   1. Bed
   2. Head stock
   3. Turret head and saddle
   4. Cross slide.
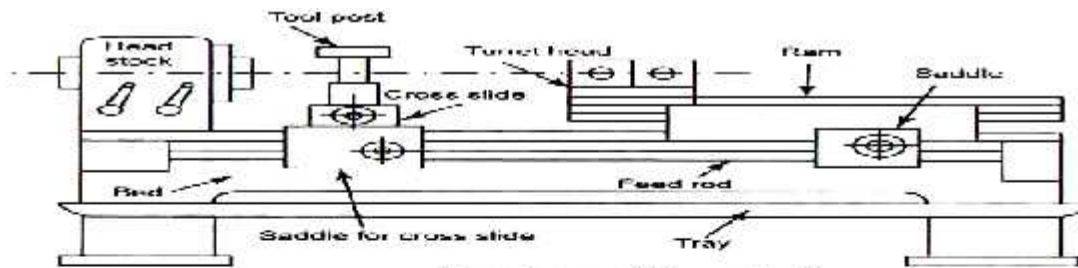
Capstan and Turret lathe

1. Bed

Bed is the base part of the lathe. It is a box type which is made of cast iron. Guide ways on the top of the bed has been provided accurately. Cross slide and turret head are mounted on these guide ways. The bed should be strong and rigid to withstand heavy loads, force and vibrations during machining task.

2. Cross slide

The two types of cross slides are

1. Reach over type
2. Side hung type

(i) Reach over type:

It is mounted on the bed guide ways in between headstock and turret which is also supported by lower rail. The cross slide has two tool posts. One is at the front end having four faces of square turret for mounting the tools. Each tool can be indexed by 90°. Stop bars are provided for controlling the motion of each tool which can be indexed automatically along with square turret for the next machining operation.

The tool post can move both in perpendicular and parallel to the spindle axis. Mostly power feed is used for movement of the tool post.

In rear tool post, the parting-off tool is clamped in inverted position to make the direction of rotation of work piece anticlockwise with respect to tool movement.

(ii) Side hung type:

This type of cross slide is entirely supported on the front way which has no rear tool post. This provides greater swing capacity to accommodate large diameter work piece. It is mainly used in turret lathe.

3. Head stock

Headstock of capstan and turret lathe is similar to that of head of ordinary center lathe but larger and heavier in construction to house the spindle and driving mechanism. A powerful motor of 30 to 2000*rpm* speeds is fitted.

The four main types of headstock are

i) Step cone pulley driven headstock.
ii) Direct electric motor driven headstock.
iii) All geared headstock.
iv) Pre-selective stock.

Step cone pulley driven headstock, direct electric motor driven headstock and all geared headstock are already discussed in detail.

Pre-selective headstock:

In this type, all geared headstock is provided with friction clutches. Rapid stopping starting and speed changing for different machining operations can be done by simply pushing a button or pulling a lever. The required speed of the next operation can also be selected in advance.

17

At the end of the first operation, the lever is actuated to rotate the spindle at the selected speed without stopping the machine.

4. Turret head

A turret head has a hexagonal block having six faces with a bore for mounting six or more than six tools at a time. The four threaded holes on these faces are used to accommodate the tool holders. The turret head is mounted on the ram fitted with turret slides longitudinally on a saddle. The ram is actuated either by hand or power. The forward movement of the ram is controlled by a preset or adjustable stop. To index the cutting tool, the ram or turret is returned to its starting position for tripping the stops. The tripped stops are locked in position by locking nuts.
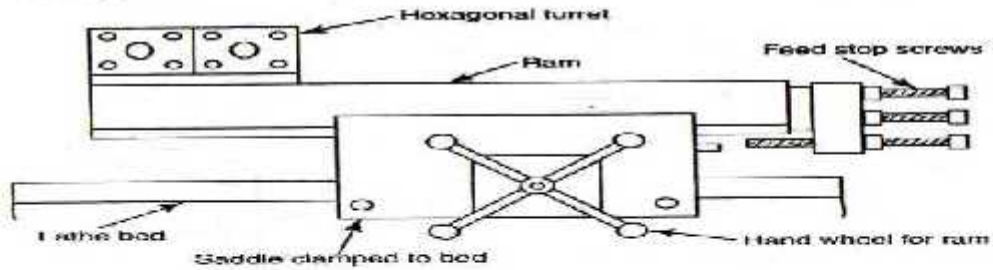
Ram of capstan lathe

Each tool is indexed through 60° by the rotation of a circular plate. The circular plate is indexed automatically along with turret head. Bringing the next tool into the cutting position is known as *Geneva mechanism*.

+

5. Saddle
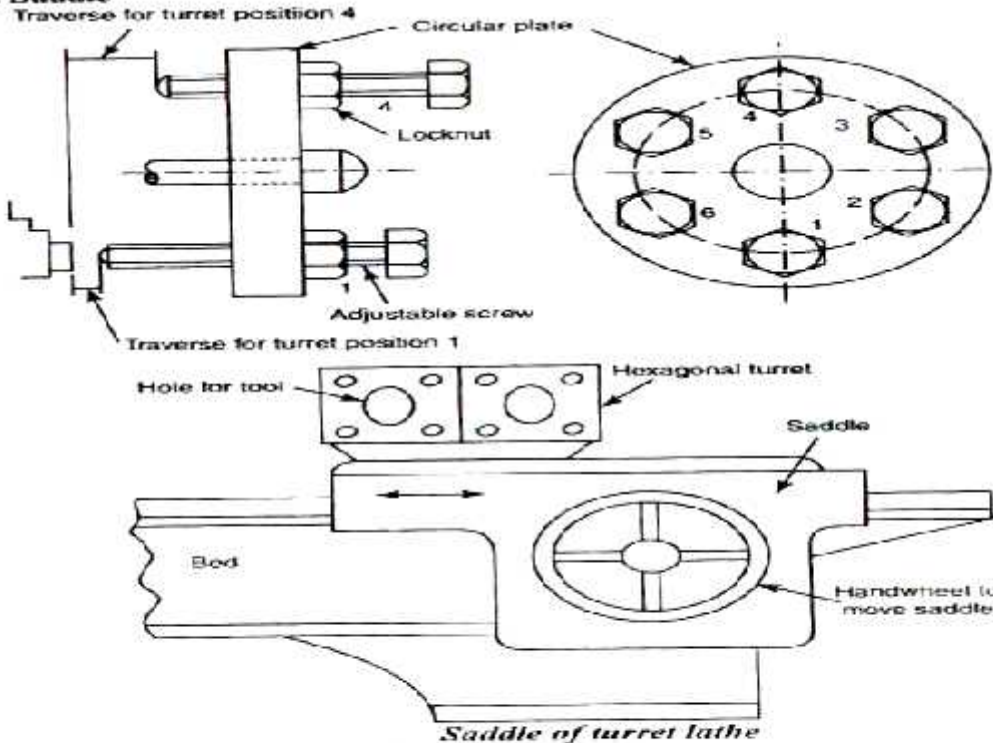
Saddle of turret lathe

In a capstan lathe, the turret head is mounted on a ram which slides on a saddle. It can be positional on a lathe bed ways and clamped well.

In a turret lathe, the turret head is mounted on the saddle itself which slides on the bed ways during machining. It is mainly used in turret lathe

18

TOOLING

12. What is meant by "Tool layout" of a Turret lathe? **(AU DEC 2010, APR 12)**

Simple Tool Layouts

Turret and capstan lathes are mainly used for machining workpieces on a rapid rate. Before starting the production, the following works are carried out

1. Selection of tools.
2. Designing of special tools.
3. Selection of speeds.
4. Selection of feeds.
5. Setting the required length of work piece and tool travel length.

These planning of operation sequence and preparation of turret or capstan are termed as *tool-layout*. The accuracy and cost of product are largely dependent on an efficient tool layout. The tool layout mainly consists of three stages.

1. Planning and scheduling stage: Preparation of operation sheet with order of operation.
2. Detailed sketching of various stages of machining operations in sequence of operations.
3. Sketching the plan showing the various tools into the hexagonal turret face and cross slides with proper sequence.

Step By Step Procedure for Preparing Tool Layout Of Turret And Capstan Lathe In Detail As Below

1. The component to be machined is thoroughly studied and the required total length of the work is calculated.
2. The number of operations involved in the component starting from the right end is roughly listed.

3. From the rough list of operations, the proper operation sequence is decided.
4. Various tools according to the sequence of operations are selected.
5. The selected tools are fitted either on hexagonal turret or on cross-slide according to the operation sequence.
6. The proper cutting speeds, feeds and depth of cut for each and every operation are selected.
7. The total time required per piece is determined. The total time includes the following time terms.
    a. Total machining time of each and every operations.
    b. Idle time between successive operations and
    c. Time required for loading and unloading the components.
8. The detailed drawing of the work piece is drawn along with the turret tools and cross-slide tools in position.

The above procedure can be recorded either on a plain paper or on a simplified process planning sheet called *operation sheet or process-layout.*

Before doing the actual layout, the tool designer should be familiar in the field of capstan and turret lathes tools, and operations.
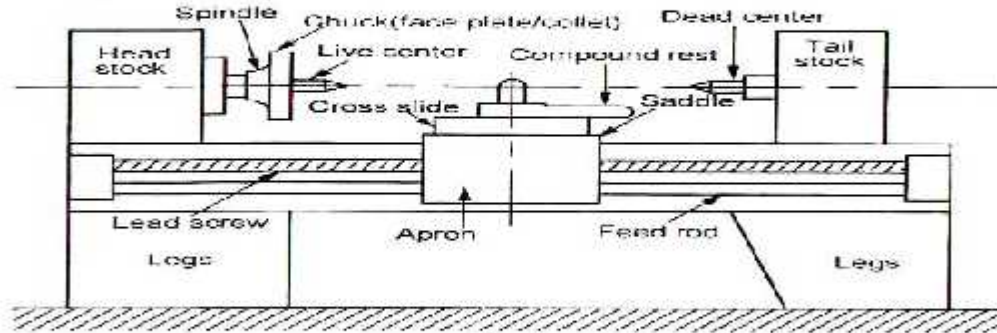
13. Name the various lathe accessories. How does a four jaw chuck differ from a three jaw chuck?

CONSTRUCTIONAL FEATURES OF A LATHE

The principal parts of an engine lathe are labelled and shown i fig. . Following are the principal parts of the lathe.

(i) Bed
(ii) Head stock
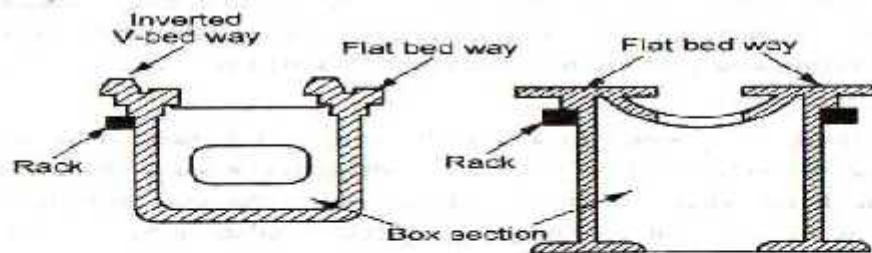(iii) Tail stock
(iv) Carriage
(v) Feed Mechanism

Engine lathe

A brief description of these parts is as follows:

1. Bed

Bed is the base of the machine. It carries a headstock on its left end and tailstock on its right end. Carriage is mounted on middle of the bed.

Lathe Bed

Headstock is stationary one. Both the tailstock and carriage move over the bed. The bed has V and dovetail guide ways as shown in fig.2.2. The bed is very strong to resist the cutting forces and vibrations. It is held rigidly by cross ribs supported by cast iron supports. The guide ways are very accurate for getting accuracy in jobs. It should be sufficiently rigid to prevent deflection under high cutting pressure transmitted through the tool post and carriage. There is a rack under the front way of the bed. A pinion gear is meshed with rack for moving the carriage when the hand wheel is turned. The bed is made of cast iron alloyed with nickel and chromium.

2. Headstock

The headstock assembly is permanently fastened to left end of the bed. It carries a hollow spindle so that the bars can be passed through it if necessary. The spindle nose of the spindle is threaded to hold the chuck or face plate. The spindle is rotated by a combination of gears and cone pulleys or by gears alone. The spindle has a taper at the front end for holding centres and other tools having a tapered shank. A live centre can be attached into the spindle. This centre is called *live centre* because it turns with the work.

The headstock has the driving and speed changing mechanisms. The headstock may be of back-geared type or all geared type. There are speed changing and feed changing leavers attached to the headstock.

3. Tailstock

Tailstock is situated at the right end of the bed. It is used for supporting the right end of work. It consists of a taper hole adjusting screw and hand wheel. It can be moved along the bed and clamped to the bed at the desired location. Tailstock is also used to hold drill, reamer or tap for drilling, reaming or tapping operations.
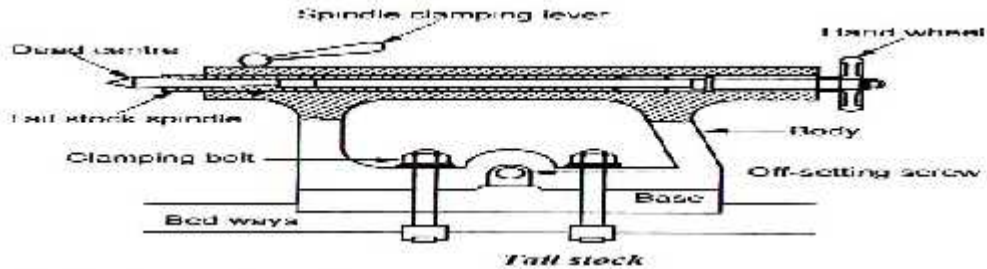
Tail stock

Tailstock consists of two main parts. The lower part rests directly on the bed ways, and the upper part rests on the lower part. Adjusting screws hold the two parts together. The upper body of the tailstock can be moved towards or away from the operator for taper turning. The tailstock body is bored and the tailstock spindle or quill moves through it. The spindle can be moved axially by means of a hand wheel. A dead centre is fixed into the taper hole of the spindle for supporting the right end of the work.

4. Carriage

The carriage is a moving part that slides over the guide ways between headstock and the tailstock. It carries the following parts.

(i) Saddle:

It is an *H* shaped component fitted across the lathe bed. It moves along the guide way. It carries the cross slide and tool post to provide various kinds of motion to the tools. It can be moved anywhere along the bed and locked to the required position.
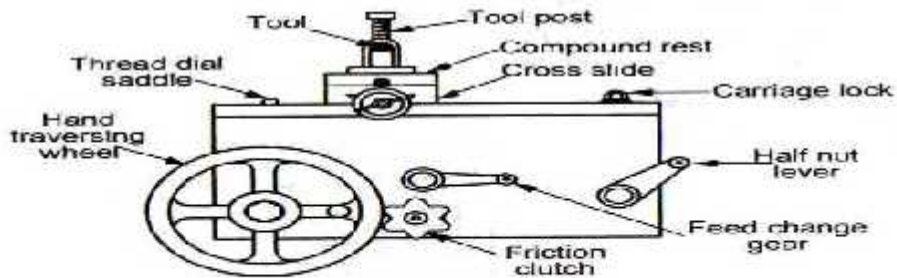

Fig. 2.4 Carriage

(ii) Cross Slide:

The cross slide is attached to the saddle. It carries the compound rest and tool post. The cross slide can be moved by power or by hand. There is a micrometer dial fitted on the cross slide hand wheel with an accuracy of 0.05 mm.

(iii) Compound rest:

Compound rest is mounted on the top of the cross slide. It is used for supporting the tool post and cutting tool in various positions. The base of the compound rest is marked in degrees. The tool post can be swiveled to various angular positions for different turning operations.

For taper turning. There is no power feed to the compound rest. It is operated only by hand to feed the tool longitudinally or at an angle to the lathe axis. There is a micrometer dial for showing the depth of cut.

(iv) Tool post:

A tool post is used to hold various tools and tool holders to create convenient working conditions. The tool post is fitted over the compound rest. The various types of tool posts are

      (a) Single screw tool post.
      (b) Open side tool post
      (c) Four bolt tool post.
      (d) Four way tool post.

(a) Single screw tool post:
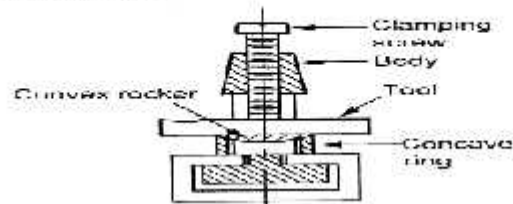
single screw tool post

This tool post is used to hold single tool only. The tool is clamped by a clamping screw. The tool rests on the top flat surface of the convex rocker. The convex rocker has a convex surface at its bottom. This convex rocker is placed over a concave ring. The height of the tool is adjusted by this arrangement.

**(b) Open-side tool post:**

This type of tool post is shown in fig. . The tool is held in position by set of screws. In order to adjust the height of the cutting
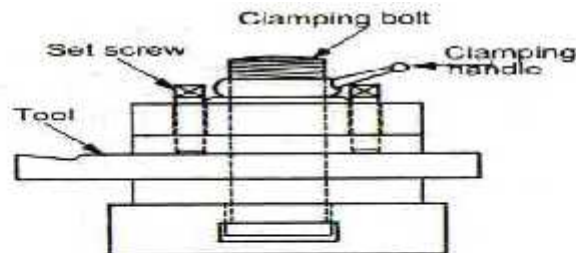
Open side tool post

point, parallel packing strips are used. The tool post is fitted on the compound rest by using clamping bolt through T-slot. The tool post can be tilted to any angle by loosening the clamping bolt and clamped.

(c) Four bolt tool post:
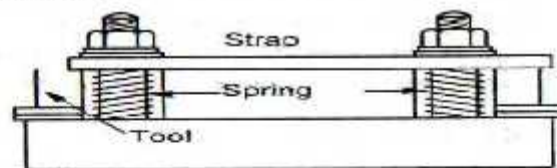
Four bolt tool post

In this type of tool post, two tools may be held in position by two straps and four bolts. The tool height is adjusted by placing parallel strips under the tool. It is generally used in heavy lathes as it gives more support to the tool.

(d) Four way tool post:

It is commonly used tool post now-a-days, because it facilitates to hold four various tools in a tool post at a time as shown in fig. . It can
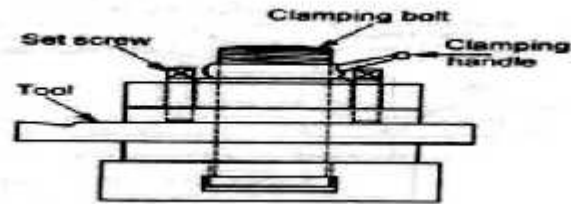
Four way tool post

be swivelled in the central screw and clamped at any angle. Here also tool height can be adjusted by using parallel strips.

(v) Apron:

The apron is fitted to the saddle and hung in front of the bed. It has several gears, levers and clutches for moving the carriage with the lead screw for thread cutting. It has a split nut for automatic thread cutting operation. The detailed mechanism is explained in further sections.

14. Discuss the features of ram type and saddle type Turret. **(AU Dec 2008, Apr 09)**

DIFFERENCE BETWEEN CAPSTAN AND TURRET LATHE

S.No	Capstan lathe	Turret lathe
1.	Turret head is mounted on a ram which slides over the saddle.	Turret head is directly mounted on saddle. But it slides on the bed.
2.	The turret movement is limited	The turret moves on the entire length of the bed without any restriction.
3.	Hence shorter workpiece can be machined.	Longer workpiece can be machined.
4.	The capstan construction does not provide rigidity due to overhanging of ram beyond the bed.	It provides rigidity and strong.
5.	So, it is very much useful in light duty applications.	It is useful in heavy-duty applications.
6.	Turret head can be moved manually.	Turret head cannot be moved manually.
7.	The maximum size of 60 mm diameter work can be accommodated.	It can accommodate only from 125 to 200 mm.
8.	No cross-wise movement to turret	Facing and turning are usually done by cross-wise movement of turret.
9.	Overhung type of cross-slide is not used.	Overhung type of cross-slide is provided for some specific operations.

23

15. Explain the feature of multi spindle automatics.

MULTIPLE SPINDLE AUTOMATIC LATHES

Multiple spindle automatic lathes are machines which can produce larger work pieces than single spindle automats. The principle advantage of the multi spindle automat is that it has a tool slide working on the jobs on all spindles simultaneously and hence the time for producing a piece is the time for the longest cut.

General Description:

Fig. shows a view of a 6-spindle automatic lathe. The headstock carries spindle carrier.

The spindle carrier is indexed so that work piece on each spindle can be machined by particular tool on the end tool slide. Turret only moves back and forth to provide the feed movement. The spindle carrier is indexed by a geneva mechanism.

I, II, III, IV, V, VI spindles
1, 2, 3, 4, 5, 6 cross slides
A, B, C, D, E, F Tool Stations
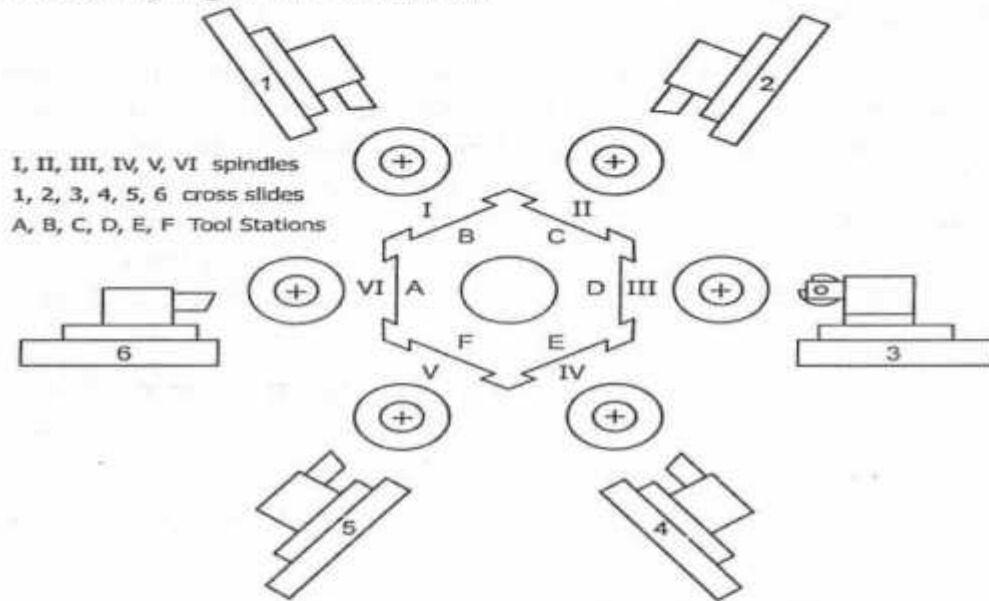
View of a six – spindle automatic lathe

The main tool slide moves longitudinally on an extension of the spindle which provides accurate alignment with the spindle. The end tool slide is advanced and retracted by a drum cam. Each spindle position has a separate cross slide which is operated by independent cams. Cross slides are mounted directly on the headstock. One of the spindle positions is used for stock loading in the case of magazine feeding or feeding of bar stock.

Classification of Multi-Spindle Automatic Lathes

Multi-spindle automatic lathes are classified as follows.

1. According to the type of work piece (stock) used.
   a. Bar type machine.
   b. Chucking type machine.
2. According to the arrangement of spindle.
   a. Horizontal spindle type.
   b. Vertical spindle type.
3. According to the principle of operation.
   a. Parallel action type.
   b. Progressive action type.

Bar-Type Automatic Machine

These machines operate on bar stock, usually round. Sometimes a bar of hexagonal shape can also be used. These machines can be specified by the largest diameter of stock that can be fed through the spindles. The sizes of bars range from about 14mm diameter. The bar stock may be fed either by gravity or by rollers.

Magazine-Loading Type or Chucking Type Machine

These machines are similar to bar type machines. They handle several work pieces held in several chucks. It can be specified according to the diameter of the work that can be swung over tool slides. The maximum size of bar stock that can be used in this machine is 250mm.

Parallel Action Multi Spindle Automats

These types of automatics are otherwise called as 'multiple-flow' machine. The line diagram of this machine is shown in fig.2.114. This machine consists of a frame with a headstock. The axes of work spindles are horizontal. These spindles are arranged in a line one above the other. The work spindles are housed in the headstock. There are two cross slides, one on left hand side and the other on the right hand side. The left hand side cross slide is called as *front tool slide*. The right hand side cross slide is called as *rear tool slide*.

These slides carry the cross feeding tools. Cams are used to obtain all working and auxiliary motions of the machines units.
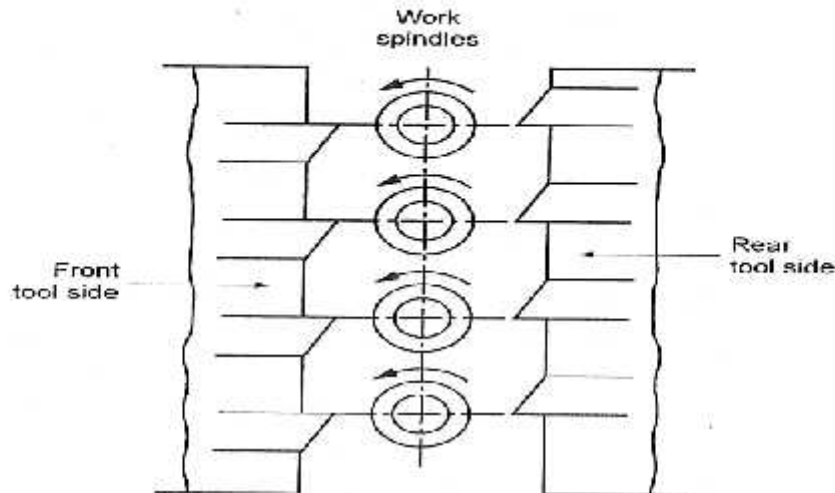
Parallel action multi spindle automatic machine

In this type of machine, the same operation is performed on each spindle. In one working cycle, each work piece is finished in each spindle. In a five-spindle machine, five components can be completed at a time. Similarly, in a eight spindle machine, eight components can be completed at a time. Hence, it is called as *parallel action multi spindle machine*. The production rate is very high in this machine. But only simple components can be machined since all the machining processes are done at one position.

Unit III – Other Machine Tools

Part A

1. **Mention the differences between shaper and planer. (AU Apr 2011)**

S . NO	SHAPER	PLANER
1	Tool reciprocates and the work is stationary	Tool is stationary and work reciprocates
2	Less accuracy due to overhanging of ram	It gives more accuracy as the tool is rigidly supported during cutting.

2. **What are the differences between drilling and reaming? (AU Apr 2011)**

   Drilling is the operation of producing cylindrical hole in a work piece. It is done by rotating the cutting edge of a cutter known as drill. The work is rotated at high speed.

   Reaming is the operation of finishing and sizing hole which is already drilled while the work is revolved at a very slow speed.

3. **Briefly describe the importance of quill mechanism. (AU Apr 2011)**

   If the taper shank of drill is smaller than the taper in the spindle hole, a sleeve is used. The sleeve with drill is fitted in the hole of the spindle. The sleeve has outside taper surface. This fits into the tapered hole of the spindle**.**

4. **List the types of sawing machines. (AU Dec 2010)**

   Types of sawing machines are

   (1)Reciprocating saw

   (2)Circular saw

   (3)Band saw

5. **Define the cutting speed, feed and machining time for drilling. (AU Dec 2010)**

   Cutting Speed: It is the peripheral speed of a point on the surface of the drill in contact with the Work piece. It is usually expressed in m/min.

   Feed: It is the distance of a drill moved into the work at each revolution of the spindle. It is expressed in mm/rev.

   Machining time: The time taken to complete the machining process without considering the idle time of machines is called machining time.

6. **What is broaching. (AU Dec 2010) (AU Dec 2009)**

   It is a process of machining a surface with a special multipoint cutting tool called "BROACH" which has successively higher cutting edges in a fixed path.

7. **What is the difference between up milling and down milling**

S.No	Event of operation	Up milling	Down Milling
1	Direction of travel	Cutter rotates against the direction of travel of workpiece	Cutter rotates in the same direction of travel of workpieces
2	Cutting Force	Increases from zero to max per tooth	Decreases from max to zero per tooth.

8. **List four applications of broaching machines. (AU Apr 2010)**

   (i) Straight and helical slots

   (ii) External surfaces of various shape

   (iii) External and internal toothed gears

   (iv) Holes of cross sectional shape

9. **How do you classify milling cutters? (AU Dec 2009)**

   They are classified based on following factors

   (i) According to the shape of the teeth.

   (ii) According to the type of operation

   (iii) According to the way of mounting on the machine

10. **What do you know about straight fluted drill and fluted drill? (AU Dec 2009)**

    The reamer with helical flutes provides smooth shear cutting action and provides better surface finish .The pitch of the flutes is made uneven to reduce vibration.

11. **What is meant by up milling and down milling? (AU Dec 2008)**

    In up milling, cutter rotates opposite to the direction of feed of the work piece whereas in down milling , the cutter rotates in the same direction of travel of the work piece.

12. **State the differences between a vertical shaper and slotters. (AU Dec 2008)**

S. No	VERTICAL SHAPER	SLOTTER
1	Vertical shapers generally fitted with rotary table to machine curved surfaces	Slides are fitted
2	Rotary table along with tools will move	Slides will move to perform slotting.

13. **Write the differences between drilling and tapping. (AU Dec 2008)**

    Drilling is the operation of producing cylindrical hole in a work piece. It is done by rotating the cutting edge of a cutter known as drill. The work is rotated at high speed.

    Tapping is the process used for making internal threads in a machine component by a tool called "TAP" 2

14. **What is a shell mill? (AU Dec 2007)**

    A shell mill is a large type of face or end mill , rather than having an integral shank. Typically there is a hollow or recess in the centre of the shell mill for mounting hardware on to a separate arbor.

15. **Mention the operations performed by a planner. (AU Dec 2006)**

    a. Planning horizontal surface

    b. Planning of an angle

    c. Planning vertical surface

    d. Planning curved surface

16. **Why is sawing a commonly used process. (AU Dec 2006)**

    a. Easy handling of machines and spindle construction

    b. Fast operation and cost of machinery is less

Part B

1. Explain various milling cutters with neat sketches? **(AU Apr 2012,Apr 13)**

MILLING CUTTERS

Classification of Cutters

These are multi tooth rotary cutting tools generally made of high speed steels or sintered carbides. Milling cutters are classified into different ways.

According to the shape of the tooth, milling cutters are classified as
- (i) Milled tooth cutters.
- (ii) Form relieved cutters.

According to the type of operation.
- (i) Plain milling cutters.
- (ii) Side milling cutters.
- (iii) End mill cutters.
- (iv) Angle milling cutters.
- (v) T-slot milling cutters.
- (vi) Slitting saws.
- (vii) Form milling cutters.
- (viii) Fly cutters.
- (ix) Wood ruff key slot milling cutter.

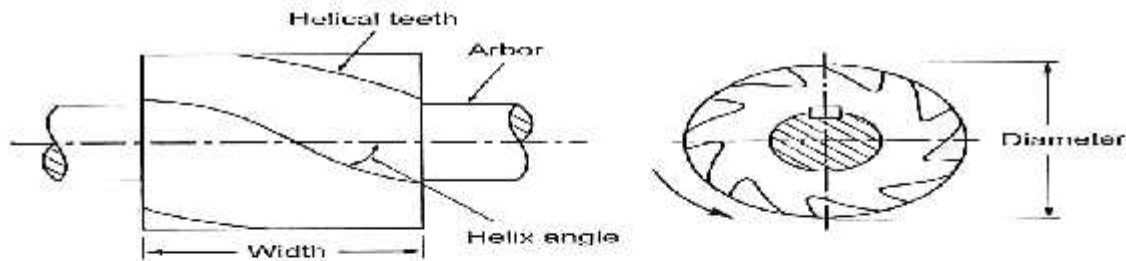According to the way of mounting on the machine.
- (i) Arbor cutters.
- (ii) Shank cutters.
- (iii) Face cutters.

L. Plain milling cutter

This is also known as a *mill cutter*. It is a disc or cylindrical shaped cutter having teeth on its circumference. It is used to machine flat surface parallel to its axis. There are two types of plain milling cutters commonly used.

- (i) Plain straight teeth cutter.
- (ii) Plain milling helical teeth cutter.

The plain milling cutters having the width more than its diameter is called *slab mill cutter*. This is used for rough machining with coarse feed. The cutter has less number of teeth.
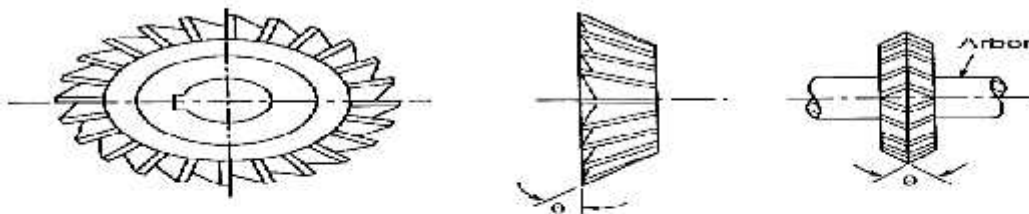
Plain milling cutter

Slab milling cutter

Straight teeth plain milling cutters are used for light operations. Helical teeth cutters are used for heavy cut operations.

Cutters of various diameters and widths are available. Roughing cutters will have less number of teeth. Finishing cutters will have more number of teeth for the same diameter.

4. Angle milling cutters

All cutters which have their cutting teeth at an angle to the axis of rotation are known as *angular cutters*. Their specific use in milling V-grooves, notches, dove tail slots, reamers teeth and other angular surfaces. Angular cutters are classified as single angle cutters and double angle cutters.

Single angle milling cutter   *Double angle milling cutter*

Single angle cutters may have their teeth either only on the angular face or on both, the angular face and the side. The later type enables milling of both the flanks of the inclined angular groove simultaneously. Their teeth may have an included angle of 45° to 60°.
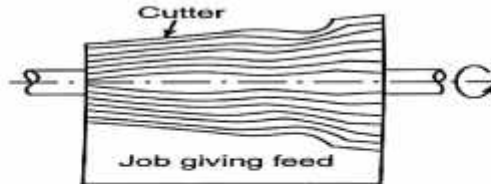
Double angle cutters differ from single angle cutters in such a way that they have two angular faces which join together to form V-shaped tooth. The included angle of this 'V' is either 45°, 60° or 90°. Angle of both sides should be equal.

5. T-slot milling cutter

It is a single operation cutter which is used only for cutting T-slots. The arrangement of cutting teeth is similar to that of a side milling cutter. But this cutter has a tapered shank. A neck is formed between the cutting face and the shank. The cutter has cutting edges on its periphery and on its sides.

T – slot milling cutter

Concave milling cutter has teeth curved inwards on its periphery. The cutter will produce a convex semi circular surface on the work piece.

Form milling cutter

Convex milling cutter has teeth curved outward on its periphery. The cutter will produce a concave semi-circular surface on the work piece.

Gear cutters have formed cutting edges. The shape of the cutter teeth is involute. The cutter will produce groove of involute shape. The involute gear tooth is formed between two grooves milled by the cutter. The profile of the gear tooth depends upon the module and the number of teeth on the gears. Therefore, for cutting different number of gear teeth of same module, different cutters are required. Corner rounding cutters are used for milling the edges and corners of the jobs to a required radius.

Fly cutters

It is actually a single point tool which is used in milling machine when standard cutters are not available. It is either mounted on a cylindrical body held in a stub arbor or held in a bar. Screws are used for tightly holding the tool in the above holders. The cutting edge of the tool is ground to the required shape. The cutter removes metal, when it rotates.

2. Discuss various hole making processes. **(AU Apr 2011,Dec 12)**
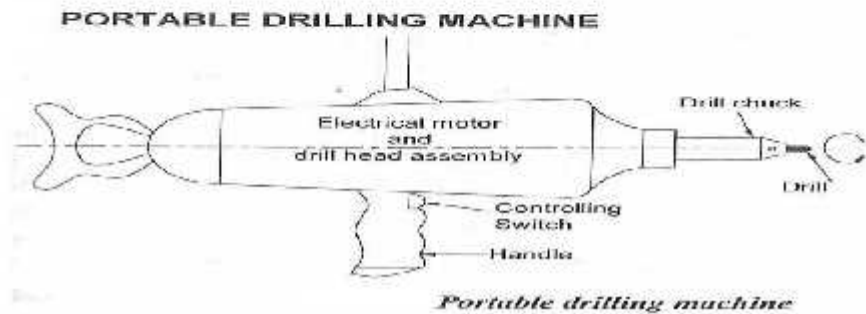
DRILLING

INTRODUCTION

Drilling is the process of producing hole on the work piece by using a rotating cutter called *drill*. The machine on which the drilling is carried out is called *drilling machines*. The drilling machine some times called *drill press* as the machine exerts vertical pressure to originate a hole. The hole is produced either by giving axial movement to the rotating drill or moving the work axially against the revolving drill. Though drilling may be done in a lathe or a vertical milling machine. It can be done conveniently, quickly and at low cost in drilling machine. Drilling machine can also used for boring, counter-boring, counter-sinking, reaming, tapping and spot facing operations. Drilling machines are used in machine assembly, repair shop, tool room, maintenance work, agricultural machinery etc.

CLASSIFICATION OF DRILLING MACHIENS

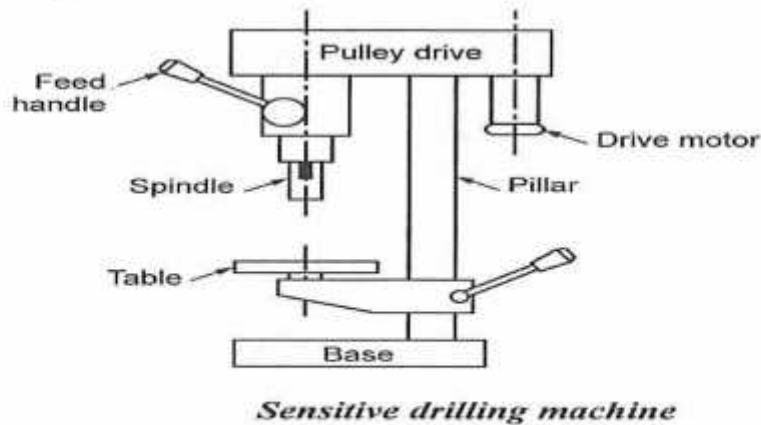The drilling machines are classified as follows:
1. Portable drilling machine.

2. Sensitive drilling machine.
   a. Bench type
   b. Floor type
3. Upright drilling machine
   a. Round column type or pillar type
   b. Box column type or square section type.
4. Radial drilling machine
   a. Plain type
   b. Semi-universal type
   c. Universal type
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Automatic drilling machine
8. Deep hole drilling machine

PORTABLE DRILLING MACHINE

Portable drilling machine

This type of machine is light in weight, compact in a smaller unit and easily handled with respect to the work piece. It is used for making small hole (up to 18*mm*) in large work piece. It is operated by hand power, pneumatic power or electric power. shows the schematic diagram of electrically operated portable *drilling machine*.

SENSITIVE DRILLING MACHINES

Sensitive drilling machines are lightweight, high-speed machines, which are generally bench type drilling machines, but pillar type machines are also available. It is used for light duty work and drill holes up to 15*mm* diameter. There is no power feeding arrangement, feeding is purely on hand control of the operator so that the operator can sense the feeding or can control the feeding. Therefore, the machine is called sensitive drilling machine.

Sensitive drilling machine

The main parts of the sensitive drilling machines are base, column, table, spindle and driving mechanism.

Boring is cutting a hole in wood with a tool called a bit. Holes of 6 mm size or larger are bored. Holes of 6 mm size are smaller are drilled Boring is the first step in making any kind of shaped opening or making holes.

Boring operation
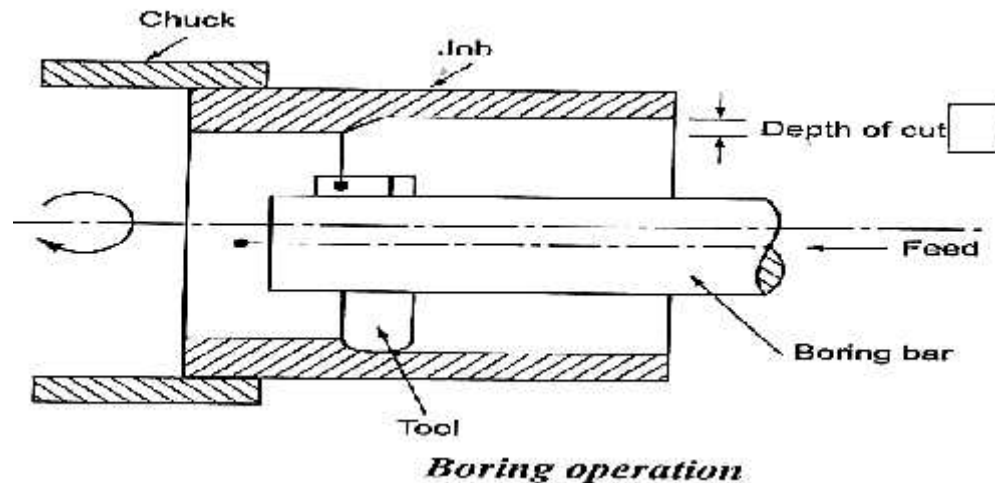
3. With a neat sketch explain the column and knee type milling machine and name its main parts. **(AU Dec 2010,Apr 11)**

Column and Knee Type Milling Machines

Column and Knee type milling machines are most commonly used for general shop floor work, maintenance work, tool room work, etc. It has a vertical column on its base. The column has machined guide ways on its front face. A knee slides up and down on these ways. The column serves as a housing for speed and feed mechanisms. The Knee carries the saddle and worktable.

There are two types of column and knee type milling machines.

(i) Horizontal type.

(ii) Vertical type.

In horizontal type, the axis of rotation of arbor is horizontal. In vertical type, the axis of rotation of arbor is vertical.

I. Plain or Horizontal milling machine

It is a horizontal column and knee type-milling machine otherwise simply a *horizontal milling machine*. A description of the principle parts of a milling machine is as follows:

(i) Base:

It is the foundation of the machine made of grey cast iron. All other parts are mounted on it. It also serves as a reservoir for cutting fluid.

(ii) Column:

It is the main support of the machine. The motor and other driving mechanisms are housed in it. It supports and guides the knee in its vertical travel.

(iii) Knee:

The knee projects from the column and slides up and down through dove tail guides. It supports saddle and the table. Elevating screw provides its vertical movement (up and down).
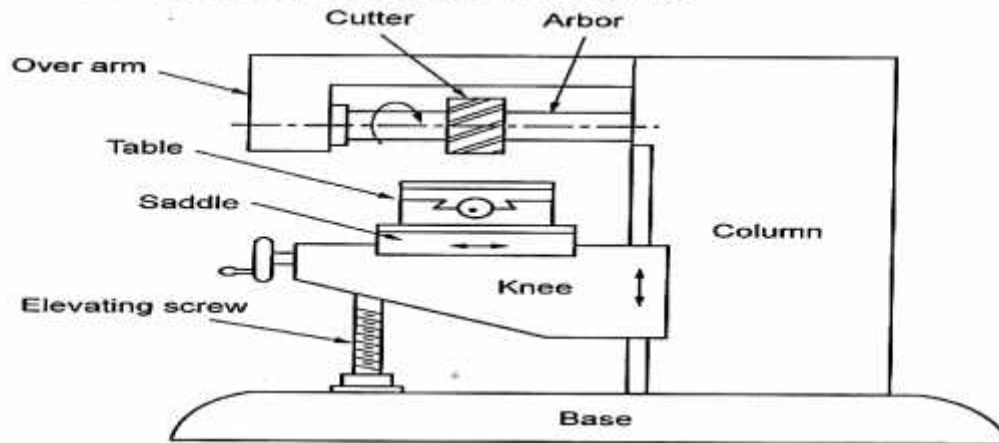
Horizontal milling machine

(iv) Saddle:

The saddle supports and carries the table and provides traversed movement.

(v) Table:

The top surface of the table is accurately machined. There are T-slots along the length of the table for holding the work.

The table rests on the guide ways of the saddle and travels longitudinally in a horizontal plane. It supports the work piece, fixtures etc.

(vi) Over arm:

It is mounted on and guided by the top of the column. The over arm is used to hold the outer end of the arbor to prevent it from bending.

(vii) Arbor:

Arbor is an accurately machined shaft. Cutters are mounted on the arbor which is rigidly supported by the over arm, spindle and end braces. It is tapered at one end to fit the spindle nose and has two slots to fit the nose keys for locating and driving it.

SAWING MACHINES

4. Explain hacksaw and band saw with neat sketches. **(AU Apr 2010)**

SAWING

Sawing is defined as the process of cutting billet or work stock to our requirements. It means, cutting the bar stock to the required length or size for machining to obtain the desired shape and size.

During sawing, the individual tooth cuts the work when either the saw or work feeds. This operation can be controlled by the direction, speed of cutting and number of teeth on the saw. Sometimes, curved cut can also be done. The main thing in sawing process is, the maximum width of cut done on work will be equal to the width of the saw itself.

SAWING MACHINES

Generally, sawing machines are classified according to the various types of power sawing machines.

1. Reciprocating saw
   - (i) Horizontal sawing machine
   - (ii) Vertical sawing machine

2. Circular saw
   - (i) Cold saw
   - (ii) Friction saw
   - (iii) Abrasive disk

3. Band saw
   - (i) Contour hand saw
   - (ii) Friction blade

Reciprocating Saw

This is same lke power hack saw. We can see it in any small size workshop itself. It consists of a frame, work table, vise, supporting base and power source. When the power supply is given, the blade reciprocates back and forth. The metal is cut only in forward stroke called *cutting stroke* as that shaper and planer.

No metal is cut during return stroke. So, depth of cut is given only at the end of return stroke by means of gravity or spring regulated ratchet mechanism or hydraulic drive. Mostly, hydraulic drives are used to lift the hack saw blade on the return stroke. In this operation, work material or stock is held between clamping saws. Sometimes, several stocks are clamped together and cut the same time depending upon the quantity of stock to be cut. By this process, both the straight and angular cuts can be made.

Circular Saw

Circular saws are in the form of revolving disc to cut the stock to the required dimensions. Teeth are formed on its full outer periphery.

1. Cold saw

It has a circular blade. Teeth are inserted on its periphery to cut the stock. Due to large diameter blades, it cuts the stock rapidly. Even it runs at slow speed, it is more powerful. Smooth and accurate cut can be obtained by using this saw. It is equipped with automatic feeding mechanism to cut the stock held in a vise effectively. Coolants may or may not be required.

2. Friction disc

These types of saws have almost no teeth. It is operated at high speeds. Due to this, heat is generated. So, the work becomes softer due to heat generation during cutting. In this case, cutting action is faster but it leaves heavier burr and less accurate.

3. Abrasive disc

In this case, cutting action takes place through abrasive discs by grinding. Resionoid or rubber bonded wheels are rotated at high speeds. In this method also, cutting action is faster and accurate but cutting action will not be true sawing.

Band Saw

A continuous blade having teeth runs over the rotating rim of the two wheels. The work is held between these two rotating wheels. So, the continuous cutting action can take place thereby making more productive.

1. Contour saw

It is the most versatile sawing machines in applications. The work can be fed in any direction. According to the feeding of work, the direction of cutting can be oriented to produce required shape. These

5. Discuss push and pull type broaching machines with neat sketches.**(AU Apr 2010,Dec 08)**

Push Down Type Vertical Broaching Machine

The push type vertical broaching machine is used for surface broaching operation. It consists of a box shape column, slide and drive mechanism. Fig.   shows the vertical push down type surface broaching machine.
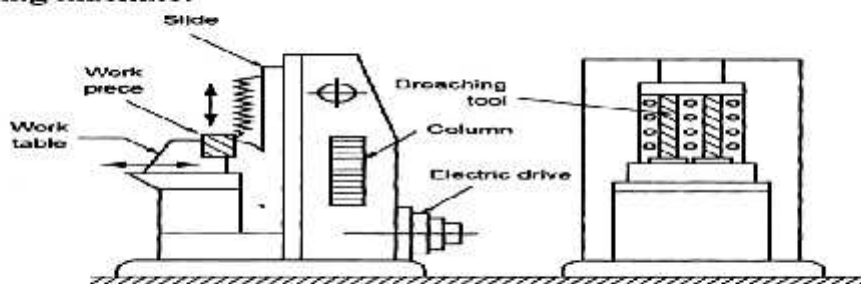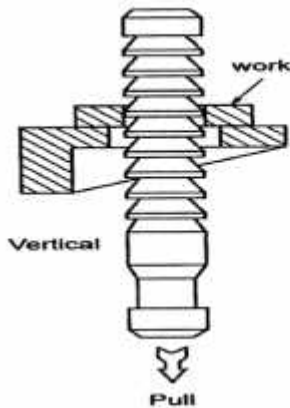

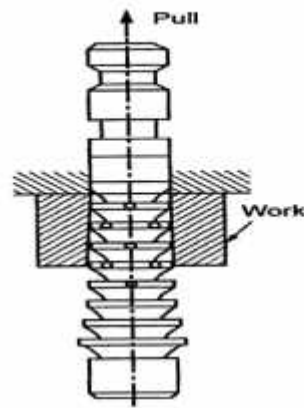*Push down type vertical broaching machine*

Broaching tools are mounted on slide which is hydraulically operated and accurately guided on the column ways. Slide with the broaches travels at various speeds which are controlled by the hydraulic drive. Its stroke is adjusted to suit the broaching operation to be performed. The slide is provided with quick return mechanism. In this type, most of the machines are provided with receding table so that the fixture may be loaded and unloaded during its return stroke.

The worktable is mounted on the base in front of the column. The fixture is clamped to the table. The work piece is held in the fixture. After advancing the table to the broaching position, it is clamped and the slide with the broach travels downwards for machining the work piece. Then the table recedes to load a new work piece and the slide returns to its upper position. The cycle is then repeated.

Pull Down Type Vertical Broaching Machine

Pull down type vertical broaching machine

Pull up type vertical broaching machine

These machines are mostly used for internal broaching. Instead of being pushed the broach, it is pulled through the job. This machine has an elevator at the top of the machine.

The pulling mechanism is enclosed in the base of the machine. The work piece is mounted on the table by means of fixture. The tail end of the broach is gripped in the elevator. The broach is lowered through the work piece. The broach is automatically engaged by the pulling mechanism and is pulled down through the job. After the operation is completed, the broach returns to its original position. The operation of this machine is shown in fig.

6. Discuss the principle of operation of a shaper with a neat sketch. **(AU Dec 09)**

PRINCIPLE OF OPERATION

The shaper which is having a reciprocating type of machine tool with single point cutting tool used to produce flat surface. The flat surface may be horizontal, vertical or inclined. It has the three important parts such as

1. Table
2. Tool head
3. Ram

The tool head is fitted on the front end of the ram while the job is rigidly fixed on the table. The tool is mounted on the tool post or head. The ram reciprocates along with the tool to remove the metal in the forward stroke called as *cutting stroke*. The tool does not cut the metal in the return stroke called as *idle stroke*. Therefore, one pass is nothing but the combination one forward and return stroke or one cutting and one idle stroke. So, we are in a position to reduce idle stroke time by increasing the speed of the return stroke. That is, the speed of cutting stroke will be lower than the speed of return stroke. This is done to reduce the time required for one pass. Hence, the overall time required will be reduced drastically. This quick return of the ram during idle stroke is obtained by a quick return mechanism. At the end of each cutting stroke, the feed (depth of cut) is given.

MACHINING VARIOUS TYPES OF FLAT SURFACES

1. The table is moved in a cross-wise direction to machine horizontal surfaces.
2. The tool head is moved perpendicular to the table in downward direction to machine vertical surfaces.
3. The tool head is fed at an angle to produce inclined surfaces.

CLASSIFICATION OF SHAPERS

Generally, shapers are classified as follows.

1. According to the type of driving mechanism
   a. Crank drive type
   b. Whit worth driving mechanism type.
   c. Hydraulic drive type.

2. According to the position of ram.
   a. Horizontal shaper.
   b. Vertical shaper.
   c. Travelling head shaper

3. According to the table design
   a. Standard or plain shaper
   b. Universal shaper

4. According to the type of cutting stroke.
   a. Push out type
   b. Draw cut type

PRINCIPLE PARTS OF A SHAPER

The different parts of a shaper are listed and described below.

1. Base
2. Column
3. Cross rail
4. Saddle
5. Table
6. Ram
7. Tool head

1. Base

The base is a heavy and robust in construction which is made of cast iron by casting process. It is the only part to support all other parts because all parts are mounted on the top of this base. So, it should be made to absorb vibrations due to load and cutting forces while machining.

2. Column

The column has a box type structure which is made of cast iron. The inside surface is made as hollow to reduce the total weight of the shaper. It is mounted on the base. The ram driving (Quick return) mechanism is housed. The two guide ways are provided on the top. The ram reciprocates on this guide ways. Similarly, there are two guide ways at the front vertical face of the column to move the cross rail along these guide ways.
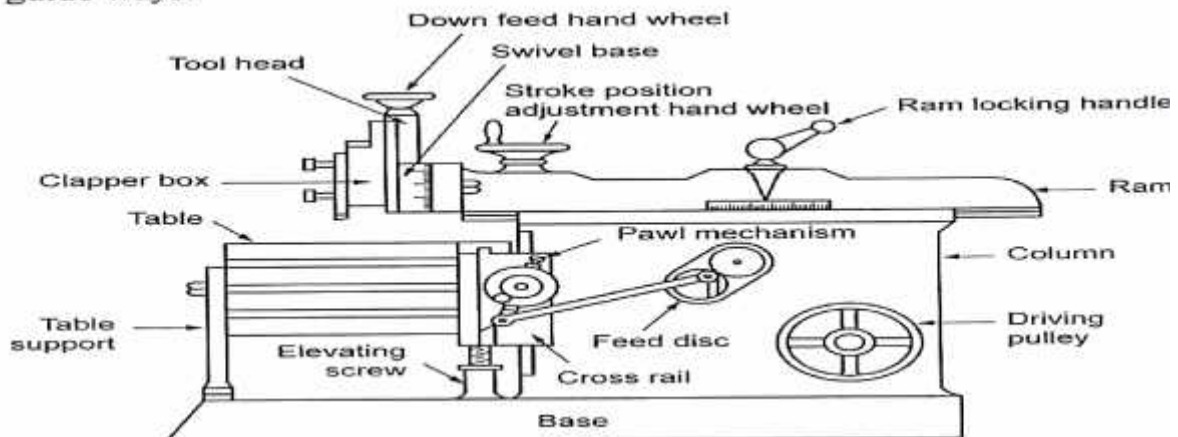
3. Cross rail

It is also a heavy cast iron construction. It slides on the front vertical ways of the column with two mechanisms. One is for elevating the table and the other one is for cross travel of the table. A saddle slides over two guide ways already provided in the front face of the cross slide. The crosswise movement of the table is obtained by cross feed screw and the vertical movement of the cross rail is obtained by an elevating screw.

4. Saddle

It is mounted on the cross rail which holds the table in position on its top without any shake.

5. Table

It is also a box type rectangular hollow cast iron block. This table slides along the horizontal guide ways of the cross rail. The work is held in the table. The table has machined surfaces on the top and sides of T-slots for clamping work. It can be moved vertically by the elevating screw. An adjustable table support supports the front face of the table.

6. Ram

Ram of cast iron has cross ribs for rigidity. Generally, it is a reciprocating type which slides over the guide ways on the top of the column. It is connected to driving mechanism of any one and also it carries the tool head at the front end.

7. Tool head

It holds the tool rigidly having swivel base with degree graduation. So, the tool head can be swiveled to any angle as required. The tool head has a vertical slide and apron to provide vertical and angular feed to the tool. A feed screw with graduated dial moves the vertical slide vertically to set the accurate movement.

7. Describe the working of a crank and slotted link mechanism. **(AU Dec 2010,Apr 08)**

In this mechanism, the ram is actuated by gear drives associated with electric motor. First, the electric motor drives the pinion gear. Next, the pinion gear drives the bull gear which rotates in opposite direction due to external gear meshing. A radial slide is provided on the bull gear. A sliding block is assembled on this slide. The block can be positioned in radial direction by rotating the stroke adjustment screw.
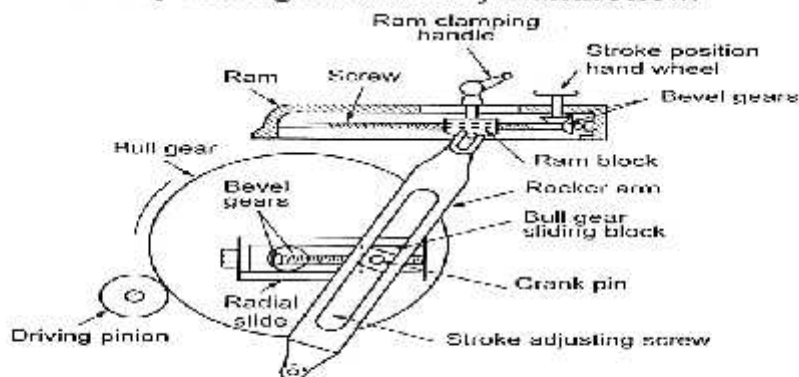

Crank and slotted lever mechanism

The sliding block has a crank pin. A rocker arm is freely fitted to this crank pin. The rocker arm sliding block slides in the slot provided in the rocker arm called as *slotted link*. The bottom end of the rocker is pivoted and its upper end has fork which is connected to the ram block by a pin.

When the pinion gear rotates along with bull gear, the crank will also rotate. Due to this, the rocker arm sliding block also rotates in the same circle. Simultaneously, the sliding block slides up and down in the slot. This movement is transmitted to the ram which reciprocates. Hence, the rotary motion is converted into reciprocating motion by this.

8. Sketch and explain the hydraulic drive of a horizontal shaper.**(AU Dec 2010, Dec 2009)**

A piston reciprocates inside the hydraulic cylinder. A piston rod is connected between the piston and ram. So, the ram reciprocates along with the piston. Two parts or entries are provided near the each end of the cylinder. A four-way control valve connects these two entries with the reservoir. The reservoir connects the value through a drain pipe and a supply pipe.
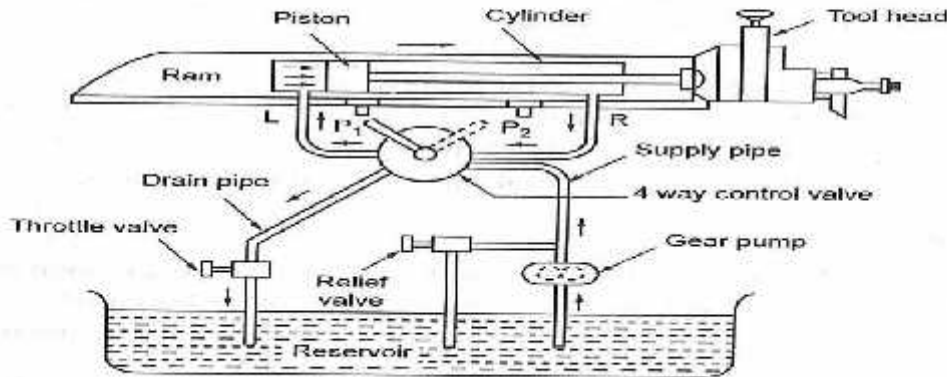
Hydraulic drive

9. What are the operations performed on a drilling machine? **(AU Apr 2010)**

DRILLING OPERATIONS

The various operations done in a drilling machine are explained as follows.

Drilling

Drilling is the operation of cutting a round hole by a rotating tool called *drill*.

Before drilling, the center of the hole is located on the work piece. For this, two lines at right angles to each other are drawn. A center punch is used to mark the center point at the intersection of two lines. The rotating drill is pressed at the center point marked on the work piece to produce the hole.
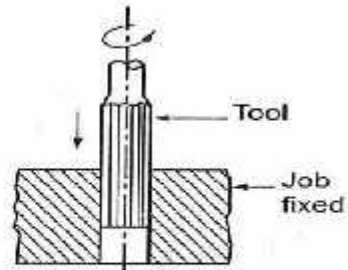
Drilling does not produce an accurate hole. The internal surface produced by drilling will be rough. The hole is lightly larger than the size of the drill used. This is because of the vibration of the drill.

Drilling

Reaming

*Reaming* is the process of sizing and finishing the already drilled hole.
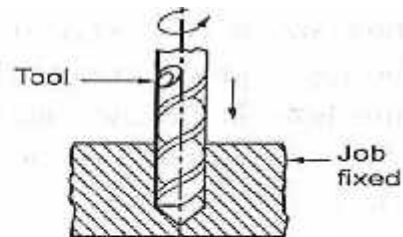
Reaming

The tool used for reaming is known as a *reamer*. Reamer is a cylindrical tool having many cutting edges. Reamer cannot produce a hole. It simply follows the path of an already drilled hole. It removes a very small amount of metal. The amount of metal removed in reaming is about 0.375*mm*. In reaming, the spindle speed is half that of drilling.

Boring

Boring is an operation of enlarging a hole by a single point cutting tool. Boring is done where suitable size drill is not available. If the hole size is very large, it cannot be drilled. Then boring is done to enlarge the hole. By boring, the hole is finished accurately to the required size. The internal surface of a hole in a casting is machined by boring. Boring corrects the out of roundness of a hole. The cutter is held in a boring bar. The boring bar has a tapped shank to fit into spindle hole. Boring is a slow process.
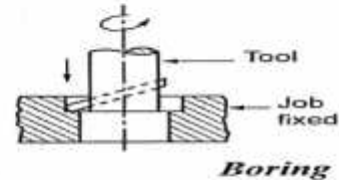
Counter Boring

The operation of enlarging the end of a hole cylindrically is known as *counter boring*.

Counter boring   *Counter sinking*
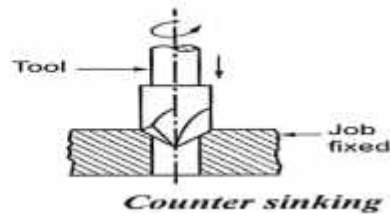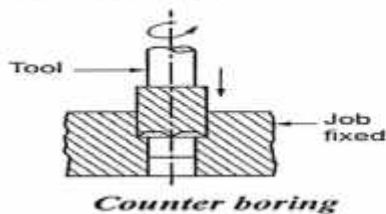
Counter Sinking

The operation of making a cone-shaped enlargement of the end of a hole is known as *countersinking*.

Spot Facing

The operation of squaring and smoothing the surface around a hole is known as *spot facing*. Fig.   illustrates the process of spot facing.

Spot facing   *Tapping*
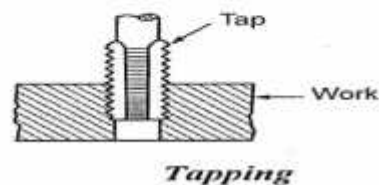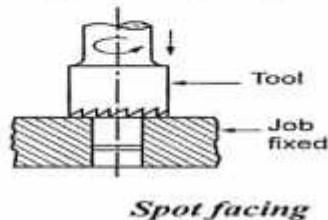
Tapping

Tapping is an operation of cutting internal threads in a hole by using a cutting tool called *tap*. A tap has cutting edges in the shape of threads. When the tap is screwed into the hole, it will remove metal and cut internal threads.

The drilled hole will be smaller than the tap size.

Tap drill size = 0.8 × Outside diameter of the thread.

Trepanning

The operation of producing a large hole (diameter over 50*mm*) by removing metal along the circumference of a hollow cutting tool is known as *trepanning*. There is a pilot inside the trepanning tool which enters the small previously drilled hole to produce the larger hole concentric. It is used for the diameter more than capacity of particular machine and where hole depth is much more in comparison with normal work.

10. Sketch a twist drill and explain **(AU Dec 08, Dec 09)**

Drilling tool nomenclature
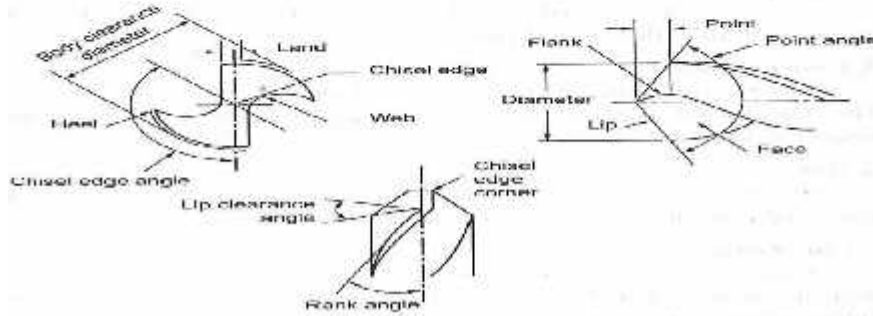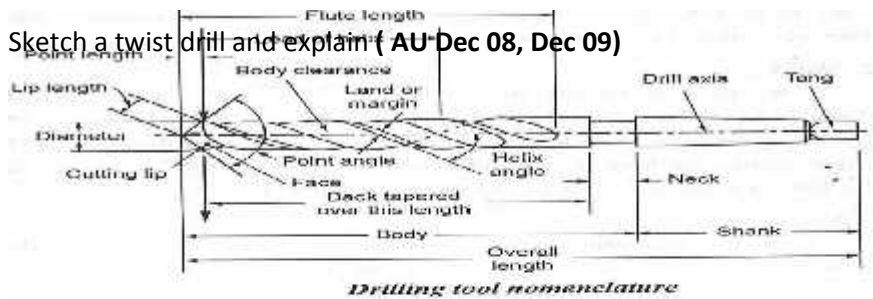
11. Explain different types of milling cutters. **(AU Dec 2009)**

These are multi tooth rotary cutting tools generally made of high speed steels or sintered carbides. Milling cutters are classified into different ways.

According to the shape of the tooth, milling cutters are classified as

- (i)   Milled tooth cutters.
- (ii) Form relieved cutters.

According to the type of operation.

- (i)   Plain milling cutters.
- (ii)   Side milling cutters.
- (iii) End mill cutters.
- (iv)   Angle milling cutters.
- (v)   T-slot milling cutters.
- (vi)   Slitting saws.
- (vii) Form milling cutters.
- (viii) Fly cutters.
- (ix)   Wood ruff key slot milling cutter.
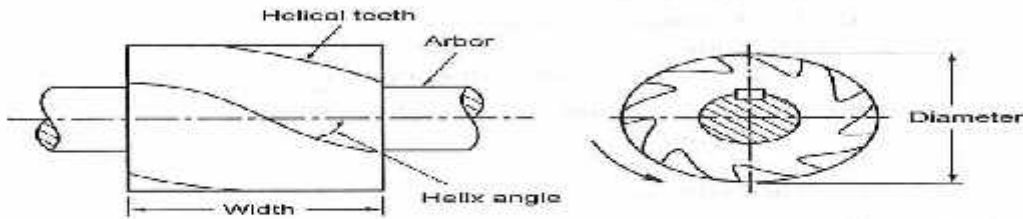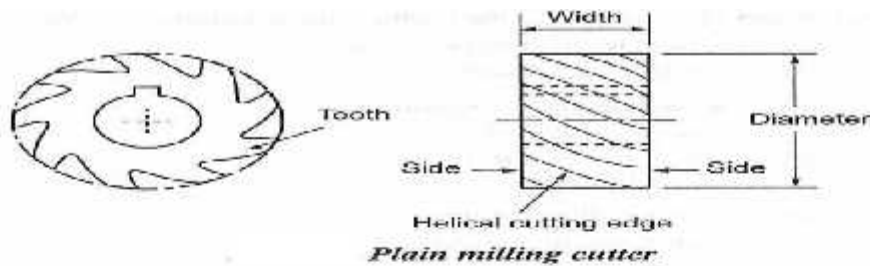
According to the way of mounting on the machine.

- (i)   Arbor cutters.
- (ii)   Shank cutters.
- (iii) Face cutters.

1. Plain milling cutter

This is also known as a *mill cutter*. It is a disc or cylindrical shaped cutter having teeth on its circumference. It is used to machine flat surface parallel to its axis. There are two types of plain milling cutters commonly used.

- (i)   Plain straight teeth cutter.
- (ii) Plain milling helical teeth cutter.

The plain milling cutters having the width more than its diameter is called *slab mill cutter*. This is used for rough machining with coarse feed. The cutter has less number of teeth.

Plain milling cutter

Slab milling cutter

Straight teeth plain milling cutters are used for light operations. Helical teeth cutters are used for heavy cut operations.

Cutters of various diameters and widths are available. Roughing cutters will have less number of teeth. Finishing cutters will have more number of teeth for the same diameter.
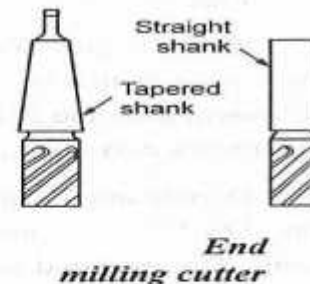
2. Side milling cutter

It has cutting edges on its periphery and also on the sides. This cutter is used for removing metal from the side of the work pieces. It is also used for cutting slots. These cutters may have plain, helical or

Side milling cutter
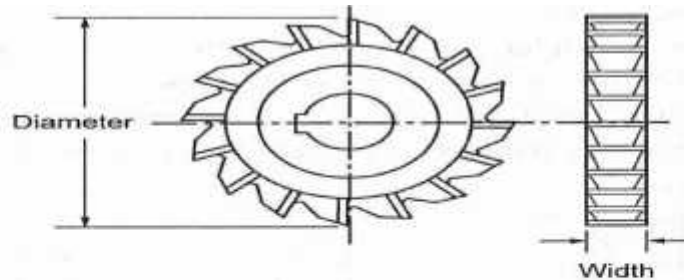
staggered teeth. Among these three, helical cutters are preferred on milling machines since they require less power for machining. And also it provides smoother operation as more than one tooth performs a milling operation at a time.

3. End milling cutters

The end milling cutters have cutting teeth on the end as well as on the periphery of the cutter. The peripheral teeth may be straight or helical. It is similar in construction to a twist drill or reamer. These cutters are generally provided with a shank on one end. The shank may be of straight or tapered. Tapered shank cutters are fitted to the spindle using adapters. Straight shank cutters are fitted to the spindle using collets.

End milling cutter

End mills are commonly used for vertical milling operations. They are used for light milling operations like cutting slots, machining accurate holes and profile milling.

4. Angle milling cutters

All cutters which have their cutting teeth at an angle to the axis of rotation are known as *angular cutters*. Their specific use in milling V-grooves, notches, dove tail slots, reamers teeth and other angular surfaces. Angular cutters are classified as single angle cutters and double angle cutters.

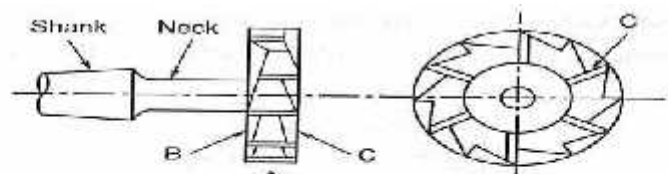**Single angle milling cutter**   **Double angle milling cutter**

Single angle cutters may have their teeth either only on the angular face or on both, the angular face and the side. The later type enables milling of both the flanks of the inclined angular groove simultaneously. Their teeth may have an included angle of 45° to 60°.

Double angle cutters differ from single angle cutters in such a way that they have two angular faces which join together to form V-shaped tooth. The included angle of this 'V' is either 45°, 60° or 90°. Angle of both sides should be equal.

5. T-slot milling cutter

It is a single operation cutter which is used only for cutting T-slots. The arrangement of cutting teeth is similar to that of a side milling cutter. But this cutter has a tapered shank. A neck is formed between the cutting face and the shank. The cutter has cutting edges on its periphery and on its sides.

T - slot milling cutter

6. Slitting saws
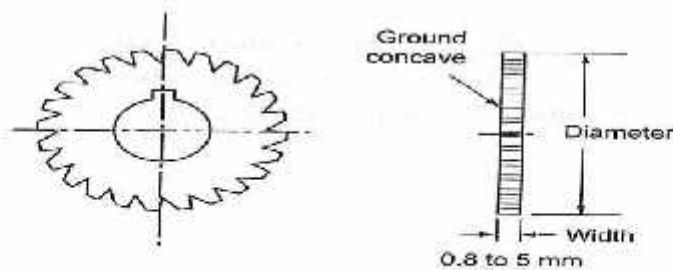
Slitting saw

These are very thin cutters in varying thickness from 0.5 to 5mm. They are used for cutting deep slots and parting off materials into pieces. These cutters are thinner at the centre than at the edges to provide clearance and reduce friction.

7. Form milling cutter

The cutters which are designed to cut definite shapes are known as *form milling cutters*. These cutters can be classified according to their shape as convex or concave cutters, gear cutters, flute cutters and corner rounding cutters.

Concave milling cutter has teeth curved inwards on its periphery. The cutter will produce a convex semi circular surface on the work piece.

Form milling cutter

Convex milling cutter has teeth curved outward on its periphery. The cutter will produce a concave semi-circular surface on the work piece.

Gear cutters have formed cutting edges. The shape of the cutter teeth is involute. The cutter will produce groove of involute shape. The involute gear tooth is formed between two grooves milled by the cutter. The profile of the gear tooth depends upon the module and the number of teeth on the gears. Therefore, for cutting different number of gear teeth of same module, different cutters are required. Corner rounding cutters are used for milling the edges and corners of the jobs to a required radius.

8. Fly cutters

It is actually a single point tool which is used in milling machine when standard cutters are not available. It is either mounted on a cylindrical body held in a stub arbor or held in a bar. Screws are used for tightly holding the tool in the above holders. The cutting edge of the tool is ground to the required shape. The cutter removes metal, when it rotates.
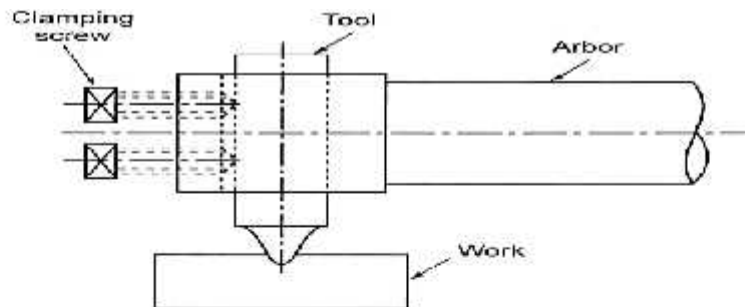
Fly cutter

9. Woodruff key slot milling cutter
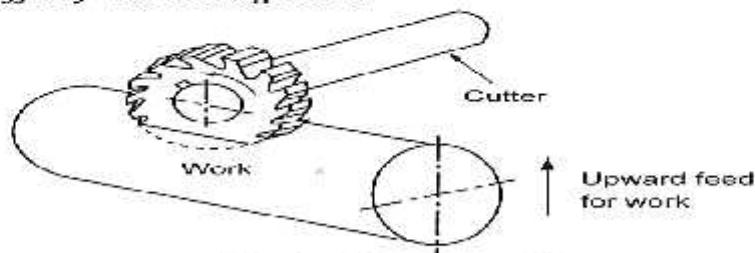
Woodruff key slot milling cutter

It is a small type of end milling cutter which is similar to plain and side mills. It has a taper shank and a neck. The cutter may have straight or staggered teeth. The sides of the cutter are ground concave. This provides clearance for the cutter movement. It is used to cut woodruff key slot in a shaft.

12. With the help of a neat sketch, discuss the working of a face broach machine. **(AU Apr 2010)**

Horizontal Type Surface Broaching Machine

Fig.   shows the horizontal type surface-broaching machine. Here, the broach is pulled over the top surface of the work piece held in the fixture on the worktable. The cutting speed ranges from 3 to 12*mpm* with a return speed up to 30*mpm*.

Horizontal type surface broaching machine

When the surface broaching is done, the broaches are always permanently connected to the draw head.

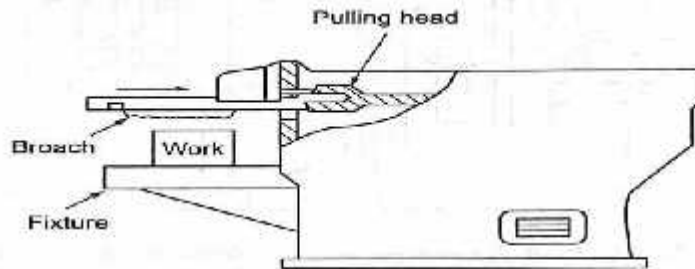13. Sketch the Quill mechanism .write its main parts and their functions? **(AU Apr 2010)**

MOUNTING THE DRILL TOOL

Both taper shank and straight shank drills can be mounted on the drilling machine spindle in a number of ways. They are:

1. Fitting directly in the spindle.
2. By using a sleeve.
3. By using a socket.
4. By means of chucks.

Fitting Directly In The Spindle

The drill is directly held in the spindle by friction. The spindle of the drilling machine and the shank of the drill has a standard tapered bore. The taper shank of the drill is forced into it. To get a positive drive, (without slipping) the tang of drill fits into a slot at the end of taper bore in the spindle. To remove the drill from the spindle, a tapered wedge called *drift* is forced into the slotted hole in the spindle referred in fig.

Drill fitted in the spindle
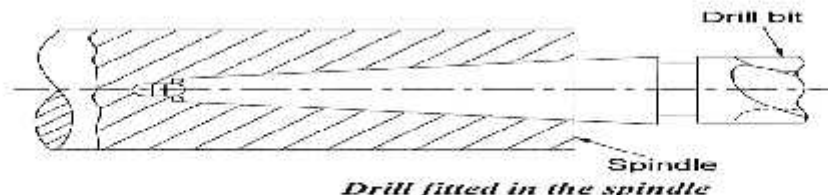
By Using a Sleeve

If the taper shank of drill is smaller than the taper in the spindle hole, a sleeve is used. The sleeve with drill is fitted in the hole of the spindle. The sleeve has outside taper surface. This fits into the tapered hole of the spindle. The inside taper of the sleeve can hold the drill or a smaller sleeve. In this sleeve also, there is a tang which is used for the same manner as explained in previous case.
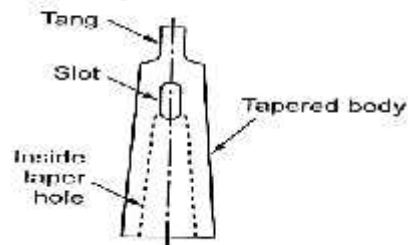
Drill sleeve

14. How will you cut the following types of surfaces on milling machines? **(AU Apr 2010)**

(a) Flat surfaces (b)Slots and splines

Plain or Slab Milling

Plain or slab milling is the operation of producing flat horizontal surface parallel to the axis of the cutter using a plain or slab milling cutter as shown in fig.

Plain milling.   *Face milling*
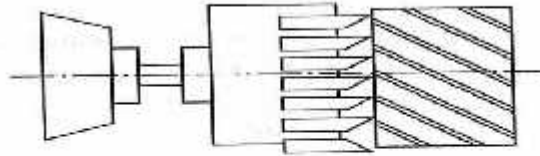
Face Milling

Face milling is the operation of producing flat surface on the face of the work piece which is at right angle to the axis of rotation of the face milling cutter. Refer fig.

Angular or Bevel Milling

It is the operation of machining a flat surface at an angle, other than right angle to the axis of the revolving cutter. The cutter used may be a single or double angle cutter, depending upon whether a single surface is to be machined or two mutually inclined surfaces simultaneous.
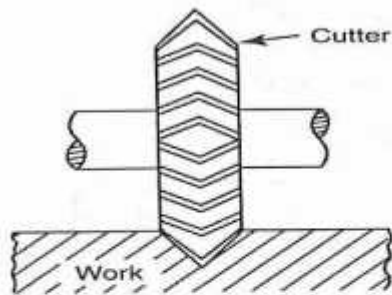
Angular milling   *Straddle milling*
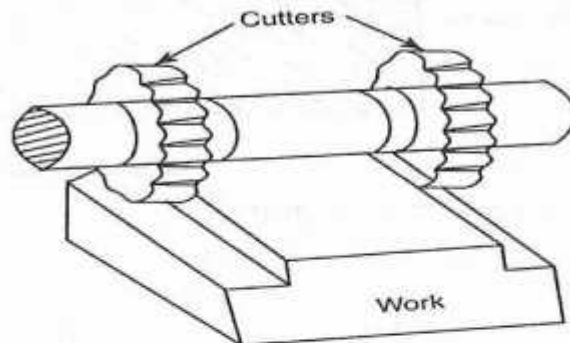
Straddle Milling

Straddle milling operation is the production of two vertical flat surfaces on both sides of the job by using two side milling cutters which are separated by collars. Straddle milling is very commonly used for milling square and hexagonal surfaces.

Gang Milling

Gang milling is the production of many surfaces of a job simultaneously by feeding the table against a number of required cutters. Fig.   shows a gang of three side milling cutters and two plain milling cutters which are fitted to the arbor. The two plain milling cutters have helical teeth of opposite hands. This method of operation saves machining time and hence it is widely used in mass production.

15. Make a note on different types of work holding devices used in a slotting machine. (**AU Dec 2008)**

WORK HOLDING DEVICES

The work is held on a slotter table by a vice, using 'T' bolts and clamps or by special fixtures. The work is placed above the parallel or packing pieces. This permits the over travel of tool. Fig.   illustrates the method of holding a work (gear) on the slotter table for cutting internal keyway. The gear is placed on a ring block.

The axis of gear is aligned with the axis of the rotary table. It is clamped by using 'T' bolts and clamps.

Cylindrical jobs can be held in a vice by using 'V' block as shown in the fig.   The vice is clamped in the table.
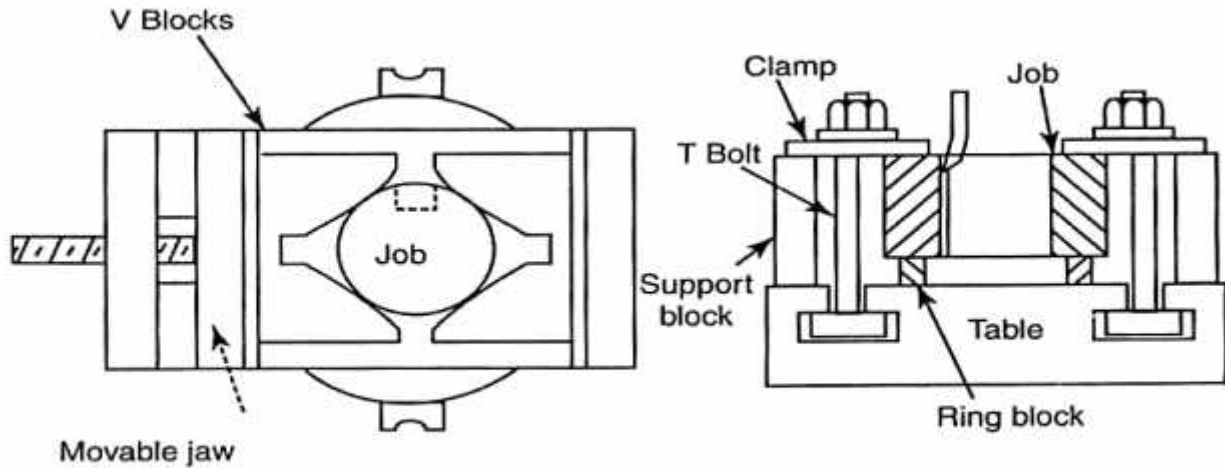
Job in vice

Special fixtures can be used as shown in fig.   . In this, a gear blank is located by a cylindrical locator. The cylindrical locator is located by a pin at the center of table. Hence, axis of gear is located at the center of table. The clamping plate and T bolts are used to clamp the work.
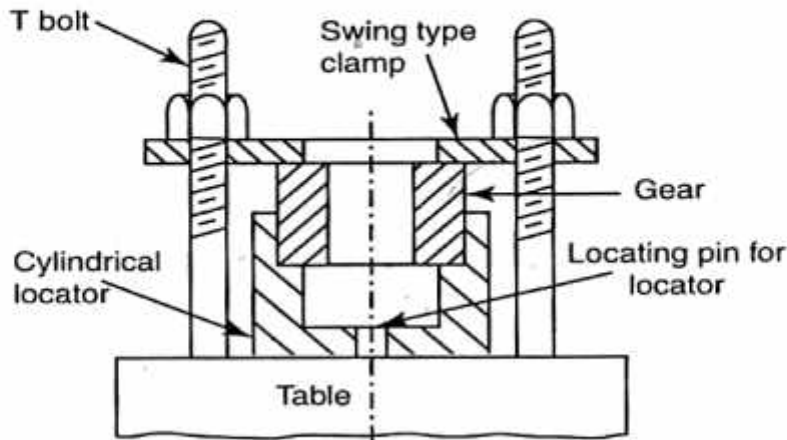
Slotting fixture

16. Explain the different types of table drive and feed mechanisms in a planning machine . **(AU Dec 2008)**

The following various types of quick return mechanism are used in planer as described below:

Open and Cross Belt Drive

A counter shaft is driven by electric motor. This shaft carries two wide faced pulleys of equal diameter. One pulley drives the open belt. Another pulley drives the cross belt.The main driving shaft is placed below the bed. One end of the shaft carries a set of two large pulleys and two small pulleys.

One of the larger pulley and one of the smaller pulleys are keyed to the shaft. They are called *fast pulleys*. The other two pulleys rotate freely on the shaft. They are called *loose pulleys*. The large pulleys are

connected to the counter shaft pulleys by cross belt. The small pulleys are connected to the counter shaft pulleys by open belt. The speed of the main driving shaft is reduced through a speed reduction gearbox. From this gearbox, the drive is transmitted to the driving pinion. This pinion meshes with the rack at the bottom of the table.

Open and cross belt drive

Referring to the figure   , the cross belt connects the larger loose pulley. No drive is transmitted by it to be main shaft. But the open belt connects the smaller fast pulley. So the drive is transmitted to the main shaft through the open belt. The return stroke of the table takes place. At the end of the return stroke, the trip dog pushes the belt shifter. The belt shifter shifts both the belts to the right. The cross belt is shifted to the larger fast pulley. The open belt is shifted to the smaller loose pulley. So, the drive is transmitted to the main shaft through the belt on the larger fast pulley. The direction of rotation of the main shaft is reversed. Because of the larger diameter of the pulley, the main shaft rotates at a

slow speed. So, the cutting stroke takes place at slow speed. No drive takes place through the open belt.

The quick return motion is obtained. At the end of the cutting stroke, the belts will be shifted to the left by another trip dog. The length and position of the stroke may be adjusted by adjusting the position of trip dogs.

Electric Drive

Electric drive

In this drive, four electrical machines are used in which one is D.C. motor with variable speed reversible motor. The D.C. motor shaft is connected to the table through gears rack and pinion. This D.C. motor receives power from a D.C. generator. This D.C. generator is again coupled with one more A.C. motor.

Working principle

When the A.C. motor runs, the D.C. motor will receive power from the D.C. generator. At that time, the table moves in forward direction. At the end of this stroke, a trip dog actuates an electrical reversing switch. Due to this action, it reverses the direction of current in D.C. generator with increased current strength. Now, the motor rotates in reverse direction with higher speed. So, the table moves in reverse direction to obtain quick return motion.

Advantages

1. Operation is smooth.
2. More number of cutting speeds and returns speeds can be obtained.
3. Quick and accurate control are possible.
4. Cutting speed, stroke length and stroke position can be adjusted without stopping the machine.

FEED MECHANISM

Hand Feed

The cross feed screw passes through a nut in the tool head. When this cross feed screw rotates, the tool will move in horizontal direction to obtain cross feed.

Automatic Feed
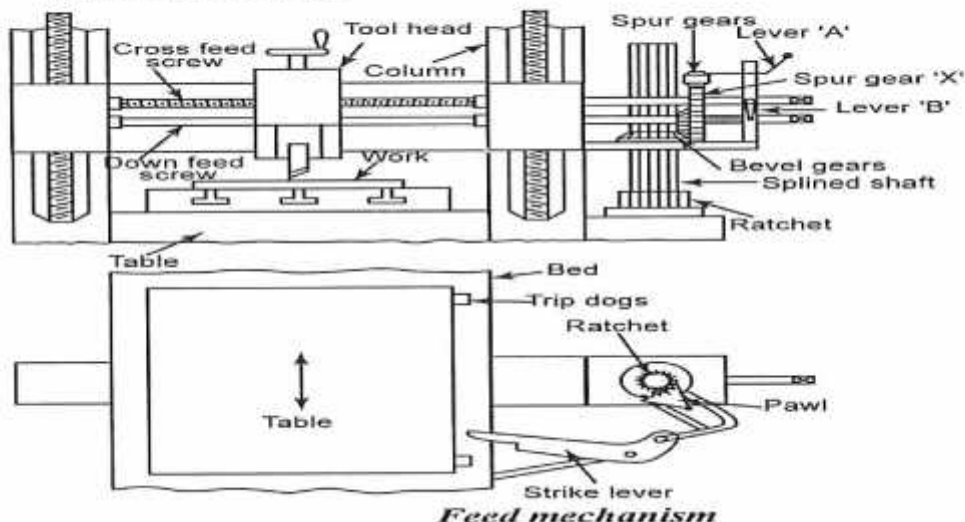
Feed mechanism

17. State the advantages of Ward- Leonard drive

Electric drive

In this drive, four electrical machines are used in which one is D.C. motor with variable speed reversible motor. The D.C. motor shaft is connected to the table through gears rack and pinion. This D.C. motor receives power from a D.C. generator. This D.C. generator is again coupled with one more A.C. motor.

Working principle

When the A.C. motor runs, the D.C. motor will receive power from the D.C. generator. At that time, the table moves in forward direction. At the end of this stroke, a trip dog actuates an electrical reversing switch. Due to this action, it reverses the direction of current in D.C. generator with increased current strength. Now, the motor rotates in reverse direction with higher speed. So, the table moves in reverse direction to obtain quick return motion.

Leonar

Advantages

1. Operation is smooth.
2. More number of cutting speeds and returns speeds can be obtained.
3. Quick and accurate control are possible.
4. Cutting speed, stroke length and stroke position can be adjusted without stopping the machine.

18. Explain with a sketch "Fast and loose pulleys" quick return mechanism of a planer table. **(AU Dec 2007)**

The following various types of quick return mechanism are used in planer as described below:

Open and Cross Belt Drive

A counter shaft is driven by electric motor. This shaft carries two wide faced pulleys of equal diameter. One pulley drives the open belt. Another pulley drives the cross belt.The main driving shaft is placed below the bed. One end of the shaft carries a set of two large pulleys and two small pulleys.

One of the larger pulley and one of the smaller pulleys are keyed to the shaft. They are called *fast pulleys*. The other two pulleys rotate freely on the shaft. They are called *loose pulleys*. The large pulleys are

connected to the counter shaft pulleys by cross belt. The small pulleys are connected to the counter shaft pulleys by open belt. The speed of the main driving shaft is reduced through a speed reduction gearbox. From this gearbox, the drive is transmitted to the driving pinion. This pinion meshes with the rack at the bottom of the table.

Open and cross belt drive

Referring to the figure , the cross belt connects the larger loose pulley. No drive is transmitted by it to be main shaft. But the open belt connects the smaller fast pulley. So the drive is transmitted to the main shaft through the open belt. The return stroke of the table takes place. At the end of the return stroke, the trip dog pushes the belt shifter. The belt shifter shifts both the belts to the right. The cross belt is shifted to the larger fast pulley. The open belt is shifted to the smaller loose pulley. So, the drive is transmitted to the main shaft through the belt on the larger fast pulley. The direction of rotation of the main shaft is reversed. Because of the larger diameter of the pulley, the main shaft rotates at a

slow speed. So, the cutting stroke takes place at slow speed. No drive takes place through the open belt.

The quick return motion is obtained. At the end of the cutting stroke, the belts will be shifted to the left by another trip dog. The length and position of the stroke may be adjusted by adjusting the position of trip dogs.

UPRIGHT OR PILLAR DRILLING MACHINE

19. Sketch and explain the working principle of upright drilling machine. **(AU Dec 2006,08)**

Upright drilling machine is a higher capacity version of sensitive drilling machine. It is stationary floor mounted drilling machine. It is used for medium sized work pieces and having medium speed. The spindle head and the drive arrangement in this machine are similar to a sensitive drilling machine. But in this case, power-feeding arrangements are available. The main parts of the machine are base, column, work table and spindle head.

1. Base

It is a supporting member on which all the parts of the machine are mounted. It is generally made of cast iron.

The top surface of the base is accurately machined. The base has T-slots which is used for mounting large work piece directly on it.

Up-right drilling machine

2. Column

It is a vertical member mounted on the base and carries table, spindle and pulley drive mechanism. It should be very strong to take the heavy cutting forces. It may be of round type or box type.

In a round type, the column is round in section also named as *pillar*. The table holding work piece can be rotated 360° about the column for locating work piece under the spindle. Drill upto *50mm* diameter is possible in this type.

In a box type, the column is square in section, heavier, more strengthy and rigid than round type. It can only be raised or lowered by an elevator screw and will not rotate. Drill diameter more than 50mm and upto 75mm is possible by this type.

3. Table

The worktable is attached to the column by means of clamping screw. It has T-slots on the surface to hold work pieces. It can move vertically along the column and can be adjusted radially about the column. As already stated, the column may be rotated about its own axis only in round column type.

4. Spindle head and drive mechanism

The spindle head is mounted on the top of the vertical column. It is driven by a motor through belt and step cone drive. Sensitive hand feed is available. A quick traverse hand feed is also available to bring down the drill quickly to the hole location and withdrawn after drilling. The different spindle speeds are obtained by using a step cone pulley arrangement.

20. Write short notes on expanding hand reamers and adjustable machine reamers. **(AU Dec 2006)**

REAMING TOOL

Reamer with helical flutes
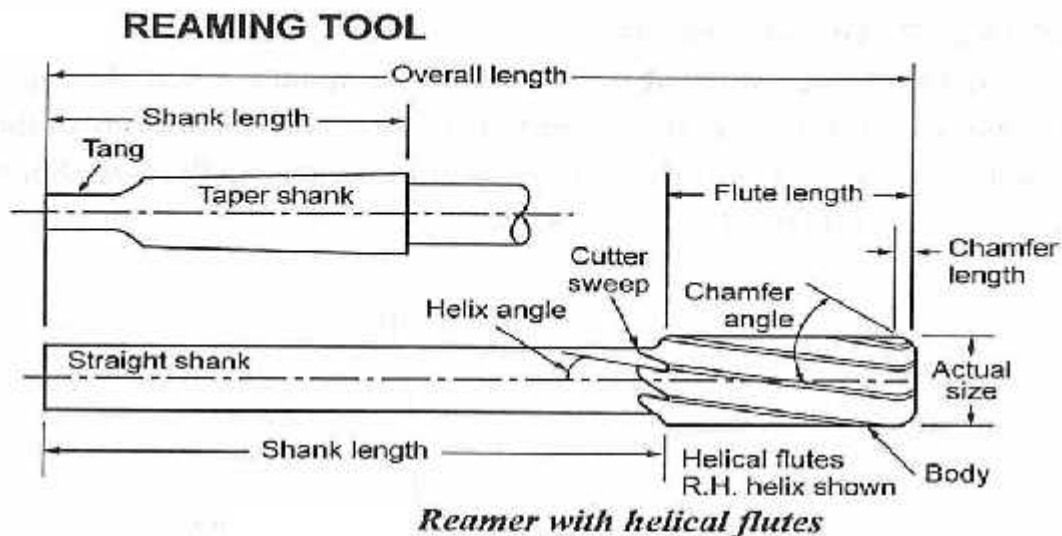
A reamer is a multi-tooth cutter which rotates and moves linearly into an already existing hole. It is used to give smooth surface as well as close tolerance on the already drilled or bored hole.

Reamer is more like a form tool, since the cylindrical shape and size of the reamer is reproduced in the hole. At the bottom of the reamer, the flutes are made slightly tapered to facilitate its entry into the

existing hole. Generally, the reamer is expected to cut from the sides not from the end. Reamer is usually manufactured with two or more peripheral grooves of flutes either parallel to the axis or as a right-angled helix as shown in fig
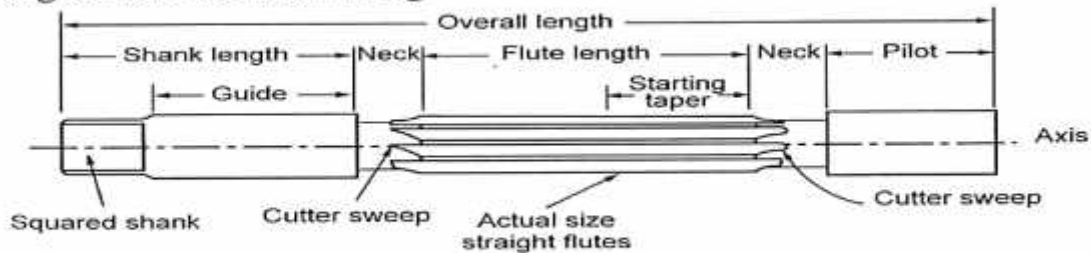
Reamer straight flutes

The reamer with helical flutes provides smooth shear cutting action and provides better surface finish. The pitch of the flutes is made uneven to reduce vibration. Small size reamers are made with straight shank whereas large size reamers are made with taper shank. There are different kinds of reamers for different applications. Shell reamers are used for reaming larger holes. For better dimensional control, adjustable reamers are used. Taper reamers are used for reaming holes to receive taper pins.

Since the reamer follows the already existing hole, any misalignment present in the hole is likely to break the reamer, if mounted in conventional spindle. Hence, a floating reamer is used between the machine spindle and the reamer to adjust for any small misalignment between the spindle axis and the hole axis.

Reamers are operated at lower speeds and higher feeds than drills of the corresponding diameter. Generally, speeds of reaming will be approximately 60 to 70% of that for drilling the same material.

21. Sketch and explain the main parts of a band saw. **(AU Dec 2006,Apr 08)**

Band Saw

A continuous blade having teeth runs over the rotating rim of the two wheels. The work is held between these two rotating wheels. So, the continuous cutting action can take place thereby making more productive.

1. Contour saw

It is the most versatile sawing machines in applications. The work can be fed in any direction. According to the feeding of work, the direction of cutting can be oriented to produce required shape. These

sawing machines are mainly used to make dies and other contour shapes in a work.

2. Friction band saw

The operating principle of the friction disk is same as that of friction saw. But dull blades remove small work that too softened particles. Friction between work and saw is more.

SELECTION OF BLADE FOR SAWING MACHINE

1. Generally, according to the type of work to be cut.standard carbon, high speed steel and bimetallic high speed steel are selected.
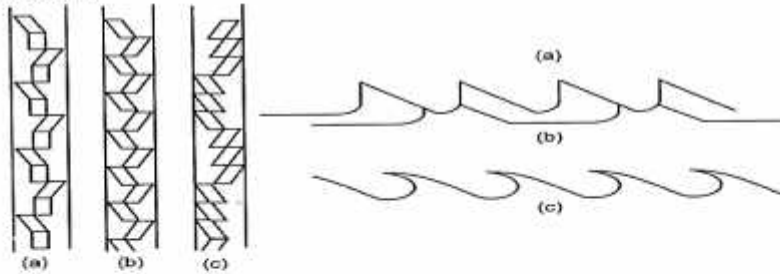
Tooth pattern and tooth form

2. Among raker, alternate and wavy tooth pattern, the required one is choosen.
3. Similarly, any one of tooth form is selected among standard, skip and hook.

22. Explain different types of drilling machines with their special features? **(AU Apr 2010,Dec 09)**

CLASSIFICATION OF DRILLING MACHINE

The drilling machines are classified as follows:

1. Portable drilling machine.
2. Sensitive drilling machine.
   a. Bench type
   b. Floor type
3. Upright drilling machine
   a. Round column type or pillar type
   b. Box column type or square section type.
4. Radial drilling machine
   a. Plain type
   b. Semi-universal type
   c. Universal type
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Automatic drilling machine
8. Deep hole drilling machine

PORTABLE DRILLING MACHINE

Portable drilling machine

This type of machine is light in weight, compact in a smaller unit and easily handled with respect to the work piece. It is used for making small hole (up to 18mm) in large work piece. It is operated by hand power, pneumatic power or electric power. Fig. shows the schematic diagram of electrically operated portable *drilling machine*.

SENSITIVE DRILLING MACHINES

Sensitive drilling machines are lightweight, high-speed machines, which are generally bench type drilling machines, but pillar type machines are also available. It is used for light duty work and drill holes up to 15mm diameter. There is no power feeding arrangement, feeding is purely on hand control of the operator so that the operator can sense the feeding or can control the feeding. Therefore, the machine is called sensitive drilling machine.

Sensitive drilling machine

The main parts of the sensitive drilling machines are base, column, table, spindle and driving mechanism.

1. Column

The column vertically stands on its base. It is a cylindrical post. It supports the table, the spindle head, motor and the driving mechanism.

2. Table

The job on which the hole to be produced is mounted on the table. It can be moved vertically along the column and clamped in any position. It can also be adjusted radially around the column. It has T-slots for clamping work piece or work holding device.

3. Spindle and driving mechanism

It is mounted at the top of the column. It has an electrical drive motor on one-side whereas it has the spindle assembly on the other side. The motor drives the spindle through cone pulley and V-belt arrangement. The belt can be shifted to different sets of pulleys to get different spindle speeds. The spindle is fed into the work piece manually using a hand lever. The spindle has a Morse taper bore at its bottom end to hold the drill chuck. Drill chuck holds the drill bit.

UPRIGHT OR PILLAR DRILLING MACHINE

Upright drilling machine is a higher capacity version of sensitive drilling machine. It is stationary floor mounted drilling machine. It is used for medium sized work pieces and having medium speed. The spindle head and the drive arrangement in this machine are similar to a sensitive drilling machine. But in this case, power-feeding arrangements are available. The main parts of the machine are base, column, work table and spindle head.

1. Base

It is a supporting member on which all the parts of the machine are mounted. It is generally made of cast iron.

The top surface of the base is accurately machined. The base has T-slots which is used for mounting large work piece directly on it.

Up-right drilling machine

2. Column

It is a vertical member mounted on the base and carries table, spindle and pulley drive mechanism. It should be very strong to take the heavy cutting forces. It may be of round type or box type.

In a round type, the column is round in section also named as *pillar*. The table holding work piece can be rotated 360° about the column for locating work piece under the spindle. Drill upto 50*mm* diameter is possible in this type.

In a box type, the column is square in section, heavier, more strengthy and rigid than round type. It can only be raised or lowered by an elevator screw and will not rotate. Drill diameter more than 50*mm* and upto 75*mm* is possible by this type.

3. Table

The worktable is attached to the column by means of clamping screw. It has T-slots on the surface to hold work pieces. It can move vertically along the column and can be adjusted radially about the column. As already stated, the column may be rotated about its own axis only in round column type.

4. Spindle head and drive mechanism

The spindle head is mounted on the top of the vertical column. It is driven by a motor through belt and step cone drive. Sensitive hand feed is available. A quick traverse hand feed is also available to bring down the drill quickly to the hole location and withdrawn after drilling. The different spindle speeds are obtained by using a step cone pulley arrangement.

RADIAL DRILLING MACHINE

This type of machine is mounted on floor and suitable for drilling medium to large and heavy work pieces. The most significant feature of this machine is a radial arm which can swing about a column. The arm can also be moved up and down with respect to the column which can be locked at any desired position as per job size. Fig.   shows the radial drilling machine.

The main parts of the machine are base, column, radial arm, drill head, spindle speed and feed mechanism.
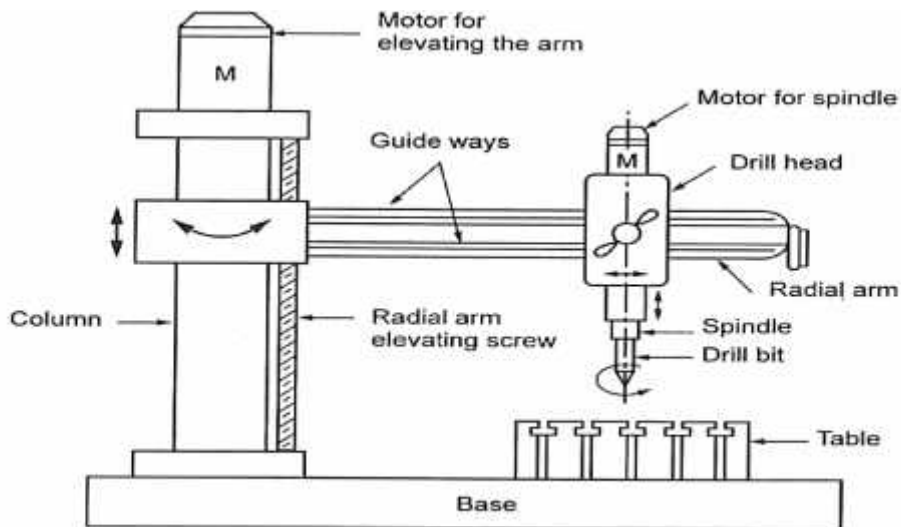
Radial drilling machine

1. Base

It is a large rectangular casting. It supports the vertical column and table. The top surface of the base is accurately machined with T-slots to mount the large size work pieces.

2. Column

Column is a cylindrical casting mounted on the base. It supports radial arm, drill head and motor. The column face should be accurately machined to slide the radial arm up and down. An elevating screw is provided on the side of the column to move the radial arm up and down. The elevating screw is rotated by the motor.

3. Radial arm

It is a heavy casting mounted on the column. The drill head is mounted on the radial arm. It has guide ways to move the drill head.

23. List the difference between shaper and planner.

Planer	Shaper
1. Tool is stationary and work reciprocates.	Tool reciprocates and the work is stationary.
2. This machine is used for machining large and heavy work pieces.	This machine is used for machining medium and small work pieces.
3. It gives more accuracy as the tool is rigidly supported during cutting.	Less accuracy due to the over hanging of ram.
4. Production time is more since it has single tool head.	Production time is less since it has two or four tool heads.
5. Work setting requires more skill.	Work setting is easier.
6. Heavy cut can be given as it has rigid base and uses strong tools.	Heavy cut cannot be given.

Unit IV – Abrasive processes and Gear Cutting

Part A

1. **What are the specifications of grinding wheel? (AU Apr 2011, Dec 2010)**

   - Type of bond

   - Grit or grain size

   - Grade

   - Structure

   - Abrasive

   - Manufacturer's Code

2. **What is honing? (AU Apr 2011, Dec 2010)**

   An abrading process of finishing previously machined surfaces is called honing.

3. **Narrate the working principle of abrasive jet machining. (AU Apr 2011)**

   In this type the electrolyte used is replaced by abrasive jet. But grinding process is as similar that of electrochemical grinding.

4. **What is gear hobbing? (AU Dec 2010)**

   The process of generating a gear by means of rotating a cutter called HOB is known as HOBBING.

5. **Define hardness of the grinding wheel. (AU Apr 2010)**

   Grade or hardness indicates the strength with which the bonding material holds the abrasive grains in the grinding wheel.

6. **Define lapping. (AU Dec 2009)**

   Lapping is a surface finishing process used for producing geometrically accurate flat, cylindrical and spherical surfaces.

7. **What is meant by "grade" and "structure" of a grinding wheel? (AU Dec 2009)**

   - Grade or hardness indicates the strength with which the bonding material holds the abrasive grains in the grinding wheel.

   - Structure denotes the spacing between the abrasive grains or in other words the density of the wheel.

8. **What are all the parameters that would affect the MRR in abrasive jet machining? (AU Dec 2008)**

   The metal removal rate is affected by the following factors

   - Grinding wheel speed

   - Type of abrasive used

- Capacity of pump
- Capacity of filter

9. **Mention four important factors that influence the selection of grinding wheel. (AU Dec 2008)**

   (1) Constant factors

   (a)Physical properties of material to be ground

   (b) Amount and rate of stock to be removed

   (c) Area of contact

   (d) Type of grinding machine

   (2) Variable factors

   (a) Work speed

   (b) Wheel speed

   (c)Condition of grinding wheel

10. **What is roller burnishing process? (AU Dec 2007)**

    It is a method of cold working metal surfaces in which hardened sphere or cylindrical roller is pressed

    against the work to be processed

11. **What is the need of truing and dressing operations in a grinding wheel? (AU Dec 2007)**

    - To break away the glazed surface so that the new sharp abrasive particles are again present to work for efficient cutting

    - To trim the cutting surface of the wheel to run true with the axis.

12. **List the advantages of honing?**

    - Simple process which can be done on any general purpose machines such as lathes and drilling machines.

    - This process can be applied for both internal cylindrical and flat surfaces.

    - Honing enables the maximum stock removing capacity out of entire surface finishing operation.

13. **State the abrasives used in manufacture of grinding wheels. (AU Dec 2007)**

    (1) Natural abrasives

    (a) Sandstone or solid quartz

    (b) Emery

    (c) Corundum

    (d) Diamond

    (2) Artificial abrasives

    (a) Aluminium oxide

    (b) Sillicon carbide

    (c) Artificial diamond

    (d) Boron carbide

(e) Cubic boron carbide

14. **What are the types of surfaces that can be produced using plain cylindrical grinders? (AU Dec 2006)**

    Plain cylindrical parts, cylinders, tapers, shoulders, fliers etc.

15. **What do you mean by loading of grinding wheels? (AU Dec 2006)**

    During operation, the chips formed get entrapped in the inner granular space of abrasive particles. This is
    called loading

Part B

1. Explain the working mechanism of cylindrical and surface grinding. **(AU Apr 2011)**

Cylindrical grinders
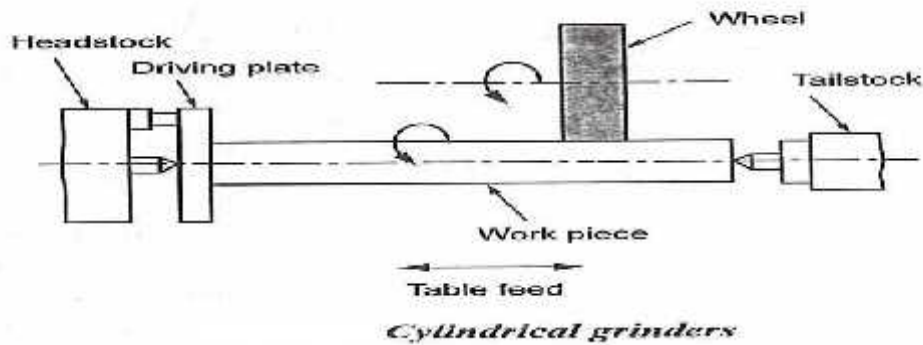
The principle of cylindrical grinder is illustrated in the fig. The work piece is held between the centers. It is rotated by a dog and a faceplate. There are four movements in a cylindrical centre type grinding.

    (i)   Rotation of cylindrical work piece about its axis.

    (ii)   Rotation of the grinding wheel about its axis.

    (iii)   Longitudinal feed movement of the work past the wheel face.

    (iv)   Movement of wheel into the work perpendicular to the axis of the work piece to give depth of cut.

Although they can also be used for grinding contoured cylinders, tapers, shoulders, fillets, cams, crank shafts etc., these grinding machines are used for grinding plain cylindrical parts.

1. Types of operations in cylindrical grinding

Two types of grinding operations are carried out.

    (i)   Traverse grinding.

    (ii)   Plunge grinding.

(i) Traverse grinding:
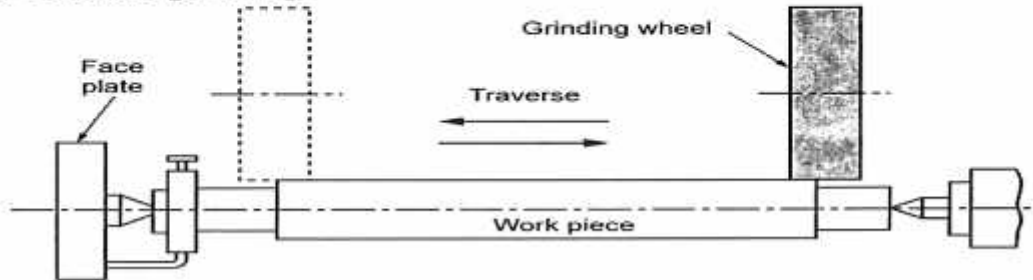
This method is used when the job length is more than the width of the grinding wheel. The job is held between two centers. The grinding wheel is made to rotate in a fixed position. The rotating work is made to traverse. The rotating work moves longitudinally in both directions. This is longitudinal feed.

(ii) Plunge grinding:

This method is used when the length of the work piece is lesser than the width of the grinding wheel. Here, the work piece need not be fed longitudinally. The grinding is done by giving only the cross feed to the grinding wheel. This is known as *plunge grinding*. Here, no longitudinal movement is given to the work piece. Therefore, the table is locked. The wheel is fed till the required diameter is obtained.

In fig. 4.15 (a) and 4.15 (b), the wheel is fed radially perpendicular to the axis of work piece. In fig. 4.15 (c), the wheel head is tilted at an angle. Angular feed is given through the wheel.

The wheel is specially shaped. Plunge grinding is used for grinding shoulders, stepping and various contours on the workpiece.
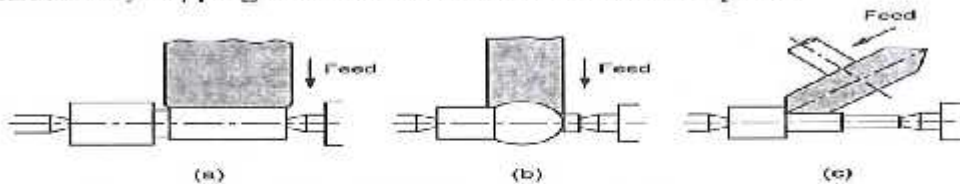
Fig. 4.15. Plunge cut grinding

2. Types of cylindrical grinding

(i) Plain centre type cylindrical grinding machine:

A plain centre type cylindrical grinding machine is shown in fig. 4.16. These grinding machines are used for grinding mainly cylindrical parts. They are also used for grinding parts such as tapers, fillets, contoured cylinders etc. The grinding machine consists of various parts.

Fig. 4.16. Plain centre type cylindrical grinding machine

1. Base

The base is the main casting that rests on the floor and supports the parts mounted on it. On the top of the base, horizontal guide ways are set on which the table slides to give traverse motion to the work piece. The table drive mechanism is incorporated in the base itself.

2. Table

There are two tables such as upper table and lower table. The lower table slides on the guide ways of the bed and provides traverse feed or longitudinal feed of the work past the grinding wheel. It can be moved by hand or power within the limits. Adjustable dogs are provided at the side of the lower table. These dogs can be set up in proper place to reverse the table of the end stroke.

The upper table is mounted on the lower table and it carries headstock and tailstock. The headstock and tailstock can be adjusted according to the length of the work piece. The upper table can be swiveled and clamped in position over the power table. The maximum angle of swivel is 10° on either side. The swiveling is used for grinding tapers.

3. Headstock

The headstock supports the work piece by means of a dead centre. The work piece is driven by headstock through dog and driving pin. A separate motor is housed in the headstock to rotate the work piece.

4. Tailstock

The tailstock can be adjusted and clamped to accommodate different length of work pieces. The work piece is held in between the centre of headstock and tailstock.

5. Wheel head

The wheel head carries a grinding wheel and rotated by a motor housed in the headstock. The wheel head is placed over the bed at its backside. The wheel head can be moved perpendicular to the table ways by hand or power. This movement is the cross feed.

Working principle

The work piece is held between centres. It is rotated by a dog or faceplate. The grinding wheel also rotates about its own axis in the opposite direction of work. The grinding wheel is fed by hand or automatically towards the work piece for successive cuts.

In most of the cases, the work speed is selected between 20 and 30 surface speed meters per minute (s.m.p.m.). Wheel speed is usually selected between 1500 and 2000 s.m.p.m. The depth of cut at each reversal is from 0.025mm to 0.125mm for rough grinding. For finishing, it should be from 0.0125mm to 0.0625mm. The longitudinal feed is

depending upon the rigidly and power of the machine which varies from 0.25 to 0.75 of the width or wheel's face.

(ii) Centre type universal grinder:

Universal grinder

Center type universal grinders are widely used in tool room for grinding tools. The features of this machine are similar to those of plain grinders but in addition, it is provided with the following features.

1. The centre of the head stock spindle can be used as alive or dead. The work can be held and revolved by a chuck. It can also be held between centres and revolved.

2. The wheel head can be swiveled in a horizontal plane in any angle. The wheel head can be fed in the inclined direction also.

3. The headstock can be swiveled to any angle in the horizontal plane.

4. The wheel head can also be arranged for internal grinding.

SURFACE GRINDERS

Surface grinding machines are used to produce and finish flat and plane surfaces. By using special fixtures and form dressing devices, angular and formed surfaces can also be ground.

The various machine parts such as machine guide ways, piston rings, valves, dies, surface plates etc are finished by surface grinding.

Heavy work pieces are clamped on the table by means of pads, strap clamps and other devices or they are held in fixtures. Small work pieces are usually held by a magnetic chuck. The various types of surface grinders are explained below:

Horizontal Spindle Reciprocating Table Surface Grinder

Horizontal spindle reciprocating table surface grinder

The line diagram of this type of grinder is shown in fig.   It consists of a horizontal spindle carrying the grinding wheel and rectangular worktable. The table is mounted on a base. Horizontal guide ways of base is a rectangular box like casting. The driving mechanisms are housed inside the base.

The table reciprocates along the guide ways for giving longitudinal feed. The table top has T-slots for mounting the magnetic chuck or fixtures. The cross feed to the grinding wheel is given by moving the column perpendicular to the table as shown in fig. 4.18. The wheel head is mounted on the column. It has an independent motor for driving the wheel. The wheel head can move up and down along the vertical guide ways of the column. Depth of cut is given by the foresaid arrangement.

Working

The workpiece is clamped on the table. The trip dogs are adjusted suitably to get the correct stroke length of the table. The work piece reciprocates under the table. The periphery of the grinding wheel does the grinding. Cross feed is given to the work piece after every stroke. Depth of cut is given by lowering the wheel head.

For rough grinding of work piece, the depth of cut may be from 0.02mm to 0.06mm. For finishing operation, the depth of cut may be from 0.005mm to 0.01mm.

6

GEAR CUTTING

2. Describe gear cutting by forming and shaping. **(AU Apr 2011)**

The other forming methods for the manufacture of gears are

1. Gear cutting by single point form tool.
2. Gear cutting by shear speed shaping process.
3. Gear milling using a formed end mill.
4. Gear broaching.
5. Template method.

Gear Cutting By Single Point Formed Tool

In this case, a single point cutting tool is used for cutting the gear in shaping machine or a planning machine. The cutting edge of the tool is made to the shape of gear tooth. By using this method, both spur and bevel gears can be cut. The work is mounted between two centers in which the work or tool reciprocates to perform cutting task. The cutting stroke should be exactly parallel and above the blank axis.

So, the blank should be accurately set. By feeding the tool downwards, the depth of cut is given.
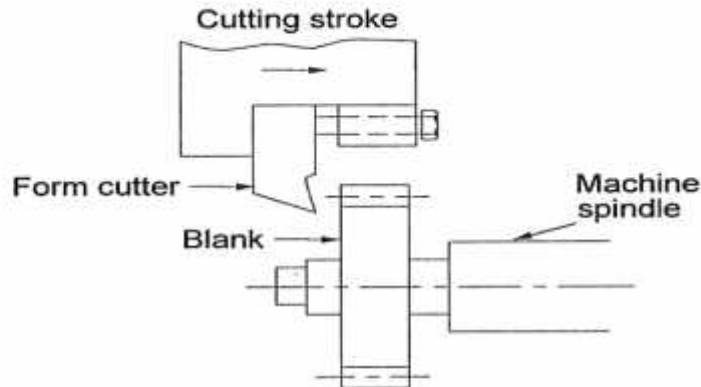
Gear cutting by a single point cutting tool

Gear Cutting By Speed Shaping Process

In this type, the form tools are arranged radially in the cutter head. The number of form tools is equal to the number teeth required on blank. So, all the tooth spaces are cut at the same time by feeding along with tools towards the centre of the blank during the cutting stroke.
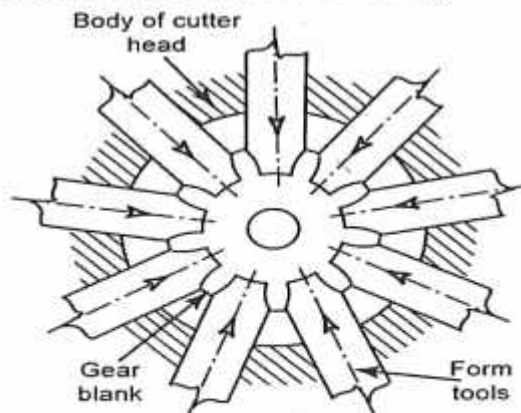
Gear cutting by speed shaping

3. Explain the working principle and various methods of centreless grinding with a neat sketch. **(AU Dec 2010)**

CENTRELESS GRINDERS

Centreless grinding is performed on work pieces which do not have centres, such as pistons, valves, rings, tubes, balls, wrist pins, drills, bushings, shafts etc. Centreless grinding can be done on both external and internal cylindrical surfaces. The principle of external Centreless grinding is shown in fig.   The grinder has two wheels, a larger grinding wheel revolving at a high speed and a small regulating wheel revolving at a slow speed.
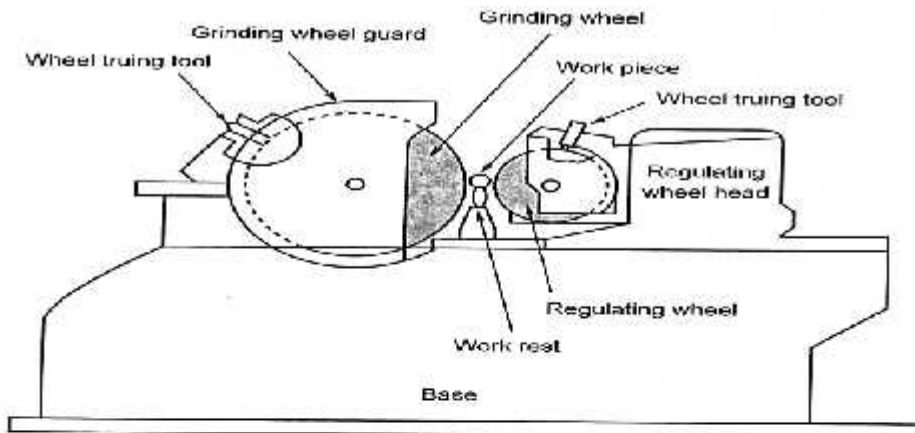
Centreless grinders
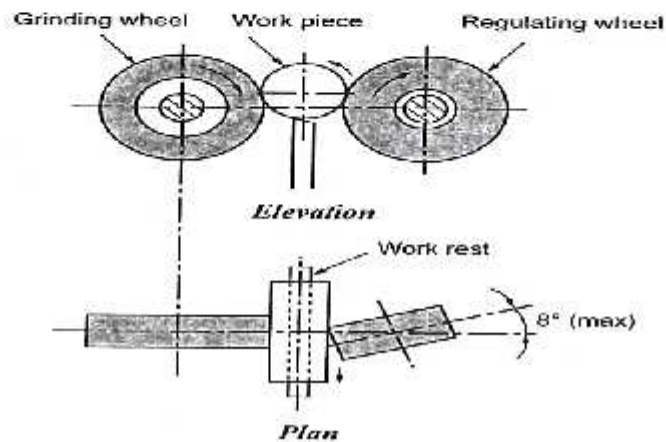
Work rest is located between wheels. The work is placed on the work rest. The regulating wheel is fed forward forcing the work against grinding wheel. So, the work on work rest is pressed against the grinding wheel surface. By friction, the regulating wheel makes the work piece to rotate. The rotating work piece is pressed between two wheels.

So, the grinding wheel grinds the work piece. The regulating wheel does not remove the metal as it rotates slowly. The grinding wheel is driven by an electric motor and rotates at a maximum surface speed of about 1850*mpm*. The regulating wheel speed ranges from 33 to 130*mpm*.

Work piece is placed in a floating condition between the grinding wheel and regulating wheel. So, it is called as *Centreless grinding*.

4. Write short notes on gear forming.

Gear Cutting By Single Point Formed Tool

In this case, a single point cutting tool is used for cutting the gear in shaping machine or a planning machine. The cutting edge of the tool is made to the shape of gear tooth. By using this method, both spur and bevel gears can be cut. The work is mounted between two centers in which the work or tool reciprocates to perform cutting task. The cutting stroke should be exactly parallel and above the blank axis.

So, the blank should be accurately set. By feeding the tool downwards, the depth of cut is given.
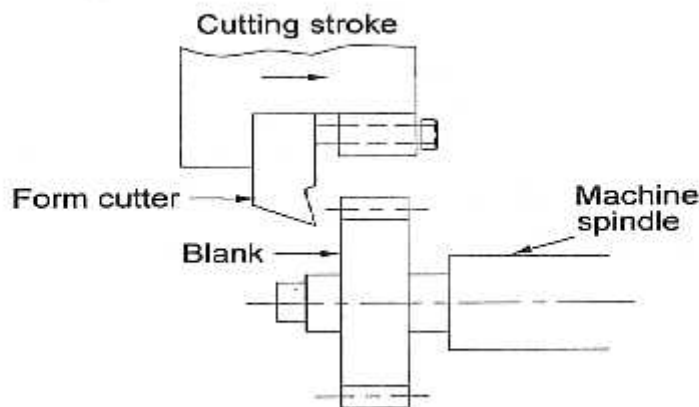
Gear cutting by a single point cutting tool

5. Write short notes on gear shaping. **(AU Apr 2010)**

GEAR GENERATION PRINCIPLE

Gear generation is based on the fact that any two involute gears of the same module will mesh together. Here, one of the meshing gears is made as the cutter. The other gear rotates and reciprocates along the width. Due to relative rolling motion of cutter and the blank, gear teeth are generated on the gear blank.

Generally, gears may be generated by a rack cutter, pinion cutter or a hob. By this gear generation method, the profile can be accurately produced as that of cutter gear.

The common gear generating processes are
    1. Gear shaping process.
    2. Gear planing process.
    3. Gear hobbing process.

Gear Shaping

Gear shaping is done on a special type of machine called *gear shaper*. Here, a pinion type of cutter is used. The cutter has ground with top rake and clearance. A hole is provided in the centre portion of the cutter for mounting on a stub arbor or spindle of the machine. Two typesof cutters are used such as disc type and shank type cutter. Both the axes of cutter and blank are parallel. After loading the work, the cutter is fed radially into the blank to give depth of cut.

Clearance angle
6° — 10°

Rake angle 5°

(a) Pinion cutter

Cutting stroke

Cutter

Blank

Mandrel

Feed of cutter

Feed of blank

(b) Cutting action
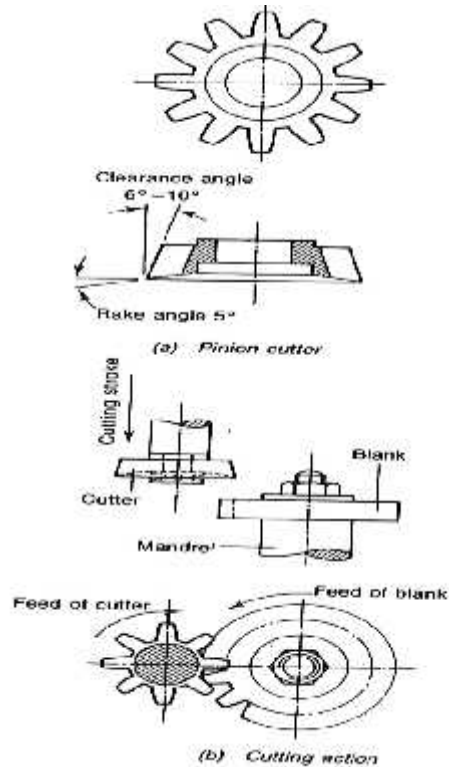
The machine is started. The cutter reciprocates vertically and parallel to the axis of the gear blank. During generation process, both the cutter and blank are made to rotate slowly together about their axis. The cutter and work spindle are connected with gear trains separately. It gives the correct relative speed of rotation to these two spindles. So, the rotation of the cutter generates the tooth profile. The rolling movement is continued until all the teeth on the blank are cut. During return stroke, the work is relieved from the cutter by a suitable mechanism. It is done to avoid rubbing of cutter over the cut surface. The various movements obtained from gear shaper are given below.

1. Rotary motion of the cutter and blank.
2. Radial feed of the cutter towards the blank.
3. Vertical reciprocating motion of cutter.
4. Withdrawal motion of the blank away from the cutter during return stroke.

Applications

1. Gear shaping is used for generating both internal and external spur gears.
2. Helical gears can also be generated using special attachments.

Advantages

1. Both internal and external gears can be generated.
2. Various sizes of gears can be generated using single cutter.
3. Special gears of non-conventional type gears such as elliptical gear, face gear, cluster gear can be cut.
4. Very high degree of accuracy can be obtained due to removal of uniform size of chips.
5. As the cutting action is continuous, the rate of production will be high.
6. Mechanism is simple.

6. Sketch and explain the three of extra cylindrical centerless grinding. **(AU Apr 2010)** s**(AU Dec 2008)**

SURFACE GRINDERS

Surface grinding machines are used to produce and finish flat and plane surfaces. By using special fixtures and form dressing devices, angular and formed surfaces can also be ground.

The various machine parts such as machine guide ways, piston rings, valves, dies, surface plates etc are finished by surface grinding.

Heavy work pieces are clamped on the table by means of pads, strap clamps and other devices or they are held in fixtures. Small work pieces are usually held by a magnetic chuck. The various types of surface grinders are explained below:

Horizontal Spindle Reciprocating Table Surface Grinder

Horizontal spindle reciprocating table surface grinder

The line diagram of this type of grinder is shown in fig. . It consists of a horizontal spindle carrying the grinding wheel and rectangular worktable. The table is mounted on a base. Horizontal guide ways of base is a rectangular box like casting. The driving mechanisms are housed inside the base.

The table reciprocates along the guide ways for giving longitudinal feed. The table top has T-slots for mounting the magnetic chuck or fixtures. The cross feed to the grinding wheel is given by moving the column perpendicular to the table as shown in fig. 4.18. The wheel head is mounted on the column. It has an independent motor for driving the wheel. The wheel head can move up and down along the vertical guide ways of the column. Depth of cut is given by the foresaid arrangement.

Working

The workpiece is clamped on the table. The trip dogs are adjusted suitably to get the correct stroke length of the table. The work piece reciprocates under the table. The periphery of the grinding wheel does the grinding. Cross feed is given to the work piece after every stroke. Depth of cut is given by lowering the wheel head.

For rough grinding of work piece, the depth of cut may be from $0.02mm$ to $0.06mm$. For finishing operation, the depth of cut may be from $0.005mm$ to $0.01mm$.

Horizontal Spindle Rotary Table Surface Grinder

In horizontal spindle rotary table surface grinders, the work pieces are mounted on magnetic chucks or on fixtures rotating slowly under the rotating grinding wheel in its horizontal axis.

The circular table rotates at specific speed and the wheel can feed axially (cross-feed). The wheel head is lowered to give the required depth of cut. The periphery of the grinding wheel takes the cut. This machine is used for small and medium size works.
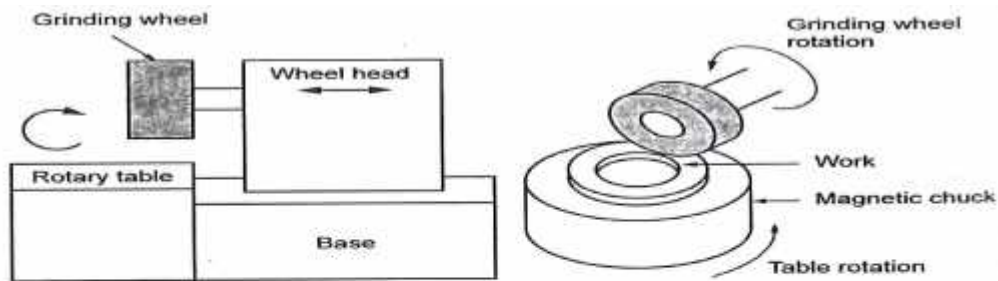
Horizontal spindle rotary table surface grinder

Vertical Spindle Reciprocating Table Surface Grinder

The work piece is clamped on the reciprocating worktable using a magnetic chuck or fixture. The grinding wheel rotates about a vertical axis. It may be of cup or cylindrical type for faster stock removal. It is used where accuracy is not stringent. The longitudinal and cross feed are given through the table. The face or side of the grinding wheel cuts the metal. The wheel head is lowered down for giving the depth of cut. This grinding machine is used for grinding flat surfaces on medium size works.
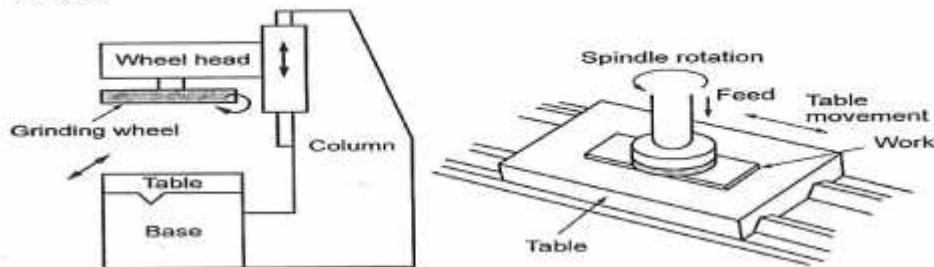
Vertical spindle reciprocating table surface grinder

7. List the advantages and disadvantages of gear shaping process. **(AU Apr 2010)**

Applications
1. Gear shaping is used for generating both internal and external spur gears.
2. Helical gears can also be generated using special attachments.

Advantages
1. Both internal and external gears can be generated.
2. Various sizes of gears can be generated using single cutter.
3. Special gears of non-conventional type gears such as elliptical gear, face gear, cluster gear can be cut.
4. Very high degree of accuracy can be obtained due to removal of uniform size of chips.
5. As the cutting action is continuous, the rate of production will be high.
6. Mechanism is simple.

8. Give the specification of grinding wheel. **(AU Dec 2009)**

DESIGNATION OF GRINDING WHEEL

Sequence	Prefix	Abrasive	Grain	Grade	Structure	Bond	Suffix
	W	A	36	K	5	R	17

Manufacturer's abrasive symbol (use optional)

Aluminum oxide A,
Silicon carbide C

Coarse	Medium
10	30
12	36
16	46
20	60
24	

Dense	Open
1	9
2	10
3	11
4	12
5	13
6	14
7	15
8	

Manufacturer's Type symbol (use optional)

V-Vetrified
B-Resinoid
R-Rubber
E-Shellac
S-Silicate
O-Oxychloride

Grade{   Soft   Medium   Hard }
A B C D E F G H I J K L M N O P Q R S T U
Indian standard marking system

The Indian standards Institution (IS: 551-1954) has specified a standard system of marking the grinding wheels. According to this system, the following elements are represented in a definite order.

9. What is meant dressing and truing of grinding wheel? **(AU Dec 2009)**

Dressing

It is the process of loading and breaking away the glazed surface so that new sharp abrasive particles are again present to work for efficient cutting is called *dressing*. Dressing is done using the tool called *dresser*.
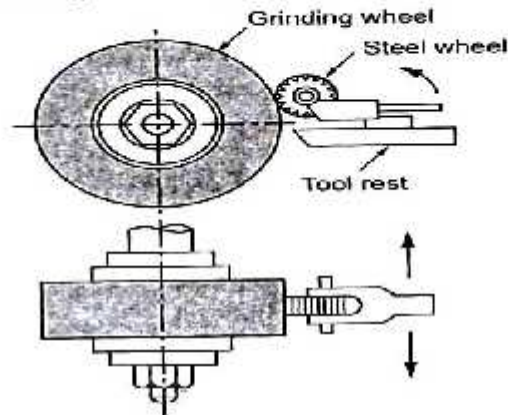
Star wheel dresser

There are various types of dressing tools available.

- a) Star dressing tool
- b) Round abrasive stick
- c) Diamond dressing tool.

shows dressing grinding wheel using a star wheel dresser. Star wheel is a steel wheel having hardened teeth on the periphery. The dresser is guided by the tool rest. The grinding wheel runs at a slow speed.
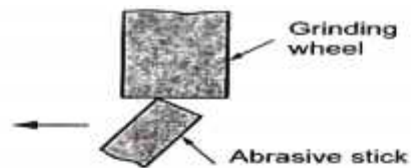
Abrasive stick dresser

The dresser is pressed against the face of the revolving wheel and moved across the face to dress the surface. This type of wheel dresser is used for grinding coarse grain abrasive wheels. Round abrasive stick type of dressing tool consists of a steel filled with a bonded abrasive. The end of the tube is held against the wheel and moves across the face.
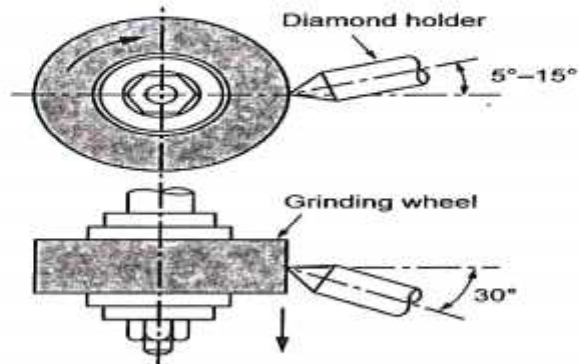
Diamond tip dresser

The grinding wheel used for precision and high finish grinding is dressed by a dresser having diamond tip. The diamond tip is hold in a holder and moved across the width of the wheel. Only the pointed tip of the diamond does the dressing. The holder is inclined at an angle shown in fig 4.4. Very light material is taken in diamond dressing.

Truing

Truing is the process of trimming the cutting surface of the wheel to run true with the axis. By truing, the cutting surface of the worn out wheel can be shaped to the original form. It is also used to produce the required contour for form grinding. Truing is done with a diamond-truing tool. The process is similar to dressing.

10. Briefly discuss about the different types of abrasives used in a grinding wheel. **(AU Dec 2008)**

Grinding wheels are made up of small abrasive particles held together by bonding material. Thus, it forms a multi-edge cutter.

Abrasive is a hard material. It can be used to cut or wear away other materials. Small abrasive particles are used in grinding wheels. They are called *abrasive grains*. Abrasives may be classified into two types.

(i) Natural abrasives
(ii) Artificial abrasives.

1 *Natural abrasives*

These are produced by uncontrolled forces of nature. These are obtained from mines. The following are the natural abrasives.

a) Sandstone or solid quartz.
b) Emery (50 to 60% crystalline Al_2O_3 + Iron oxide).
c) Corundum (75 to 90% crystalline Al_2O_3 + Iron oxide)
d) Diamond.

Natural abrasives lack uniformity of properties and reliability have been largely replaced by manufactured or artificial abrasives.

2. *Artificial abrasives*

These are manufactured under controlled conditions in closed electric furnace in order to avoid the introduction of impurities and to achieve necessary temperature for the chemical reaction to take place. These abrasives have better cutting properties and higher efficiency than natural abrasives. The various manufactured abrasives are

a) Aluminium oxide.
b) Silicon carbide.
c) Artificial Diamond.
d) Boron carbide.
e) Cubic boron nitride.

a) Aluminium Oxide (Al₂ O₃):

It is the crystalline form of aluminium oxide. This abrasive carries very hard and tough grains having sharp cutting edges. It is manufactured by fusing mineral *Bauxide* in an electric arc furnace mixed with coke and iron scrap. Here, iron scrap acts as a flux. After fusing, it is crushed, washed and treated with alkalis. Again, it is washed and finally, ground.

11. Describe Honing process. **(AU Dec 2007)**

HONING

It is also an abrasive process used for finishing previously machined surfaces. It is mostly used for finishing internal cylindrical surfaces such as drilled or bored holes.

The tool used called *a hone* is a bonded abrasive stone made in the form of a stick. Although honing enables the maximum stock removal out of the entire surface finishing operations, this higher stock removing capacity enables the application of honing for correcting slight out of roundness or taper. The usual amount of stock left for removal by honing is from 0.1mm to 0.25mm. Honing is performed at relatively slow speeds in the range of 10–30 *metres/min*.

The *honing* tool works more or less in the same way as an expanding reamer. The honing stones are so held in a *holder or mandrel* that they can be forced outwards by mechanical or hydraulic pressure against the surface of the bore. Aluminium oxide, silicon carbide or diamond grains of suitable grit are bonded in resinoid, vitrified or shellac bond to form the honing stones usually carrying impregnated traces of sulphur or wax for longer tool life and better cutting action.
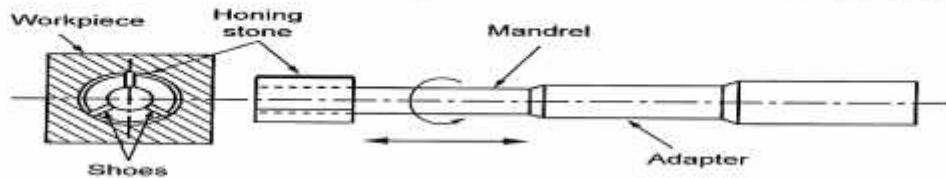
A hand honing tool and honing process

12. Express centreless grinding process with neat diagram. **(AU Dec 2007)**

Centreless Grinding

The external centreless grinding principle is also applied to internal grinding. In internal centreless grinding, the work is supported by three rolls.

One is the regulating wheel, the second one is a supporting roll and the last one is pressure roll to hold the work piece against the support and regulating rolls. The regularity roll is a rubber bonded wheel. This roll makes the work piece to rotate.
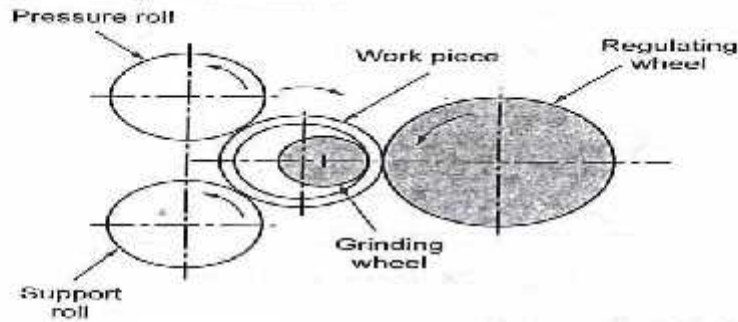
Centreless grinding

The grinding wheel contact inside diameter of the work piece directly and reciprocates about its axis for giving the feed. The depth of cut is given by moving the grinding wheel in a crosswise direction. The pressure roll is mounted to swing aside to permit loading and unloading.

13. Explain the abrasive jet grinding with diagram (AU Dec 2007)

In electrochemical grinding, machining takes place by both grinding and chemical reaction. The grinding wheel impregnated with a on- conductive abrasive acts as anode and work acts as a cathode. When the supply is given, grinding wheel rotates. At that time, electrolyte solution is passed trough the nozzle in the grinding zone. Due to this, electrical bridge is completed between anode and cathode. Here, the work and wheel are not made to contact directly. Due to rotating action of the grinding wheel, the electrolyte is passed the work at higher speed. So, the metal is removed by both abrasive and electrolyte action.

In case of abrasive jet grinding, only the electrolyte used in electrochemical grinding is replced by abrasive jet. But grinding process is carried out in the same manner as that of electrochemical grinding as shown in fig.

Abrasive jet grinding
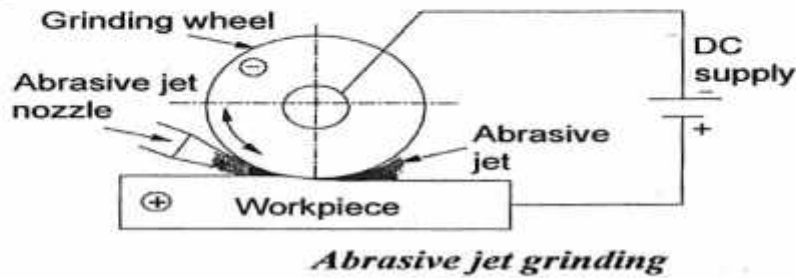
Production Of Abrasive Jet

Abrasive jet production
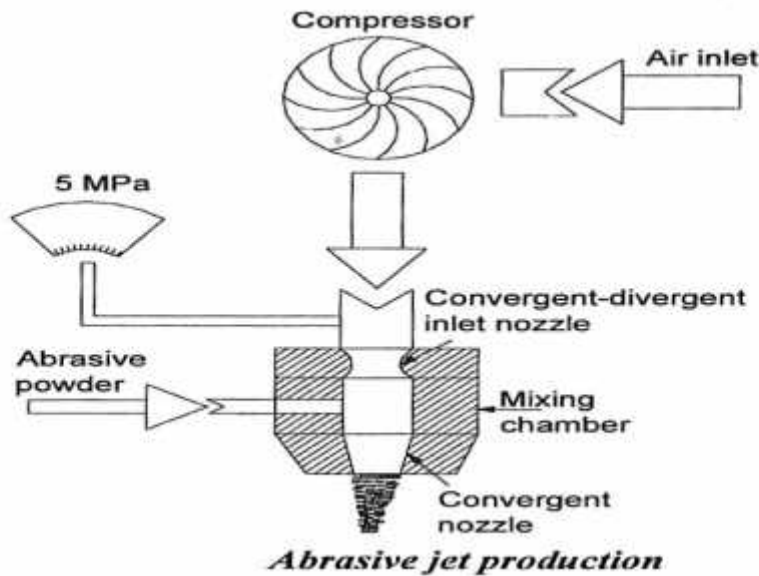
14. How do you classify cylindrical grinders? What is the difference between "Plain and universal "cylindrical grinder? **(AU Dec 2006)**

Plain centre type cylindrical grinding machine:

A plain centre type cylindrical grinding machine is shown in fig.

These grinding machines are used for grinding mainly cylindrical

parts. They are also used for grinding parts such as tapers, fillets, contoured cylinders etc. The grinding machine consists of various parts.

Plain centre type cylindrical grinding machine

1. Base

The base is the main casting that rests on the floor and supports the parts mounted on it. On the top of the base, horizontal guide ways are set on which the table slides to give traverse motion to the work piece. The table drive mechanism is incorporated in the base itself.

2. Table

There are two tables such as upper table and lower table. The lower table slides on the guide ways of the bed and provides traverse feed or longitudinal feed of the work past the grinding wheel. It can be moved by hand or power within the limits. Adjustable dogs are provided at the side of the lower table. These dogs can be set up in proper place to reverse the table of the end stroke.

The upper table is mounted on the lower table and it carries headstock and tailstock. The headstock and tailstock can be adjusted according to the length of the work piece. The upper table can be swiveled and clamped in position over the power table. The maximum angle of swivel is 10° on either side. The swiveling is used for grinding tapers.

3. Headstock

The headstock supports the work piece by means of a dead centre. The work piece is driven by headstock through dog and driving pin. A separate motor is housed in the headstock to rotate the work piece.

4. Tailstock

The tailstock can be adjusted and clamped to accommodate different length of work pieces. The work piece is held in between the centre of headstock and tailstock.

5. Wheel head

The wheel head carries a grinding wheel and rotated by a motor housed in the headstock. The wheel head is placed over the bed at its backside. The wheel head can be moved perpendicular to the table ways by hand or power. This movement is the cross feed.

Working principle

The work piece is held between centres. It is rotated by a dog or faceplate. The grinding wheel also rotates about its own axis in the opposite direction of work. The grinding wheel is fed by hand or automatically towards the work piece for successive cuts.

In most of the cases, the work speed is selected between 20 and 30 surface speed meters per minute (s.m.p.m.). Wheel speed is usually selected between 1500 and 2000 s.m.p.m. The depth of cut at each reversal is from $0.025mm$ to $0.125mm$ for rough grinding. For finishing, it should be from $0.0125mm$ to $0.0625mm$. The longitudinal feed is depending upon the rigidly and power of the machine which varies from 0.25 to 0.75 of the width or wheel's face.

(ii) Centre type universal grinder:

Fig. 4.17. Universal grinder

Center type universal grinders are widely used in tool room for grinding tools. The features of this machine are similar to those of plain grinders but in addition, it is provided with the following features.

1. The centre of the head stock spindle can be used as alive or dead. The work can be held and revolved by a chuck. It can also be held between centres and revolved.

2. The wheel head can be swiveled in a horizontal plane in any angle. The wheel head can be fed in the inclined direction also.

3. The headstock can be swiveled to any angle in the horizontal plane.

4. The wheel head can also be arranged for internal grinding.

15. Describe the use of cutting fluids in grinding.

CUTTING FLUIDS IN GRINDING

(i) It cools the workpiece

Water solutions are liquids that consist of water with synthetic additives in order to increase its wetting performance and prevent corrosion. Such fluids contain no oil and provide good cooling performance but poorer lubrication performance.

(ii) It acts as a lubricant and reduce friction between the chips, workpiece and grinding wheel

Emulsions consist of water with an admixture of 2—5% of oil in an extremely finely distributed form. Sulphur or chlorine additives may also be used as EP additives.

Cutting oils are composed of a mineral oil base with EP-type additives. Cutting oils provide effective lubrication but poorer cooling. Water solutions are most suitable when grinding with diamond wheels. Emulsions are used nowadays for the majority of grinding operations because they are ecologically beneficial and perform adequately.

(iii) It removes chips from the contact area.

16. Explain gear hobbing process over other gear generation processes. **(AU Dec 2006)**

Gear Hobbing Process

In addition to the gear shaping process another process used for gear generation is gear hobbing. In this process, the gear blank is rolled with a rotating cutter called hob. Gear hobbing is done by using a multipoint cutting tool called gear hob. It looks like a worm gear having a number of straight flutes all around its periphery parallel to its axis. These flutes are so shaped by giving proper angles to them so that these work as cutting edges. In gear hobbing operation, the hob is rotated at a suitable rpm and simultaneously fed to the gear blank. The gear blank is also kept as revolving. Rpm of both, gear blank and gear hob are so synchronized that for each revolution of gear bob the gear blank rotates by a distance equal to one pitch distance of the gear to be cut. Motion of both gear blank and hob are maintained continuously and steady. A gear hob is shown in Figure and the process of gear hobbing is illustrated in Figure .The hob teeth behave like screw threads, having a definite helix angle. During operation the hob is tilted to helix angle so that its cutting edges remain square with the gear blank. Gear hobbing is used for making a wide variety of gears like spur gear, helical, hearing-bone, splines and gear sprockets, etc

Process of Gear Hobbing
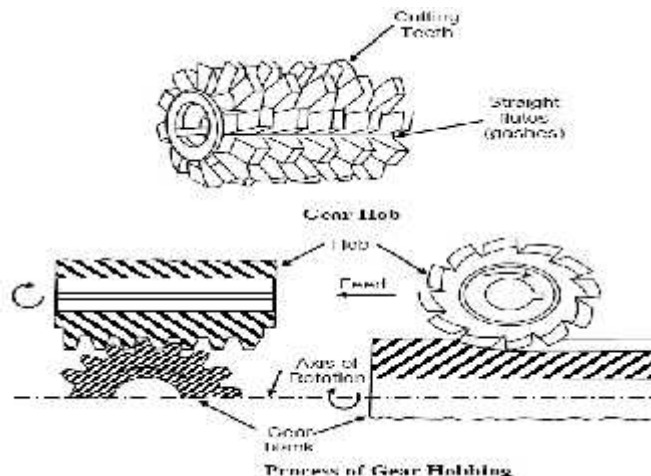
Three important parameters are to be controlled in the process of gear hobbing indexing movement, feed rate and angle between the axis of gear blank and gear hobbing tool (gear hob). A schematic diagram of the setup of a gear hobbing machine is illustrated in Figure .The aims of hob areset at an inclination equal to the helix angle of the hob with the vertical axis of the blank. If a helical gear is to be cut, the hob axis is set at an inclination equal to the sum of the helix angle of the hob and the helix angle of the helical gear. Proper gear arrangement is used to maintain rpm ratio of gear blank and hob

Setup for Gear Hobbing Machine
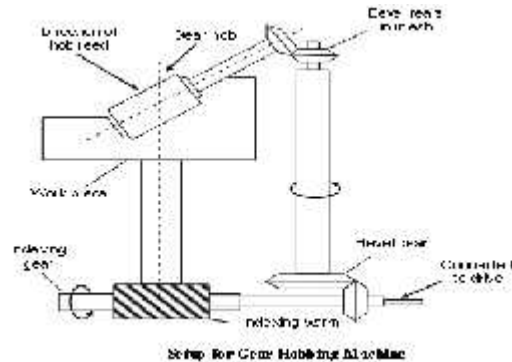
The operation of gear hobbing involves feeding the revolving hob till it reaches to the required depth of the gear tooth. Simultaneously it is fed in a direction parallel to the axis of rotation. The process of gear hobbing is classified into different types according to the directions of feeding the hob for gear cutting. The classification is described as given below.

Hobbing with Axial Feed

In this process the gear hob is fed against the gear blank along the face of the blank and parallel to its axis. This is used to make spur and helical gears.

Hobbing with Radial Feed

In this method the hob and gear blanks are set with their axis normal to each other. The rotating hob is fed against the gear blank in radial direction or perpendicular to the axis of gear blank. This method is used to make the worm wheels.

Hobbing with Tangential Feed

This is also used for cutting teeth on worm wheel. In this case, the hob is held with its axis horizontal but at right angle to the axis of the blank. The hob is set at full depth of the tooth and then fed forward axially. The hob is fed tangential to the face of gear blank.

Advantages and Limitations of Gear Hobbing Process

(a)Gear hobbing is a fast and continuous process so it is realized as economical process as compared to other gear generation processes.

(b)Lower production cycle time, i.e. faster production rate.

(c)The process has a larger variability's in the following of sense as compared to other gear Machining processes.

(d)Capable to make wide variety of gears like spur gear, helical gears, worms, splines, sprockets,etc.

(e)Process of required indexing (named so) is quite simplified and capable to make any number Of teeth with consistent accuracy of module.

(f)A special type of gear named harringbon gear cam be generated by gear hobbing exclusively.

(g)Wide variety of batch size (small to large volume) can be accommodated by this process.

(h)Several gear blanks, mounted on the same arbor, can be processed simultaneously.

(j)Hob is multipoint cutting tool having multi cutting teeth or edges at a time few number of cutting edges work so lots of time is available to dissipate the generated heat. There is no over heating and cutting tool.In addition to above mentioned large number of advantages there is

one glaring limitation of the process of gear hobbing. That is manufacturing of internal gears
 is not possible

Unit V – CNC Machine Tools and Part Programming

Part A

1. **List the differences between NC and CNC.(AU Apr 2011)**

S.No	NC Machines	CNC Machines
1	NC system is produced in sixties and used electronic hardware based upon digital circuit technology.	It employs a mini or micro computer to control machine tool and eliminate as far as possible, additional hardware circuits in control cabinet.
2	Less flexibility	More flexibility

2. **What are linear bearings? (AU Apr 2011)**

   A linear motion bearing or linear slide is a bearing designed to provide free motion in one dimension .Linear motion bearings are widely used to guide, support , locate and accurately move machinery components and products in a wide range of automation application.

3. **Mention the type of ball screws. (AU Dec 2010)**

   Ball screws can be classified as follows;

   (1) By ball circulation method

         (a) Return pipe type

         (b) Deflector type

         (c)End cap type

   (2) By preloading method

         (a) Fixed point preloading method

         (b) Constant pressure preloading type.

   (3) By screw shaft

         (a) Precision ball screws

         (b) Rolled ball screws

4. **What are feed drives? (AU Dec 2010)**

   Feed drives are used to drive the axis as per the programme fed in the CNC machine.

5. **What are the types of motion control system used in NC machines? (AU Dec 2010)**

   (a) point to point or positional system

   (b) Straight line or paraxial system

   (c) Continuous path system

6. **What is meant by APT language? (AU Apr 2010)**

   It is the abbreviation of automatically programmed tools.APT program is used to command the cutting tool through its sequence of machining process.APT is also used to calculate the cutter positions.APT is a three dimensional system controlling up to five axes including rotational coordinates.

7. **Compare a closed loop NC system with open loop system. (AU Apr 2010)**

S.No	Open loop system	Closed loop system

1	No feedback about the result produced due to open loop	Instantaneous feedback about the result produced
2	No reference for the results	Definite reference for the results

8. **What is a preparatory function? How is it important in CNC programming? (AU Apr 2010)** Preparatory commands which prepare the machine or tool for different modes of movement like positioning contouring , thread cutting and also proceed the dimension word .They are grouped .Group cannot affect each other. Only one function from the same group can be at the same time.

9. **State the limitations of CNC machine tools. (AU Dec 2009)**

   (i)CNC machines are more expensive than manually operated machines, although costs are slowly coming down.

   (ii) The CNC machine operator only needs basic training and skills, enough to supervise several machines. In years gone by, engineers needed years of training to operate centre lathes, milling machines and other manually operated machines. This means many of the old skills are been lost.

   (iii) Less workers are required to operate CNC machines compared to manually operated machines

10. **What is a canned cycle? (AU Dec 2009)**

    Canned cycle is a combination of machine moves that performs anyone particular machining function such as drilling, turning, milling, boring etc.

11. **Define NC. (AU Dec 2009)**

    Controlling a machine tool by means of a prepared program is known as Numerical control or NC.

12. **Name the major elements of NC machines. (AU Dec 2009)**

    (i) Tape reader

    (ii) Mini computer

    (iii) Servos and interface logic

    (iv) Motion feedback

13. **What are the classifications of NC machines? (AU Dec 2008)**

    (i)Point to point NC system

    (ii)Straight cut NC system

    (iii) Contouring NC system

14. **What is the difference between incremental and absolute system. (AU Dec 2008)**

    (a) In absolute programming the distance at my point at any instant will be measured from the origin (X=0, Y =0).

    (b) Whereas in incremental programming, the instant point will be noted as (X =0 , Y = 0) .Further measurement will be made from the particular point only.

15. **What is the role of computer for NC machine tool? (AU Dec 2007)**

    Computer numerical control is an NC system that utilizes stored program to perform basic numerical control functions .Mini or micro computer based controller unit is used.

16. **What is point –to – point (PTP) system? (AU Dec 2007)**

    It is also called positioning system. The objective of the machine tool control is to move the cutting tool to a predefined location. The speed or path is not important in this system.

17. **What are G-Codes and M-Codes? Give examples. (AU Dec 2006)**

    - G- Codes are preparatory function codes which prepare the machine or tool for different modes of movement like positioning, contouring, thread cutting etc.

    - M-codes are miscellaneous function codes which denote the auxiliary or switching information such as coolant on / off, spindle speed etc.

18. **List the commonly used coordinate Systems are enable to**
    (a) Cantilever construction
    (b) Bridge construction
    (c) Column construction
    (d) Gantry construction

19. **Write down the types of statements in APT language. (AU Dec 2006)**
    (a) Geometric statements
    (b) Motion statements
    (c)Post processor statements
    (d)Special control or auxillary statements

Part B

1. Narrate the design considerations of CNC machines. **(AU Apr 2011, Dec 09)**

    1. Static load
    2. Dynamic load
    3. Thermal load
    4. Guideways
    5. Feed drive:
            1) Servo motor,
            2) Mechanical Transmission System
    6. Spindle / spindle bearings
            1) Hydrodynamic
            2) Hydrostatic
            3) Antifriction
    7. Measuring Systems:
            1) Direct
            2) Indirect
    8. Controls, Software and user interface
    9. Gauging
    10. Tool monitoring systems:
            1) Direct
            2) Indirect

2. Discuss about slide ways used in CNC machine tools. **(AU Apr 2011, Dec 10)**

SLIDE MOVEMENT ELEMENT

Precise positioning and repeatability of machine tool slides are the major functional requirements of CNC machines. The inaccuracies that are caused are mainly due to the stick slip motion when plain (metal to metal contact) slideways are used.

To fulfill the requirements of elimination of stick-slip, there are different slideway systems such as rolling friction slideways and slideways with low friction. These have low wear negligible stick-slip, good vibration damping easy machinability, low price and low coefficient of friction properties.

Combinations of Machine Tool Slideway Systems

Table

Plain	Rolling friction
(Metal to metal)	Linear motion system
CI - CI	with recirculating bars
CI - Steel	recirculating rollers.
Steel-Steel	
Plastic - CI	
Plastic - Steel	

In addition to this, both hydrostatic and aerostatic slide way systems (as in coordinate measuring machines) can also be used.

The Requirement of a Good Slideway System

A good slideway system must possess:
1. Low co-efficient of friction at varying slide velocities.
2. Minimum difference between static and dynamic friction co-efficient - positive slope for friction - velocity characteristics.
3. Low rate of wear.
4. High stiffness at the sliding joints.

3. Describe the spindle drives used in CNC machine tools. **(AU Apr 2011)**

DRIVE SYSTEMS

Basically the NC and CNC components are divided into two groups. They are

    1. Electromechanical devices

    2. Digital Circuits

Every system includes a drive which converts the electrical command signals to mechanical motions. These are known as *electromechanical devices*. Drives for NC and robot systems are hydraulic actuators, DC motors or stepping motors. The selection depends upon the power requirements of the machine tool and the power sources available.

AC Drives

Nowadays, CNC manufacturers started to use Alternate current motors as drives to CNC machine tools. AC motors are sometimes referred to AC synchromotors which would operate without brushes and eliminates one of the main maintenance problems associated with dc motors.

Principle of operation

The velocity of the AC synchromotor is controlled by manipulation of the voltage frequency supplied to the motor. The frequency manipulation requires the use of an electrical inverter. The inverter contains a DC power supply and the circuit inverts the DC voltage into AC voltage with a continuously controllable frequency.

Advantages of AC motor over DC motor

1. AC motors are more reliable than DC motors
2. AC drive provides stable and smooth operation
3. AC cooling system allows high-speed, high output with compact size.
4. AC motors are free from brushes which avoids maintenance.

Disadvantages of AC drives

1. Inverters used *for* converting DC into AC are very costly.
2. Size of the inverters is big which occupies more space.

Direct Current Motors

Direct current (DC) motors allow precise control of the speed over a wide operating range by manipulation of the voltage applied to the motor. They are ideally suited for driving the axes of small-to medium-sized NC machines and robots. DC motors are also used to drive the spindle in lathes and milling machines, when a continuous control of the spindle speed is desired.

Principles of operation
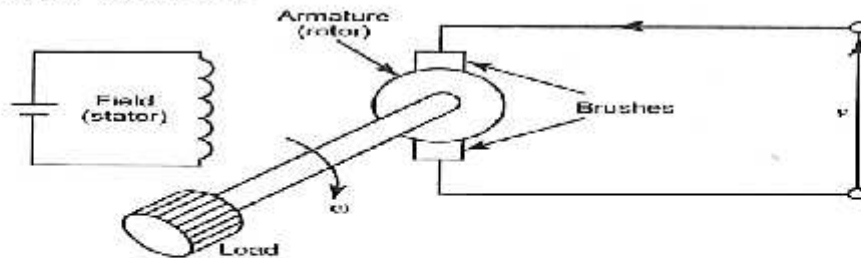
A separately excited dc motor

The DC motor is actually a DC machine which can function either as a motor or as a generator. The principle of operation of a DC machine is based on the rotation of an armature winding within a magnetic field. The armature is the rotating member, or rotor, and the field winding is the stationary member, or stator. The armature winding is connected to a commutator which is a cylinder of insulated copper segments mounted on the *rotor* shaft. Stationary carbon brushes which are connected to the machine terminals are held against the commutator surface and enable the transfer of a DC current to the rotating winding as illustrated in fig 5.5.

For the case in which the DC machine serves as a generator, the rotor is turned at a constant speed by an external device connected to the shaft. The generator receives the mechanical energy from the shaft and converts it into electrical energy which is provided through the armature output terminals. By contrast in a motor, electrical energy is supplied to the armature from an external DC source and the motor converts it into mechanical energy.

4. List the difference between manual and computer assisted part programming. **(AU Apr 2011, Dec 08)**

S.No	Conventional system	NC system	CNC system
1.	It requires more manual work.	It requires less manual work.	It requires less manual work.
2.	Skilled labour is needed.	Less skill is enough.	Less skill is enough.
3.	Less accuracy is obtained.	More accuracy is obtained.	More accuracy is obtained.
4.	The system has less flexible.	The system has medium flexible.	The system has more flexible.
5.	Part programming is not required.	Part programming is used.	Re - programming is easy.
6.	Machining is done every time.	Programming and punched tape are read each time.	Only one time, the tape is read and storing is possible.
7.	Simulation cannot be done.	Simulation is also possible.	Simulation is also possible.
8.	It is more suitable for less production rate.	It is more suitable in medium production rate.	More suitable for mass production.

5. Explain the following in CNC machining. **(AU Dec 2010)**

   (a)Linear Interpolation

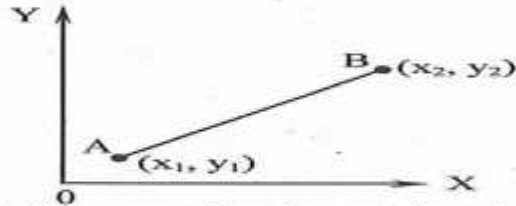   (b)Circular Interpolation

   (c) Cubic interpolation

Interpolation in NC machining is required to calculate the intermediate points of a curve or straight line when its starting and end coordinated are given. Interpolation may be linear, circular or cubic/parabolic. The type of interpolation used in NC

machine depends on which the given profile is approximated with the help of straight line, arcs of circles or segments of parabolae.

(a)   Linear interpolation

Linear interpolation is mostly used approximate straight lines. Consider the interpolation of a straight line AB shown in Figure, having (x_1, y_1) as starting point and (x_2, y_2) as end point. The coordinates of successive intermediate points are calculated from the consideration that distances $x_2 - x_1$ and $y_2 - y_1$ must be traversed in equal time. This implies that the cutting tool should move along line AB at constant speed.

Linear interpolation can also be employed to approximate curved profiles. In this process, the curve is represented as a series of finite straight line increments. The length of these finite increments should be such that the profile obtained by their sequential joining fits the curve within the required tolerances.

(b)   Circular interpolation

Circular interpolation is mostly used in machining of circles, arcs of circles and profiles consisting of different radii. For machining an arc using this method, the coordinates of the starting and end points of the arc, radius of the circle, coordinates of the centre and direction of movement needs to be programmed.

Circular interpolation is basically similar to linear interpolation in the way that the circular interpolation also breaks the arc profile into extremely small straight lines. However, the operational difference is significant as the required number of coordinates is calculated in the case of circular interpolation by the interpolator which generates the controlling signals that move the cutting tool along the programmed arc.

(c)   Cubic/parabolic interpolation

Parabolic interpolation is particularly suitable in machining complicated profiles which are free-formed as in the automotive or aeronautical industries. Cubic interpolation is based on the parabolic equation which is very flexible and can be made to fit almost any curve. The parabolic interpolation can be employed in two modes: tangent and three-point. The tangent parabola is tangent to the curve at the beginning and end of the span. The three-point parabola joins three non straight line points on the curve in a trajectory which is either a complete parabola or a part of it. In the first method, maximum error occurs at the middle of the span where as it occurs half way between the middle and starting or end points in the second case.

6. With a neat sketch, explain the working of ATC?

The CNC machines are designed to perform a number of operations in a single setting of the job. A number of tools may be required for making a complex part. In a manual machine, the tools are changed manually whenever required. In a CNC machine, tools are changed through program instructions. The tools are fitted in a tool magazine or drum. When a tool needs to be changed, the drum rotates to an empty position, approaches the old tool and pulls it. Then it again rotates to position the new tool, fits it and then retracts. This is a typical tool changing sequence of an automatic tool changer (ATC).

The concept of the ATC is that the range of tools for a specific job shall be made available for automatic selection and positioning. ATC cab be

Drum Type

For holding small number of tools usually not more than 30, Stored on periphery of drum and tool search speed is faster.

Chain Type

For more number of tools (40 or more), tools search speed is less.

As soon as the tool selection command is received by the system, the selected tool comes to a fixed place known as tool change position. The selected tool is transferred to the spindle from magazine after the previous tool is transferred to the magazine from spindle. This is called tool change cycle.

Advantages:

(a) Lines changed in seconds instead of hours.

(b) Increase operator safety by changing tools automatically.

(c) Change tools in seconds for maintenance and repair.

(d) Increase flexibility.

(e) Heavy and large multi-tools that are automatically exchanged.

7. Explain the main difference between point to point and continuous path of numerically controlled machine tools. **(AU Apr 2009)**

There are three types of NC used for motion control. They are

      1.   Point to point NC system.

      2.   Straight cut NC system.

      3.   Contouring NC system.

1. Point to Point NC system

It is also called *positioning system*. The objective of the machine tool control is to move the cutting tool to a predefined location. The speed or path is not important in this system.

### 2. Straight cut method NC system

This system is capable of moving cutting tool parallel to one of the major axes at a controlled rate for machining. It is preferred for milling operations. Here, it is not possible to combine more than a single axis direction. Angular cuts are not possible.

3. Contouring NC system

It is a complex and flexible method of tool control. It is capable of performing both point to point and straight-cut operations. More than one axis movement of the machine tool is possible. The path of NC cutter is continuously controlled to generate the desired geometry of the work piece. This system is also called as *continuous path NC system.*

8. Explain the various elements of NC machine with closed loop control system. **(AU Apr 2008)**

Every control process, and NC system tool, may be designed as an open-or a closed-loop control. The term open-loop control means that, since the loop is open there is no feed back and the action of the controller has no reference to the result it produces.
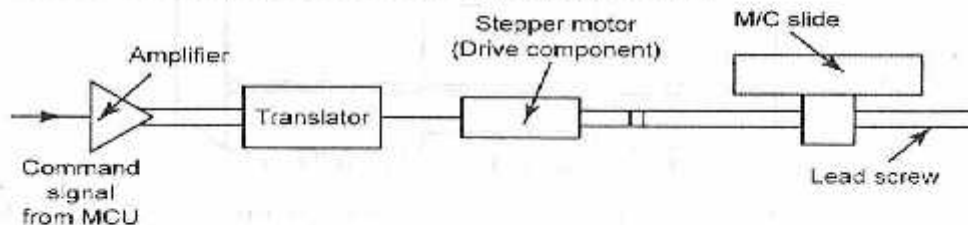
Open loop machine slide control

The open-loop NC systems are always of digital type and are using stepping motors for driving the slides. A stepping motor is defined as one whose output shaft rotates through a fixed angle in response to an input pulse. The stepping motors are the simplest way for converting digital electrical signals into proportional moment. So, they are a relatively cheap solution to the control problem. Since there is no check

on the slide position, the system accuracy is solely a function of the motor's ability to step through the exact number of steps provided at the input
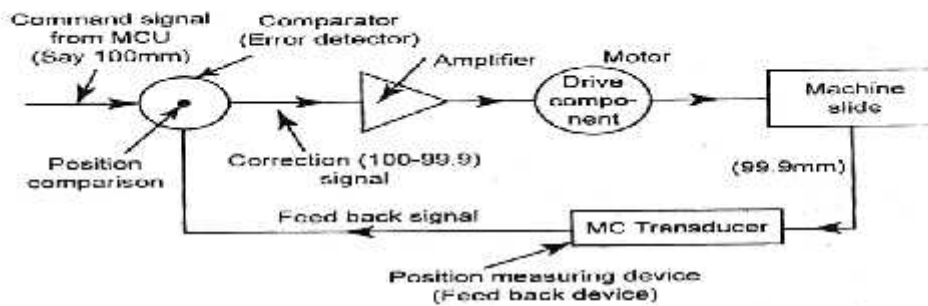
Closed loop positioning control

In closed loop, feed back system is used to close the loop. Position transducer acts as a feed back device. Figure 5.16 and 5.17 compare an open-loop and a closed-loop digital control for one axis of motion. The closed-loop control measures the axis actual position and compares it with the desired reference position. The difference between the actual and the desired valves is the error, and the control is designed in such a way as to eliminate or to reduce the error to a minimum. In this case, the system is a negative feed back one.

9. List any five motions and control statements of computer assisted NC programming and explain. **(AU Apr 2009)**

COORDINATE SYSTEMS

To determine the sequence of positions and movements of the cutting tool relative to the workpiece, it is necessary to establish a standard axis system. Two axes X and Y are defined in the plane of the table: The Z axis is perpendicular to this plane and movement in the Z direction is controlled by the vertical motion of the spindle. The positive and negative directions of motion of the tool relative to table along these axes are shown in fig
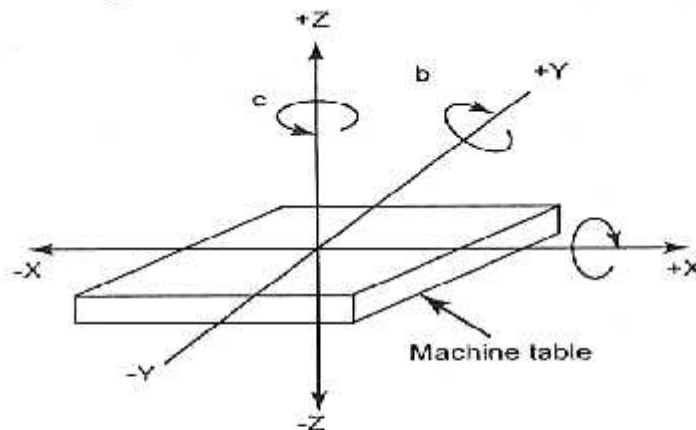
Coordinate system for milling and drilling process

There are 3 rotational axes a, b, c as shown in figure   These axes specify angles about the X, Y, and Z axes, respectively. To

differentiate positive from negative angular motion, the right-hand rule is normally used. Using the right hand with the thumb pointing in the positive linear axis direction, the figures hand are curled to point in the positive rotational direction.

For turning operations, two axes are required to command the movement of the tool relative to the rotating workpiece. The Z axis is the axis of rotation of the workpart and X axis defines the radial location of the cutting tool.

Zero Points and Reference Points

Origin is considered as zeropoint of the coordinate system. NC machines have either of two methods for specifying the zero point. They are *fixed zero* and *floating zero*. In fixed zero, the origin is always located at the southwest corner (i.e) lower left-hand corner of the table and all tool locations will be defined by positive X and Y coordinates.

In floating zero, the machine operator set the zero point at any positions on the machine table. The part programmer decides the zero point to be located. This is also known as *reference point*. At the beginning of the job, the operator moves the tool under manual control to some 'target point' on the table. The target point is some convenient place on the workpiece or table for the operator to position the tool. Then the operator presses zero buttons on the machine tool which tells the machine as a zero point.

Machine tool axis system
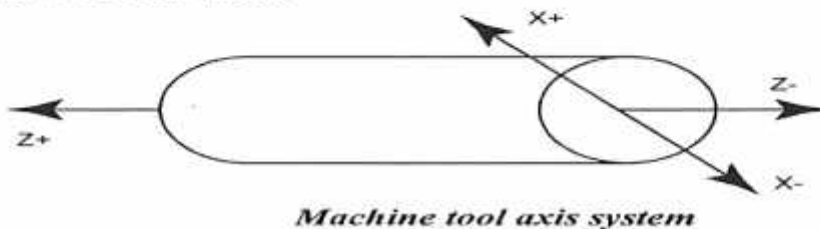
10. Describe the spindle and feed drives. State the requirement of the drives of CNC machine tools. **(AU Dec 2010)**

In CNC machines, large variation of cutting speed is required. Normally, cutting speed varies from 10m/min to 1000m/min which are provided by spindle drives based on the programme. Further, the speed is generally infinitely variable. Hence to provide such a control generally DC motors are used. The speed is controlled by varying the voltage infinitely. However, microprocessor controlled frequency converters are in

use for current generation CNC machine tools. AC motors are also used as spindle drives in many CNC machines. The advantage of using the AC drive for spindle is that it can also be used for positioning the spindle axis such as in turn mill centres. Classification of spindle drives with type of controller for each type is as follows:

```
                ┌──────────────────────────────────┐
                │  Classification of spindle drives │
                └──────────────────────────────────┘
                     │                        │
                     ▼                        ▼
          ┌──────────────────┐      ┌──────────────────┐
          │ DC spindle drives│      │ AC spindle drives│
          └──────────────────┘      └──────────────────┘
                     │                        │
                     ▼                        ▼
```

Separately excited DC shunt motor	Squirrel cage induction motor
Controller	Controller
➤ Thyristor (SCR) amplifier or	➤ Microprocessor based pulse width modulated (PWM) inverer
➤ Microprocessor based self-tuned thyristor amplifier	Speed control
Speed control	➤ Frequency vector control
➤ Armature and field control	

Feed drive consists of a feed servomotor and electronic controller. Unlike a spindle drive, the feed drive motors has some special characteristics, like constant torque and positioning. Also, in contouring operations, several feed drives have to work simultaneously because of the requirement to follow a prescribed path continuously. This requires a sufficiently damped servo-system with high band width i.e., fast response and matched dynamic characteristics for different axes. Feed drives that are used in CNC machine tools are:

- DC servomotors
- Brushless DC servomotors
- AC servomotors
- Stepper motors
- Linear motors

Requirements of the feed drive in CNC machine

➤ Constant torque for overcoming frictional and working force
➤ Infinitely variable drive speed with a speed range of at least 1:20,000
➤ Maximum speed up to 3000 rpm
➤ Possibility of smallest position increments like 1 - 2 μm
➤ Four quadrant operation and quick response characteristics
➤ Permanent magnet construction
➤ Low armature or rotor inertia
➤ Low electrical and mechanical time constants
➤ Integral mounting feed back devices

11. Write the part program for the part shown below. **(AU Dec 2010,Apr 08)**
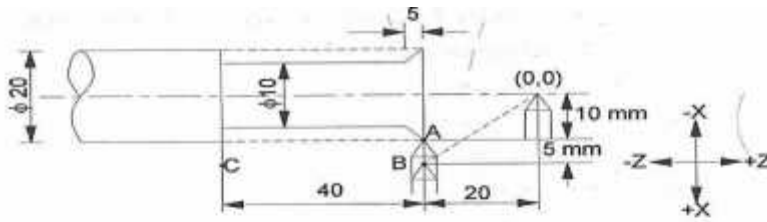
Figure 1
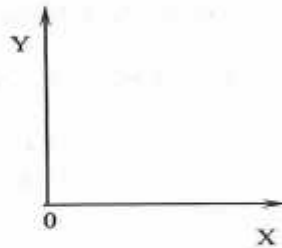
Programming in incremental mode

N01	G01	Z – 60	X0	F80 T1
N02	G01	Z –20	X15	
N03	G01	Z0	X –5	
N04	G01	Z –5 X –5		
N05	G02	Z –35	X0	
N06	G01	Z0	X5	
N07	M02			

Programme in absolute mode

N00	G90				
N00	G92	Z 0	X 0		
N01	G01	Z – 60	X 0	F80	T1
N02	G01	Z – 20	X 15		
N03	G01	Z – 20	X 10		
N04	G02	Z – 25	X 5		
N05	G01	Z – 60	X 5		
N06	G01	Z – 60	X 10		
N07	G00	Z 0	X 0		
N12	G00	Y0			
N13	M02				

12. Write the part program for drilling holes in the part shown below. The plate thickness is 20mm. **(AU Dec 2009, Apr 08)**
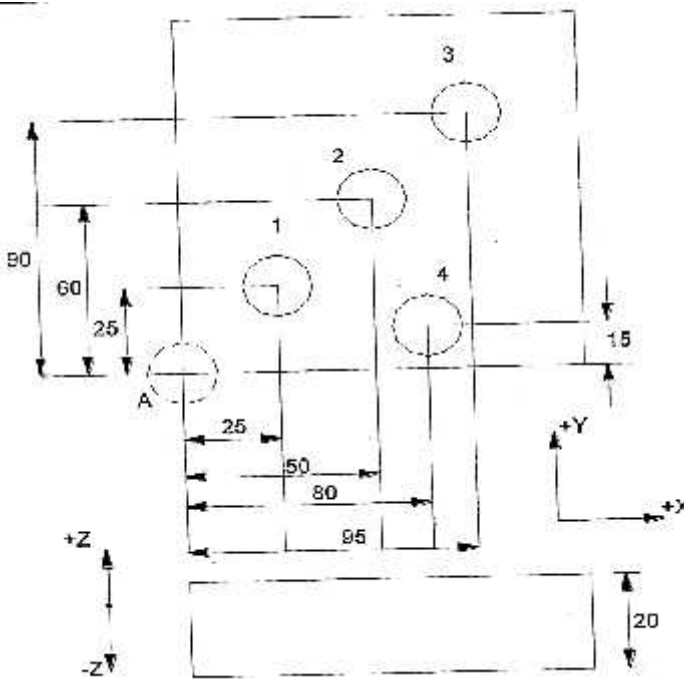
N100	G71	G91		
N110	M06T1			
N120	M03S1000			
N130	G00	X00	Y00	Z10
N140	G01	Z–20	F0.5	
N150	G00	X25	Y25	Z10
N160	G01	Z–20	F0.5	
N170	G00	X50	Y60	Z10
N180	G01	Z–20	F0.5	
N190	G00	X95	Y90	Z10
N200	G01	Z–20	F0.5	
N210	G00	X80	Y15	Z10
N220	G01	Z–20	F0.5	
N230	G00	X80	Y00	Z10
N240	G00	X00	Y00	Z10
N250	M05 M02			

13. How is manual programming of a NC machine done

Basically, we can write program in two ways. They are
     1 Absolute programming
     2. Incremental programming
The computer will be however informed to interpret properly.
     The G codes for the above two types are
     G 90 - Absolute programming
     G 91-Incremental programming

For example in absolute programming, the distance at my point at any instant will be measured from the origin (X=0, Y=0).

Whereas in incremental programming, the instant point will be noted as (X=0, Y=0). Further measurement will be made from the particular point only.

The following steps should be kept in mind while writing the programme.
     1. Fixation of coordinate system.
     2. Reference of G and M codes
     3. Dimensions of work and tools.
     4. Locating the fixture and machine table.
     5. Speed and feed according to the work and tool material.

14. Discuss the advantages of computer numerical control system. **(AU Dec 2006)**

Computer Numerical Control possesses a number of existing advantages over conventional NC. These are

(i) An increase in flexibility.

(ii) An improvement in the possibilities for correcting errors in part programming.

(iii) The possibility of using the computer's peripheral equipment.

(iv) Tape and Tape reader are used only once for resulting improved reliability.

(v) CNC is more compatible.

(vi) CNC can accommodate conversion of tapes prepared in units of inches to the international unit system.

1. Point to Point NC system

It is also called *positioning system*. The objective of the

15. What is the difference between positioning machines and contouring machines? **(AU Dec 2006)**

machine tool. It is used for positioning machines and contouring machines. The speed or path is not important in this system.

2. Straight cut method NC system

This system is capable of moving cutting tool parallel to one of the major axes at a controlled rate for machining. It is preferred for milling operations. Here, it is not possible to combine more than a single axis direction. Angular cuts are not possible.

3. Contouring NC system

It is a complex and flexible method of tool control. It is capable of performing both point to point and straight-cut operations. More than one axis movement of the machine tool is possible. The path of NC cutter is continuously controlled to generate the desired geometry of the work piece. This system is also called as *continuous path NC system*.

16. State a few typical applications where the use of numerical control would be justified. **(AU Dec 2007)**

Advantages

1. Greater accuracy.
2. Lesser production cost per piece due to reduction in lead time and also setup time.
3. Improved product quality and provision of high order of repeatability.
4. High production rates as the machining conditions are optimized and the non-machining times are reduced to a minimum.
5. Less scrap due to consistent accuracy and absence of human errors.
6. Reduced inventory in work-in-process (WIP).
7. Less operator skill is required.
8. Machine utilization is better.
9. Lower tooling cost.
10. Cycle time is reduced thereby increasing tool life.

Disadvantages

The major disadvantages of NC machines are their costs and requirements of highly knowledgeable person in this field. Long preparation time required for each production series. Flexibility is not there since machine is for only fixed cycle of operation.

17. Describe in brief the basic components of a tape operated NC machine tool. **(AU Dec 2008, Apr 10)**
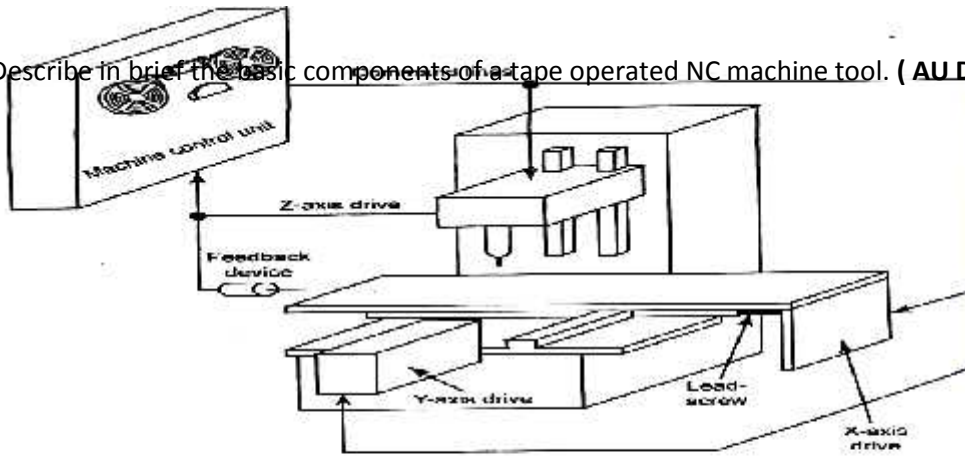
Numerical control system

The part program is arranged in the form of blocks of information. The block contains the numerical data required to produce one segment of workpiece. The punched tape is moved forward by one block each time the cutting of a segment is completed. Dimensional Information is taken from the engineering drawing. Dimensions are given separately for each axis of motion (x, y).

18. Write short notes on APT language. **(AU Dec 2008)**

There are four types of statements in the APT language.

    (i)   Geometric statements

    (ii)   Motion statements

    (iii) Postprocessor statements

    (iv)   Special control or Auxiliary statements

1. Geometric statements

These statements are used to define the part configuration, which includes points, lines, circles, planes, cylinders, ellipses, cones, general conics and quadrics with a total of fifteen different surfaces.

The format used for geometry statement is:

Symbol = geometry type / descriptive data.

2. Motion statements

These statements are used to control the cutter path to generate the part and include start-up procedures, point-to-point programming, cutter description and direction modifiers.

The format used for motion, statement is:

Motion command / descriptive data

3. Postprocessor statements

To write a complete part program, statements must be written to control the operation of the spindle, feed, and other features of the machine tool. These are called *postprocessor statements.*

The postprocessor allows the transformation of a postprocessor control statement into an appropriate code of the control.

The computer calls the part program instructions from bulk storage and sends them to individual machines. It also receives data back from

19. Discuss the important design features of CNC machine tools. **(AU Dec 2009)** time between the central computer and the individual machine tools. illustrates general configuration of DNC system.

Main Difference between CNC and DNC

CNC System can do operations on only one machine at a time. But Direct Numerical control involves that at a time a large central computer to direct the operations of a number of separate NC machines.

Advantages of CNC

Computer Numerical Control possesses a number of existing advantages over conventional NC. These are

(i)   An increase in flexibility.

(ii) An improvement in the possibilities for correcting errors in part programming.

(iii) The possibility of using the computer's peripheral equipment.

(iv) Tape and Tape reader are used only once for resulting improved reliability.

(v)   CNC is more compatible.

(vi) CNC can accommodate conversion of tapes prepared in units of inches to the international unit system.

20. Under what conditions of production the numerically controlled machine tools are employed. **(AU Apr 2010)**

The initial stage involved in the development of a prototype NC milling machine by retrofitting (back fit) a conventional tracer mill i[th] position. Servo mechanisms have for three machine tool axes. The First demo of the NC prototype was held in 1952. By 1953, the usefulness of NC concept had been proven.

Shortly there after, the machine tool builders began initiation of their development projects to introduce commercial NC units. Also certain user industries, airframe builders worked to device numerical control machines to satisfy their needs. Additional researches were going on at MIT.

They developed part programming language which could be used for NC machines which resulted in the Automatically Programmed Tools (APT) language. APT is utilized in many industries and most other languages are based on APT language.

There are numbers of problems in conventional NC machines which have motivated the machine tool builders to seek improvements in basic NC system.

Some of the problems are
    (i)   Part Programming mistakes.
    (ii) Non optimal speeds and feeds.
    (iii) Punched tape wear and tear.
    (iv) Least reliable tape reader.
    (v) Less management information.

To rectify the above said problems, the use of the digital computer has also permitted substantial improvements made in the controls for NC.

Direct Numerical Control (DNC) was the first of the computer control systems to be introduced around 1968. In this evolution, the

computer of that era was quit large and expensive, and the only feasible approach was to use large computer to control a number of machine tools on a time-shared basis. The advantage of DNC was that a direct control link between the computer and the machine tool which eliminates the punched tape input.

The next stage after getting less expensive computers was introducing single small computer to one machine tool. This concept is then called Computer Numerical Control (CNC). The CNC systems were first commercially introduced around 1970, and they applied the soft-wired controller approach to good advantage. One standard computer control could be adapted to various machine tools by programming control functions into the computer memory for particular machine. Being less expensive, the machine tool builders design the CNC control panel as an integral part of the machine tool rather than as a separate stand-alone cabinet. This reduces the floor space requirements for the machine. The very large scale integrated (VLSI) circuits used in these controllers are advantageous to the machine tool designer and to the machine user.

21. Define CNC and DNC. With a help of a diagram explain the working of NC machine tool. **(AU Dec 2008, Apr 09)**

The initial stage involved in the development of a prototype NC milling machine by retrofitting (back fit) a conventional tracer mill ith position. Servo mechanisms have for three machine tool axes. The First demo of the NC prototype was held in 1952. By 1953, the usefulness of NC concept had been proven.

Shortly there after, the machine tool builders began initiation of their development projects to introduce commercial NC units. Also certain user industries, airframe builders worked to device numerical control machines to satisfy their needs. Additional researches were going on at MIT.

They developed part programming language which could be used for NC machines which resulted in the Automatically Programmed Tools (APT) language. APT is utilized in many industries and most other languages are based on APT language.

There are numbers of problems in conventional NC machines which have motivated the machine tool builders to seek improvements in basic NC system.

Some of the problems are
 (i) Part Programming mistakes.
 (ii) Non optimal speeds and feeds.
 (iii) Punched tape wear and tear.
 (iv) Least reliable tape reader.
 (v) Less management information.

To rectify the above said problems, the use of the digital computer has also permitted substantial improvements made in the controls for NC.

Direct Numerical Control (DNC) was the first of the computer control systems to be introduced around 1968. In this evolution, the

computer of that era was quit large and expensive, and the only feasible approach was to use large computer to control a number of machine tools on a time-shared basis. The advantage of DNC was that a direct control link between the computer and the machine tool which eliminates the punched tape input.

The next stage after getting less expensive computers was introducing single small computer to one machine tool. This concept is then called Computer Numerical Control (CNC). The CNC systems were first commercially introduced around 1970, and they applied the soft-wired controller approach to good advantage. One standard computer control could be adapted to various machine tools by programming control functions into the computer memory for particular machine. Being less expensive, the machine tool builders design the CNC control panel as an integral part of the machine tool rather than as a separate stand-alone cabinet. This reduces the floor space requirements for the machine. The very large scale integrated (VLSI) circuits used in these controllers are advantageous to the machine tool designer and to the machine user.
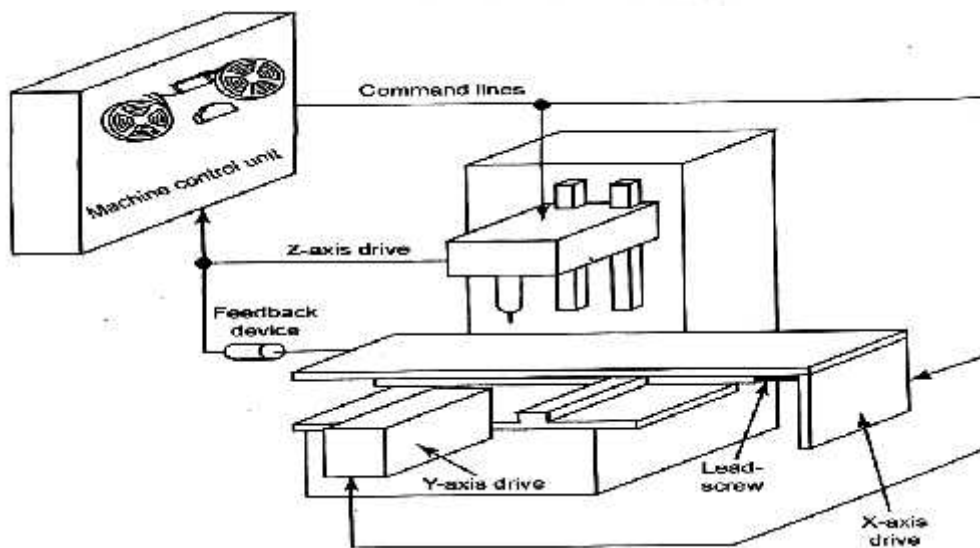
NUMERICAL CONTROL SYSTEM

Controlling a machine tool by means of a prepared program is known as *Numerical Control or NC*.

Definition of NC System

A system in which actions are controlled by the direct insertion of numerical data at some point is known as *NC system*. The system must automatically interpret at least some portion of this data. A general configuration of NC system is shown in fig

In NC system, the numerical data which is required for producing a part is maintained on a punched tape called as *part program*.

Numerical control system

The part program is arranged in the form of blocks of information. The block contains the numerical data required to produce one segment of workpiece. The punched tape is moved forward by one block each time the cutting of a segment is completed. Dimensional information is taken from the engineering drawing. Dimensions are given separately for each axis of motion (x, y).