1

THEORY OF METAL CUTTING

PART A

1. What is orthogonal rake system?

The cutting edge of the tool is perpendicular to the cutting speed direction (or) cutting force of the tool is 90° to line of action.

2 .Why is lubrication is not required while machining cast iron?

Lubrication is not required while machining cast iron, because cast iron contains graphite which act as a self –lubricant.

3.What are the conditions that would allow a continuous chip to be formed in metal cutting?

- Smaller depth of cut
- High cutting speed
- Large rake angle
- Sharp cutting edge
- Proper cutting fluid

4.If the taylor's tool life constants for a given operation are specified as n = 0.5 and C = 400, what is the percentage increase in tool life when the cutting speed is reduced by half?

n = 0.5

C = 400

Cutting speed reduced by half V_2 =

$0.5V_1$, From Taylor's tool life equation

$V_1 T_1^n = C$, $T_1^n = C/V_1$ (n=0.5, C=400)

Solution:

From Taylor's eqn. $V_1 T_1^n = C$, $T_1^n = \frac{C}{V_1}$

$$(T_1)^{\frac{1}{2}} = \frac{400}{V_1}$$

$$T_1 = \left(\frac{400}{V_1}\right)^2 \qquad (1)$$

Also

$$V_1 T_1^n = V_2 T_2^n \qquad (2)$$

Sub eqn (1) in (2)

$$V_1 \frac{C}{V_1} = 0.5V_1 T_2^n \qquad T_1^n = \frac{C}{V_1}, V_2 = 0.5V_1$$

$$(T_2)^{0.5} = \frac{C}{0.5V_1}, \quad (T_2)^{\frac{1}{2}} = \frac{400}{0.5V_1}, \quad T_2 = \left(\frac{400}{0.5V_1}\right)^2$$

$$T_2 = \left(\frac{400}{\frac{1}{2}V_1}\right)^2$$

$$T_2 = 4\left(\frac{400}{V_1}\right)^2$$

$$\text{Increase in tool life} = \frac{T_2}{T_1} \times 100$$

$$= \frac{4\left(\frac{400}{V_1}\right)^2}{\left(\frac{400}{V_1}\right)^2} \times 100$$

$$400$$

5. The useful tool life of an HSS tool, machining mild steel at 25m/min is 5 hours. Calculate the tool life when tool operates at 40m/min

Given data:

V_1 = 25m/min

T_1 = 5 hours = 300 min

V_2 = 40m/min

T_2 = ?

n = 0.2 (machining constant for HSS)

Taylor's equation

$V_1 T_1^n = V_2 T_2^n$

$25 \times 5^{0.5} = 40 \times T_2^{0.2}$

T = 0.477 hours = 28.62 min

6.Mention the condition that induces the formation of built up edge.

- Low cutting speed
- Small rake angle
- Coarse feed
- Strong adhesion between chip and tool face

7.Write a short note on heat zones in cutting

- Shear zone
- Chip tool interface region
- Tool-work interface region

8.Write a short note on any two modern tool materials

- Ceramics
- Diamonds

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.

Diamonds:

Diamond is the hardest cutting material. Poly crystalline diamond is manufactured by sintering under high pressure and temperature. It has low co-efficient of friction, high compressive strength, and it is extremely wear resistant. It is used for machining very hard materials such as glass, plastics, ceramics etc.

9. What is tool signature?

The various angles of tools are mentioned in a numerical number in particular order. That order is known as tool signature.

10.What are the favourable factors for continuous chip with built up edge?

- Low cutting speed.
- Small rake angle.
- Course feed.
- Strong adhesion between chip and tool face.
- Insufficient cutting fluid.

11.What are purposes of chip breakers?

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

12.Classify the different types of chip breakers?

The chip breakers are classified into three types.

Step type.

Groove type.

Clamp type.

13.What are the assumptions made by merchant circle?

The chip formation will be continuous without built up edge.

During cutting process cutting velocity remains constant,

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

14.Define machinability of metal?

Machinability is defined as the ease with which a material can be satisfactorily machined.

15.What are the factors affecting the Machinability?

Chemical composition of work piece material,

Microstructure of work piece material

Mechanical properties like ductility, toughness etc.

Physical properties of work materials.

Method of production of the work materials.

16.What are the factors should be considered for selection of tool materials?

Volume of production

Tool design

Type of machining process

Physical & Chemical properties

Rigidity and condition of machine.

17.What do you understand by cutting tool signature ? (Apr/May 2017)

The various angles of tools are mentioned in a numerical number in particular order. That order is known as tool signature. +

Tool angles have been standardized by the American standard associa- tion (ASA).

18.Define the term machinability and machinability index. (Apr/May 2017)

Mach inability is defined as the ease with which a material can satis- factorily be machined.

Mach inability Index

It is a comparison of mach inability of different material to standard material. It is denoted by “I”

$$I = \frac{\text{Cutting speed of metal investigated for 20 minutes tool life}}{\text{Cutting speed of standard metal for 20 minutes tool life}}$$

19.How does rake angle affect the life of the cutting tool? (Nov/Dec 2017)

Rake angle is the angle between. The tool face and a plane parallel to the tool base. If top take angle increases by keeping the other condi- tions constant, then tool life will increase slightly and required cutting forces decreases. Rake angle may be positive negative.

20.Classify the types of cutting fluids?(Nov/Dec 2017)

i) Water based cutting fluid

ii) Straight or hear oil based cutting fluids

- Mineral oil
- Straight fatly oil
- Mixed oils or compounded oil
- Sulphurised oils
- Chlorinated oils

21.What are the functions of cutting fluids? (apr/may 2019)

It prevents the work piece from excessive thermal distortion.
It improves the surface finish as stated earlier.

It causes the chips to break up into small parts. It protects the finished surface from corrosion.

It washes away the chips from the tool. It prevents the tool from fouling.

It prevents the corrosion of work and machine.

22.List the physical functions of a machine tool in machining. (apr/may 2018)

A machine tool is a machine for shaping, machining metal or other rigid materials by cutting, boring, grinding, shearing or other forms of deformation. Machine tools employ some sort of tool that does the cutting or shaping. All machine tools have some forms of constraining the workpiece and provide a guided movement of the parts of the machine.

23. Define the oblique cutting. (apr/may 2018)

The cutting edge of the tool is inclined at an acute angle with the normal to the cutting velocity vector.

Tool life is more.

24.How tool life is estimated? (nov/dec 2019)(apr/may 2019)

Tool life is estimated by using Taylor's tool life equation.

$VT_n=C$

V – Cutting speed m/mim

T – Tool life in minute

C – Constant

n – index depends upon tool and work

25.Differentiate between orthogonal and oblique cutting.(nov/dec2019)(apr/may 2018)

Orthogonal cutting	**Oblique cutting**
The cutting edge of the tool is perpendicular to the cutting velocity vector	The cutting edge of the tool is inclined at an acute angle with the normal to the cutting velocity vector
Tool life is less	Tool life is more

26.Name the seven elements of tool geometry for a single point cutting tool.
(apr/may 2019)

Shank
Face
Flank
Base
Nose
Cutting edges
Cutting edge angles

27. What is chip and mention its different types? (apr/may 2019)

The sheared material begins to flow along the cutting tool face in the form of small pieces is called chip. The chips are mainly classified into two types.

a. Continuous chip. b. Discontinuous chip. c. Continuous chip with built up edge e. Built Up Edge

PART B

1.How is metal removed in Metal cutting? Explain the process with simple sketch.

Mechanism of Metal Cutting

During Machining, the cutting tool experts a compressive force on the work piece. The material of the work piece is stressed beyond its yield point under this compressive force. It causes the material to deform plastically and shear off. The plastic flow takes place in a localized region called shear plane as shown in figure.1.1. This shear plane extends from the cutting obliquely up to the uncut surface ahead of the 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.

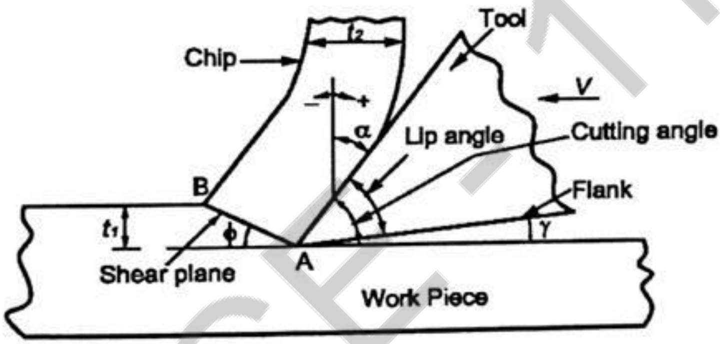


Figure 1.1 Mechanism of Metal Cutting

When the chip flows over the tool, it will wear off the tool. Due to friction, wearing heat is produces. 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 losss of keenness in the cutting edge thereby leading to its failue. The cutting force, heat and abrasive wear are the basic features of the metal cutting process.

The following points are worth to be noted:

The 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.

Hardness

Abrasive qualities

Toughness

Tendency to weld

Inherent hard spots and surface inclusions.

The desirable properties of tool material are hard, strong, tough and wear resistance.

Mechanics of Chip Formation

The mechasim that involves during formation of chip is explained in mechanism of metal cutting itself. The various types of chips are formed during the metal cutting. The type of chip formed during metal cutting depends upon the machining condition and material to be cut. The following variables are influencing in producing the type of chip such as

Mechanical properties of material to be cut in

Depth of cut

various angles of tool especially rake angle

Cutting speed

Feed rake

Type of cutting fluid

Machining temperature of cutting region

Surface finish required on work piece

Coefficient of friction between chip and tool interface

2.Explain the various methods to be applied while using cutting fluids during machining

Method of applying cutting fluid

The method of applying a cutting fluid is very important if one wants to use full benefit and to conserve it or reduce its wastage. The various methods are

(i) Nozzle-Pump Tank Method:

A Pump is mounted on the tank containing fluid and outlet of pump is connected to nozzle through flexible hose. The nozzle directs the stream of fluid at desired point.

(ii) Mist Application:

In this method fluid is passed through a specially designined nozzle so that it forms very fine droplets of cutting fluid or produce a mist of size 5 to 25 μ m directed at cutting zone.

(iii) High Jet Method:

A Narrow jet at high velocity is directed at the flank surface of the tool. It is the most recent method.

3.List the important characteristics of a cutting tool material

Types of cutting tool materials

The various types of cutting tool materials are:

- Carbon tool steels or carbon steels
- Medium alloy steels or Alloy tool Steels
- High Speed Steels (HSS)
- Cast alloys (or) Stellites
- Cemented carbide tool Materials
- Oxide or Ceramic Tool Materials
- Diamond

Characteristics of Carbon Steels

- Carbon Steels have low hot hardness and poor hardenability, they can be worked upto 200 to 250°C. At higher temperature, they loose hardness rapidly.
- Carbon steels are used for cutting soft materials like Wood, Plastic, Aluminium, Copper etc.,
- Carbon Steels are used for making taps and core drills for machining soft materials and for making wood working tools.

Effect of alloying element:

- Tungsten increases the wear resistance
- Chromium and Manganese improves hardenability.
- Vanadium increases toughness by giving heat treatment.

Medium Alloy Steels

In medium alloy steels, alloying elements like Tungsten, Chromium, Molybdenum are added to improve hardenability.

The carbon content in these alloy steel is around 1.2 to 1.3%. Higher Carbon content increases hardness and wear resistance.

Tools of these material can work between 250°C to 300°C and speed is 20 to 40% more than carbon steels.

These steels materials are used in making drills, taps and reamers.

High Speed steels (HSS)

The composition of High Speed Steel is 18% Tungsten, 5.5% Chromium 0.7%, Carbon and small amount of Manganese, Vanadium and Silicon. This HSS steel was develpoed by Frednenck W. Taylor and M. White. It can work upto 600°C at 40 m/min.

Characteristics of HSS

High Tungsten HSS is the best of the above three for all purpose tool steels.

Tungsten and Molybdenum increase the hot hardness.

Vanadium iron Carbide tools are very hard constituents of HSS and imparts high wear resistance to tool at all temperatures.

To increase the cutting effeciencey, 2 to 5% of cobalt is added. One of the composition 2% W, 4% Cr, 2% V, 12% Cobalt are called Super High Speed Steels. Because of heavy cost, it is used for heavy cut operations only.

HSS hot hardness is quite high so it retains the cutting ability upto 600°C at 40 m/min.

HSS has high wear resistance and good hardenability.

Characteristics of Stellites

Cast alloys are not hard at room temperature but becomes very hard above 1000°F (hardness more than HSS)

Cast alloys are very brittle hence not widely used.

Cast alloys have less toughness but more wear resistance than HSS and allow cutting speed thrice than that of HSS.

Uses: Used in manufacture of Valve seats, Push rod sheets and Erosion shield of steam turbine etc.

Characteristics of Cemented Carbide Tools These tools have /are

High hardness, heat resistance, weare resistance, high hot hardness.
These tools can be used upto 1000°C
High thermal conductivity and low thermal expansion compared to steel.
No plastic flow to stress upto 3500 N/mm$_2$
Low impact resistance
Very expensive
Operate at cutting speed upto 45 to 360 m/min.
These are very brittle and hence rigidly supported and have low shock resistance.

Characteristics of ceramic tools

They have very high compressive strength. It is quite brittle.
Low heat conductivity, so not coolant is required during machining.
Have high strength and hot hardness upto 1200°C.
Have low coefficient of friction and hence low heat generated.
Have 2 to 5 times more cutting speed than other tools.

Characteristics of diamond

They are very hard, hence very brittle.
They are abrasion resistant with low coefficient of friction and low thermal coefficient of expansion.
They burn to Co_2 to 800°C
They cannot take shock loads.
High heat conductivity and poor electrical conductor.

4.What is the main function of cutting fluids? Mention its types.

Functions of Cutting Fluids

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 the surface finish will also increase. It prevents the work piece from excessive thermal distortion.

It lubricates the cutting tool and thus it 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.

It improves the surface finish as stated earlier.

It causes the chips to break up into small parts. It protects the finished surface from corrosion.

It washes away the chips from the tool. It prevents the tool from fouling.

It prevents the corrosion of work and machine.

5.With reference to orthogonal cutting, explain the following terms: Shear stress plane, shear strain, cutting ratio, shear angle.

Shear Stress in Shear Plane

During metal cutting, the chips are produced due to the plastic deformation of the metal along the shear plane.

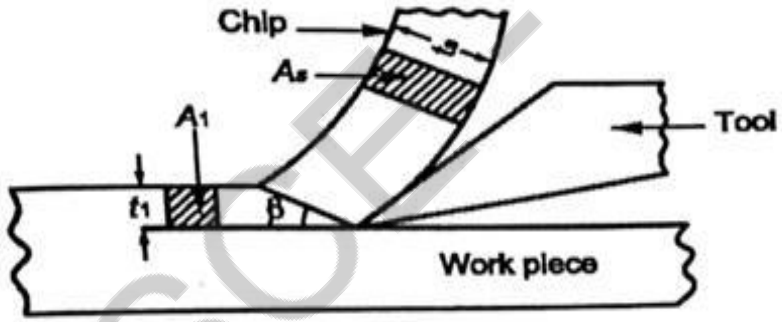


Figure 1.5

Let, A_1 – Area of the chip before removal

A_s – Area of the shear plane

τ – Shear stress in the shear plane

$$\text{Shear stress, } \tau = \frac{\text{Shear force}}{\text{Area}} = \frac{F_s}{A_s}$$

$$A_s = \frac{A_1}{\sin \beta}$$

$$\therefore \tau = \frac{F_s \sin\beta}{A_1}$$

$$= \frac{(F_z \cos\beta - F_x \sin\beta)\sin\beta}{A_1}$$

$$\text{Shear stress, } \tau = \frac{F_z \cos\beta \sin\beta - F_x \sin^2\beta}{A_1}$$

Shear strain

Generally, the chip consists of series of plate elements of thickness t and it is displaced through a distance s relative to each other as shown in Figure 1.6. It is clear that the strain is defined as the deformation per unit length.

$$\text{Shear strain, } e = \frac{s}{t} = \frac{AB}{CD}$$

$$= \frac{BD}{CD} + \frac{DA}{CD} \qquad (AB = BD + DA)$$

$$e = \cot\beta + \tan(\beta - \alpha)$$

$$e = \cot\beta + \frac{\tan\beta - \tan\alpha}{1 + \tan\beta\tan\alpha}$$

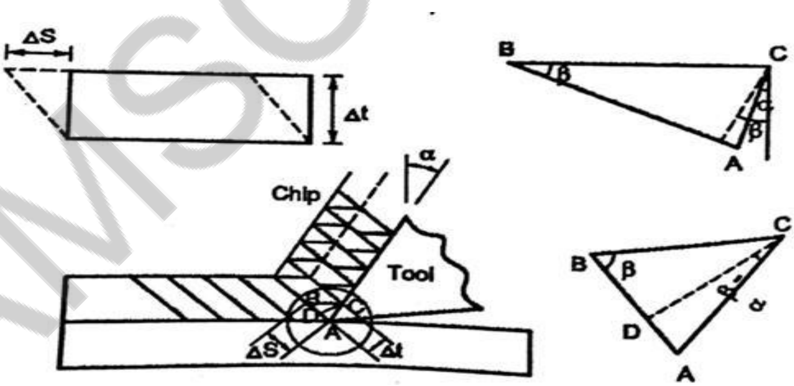


Figure 1.6 Shear strain

We know that

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

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

$$= \frac{\cos\alpha}{k - \sin\alpha}$$

where, $k = \frac{1}{r}$ = Chip reduction coefficient

Substituting tan β value in equation (1.1)

$$e = \frac{k - \sin\alpha}{\cos\alpha} + \frac{\frac{\cos\alpha}{k - \sin\alpha} - \tan\alpha}{1 + \frac{\cos\alpha}{k - \sin\alpha} \times \tan\alpha}$$

$$\frac{k - \sin\alpha}{\cos\alpha} + \frac{\cos\alpha - \tan\alpha \times (k - \sin\alpha)}{k - \sin\alpha + \cos\alpha\tan\alpha}$$

$$\frac{k - \sin\alpha}{\cos\alpha} + \frac{\cos^2\alpha - k\sin\alpha + \sin^2\alpha}{k\cos\alpha}$$

$$\frac{k - \sin\alpha}{\cos\alpha} + \frac{1 - k\sin\alpha}{k\cos\alpha}$$

$$= \frac{k^2 - k\sin\alpha + 1 - k\sin\alpha}{k\cos\alpha}$$

$$= \frac{k^2 - 2k\sin\alpha + 1}{k\cos\alpha}$$

$$\text{Cutting ratio} = \frac{\text{Velocity of chip}}{\text{Velocity of cutting}}$$

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

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

6. Prove that in orthogonal cutting, the kinetic coefficient of friction (μ) is given by

$$\mu = \frac{F_c\sin\alpha + F_t\cos\alpha}{F_c\cos\alpha - F_t\sin\alpha}$$

Merchant Circle Diagram of Forces

The following assumptions are made by Merchant to work out the force relations.

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’

The chip formation will be continuous without built up edge.

During cutting process, the cutting velocity remains constant.

The cutting tool has a sharp cutting edge so that it does not make a flank contact with the work piece.

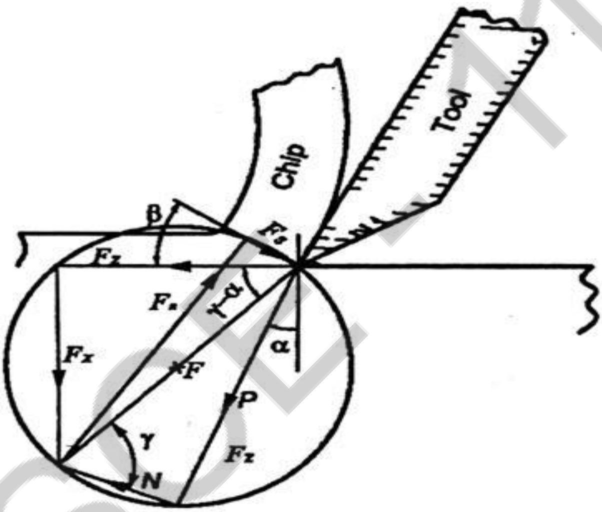


Figure 1.4 Merchant’s circle diagram

Figure 1.4 shows a Merchant circle diagram which is convenient to determine the relation between various forces and angles. In this diagram, two force triangles of Figure 1.3 are combined, and F and F’ together are replaced by F. The circle has a diameter equal to F or F’ passing through tool point as shown in Figure 1.4.

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

The shear angle (β) are obtained from the relation. Then all force components on the chip are determined from the geometry of Figure 1.4. In Figure 1.4, let

= Rake angle of

tool β = Shear angle

γ = Friction angle

When the chip slides over the tool face under the pressure, there is some friction between these two. Therefore, the kinetic coefficient of is obtained below.

Friction (μ) can be expressed as Coefficient of friction,

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

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

$$\tan \beta = \frac{r \cos \alpha}{1 - r \sin \alpha}$$ [Refer Figure 1.4]

Chip thickness ratio, $r = \frac{t_1}{t_2}$ where, t_1 and t_2 – chip thickness before and after cutting respectively.

P – Frictional resistance

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

α N = Normal force

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

α F = Resultant force

Resultant force, $F = \sqrt{F_z^2 + F_x^2}$

F_z = Cutting force

$$F_z = F \cos(\gamma - \alpha)$$

Cutting force, F_s = Shear force

$$F_s = F \cos \theta$$

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

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

Substituting F value in F_z equation,

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

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

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

We know that

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

The coefficient of friction,

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

The relationship for F_s and F_n are given by

$F_s = F_z \cos \beta - F_x \sin \beta$

$F_n = F_z \sin \beta - F_x \cos\beta$

7.Tool life test in turning yield the following data: (1) V=110 m/min,T=20 min; (2) V = 85 m/min, T = 40 min. (a) Determine the n and C values in the Taylor tool life equation. Based on the equation, compute (b) the tool life for a speed of 95m/min and (c) the speed corresponding to a tool life of 30 min.

<u>Given data:</u>

$V_1 = 110$ m/min

$T_1 = 20$ min

$V_2 = 85$ m/min

$T_2 = 40$ min

<u>Solution:</u>

From Taylor's tool life equation

$V_1 T_1^{\,n} = V_2 T_2^{\,n}$

$110 \times 20^n = 85 \times 40^n$

$$\frac{\;}{85} = \frac{40}{20}^{\,n}$$

$1.294 = (2)^n$

$\log(1.294) = n \log(2)$

$$= \frac{\log(1.294)}{\log(2)} = 0.372$$

$V_1 T_1^{\,n} = C$

$110 \times 20^{0.372} = C$

$C = 335.26$

For 95 m/min speed

$95 \times T^{0.372} = 335.26$

T = 29.66 min

For 30 min life

$V \times (30)^{0.372} = 335.26$

V = 94.6 m/min

8.Explain different types of chips produced in cutting with neat sketches.(apr/may 2019)

Types of chips

Generally, there are following three types of chips.

Continuous chip

Discontinuous chip

Continuous chip with build-up edge.

Continuous Chip with Built-Up Edge

During cutting process, the interface temperature and pressure are quite high and also high friction between tool-chip interface. It causes the chip material to weld itself to the tool face near the nose called “built-up edge” as shown in Figure 1.10.

The formation of a built-up edge in continuous chip is a transient and not-stable phenomenon. The accumulated built-up of chip material will then break away, part adhering to the underside of the chip and part to the work piece. Thus, the process gives a rise to the poor surface finish on the machined surface accelerated wears on the tool face.

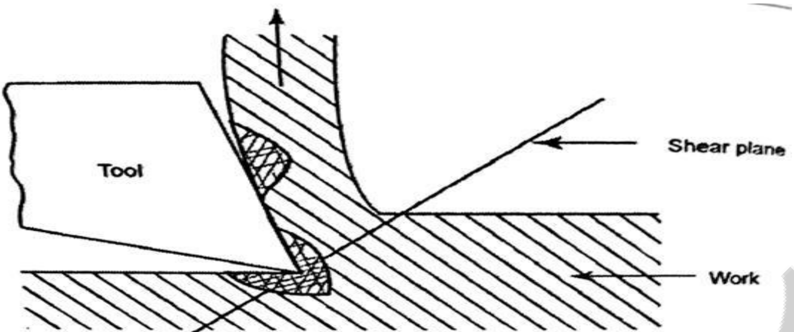


Figure . Continuous chip with built-up edge

However, this type of chips has some advantages. The one important favour of it is that the rake face of the tool protected from wears due to moving chips and the action of heat. It may result the increasing of tool life.

The following conditions favour the formation of continuous chips with built-up edge

- Low cutting speed
- Small rake angle
- Coarse feed
- Strong adhesion between chips and tool interface
- Insufficient cutting fluid
- Large uncut thickness
- Large rake angle
- Sharp cutting edge
- Proper cutting fluid
- Low friction between tool face and chip interface.

Discontinuous or Segmental Chip

Discontinuous chips as shown in Figure 1.9 are produced while machining brittle materials such as grey cast iron, bronze, high carbon steel at low cutting speeds without fluids when the friction exists between tool and chip interface.

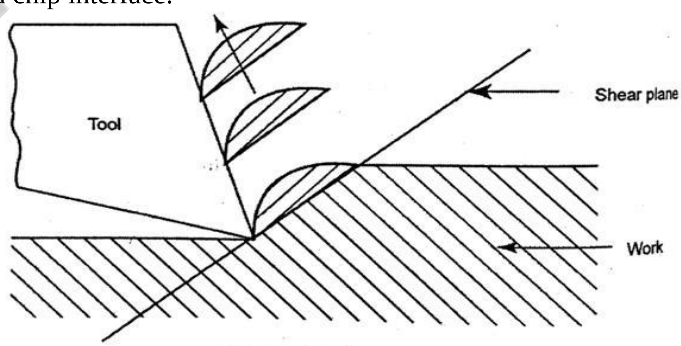


Figure 1.9 Discontinuous chip

During machining, the brittle material lacks its ductility which is necessary for the plastic chip formation. But, it should be less. It results the formation of discontinuous chip. In the case of continuous chip, the formation shearing occurs at the head of the cutting tool formation, the rupture occurs intermittently which will produce segments of chips.

Handling of these chips is easier and it can be easily disposed off since they are having small lengths. Also, it will not spoil the finished work surface as they do not interface.

The following conditions favours the formation of discontinuous chips

- Machining of brittle material
- Small rake angle
- Higher depth of cut
- Low cutting speeds
- Excess cutting fluid
- Cutting ductile material at very low feeds with small rake angle of the tool.

Continuous Chip

During cutting of ductile material, a continuous ribbon such as chips is produced due to the pressure of the tool cutting edge in compression and shear. These types of chips are in the form of long coil and have the same thickness throughout the length.

This type of chip is most required, since it gives the advantage of good surface finish, improving the tool life and less power consumption. However, the chip disposal is not easy and the surface finish of the finished work gets affected.

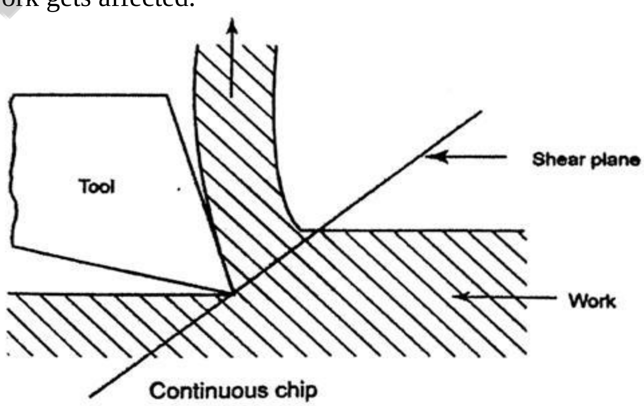


Figure 1.8 Continuous chip

The following condition favours the formation of continuous chips.

Ductile material such as low carbon steel, aluminium, copper etc.
Small depth of cut
High cutting speed

9.Discuss any four cutting tool materials used in metal cutting.

Classification of Tool Materials

The following metals are suitably heat treated wherever required in manufacturing cutting tools.

Carbon tool steel
High speed steel
Cemented carbides
Ceramics
Diamonds

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 – 01 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 up to 5%. Chromium and molybdenum are added to increase hardenability of steel whereas the tungsten is added to improve wear resistance. The hardness is lost at 350°C. These metals are used to make taps, reamers, punches, dies, knives etc.

High speed steels (HSS)

This tool steel effectively cuts the metal 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 up to 900°C. The various alloying elements to improve hot hardness and wear resistance are tungsten, chromium, vanadium, cobalt and molybdenum. HSS is widely used for drills, milling cutters, broaches, taps, turning tools and dies.

The various types of High-speed steels are:

- 18-4-1 High speed steel
- Molybdenum High speed steel
- 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 commoly used for all purposes. This type of material gives excellent performance over a great range of materials and cutting speeds and retains its hardness up to 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 are 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 such as planer tools, milling cutters, lathe tools etc.

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. It is combined with cobalt, compacted and sintered in a furnace about 1400°C and it can be used at much higher cutting speeds. The composition is 82% tungsten carbide, 10% titanium carbide and 8% Cobalt. Then usually take the form of inserts (either braced or clamped form). The clamped inserts can be thrown, after wearing out of all cutting edges take 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 it has low resistance to shock. It must be supported strongly to prevent cracking.

These tool materials are classified into two main types, namely

- Straight tungsten carbides
- Alloyed tungsten carbides

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

Titanium carbide improves the hot hardness and it reduces the tendency of chips to weld to the tool. The addition of titanium carbides helps to improve resistance to crater wear and it makes the structure fine grained. For optimum results, both titanium and tantalum carbides are often made. Carbides are used for machining hard steels and for machining brittle materials such as cast iron and bronze.

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 cannot be used where more shocks 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.

This material is used for making single point cutting tools to machine cast iron and plastics. No coolant is needed but the tool must be strongly supported.

The various conditions for the effective use of carbide or ceramic tools are:

- High cutting speeds
- Rigidity of tool and work piece
- Highly finished surface on cutting tool
- Use of effective chip removal and chip guards
- Elimination of any unbalanced forces

10.In an orthogonal cutting test with a tool of rake angle 8°, the following observations were made:
Chip thickness ratio: 0.2

Horizontal component of the cutting force = 1190N

Vertical component of the cutting force = 1450N

From Merchant's theory calculate the various components of the cutting forces and the coefficient of friction at the chip tool interface.

Given Data:

F_H = 1190N, F_V = 1450N
= 0.2 α = 8°

To find:

(i) Friction force P, Normal force N, Shear force F_s,
F_n (ii) Resultant force F,
(iii) Coefficient of friction
'μ' (iv) Shear angle 'β'

Formula to be used:

(i) $\beta = \tan^{-1}\dfrac{\gamma\cos\alpha}{1-\gamma\sin\alpha}$

(ii) Coefficient of friction $\mu = \frac{P}{N}$

(iii) Friction force $P = F_H\sin\alpha + F_v\cos\alpha$ Normal force $N = F_H\cos\alpha - F_v\sin\alpha$

(iv) Shear force $F_s = F_H\cos\beta - F_\gamma\sin\beta$

$F_n = F_\gamma\cos\beta + F_H\sin\beta$

Resultant force $F = \sqrt{F_s^2 + F_n^2}$

Solution:

(i)

$\beta = \tan^{-1}\dfrac{\gamma\cos\alpha}{1-\gamma\sin\alpha}$

$= \tan^{-1}\dfrac{0.2\times\cos 8}{1-0.2\times\sin 8}$

$\tan^{-1}\dfrac{0.1980}{0.9722}$

$\tan^{-1}(0.203)$

$= 11.51$

Friction force $P = F_H \sin\alpha + F_v \cos\alpha$

$= 1190 \times \sin 8 + 1450 -$

$\cos 8$ $P = 1601.5N$

Normal force $N = F_H \cos\alpha - F_v \sin\alpha$

$= 1190 \times \cos 8 - 1450 -$

$\sin 8$ $N = 976.62N$

Coefficient of friction at chip tool interface $\mu = \frac{P}{N} = \frac{1601.5}{976.62}$

$= 1.6398$

$\tan \gamma^5 = \mu$

$^5 = \tan^{-1} \mu$

$^5 = \tan^{-1} (1.6398)$

$^5 = 58.6$

$= \tan \gamma^5$

$\tan^{-1} \mu = \gamma^5$

$^5 = \tan^{-1} (1.887)$

$^5 = 62°$

(v) Shear force $F_s = F_H \cos\beta - F_\gamma \sin\beta$

$1050 \cos(11.51) - 1450$

$\sin(11.51)$ $F_s = 739.55N$

(vi) Force acting per pendicular to shear plane (F_n)

$F_n = F_\gamma \cos\beta + F_H \sin\beta$

$1450 \cos(11.51) + 1050 \sin(11.51)$

$F_n = 1630N$

Resultant cutting forces

$= \sqrt{F_s{}^2 + F_n{}^2}$

$\sqrt{(739.55)^2 + (1630)^2}$

= 1789.9 η1790N

Result:

β = 11.51

Coefficient of friction μ = 1.6398

Resultant force F = 1780 N

11.Explain in detail Tool Wear and also factors influencing tool wear. (nov/dec 2019)

12.Explain the different types of tool wear that occur in metal cutting. (apr/may 2019)

13.Discuss briefly the various types of tool wear with neat sketches. (apr/may 2018)

Tool wear

During machining process, the tool is subjected to three important factors such as forces, temperature and sliding action due to relative motion between tool and work piece. In foresaid factors, the tool will be giving unsatisfactory performance after sometime. It results the loss of dimensional accuracy, increased surface roughness and increased power requirements etc. the unsatisfactory performance results tool wear due to its continuous use. Therefore, the tool techniques a periodical reconditioning or replacement. It will result the loss of production and also the cost of replacing or reconditioning. Hence, the study of tool wear is important.

Mechanism/Forms of Tool Wear

1. Attrition:

In low cutting speeds, the flow of metal from the cutting edge is irregular and less streamlined. Sometimes, the built-up edge might be formed but the contact will not be continuous. In this situation, the tool will start to tear from the tool surface. It is called as attrition. It occurs in continuous cutting but with interrupted cutting or due to lack of rigidity of the machine tool which will generate enormous vibrations and uneven work surfaces. All these reasons will lead the tool to destroy its cutting edges. Attrition could be minimized by increasing the cutting speed or using carbide tips as cutting edges where the built-up edge forms.

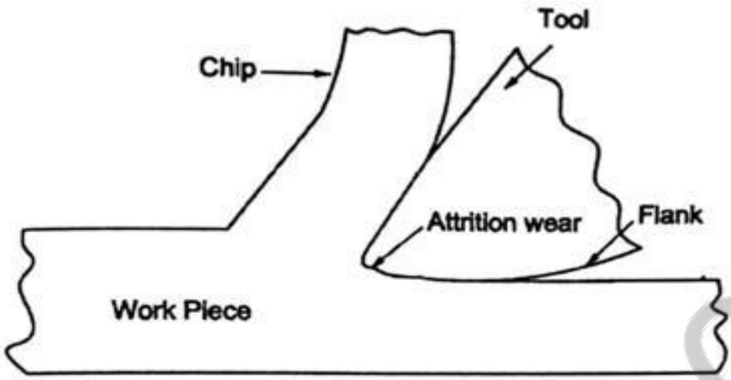


Figure 1.41 Attrition wear

2. Diffusion:

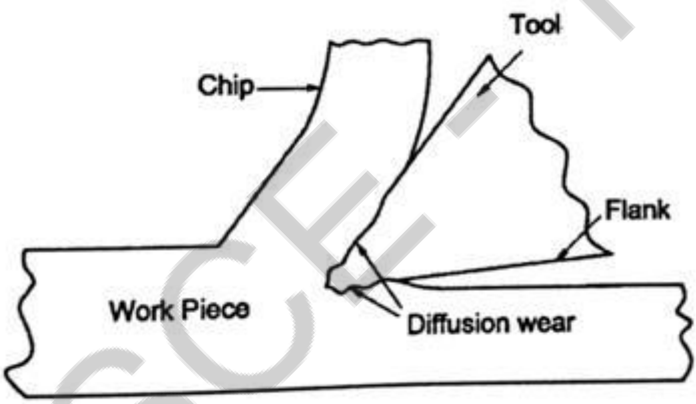


Figure 1.42 Diffusion wear

Diffusion wear happens due to the diffusion of metal and carbon atoms from t he tool surface into the work material and chips. It is also due to high temperature and pressure existing at the contact surfaces in metal cutting and rapid flow of chips. It mainly depends on the metallurgical properties of tool and work.

Classification of Tool Wear

The tool wear is generally classified as follows.

Flank wear or Crater wear

Face wear

Nose wear

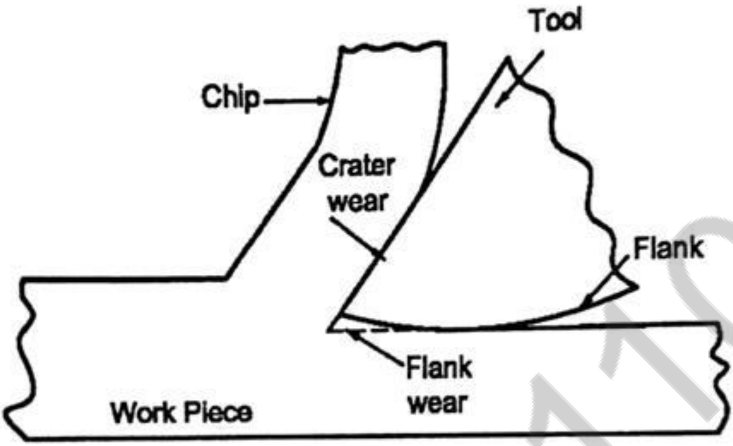


Figure 1.43 Tool wear

1. Flank wear:

This is also called “edge wear”. Friction, abrasion, adhesions are the main causes for this type of wear. Flank wear is a flat worn out portion behind the cutting edge. The worn out region of the flank is known as wear land. The wear takes place when machining the brittle material such as cast iron. It also occurs when the feed is less than 0.15mm/revolution. When the wear land increases, the frictional heat will cause excessive temperature of the tool at the cutting edge thereby decreasing its hardness rapidly and hence, the catastrophic failure of the tool will occur. Flank wear results a rough machined surface.

2. Crater wear:

The face of the tool is always contacted with the chip. The chip slides over the face of the tool. Due to the pressure of the sliding chip, the tool face gradually wears out. A cavity is formed on the tool face. The cavity is called crater. This type of wear is known as crater wear. The major tendency of this type of ware is abrasion between chip and face of the tool. When the cratering becomes excessive, the cutting edge may break from the tool.

Cratering is commonly occurred while machining a ductile material which produces continuous chips. Diffusion of metal may be one of the causes of this type of wear. The maximum depth of the crater is usually a measure of the amount of the crater wear. The tool life due to crater wear can be determined by fixing the ratio of width of crater to its depth.

3. Nose wear:

It is similar to flank wear in certain operations. The wear occurs on the nose radius of the tool. When the nose of the tool is rough, abrasion and friction between tool and work piece will be high. Due to this type of wear, more heat will be generated. Also more cutting force will act on the tool. This type of wear is more prominent than flank wear.

14.Mention the desirable properties of a cutting tool material and the improvements caused by coated carbides.

15.Detail on the desirable properties of cutting fluids. (Nov/Dec 2019)

<u>Properties of cutting fluids</u>

A cutting fluid should have the following properties

- It should have good lubricating properties to reduce frictional forces and to decrease the power consumption.
- It should have high heat absorbing capacity.
- It should have a high specific heat, high heat conductivity and high film coefficient.
- It should have 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 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.

16.In an orthogonal cutting test with a tool of rake angle 10°, the following observations were made:

Chip thickness ratio = 0.3

Horizontal component of cutting force = 1290N

Vertical component of cutting force 1650N

From Merchant's theory, calculate the various components of the cutting forces and the coefficient of friction at the chip tool interface.

Given data:

$F_H = 1290N$

$F_v = 1650N$

$r = 0.3$

Solution:

$$\text{Shear angle, } \beta = \tan^{-1} \frac{r \cos \alpha}{1 - r \sin \alpha}$$

$$= \tan^{-1} \frac{0.3 \cos 10}{1 - 0.3 \sin 10} = 17.31°$$

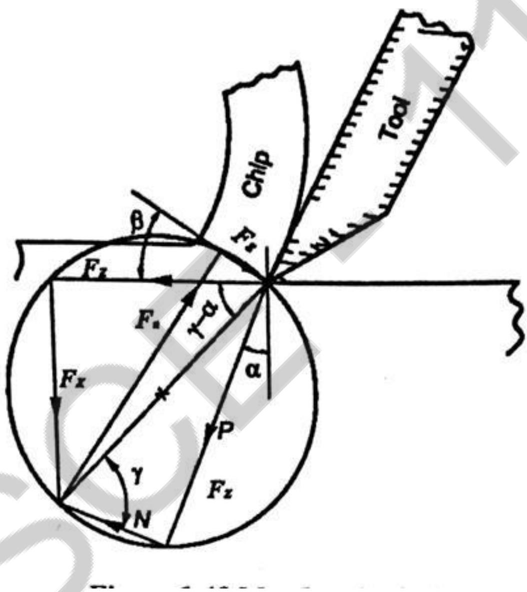


Figure 1.45 Merchant's circle

The friction force,

$P = F_H \sin \alpha + F_V \cos \alpha$

$1290 \sin 10 + 1650 \cos 10$

$1848.9N$

The normal force, $N = F_H \cos \alpha - F_V \sin \alpha$

$1290 \cos 10 - 1650 \sin 10$

$983.9N$

The coefficient of friction at chip-tool interface

$= \frac{P}{N}$

$= \frac{1848}{983.9} = 1.8792$

$= \tan \gamma$

$= \tan^{-1} \mu$

$\tan^{-1} (1.8792) = 62°$

Shear force, $F_s = F_H \cos \beta - F_v \sin \beta$

$1290 \times \cos 18.43° - 1650 \times \sin 18.43$

$F_s = 740.6N$

Force acting perpendicular to shear plane,

$F_n = F_v \cos \beta + F_H \sin \beta$

$1650 \times \cos 18.43° + 1290 \times \sin$

$18.43\ F_n = 1959.1N$

Resultant cutting forces,

$= \sqrt{F_s^2 + F_n^2}$

$\sqrt{1290^2 + 1650^2}$

$F = 2094.4N$

17.What are the functions of a cutting fluid ?

Functions of Cutting Fluids

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 the surface finish will also increase. It prevents the work piece from excessive thermal distortion.

it lubricates the cutting tool and thus it 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.

It improves the surface finish as stated earlier.

It causes the chips to break up into small parts. It protect the finished surface from corrosion.

It washes away the chips from the tool. It prevents the tool from fouling

It prevents the corrosion of work and machine.

18.In an orthogonal cutting test with a tool of rake angle 8°, the following observations were made:
Chip thickness ratio = 0.2
Horizontal component of cutting force = 1050N
Vertical component of cutting force 1450N
From Merchant's theory, calculate the various components of the cutting forces and the coefficient of friction at the chip tool interface.

Given data:

$F_H = 1050N$

$F_v = 1450N$

$r = 0.2$

$\alpha = 8°$

Formula to be used:

(i) $\beta = \tan^{-1} \frac{r \cos \alpha}{1 - r \sin \alpha}$

Coefficient of friction $= \frac{P}{N}$

Friction force $P = F_H \sin \alpha + F_v \cos \alpha$ Normal force $N = F_H \cos \alpha - F_v \sin \alpha$

Shear force $F_s = F_H \cos \beta - F \sin \beta$

$F_n = F \cos \beta + F_H \sin \beta$

Resultant force $F = \sqrt{F_s^2 + F_n^2}$

Solution:

(i) Shear angle, $\beta = \tan^{-1} \frac{r \cos \alpha}{1 - r \sin \alpha}$

$= \tan^{-1} \dfrac{0.2 \cos 8}{1 - 0.2 \sin 8}$

$\tan^{-1} \dfrac{0.1980}{0.9722}$

$\tan^{-1}(0.203)$

$= 11.51°$

Friction force

$P = F_H \sin\alpha + F_v \cos\alpha$

$= 1050 \times \sin 8 + 1450 - \cos 8$

$P = 1582N$

Normal force $N = F_H \cos\alpha - F_v \sin\alpha$

$1050 \cos 8 - 1450 \sin 8$

$N = 837.98N$

Coefficient of friction at chip tool interface $\propto = \dfrac{P}{N} = \dfrac{1587}{837.98}$

$\mu = 1.887$

Shear force

$F_s = F_H \cos\beta - F_\gamma \sin\beta$

$1190 \cos(11.51) - 1450 \sin(11.51)$

$F_s = 876.74N$

Force acting per pendicular to shear plane (F_n)

$F_n = F_\gamma \cos\beta + F_H \sin\beta$

$= 1450 \cos(11.51) + 1190$

$\sin(11.51)$ $F_n = 1658.3N$

Resultant cutting forces

$= \sqrt{F_s^2 + F_n^2}$

$\sqrt{(876.74)^2 + (1658.3)^2}$

$F = 1875.8N$

Result:

$\beta = 11.51°$

Coefficient of friction $\mu = 1.64$

Resultant force $F = 1875.8$ N

19.Define machinability. What are the factors influencing machineability of a cutting tool.(Nov/Dec2019)

1.27. MACHINABILITY

Machining may be easier in some materials whereas it may be difficult in other. This difference may be attributed to the machinability of various materials. *Machinability* is defined as the ease with which a material can be satisfactorily machined. It can also be measured by the following factors.

- The life of tool before tool failure or resharpening.
- The quality of the machined surface.
- The power consumption per unit volume of material removed.

In general, a good machinability is associated with the removal of material with moderate forces. The action of proper chips does not cause excessive tool wear and it produces a good surface finish. Generally, high hardness gives poor machinability because of high temperature, more power consumption and high tool wear.

1.27.1. Variables Affecting Machinability

1. Work variables:

The various work variables affecting machinability are:

- chemical composition of workpiece material
- micro-structure composition of workpiece material

- mechanical properties such as ductility, toughness, brittleness etc.
- physical properties of workpiece material
- method of production of the work material.

2. Tool variables:

The various tool variables affecting machinability are:

- the geometry and tool material
- nature of engagement of tool with the work
- rigidity of tool.

3. Machine variables:

The machine variables are:

- rigidity of the machine
- power and accuracy of the machine tool.

The machine should be rigid and it has sufficient power to withstand the induced cutting forces and to minimize deflections.

4. Cutting conditions:

Cutting speed has the greatest influence on tool life. The surface finish is improved by increasing the cutting speed. Dimensions of cut also have an influence on tool life.

1.27.2. Evaluation of Machinability

The following are the criteria suggested for evaluating machinability:

- tool life per grind
- rate of metal removal per tool grind
- magnitude of cutting forces and power consumption
- surface finish
- dimensional stability of the finished work
- heat generated during cutting
- ease of chip disposal
- chip hardness
- shape and size of chip.

1.27.3. Advantages of High Machinability

The following are the advantages of having high machinability.

(i) Good surface finish can be produced.

(ii) Higher cutting speed can be used.

(iii) It needs less power consumption.

(iv) Metal removal rate is high.

(v) Less tool wear occurs.

1.27.4. Machinability Index

It is a quantitative measure of machinability. It is used to compare the machinability of different metals and acts as a quick and reliable checking method. The rated machinability of two or more metals may vary for different processes of cutting such as heavy turning, light turning, forming, milling etc. US National Standard for 100% machinability is SAE 1112 hot rolled steel. This steel is widely used as standard steel for comparison.

Machinability index,

$$I = \frac{\text{Cutting speed of metal investigated for 20 minutes tool life}}{\text{Cutting speed of standard steel for 20 minutes tool life}} = \frac{V_i}{V_s}$$

The machinability index for some common materials is given below.

Low carbon steel	-	55 - 60%
Stainless steel	-	25%
Red brass	-	180%
Aluminium alloy	-	390 - 1500%
Magnesium alloy	-	500 - 2000%.

20. Explain in detail Orthogonal and Oblique cutting. (Nov/Dec 2019)

1.3.1. Orthogonal Cutting Process

In orthogonal cutting, the cutting edge is straight, parallel to the original plane surface on the workpiece and perpendicular to the direction of cutting. For example: Lathe cut-off operation, straight milling, etc. Orthogonal cutting involves only two forces and it makes the analysis simpler.

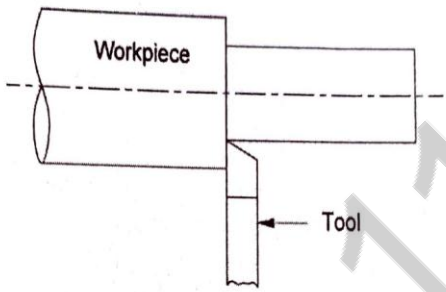


Figure 1.1 Orthogonal cutting

1.3.2. Oblique Cutting Process

In oblique cutting, the cutting edge is inclined at an acute angle with the normal to the cutting direction. The analysis of the oblique cutting is more complex. In actual machining, cutting operations such as turning, milling etc. are oblique cutting.

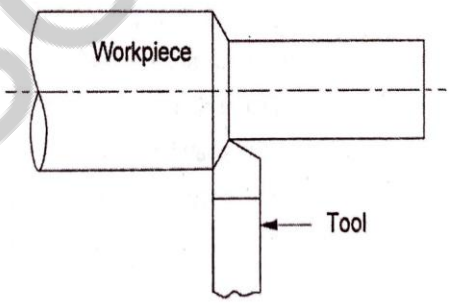


Figure 1.2 Oblique cutting

1.3.3. Comparison of Orthogonal and Oblique Cutting

S. No.	*Orthogonal cutting*	*Oblique cutting*
1.	The cutting edge of the tool is perpendicular to the direction of cutting.	The cutting edge is inclined at an acute angle with the normal to the direction of cutting.
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 is longer than the width of the cut.	The cutting edge may or may not be longer than the width of the cut.
4.	The maximum chip thickness occurs at its middle.	The maximum chip thickness may not occur at the middle.
5.	The tool is perfectly sharp and it contacts the chip on rake face only.	Frequently, more than one cutting edge is 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.

2

TURNING MACHINES

PART A

1.What are the various methods available for taper turning in a lathe?

Form tool method
Tailstock set over method
Compound rest method
Taper turning attachment method

2.Differentiate between an automatic and a semi-automatic lathe?

Automatic lathe	Semi-Automatic lathe
All operations including loading and unloading are automatically done	Unloading and loading of job, bringing the tools in correct positions, codant on & off selection of spindle speed are manually performed.
Time of production is minimized	Time of production is maximum compare to automatic lathe

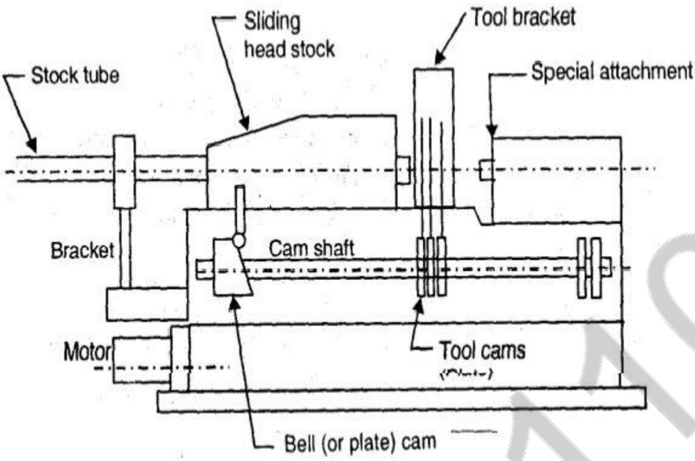
3.How do you specify a lathe?

The length of bed
Maximum distance between dead and live centres
Type of bed
The height of centres from the bed
Spindle speed

4.What are the difference between automatic lathe and capstan lathe?

Automatic lathe	Capstan lathe (Semi – Automatic)
All operations including loading and unloading are automatically done	Loading and unloading of job coolant, on & off, selection of spindle speed are manually performed
Time of production is minimized	Time of production is maximum compare to automatic lathe

5.Give a sketch illustrating the principle of operation of swiss type automatic lathe.



6.What is meant by "Swing of the lathe"?

The largest diameter of work that will revolve without touching the bed and twice the height of the center measured from the bed of the lathe.

It can also be defined as the "swing of a lathe" which describes the maximum diameter of an object that will clear of the bed of the machine when gripped in the chuck.

7.What do you mean by copy turning?

The turning is performed by the tool by following a "temperature or master" through a stylus or tracer. The tracer is connected to the cutting tool through hydraulic devices. According to the tracer movement, the tool moves to machine the job.

8.What is a centre gauge that is used in threading?

A Centre gauge is a tool used in machining to check angle of tool bits used to cut the screw threads i.e. threading

Centre gauge is a small flat hand held object made of metal, triangular notches are cut into the metal of precise dimensions and angles and these notches are used as templates for shaping the machine tool bit.

9.What are programmed automatic lathes?

The standard automatic lathe is programmed to produced parts by means of cams, stops or other mechanical methods.

Cam controlled lathes are not referred as programmed lathes, but the complete versatility in programming is provided by numerical control. In NC lathe, the programming is provided by punched tape and no cams are required. Latest development of NC machine is called as CNC. It is controlled by a central processing unit (CPU).

10.What are the various operations can be performed on a lathe?

Turning 2) Facing. 3) Forming. 4) Knurling 5) Chamfering 6) Thread cutting. 7) Drilling 8) Boring 9) Recessing 10) Tapping 11) Grooving etc.

11.State the various feed mechanisms used for obtaining automatic feed. (apr/may 2018)

Tumbler gear mechanism
Quick change gearbox.
Tumbler gear-Quick change gearbox.
Apron mechanism.

12.List any four work holding devices.

1) Chucks, 2) Centres, 3) Face plate, 4) Angle plate 5)mandrel 6)carriers

13.Define steady and follower rest.

Steady rest: - It is fixed on bed ways of the lathe by .clamping the bolts.

Follower rest: - The saddle is mounted on the saddle and moves together with the tool.

14.What is the use of Mandrels?

Mandrels are used for holding hollow work pieces.

15.Define the term "Conicity".

The ratio of the difference in diameters of the taper to its length. K = (D-d) / l

Where,

D - Larger diameter
d - Smaller diameter
l - Length of the work piece.

16.State the important requites of capstan and turret lathe.

l) Bed 2) Head stock. 3) Turret head 4) Saddle and Cross slide.

17.Name any four work holding devices in capstan lathe.

1) Collets 2) Chucks 3) Fixtures 4) Power chucks

18.Name any four tool holding devices

Multiple cutter holders. 2) Offset cutter holder.

Sliding cutter holder. 4) Knee tool holder.

19.What is reaming and boring operation?

Reaming: - It is the operation of finishing and size a already drilled hole.
Boring: - It is the process of enlarging a already drilled hole.

20.Define filing operation.

Filing is the process of removing bars, sharp corners and feed marks on a work piece by removing very small amount of metal.

21.How do you specify a lathe? (Apr/May 2017)

- The length of bed
- Maximum distance between dead and live centres
- Type of bed
- The height of centres from the bed
- Spindle speed

22.What are the various methods available for taper turning in a lathe? (Apr/May 2017)

- Form tool method
- Tailstock set over method
- Compound rest method
- Taper turning attachment method

23.What are the principle pelts of lathe? (Nov/Dec 2017)

a) Bed b) Headstock

c) Tailstock d) Carriages

e) Feed mechanism f) Thread cutting mechanism

24.List of the various types of lathe? (Nov/Dec 2017)

i) Bench lathe ii) Speed lathe

iii) Engine lathe iv) Tool room lathe

v) Capstan & Turret lathe vi) Automatic lathe

vii) Special purpose lathe

.

25.Write the advantages of automats over conventional lathes. (apr/may 2018)(nov/dec 2018)

a) Mass production of identical parts
b) High accuracy
c) Time of production is minimized
d) The bar stock is fed automatically.

26.What are the various mechanisms that are used for automatic feding in lathes? (apr/may 2018)

- Tumbler gear reversing mechanism
- Quick-change gearbox
- Tumber gear quick-change gearbox
- Apron mechanism

27.Write down any four operations performed on a center lathe. (nov/dec 2018)

- Centering
- Turning
- Facing
- knurling

28.How does a turret lathe is differ from an engine lathe?(apr/may 2019)

In the turret lathe (semi-automatic lathe) a hexagonal turret head replaces the tailstock.

29.How is turret lathe classified ? (nov/dec 2019)

Classification according to the type of turret head

a) Ram-type
b) Saddle type

30.Write short notes on tool layout. (nov/dec 2019)

These planning of operation sequence and preparation of turret or capstan are termed as tool layout. The accuracy and cost of the product are largely dependent on an efficient tool layout.

The tool layout mainly consist of three stages.

- Planning and scheduling stage: preparation of operation sheet with the order of operation.
- Detailed sketching of various stages of machining operation in a sequence of operations.
- Sketching the plan showing the various tools into the hexagonal turret faces and on the cross slides in a proper sequence

PART B

1.**Explain the method of thread cutting using compound slide in a lathe. (Nov/Dec 2018)**

There should be a certain relation between job revolutions and the revolution of the lead screw to control the linear movement of the tool parallel to the job when the half nut is engaged with the lead screw.

The tool should be ground to the proper shape or profile of the thread to be cut.

In modern lathe, quick change gear box is provided in which different ratios of spindle and lead screw revolutions can be easilty obtained by simply shifing the change gear level.

In ordinary lathe, this is effected by set of change gears arranged between the spindle and the lead screw.

The principle of thread cutting is illustrated in Fig. 2.77 using compound slide method

Pitch is the distance between adjacent, corresponding points on a helix thread measured parallel to the axis.

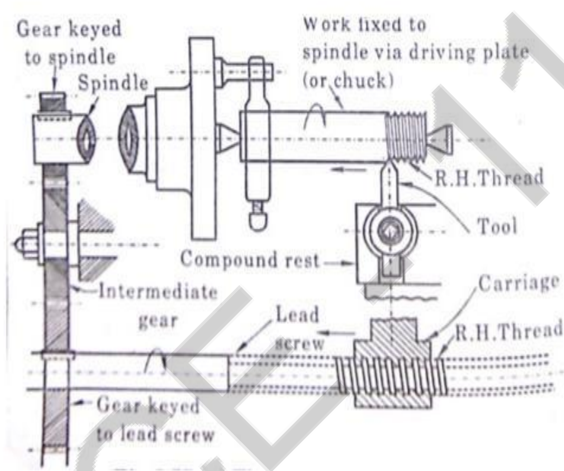


Fig. 2.77. (a) Thread Cutting Princple

Lead is the axial distance a point moves along the helix in one revolution (i.e the distance a nut would move along a bolt in one revolution)

Pitch and lead for single start helix and two start helix is shown in Fig 2.78

For single start helix, Lead = Pitch and for Multistart Lead = Pitch X Number of Start.

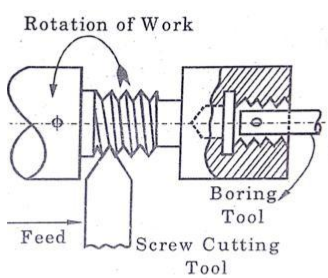


Fig. 2.77 (b) External and Internal Thread Cutting.

2.List the types of Work holding devices and Tool holding devices that are generally used in a turret lathe.

Work holding devices

Some of the standard work holding devices used to hold the work in a latch below.

- Chucks
- Centres
- Faceplate
- Angle plate
- Mandrels
- Steady and follower rest.

Chucks

Chucks are used to hold the workpieces of small length (L<4D) and large diameters. It can also hold the irregular shape workpieces. Workpieces which cannot be mounted between centres are mounted in chuck is attached to the headstock spindle of the lathe. The work is clamped jaws of the chuck and jaws are tighted. The right end of the workpiece can be supported by the dead centre if needed. There are three types of chucks.

- Three jaw chuck of self-centering chuck
- Four jaw chuck or Independent chuck
- Magetic chuck.

Three jaw or self-centering chuck:

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

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 the disc. By rotating any one of these bevel pinions, the disc will rotate. Hence, jaws meshed with scroll move. This chuck is used for holding round, hexagonal and other regular shaped workpiece.

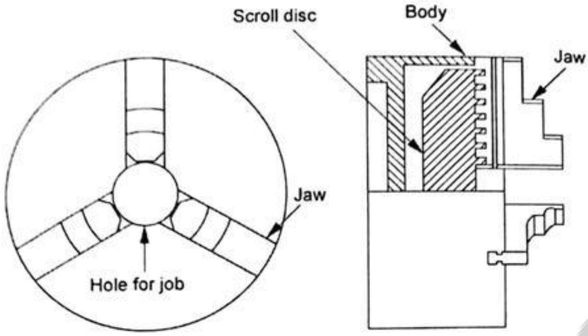


Figure 2.16 Three jaw chuck

Four jaw or Independent Chuck:

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

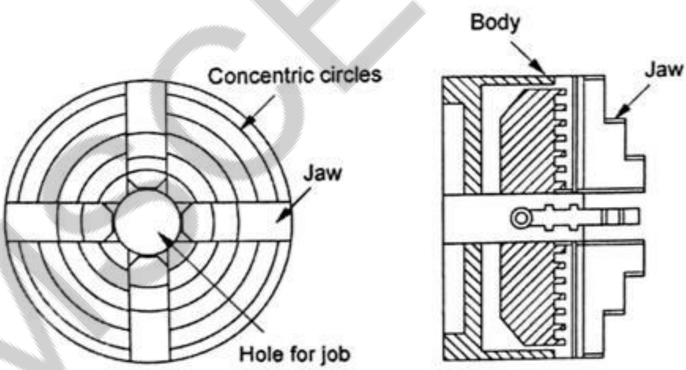


Figure 2.17 Four jaw chuck

Magnetic chuck:

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

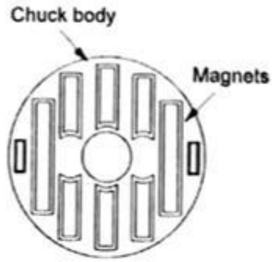


Figure 2.18 Magnetic chuck

Centres

Generally, the long shaft can be held between centres. Catch plate and dog carriers are used to hold the job between centres. The catch plate is in the form of a circular disc as shown in Figure 2.19 and it is screwed on the spindle nose. The various dog carriers are shown in Figure 2.20. These dog carriers are clamped to the job by a screw. The tail of the dog carrier is attached to the catch plate.

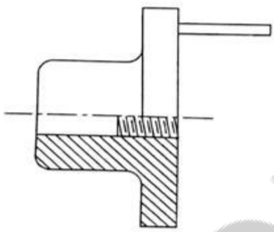


Figure 2.19 Catch plate

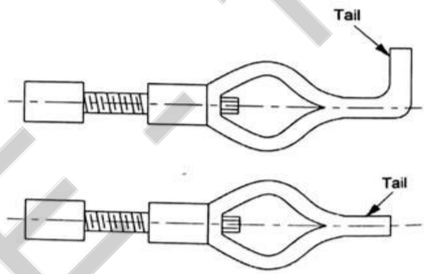


Figure 2.20 Lathe dogs

The live centre is inserted in the headstock spindle. The tailstock carries a dead centre. Small holes are drilled on both ends of the job and they are supported by centres. The various lathe centres are shown Figure 2.2

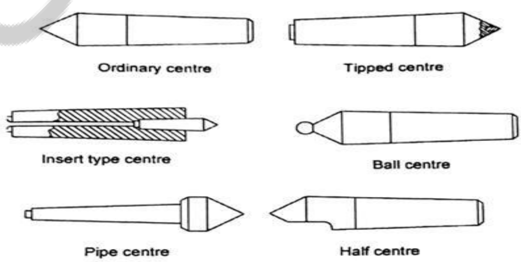


Figure 2.21 Lathe centres

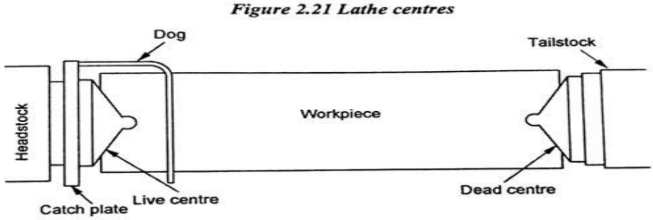


Figure 2.21 Lathe centres

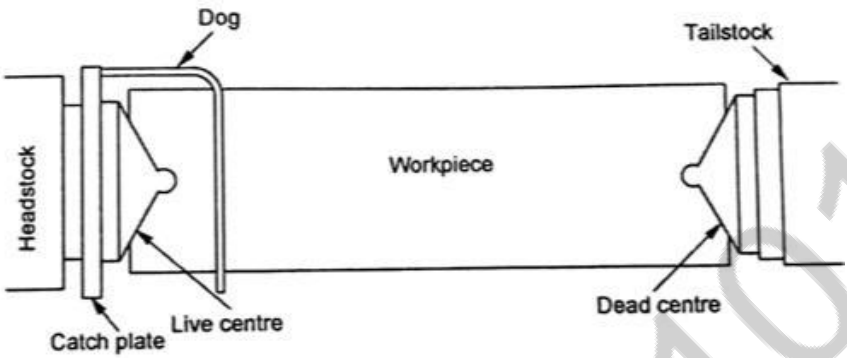


Figure 2.22 Work held between centres

When the spindle rotates, the workpiece will rotate through the catch plate and carrier arrangement as shown in Figure 2.22. The live centre will revolve the workpiece and the dead centre will support the right end of the work.

Faceplate

The facplate is a circular cast iron disc and has four T-slots and a number of plain radial slots as shown in Figure 2.23. These slots are used for holding the work by bolts and clamps. It is highly efficient for holding the asymmetrical work or work of complex and irregular shapes which are incovenient to clamp by other means. When the spindle rotates, the faceplate will also rotate. So, the work will rotate.

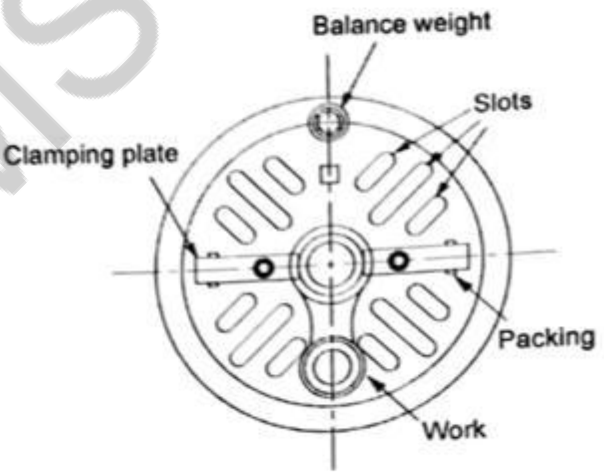


Figure 2.23 Facplate

Angle Plate

Angle plate is a cast iron block and it has two accurately machined faces at right angle to each other. It has holes and slots on both faces so that its one face may be clamped on the faceplate and the workpiece is mounted on the other face.

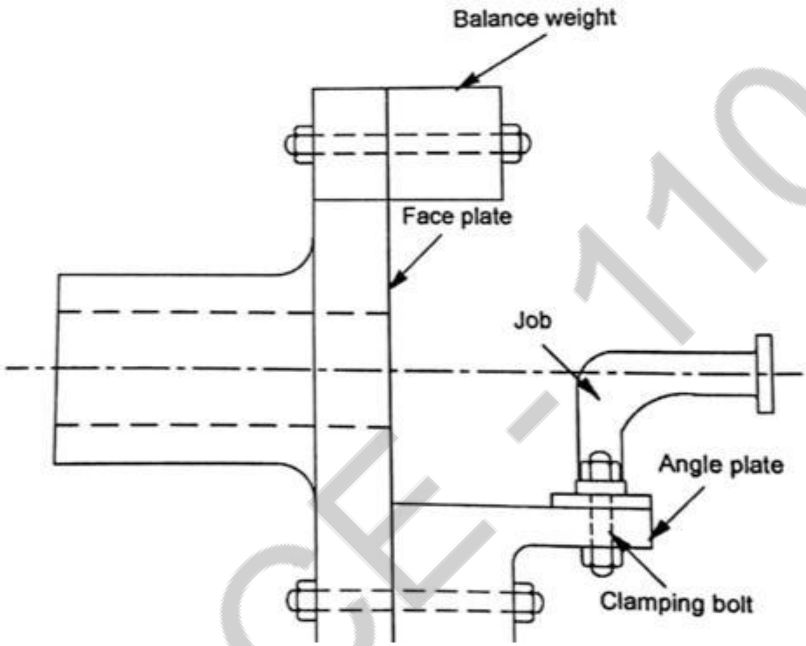


Figure 2.24 Angle plate

When the spindle rotates, the faceplate will also rotate. So, the angle plate and job also rotate. Usually, the counterweights are fitted to balance the weight of the job. The job jis eccentrically fitted or fitted in angle plate. The angle plate used for holding elbow piece is shown in Figure 2.24.

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 various types of jobs. They are shown in Figure 2.25. The outside diameter of mandrel should be equal to the inside diameter of the job.

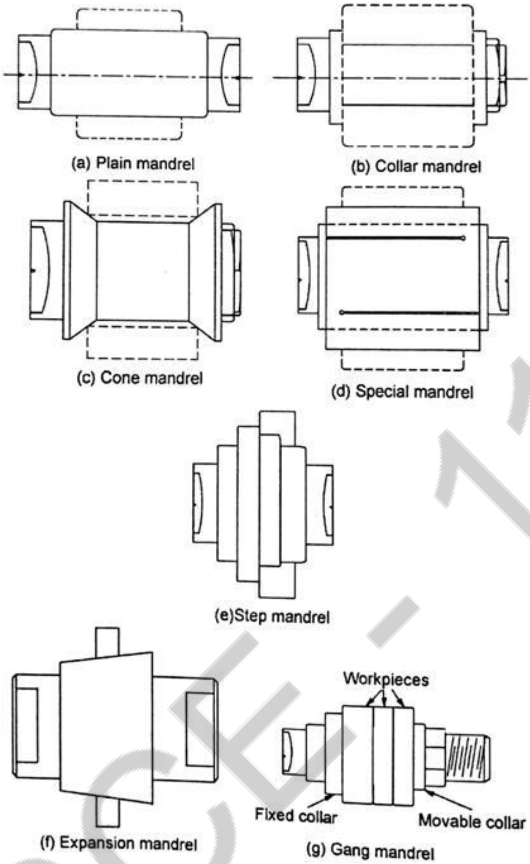


Figure 2.25 Various types of mandrels

Steady and Follower Rest

The rest is a device which supports long workpieces i.e. $\frac{L}{D} > 10$ or 12 when machined between centres or held by a chuck. It is place in between headstock and tailstock. It prevents the vibration and bending of the workpiece. There are two types of rests.

Steady rest

Follower rest

1. Steady rest

These types of rests are fixed on bed ways of the lathe by clamping 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. It is used to remove the job without disturbing the steady rest. The workpiece is supported by three jaws arranged as shown in figure 2.26.

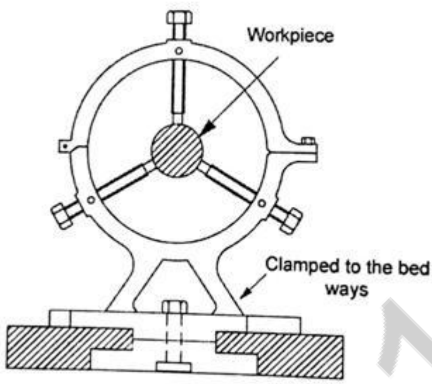


Figure 2.26 Steady rest

The jaws can separately be adjusted in the radial direction. For the work to be turned at high velocity, the jaws have built up balls or roller bearings to support it. After setting the jaws over the workpiece, the rest is clamped to the lathe bed to the required position. Since the carriage cannot pass over it the job is turned in two stages by reversing on end efter half machining the length. For longer work pieces, two or more steady rests can be used.

2. Follower rest:

The rest is mounted on the saddle and it moves together with the tool. It has a C type casting and two adjustable jaws to support the workpiece shown in Figure 2.27. The jaws always follow the tool. Therefore, it gives a continuous support to the workpiece.

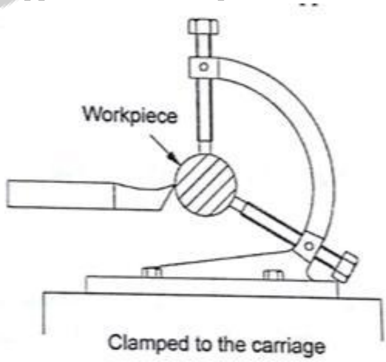


Figure 2.27 Follower rest

Tool holding devices

For mass production of variety of work in turret and capstan lathe, many different types of tool holders for holding various tools are used for typical operations.

Tool holders may be fitted in hexagonal turret, front tool post or in rear tool post.

The various tool holders are

Straight cutter holder
Adjustable angle tool holder
Multiple tool holder
Offset cutter holder
Slide tool holder
Knee tool holder
Drill holder
boring bar holder
Knuring tool holder
Form tool holder
Die holder etc.

3.Explain parallel action and progressive action multi-spindle automatics

Multiple Spindle Automatics

In these machines, there is more than one spindle, where the workpiece can be mounted. As a result more than one workpiece can be machined simultaneouly in these machines. The number of spindles present could be four, five, six, or eight. Each of the spindle is provided with its own set of tools for operation.

The two types of multi-spindle machines are:

Parallel action multispindle automats
Progressive action multispindle automats

Parallel Action Multi Spindle Automats

These types of automatics are also called as multiple-flow machine. The line diagram of this machine is shown in Figure 2.92. 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 order 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 care used to obtain all working and auxiliary motions of the machine units. In this type of machine, the same operation is perfomed on each spindle. In a five-spindle machine, five components can be completed at a time. Similarly, in an 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 machining processes are done at one position.

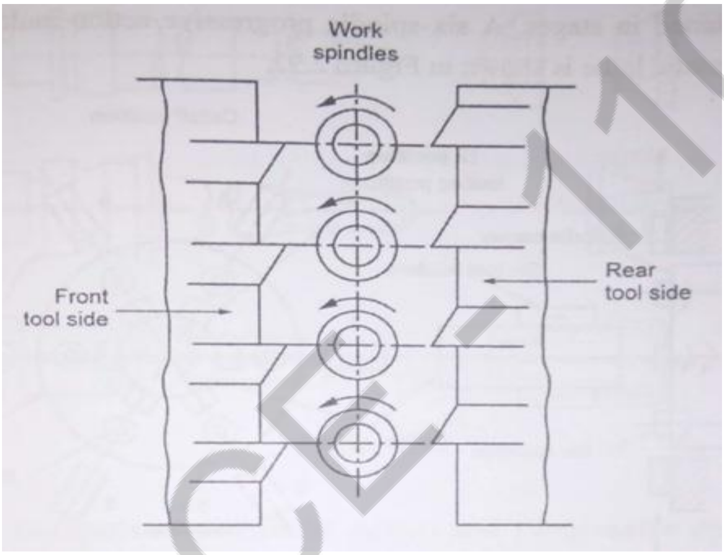


Figure 2.92 Parallel action multi spindle automatic machine

Progressive Action Multi Spindle Automats or Cutting Off Machine

In this type of machine, the work pieces are machined in stages. A six-spindle progressive action multi spindle automatic lathe is shown in Figure 2.93. The headstock has a spindle carrier. This carrier rotates about a horizontal axis through the centre of the machine. The working spindles are mounted in the spindle carrier. Work pieces are held in the collect in the spindles. The bar stock is fed to the spindle from the rear. Cross slides are mounted in a frame above the face of the spindle carrier. These tool slides carry forming, Chamfering, facing and cutting off tools. These cross slides travel radially inward for cutting operation. The cross slide movement is controlled from a cam in the camshaft. In this type of machine, the work pieces are machined in stages.

A Six-spindle progressive action multi spindle automatic lathe is shown in Figure 2.93.

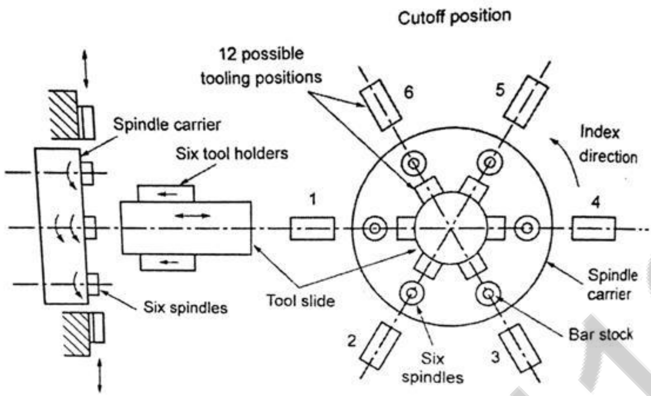
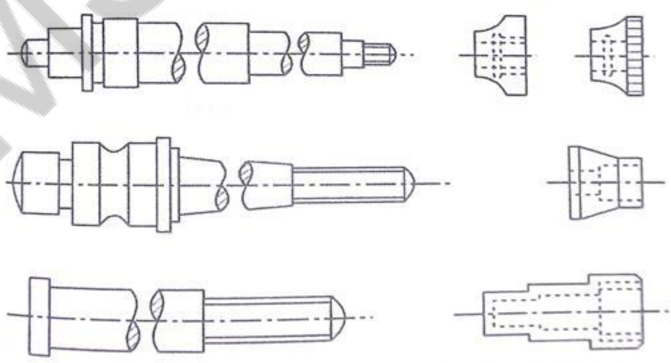


Figure 2.93 Progressive action multi spindle machine

The main tool side (or end tool slide) is situated in front of the spindle carrier. It carries tool slides around its periphery. There is one tool slide corresponding to each spindle. The tool slides move towards the spindle while machining. Operations such as straight turining, boring and threading are done by tools mounted on these tool slides. The spindle carrier indexes on its own axis by 60° at the end of tool return. As the spindle carrier indexes, it carries the work from station to station. In the first station, the bar stock is fed. In every station, various types of operations are progressively done (one after another in each station). At the sixth station, the component is completed and cut off. A finished component is obtained at each time the spindle carrier indexes. Some components produced in multi spindle automats are shown Figure 2.94.



4.Explain the salient features of an Automatic screw Machining. (Refer April/May 2015)

5.Enumerate the purpose of various attachments used on a centre lathe. (Nov/Dec 2018)

SPECIAL ATTACHMENTS

Most of the lathe operations discussed so far allow for general purpose machining operations to be carried using a centre lathe. In addition to these operations, it is possible to provide some special attachments to the capability of lathe so that the lathe can be used for special machining applications using these attachments. The taper turning attachment discussed earlier for producing tapers on cylindrical workpieces is one such attachment. Moreover, milling and grinding operations can also be performed on lathes by using special attachments.

Milling Attachment

Milling is the process of removing metal by moving the work against a rotating cutter. Milling cutters have multipoint cutting edges. Milling attachment is used in lathes to carry out milling operations. The attachment is provided with a motor, a small gear box and a separate spindle where the milling cutter could be located as shown in Figure 2.57. It is attached to the crss slide or saddle and replacing the compound slide. The milling cutter can normally be fed in all three directions, thus permitting any type of milling operations. Milling attachments are generally used for making flat surface, straight and helical grooves, splines, long and deep screw threads, worms etc, in centre lathes by using suitable milling cutters.

Milling operation can be 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 the 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, the work is held stationary between centres. The attachment is mounted on the cross slide on the carriage which is driven by a separate electric motor. The feeding is given by the carriage and the 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 head stock spindle to divide the work equally.

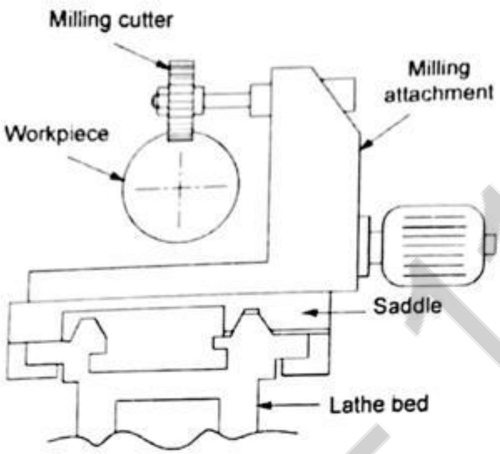


Figure 1.57 Milling attachment used in lathe

Grinding Attachment

Grinding is the operation of removing metal in the fine of chips. It is done by moving the work against a rotating abrasive wheel. This abrasive wheel is known as grinding wheel. Grinding attachment is very similar to milling attachment. But in the former, there is no gear box and the spindle speed is much higher as needed for grinding operation. Both external and internal grindings can be cut be cut by using special attachments on a lathe. The work 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 the cross slide is moved for giving the depth of cut. Generally, grinding is done on lathes using attachments for finishing workpieces, sharpening a cutting tool and sizing workpieces to close tolerance.

Copy Turning Attachment

Sometimes, it is required to machine the complex contours on the work which require the feeding of the tool in two axes (x and y axes) simultaneously similar to taper turning. For such purpose, copy turning attachment is useful. In this, the cross slide is directly driven by a stylus which can trace a master template for the actual contour to be produced. There are two common types of copy turning:

Mechanical type

Hydraulic type

(a) Mechanical copy turning attchement

A simple mechanical type copy turning attachment is shown in Figure 2.58. The entire attachment is mounted on the saddle by removing the cross slide. The template replicating the job-profile desired is clamped at a suitable position on the bed. The stylus is fitted in the spring loaded tool slide. When the tool slide travels longitudinally along with saddle, the stylus is moved in the transverse direction according to the template profile. It enables the cutting tool to produce the same profile on the job.

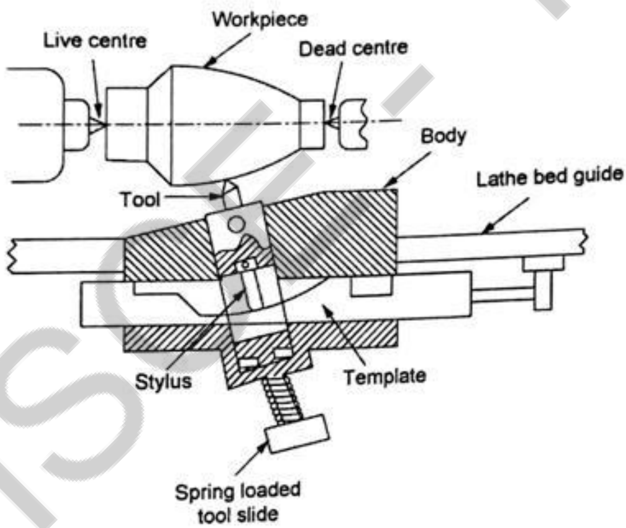


Figure 2.58 Mechanical copy turning attachment

(b) Hydraulic copy turning attachment

In the mechanical system, the heavy cutting force is transmitted at the tip of the stylus which causes vibration, large friction and faster wear and tear. Such problem are almost absent in hydraulic copying where the stylus works simply as a spool valve against a light spring and it is not affected by the cutting force. Hydraulic copying attachment is costlier than the mechanical type but it works much smoothly and accurately. The cutting tool is than the mechanical type but it works much smoothly and accurately. The cutting tool is rigidly fixed on the cross slide which also acts as a valve-cum-cylinder as shown in Figure 2.59. As long as the stylus remains on a straight edge parallel to the lathe bed, the cylinder does not move transversely and the tool causes straight turning. As soon as the stylus starts moving along a slope or profile, i.e., in cross feed direction the ports open and the cylinder starts moving accordingly against the piston fixed on the saddle. Again the movement of the cylinder i.e., the slide holding the tool for the same amount travelled by the stylus closes the ports.

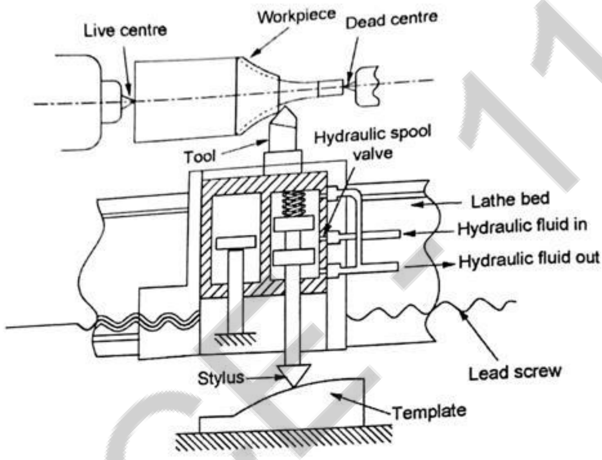


Figure 2.59 Hydraulic copy turning

attachment Spherical Turning Attachments

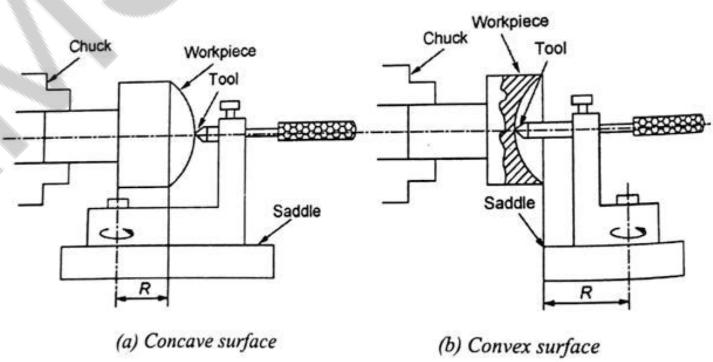


Figure 2.60 Spherical turning without template

These simple attachments are used in centre lathes for machining spherical, both convex and concave surfaces and similar surfaces. I these attachments, the cross slide is attached to the bed by means of a radius arm whose length is same as the radius of the spherical component to be produced. The radius arm whose length is same as the radius of the spherical component to be produced. The radius arm couples any movement of the cross slide or the carriage and hence, the tool tip is traced a radius R as shown in Figure 2.60. The distance R in Figure 2.60(a) and Figure 2.60(b) can be set on the basis of radius of the curvature desired.

In the type shown in Figure 2.61(a) and Figure 2.61(b), the desired path of the tool tip in controlled by the profile of the template which is pre-made as per the radius of curvature required. The saddle is disconnected from the feed rod and the lead screw. So, the tool moves axially freely being guided by the template only when the cross slide is moved manually in the transverse direction.

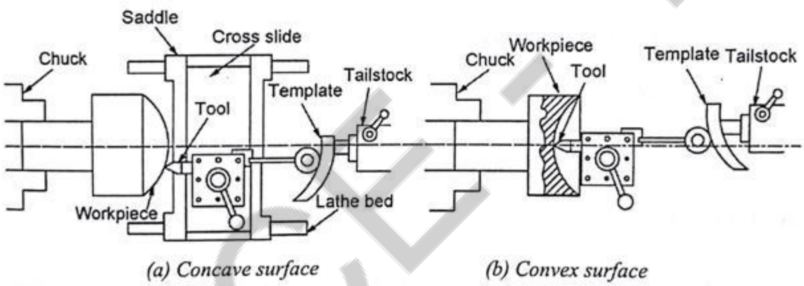


Figure 2.61 Spherical turning using template

6.Explain with a neat sketch single spindle automatic lathe

<u>Single Spindle automatic lathes</u>

A single spindle automatic lathe is a modified form of turret lathe. These machines have an addition to a 6-station or 8-station turret, a maximum of 4 cross slides. These cross slides are operated by disc cams. The cams are mounted on a shaft which draws the power from the main spindle through a set of gears called cyclic time change gears.

Turret operation is also synchronized with the cross slide operation and is driven by another cam called main cam. The tools used on the cross slides are usually form tools and are plunged into the work piece at the desired feed rate. The tools used in the turret may be turning tool, drilling tools etc. It is common to use more than one tool on a turret station. External threading is usually carried out by a thread chasing attachment. Internal threads are made using taps. In addition, milling of slots, flats, grooves, cross-drilling etc. can be carried out.

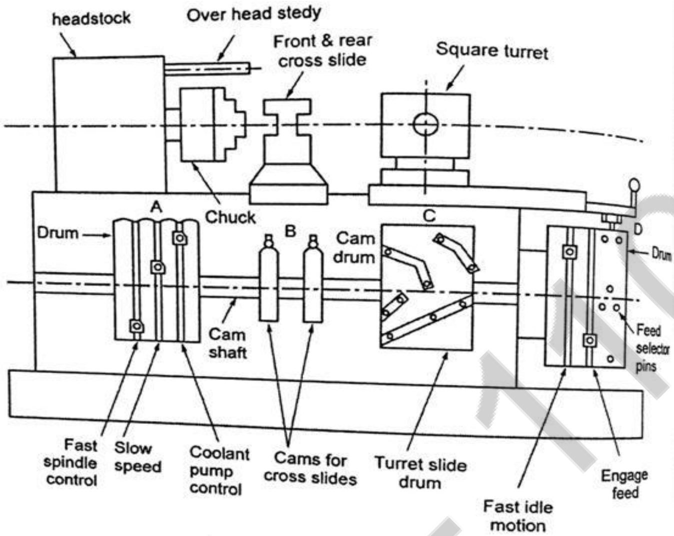


Figure 2.83 A single spindle automatic lathe

It can be performed in an automatic lathe with the help of special attachments. It is one the outstanding features of automatic lathe. The reduction in number of set ups and total machining time enables the parts to be produced at an economical cost in an automatic lathe. Because of their application to produce screws at low cost, these are called screw cutting machines.

Figure 2.83 shows the single spindle automatic lathe. The lathe has a geared headstock. The spindle of the headstock has one slow speed and one fast speed. The spindle speed is changed by the trip dogs on the drum A. At the end of bed, a square turret is provided. The travel of the turret slide is controlled by the adjustable cam drum C. The turret indexed to the next at the end of each stroke.

Two cross slides are situated between headstock and turret. One cross slide is at the front side and the other at the rear side. The cross slides have independent movements. The travel of cross slides are independently controlled by a cams B. overlapping of operations by the tool in the turret and the tools in the cross slide can be done. The correct feed for each machining operation can automatically be selected y the feed selector pins on the drum D.

The following types of single spindle automatic lathe are mostly used.

- Automatic cutting off machine
- Automatic screw cutting machine
- Swiss type automatic screw machine.

7.Explain the salient features of an automatic screw machines.

<u>Single spindle Automatic Screw Cutting Machine</u>

(Nov/Dec 2018)

These machines are essentially automatic bar type turret lathes.

They are widely used for production of all sorts of small turned parts. It mainly consists of a cross slide and turret. Two cross slides, one front cross slide and another rear cross slide are provided for cross feeding tools. An additional vertical slide is also employed in this machine. This third slide is installed above the work spindle.

The turret slide is placed at the right end of the bed. It carries the turret having six tool holes. The various tools used in the machine are mounted around the turret in a vertical plane in line with the spindle which rotates in either direction. The bar stock is held in a chuck. It is advanced by a feed finger after each piece is finished and cut off. A camshaft is mounted at the front of the machine. It carries three plate cams. These plate cams control the travel of cross slides. The turret head rotates about a horizontal axis. The turret slide travel is controlled by a lead cam. The lead cam gives a slow forward and fast return movement to the turret slide.

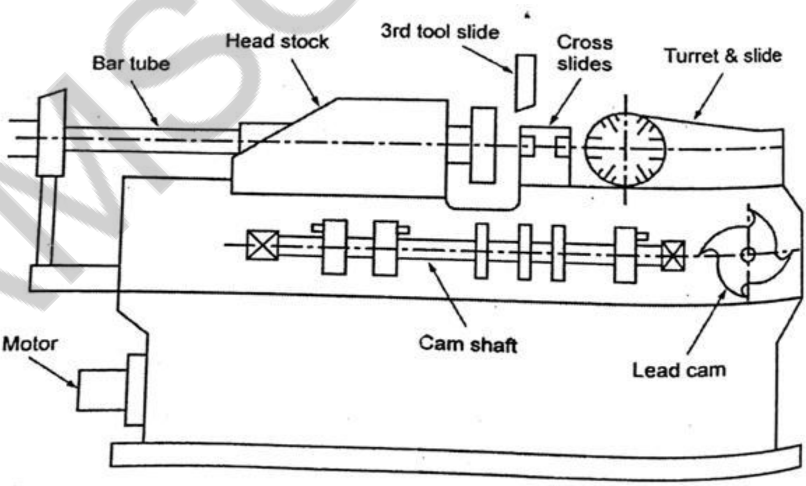


Figure 2.89 Automatic screw cutting machine

The discs cams are used to control the cross slide. All operations such as turning, drilling, boring, threading, reaming, spot facing, knurling can be performed on the machine. Special attachments are also available to perform slotting work, milling flats, cross-drilling etc. in this machine, any type of bar stock round, square, hexagonal can be machined. These machines are made in several sizes for bar work from 12 mm to 60 mm diameter.

The line diagram of this machine is shown in Figure 2.80. The parts produced in an automatic screw-cutting machine are shown in Figure 2.90.

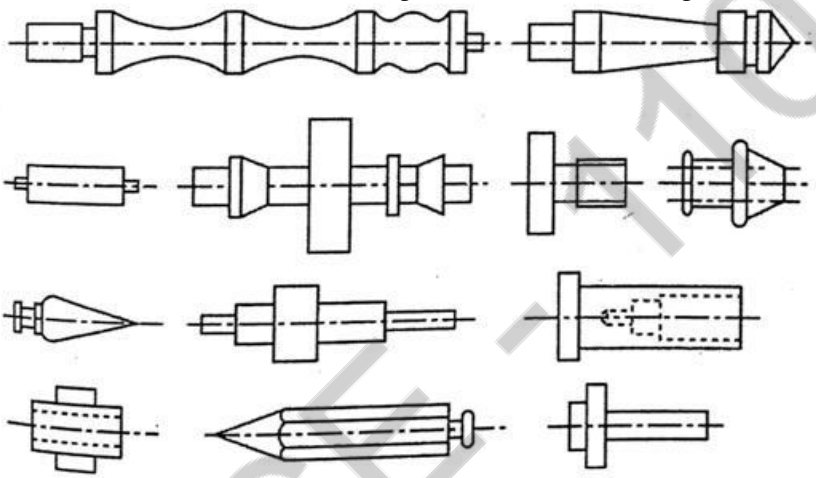


Figure 2.90

Applications:

It is used for producing small jobs, screws, stepped pins, taper pins, bolts etc.

Salient features:

It is more compact in size. So, it allows an operator to operate more than on units simultaneously.

It has good adaptability which improves the productivity.

There is no need to align the screws.

It is widely applicable in screws of various types, length and head shape.

It has unique testing loop which allows for the minimal running time.

8.Discuss any two operations that can be performed on a lathe ?

<u>Centering</u>

When the work is required to be turned between centres, conical shape holes must be provided at both ends of the work piece to provide the bearing surface for lathe centres. Centering is the operation of producing conical holes on both ends of the work piece.

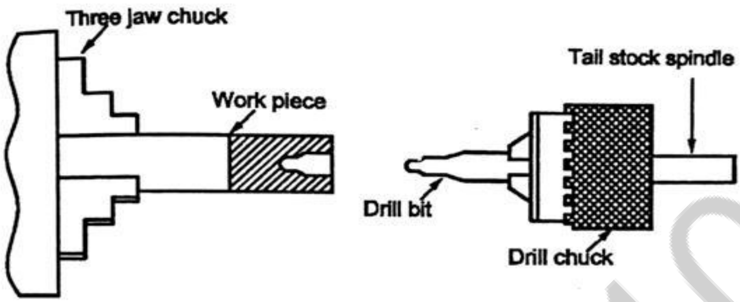


Figure 2.28 Centering operation

First, the centres of the work piece ends are marked by using a centre punch. The workpiece is held by a three-jaw chuck. The drill bit is held using a tailstock with a drill chuck or socket. When the job rotates, the drill bit will move into the work by turning the tailstock hand wheel.

Straight Turning

Straight turning is the operation of producing a cylindrical surface by removing material from the outside diameter of a work piece. It is done by rotating the work piece about the lathe axis and feeding the tool parallel to the lathe axis.

The job is held between centres or held in chuck. The trueness or centreness of the work piece is checked by a dial indicator or a scriber against the rotating work piece. A right hand turning tool is clamped on the tool post. For light cuts, the tool may be inclined towards the headstock but the tool may be inclined towards the tailstock for heavy cuts. The automatic or hand feed can be used.

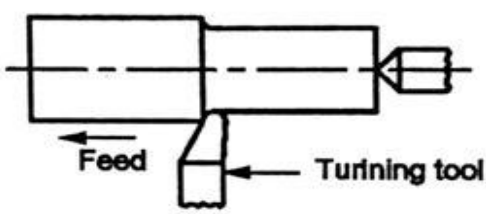


Figure 2.29 Straight Turning

There are two types of straight turning

Rough turning

Finish turning

1. Rough turning:

For rough turning, the rate of feed of the tool is fast and depth of cut is heavy. The depth of cut for this turning is about 2 to 5mm and the feed rate is about 0.3 to 1.5mm per revolution. For rough turning, the rough turning tool is used.

2. Finish turning:

For finish turning, the high cutting speed, the feed is light and the depth of cut is required. A finish turning tool having sharp cutting edge is used. The depth of cut will be from 0.5 to 1 mm and the feed rate is from 0.1 to 0.3mm per revolution of the work piece.

9.What are the various methods available for supporting long components and fragile components in a lathe ? Explain with sketches.

<u>Steady and Follower Rest</u>

The rest is a device which supports long work pieces $\frac{L}{D} > 10$ or 12 when machined between centres or held by a chuck. It is placed in between headstock and tailstock. It prevents the vibration and bending of the work piece. There are two type of resets.

Steady rest

Follower rest

1.Steady rest

These types of rests are fixed on bed ways of the lathe by clamping bolts. There is a cast iron based which is used to clamp the rest on the bed. The upper portion of the rest is hinged at one end. It is used to remove the job without disturbing the steady rest. The work piece is supported by three jaws arranged as shown in Figure 2.26

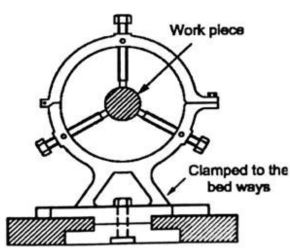


Figure 2.26 Steady rest

The jaws can separately be adjusted in radial direction. For the work to be turned at high velocity, the 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 over it. The job is 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:

The rest is mounted on the saddle and it moves together with the tool. It has a C type casting and two adjustable jaws to support the work piece shown in Figure 2.27. The jaws always follow the tool. Therefore, it gives a continuous support to the work piece.

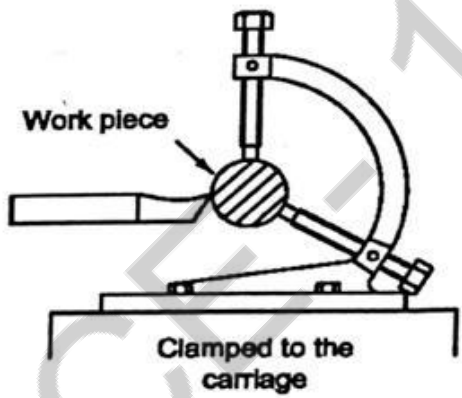


Figure 2.27 Follower rest

10.Enumerate the neat diagram the principal parts of the capstan and turret lathe.

The principal parts of the capstan and turret lathes are as follows.

Bed

Headstock

Turret head and saddle

Cross slide.

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 have accurately been provided. The headstock is mounted on one end of the bed. The other end carries saddle and the turret is mounted on it. The cross slide is mounted on the bed in between the turret head and headstock. The bed should be strong and rigid to withstand heavy loads, force and vibrations during machining.

2. Headstock:

The headstock of capstan and turret lathe is similar to a head in ordinary centre lathe but it is larger and heavier in construction to house the spindle and driving mechanisms. One of the main features of this headstock is the provision for rapid stopping, starting and speed changing. It helps in the rapid selection of required cutting speed and at the same time to minimize the loss of time in speed changing, stopping and starting. A powerful motor of 30 to 2000 rpm speeds is fitted.

The four main types of headstock are as follows.

Back geared or Step cone pulley driven headstock

Direct electric motor driven headstock

All geared headstock

Pre-selective stock.

Step cone pulley driven headstock and all geared headstock are same as the one already discussed in centre lathe on Chapter 2.5 in Page 2.11.

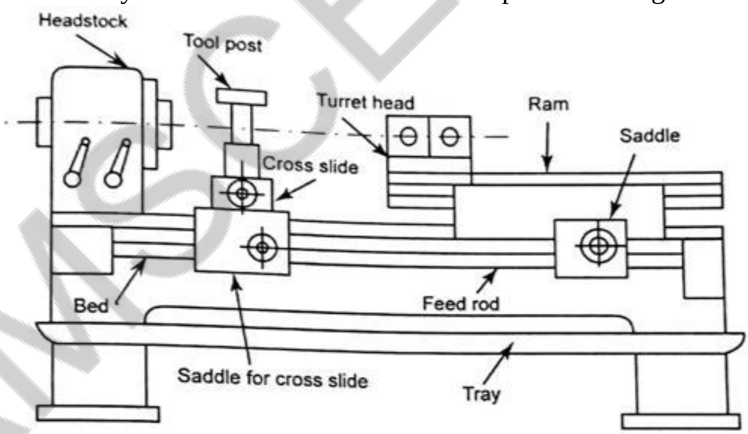


Figure 2.62 Capstan and Turret lathe

Direct electric motor driven headstock:

In this type of headstock, the spindle of the lathe and the armature shaft of the motor are one and the same. It is mounted with a variable speed electric motor. With three or four speeds, the lathe is suitable for small diameter works rotated at high speed during working. Different spindle speeds are obtained by controlling the motor regulator.

Pre-selective headstock:

In this type, an 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. At the end of the first operation, the lever is actuated to rotated the spindle at selected speed without stopping the machine.

3. Turret head and saddle:

In a capstan lathe, the turret head is mounted on a ram which slides on a saddle. It can be positioned on lathe bed ways and clamped well. The turret head is mounted on the ram fitted on a saddle which in turn it is sliding on the bed as shown in Figure 2.63. The forward movement of the ram is controlled by a preset or adjustable stop screws.

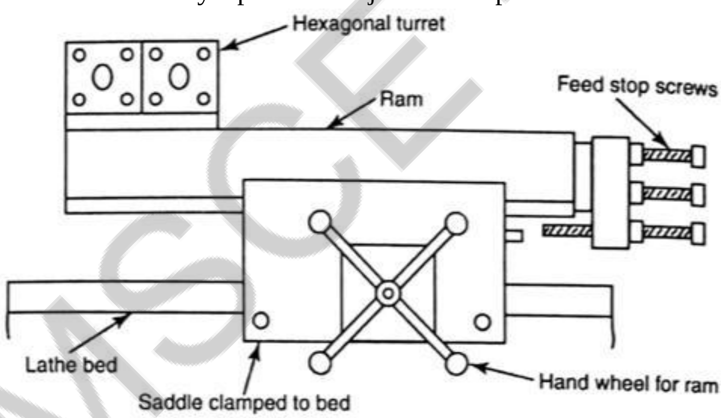


Figure 2.63 Ram of capstan lathe

In a turret head is mounted on the saddle itself which slides on the bed ways during machining as shown in Figure 2.64.

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 tool holders. The different tools are brought to the machining position by indexing i.e. rotated through a fixed angle. The turret can be indexed about a vertical axis. Each tool is indexed along with the turret head. Bringing the next tool into the cutting position is done by a mechanism called Geneva mechanism.

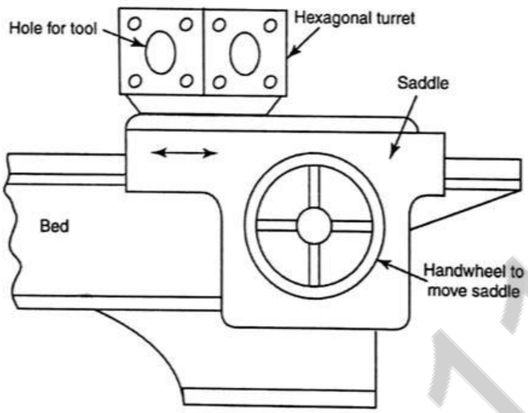


Figure 2.64 Saddle of turret lathe

There are 6 adjustable stops i.e. adjustable screws on the circular plate, one for each of the six turret faces as shown in Figure 2.65. These stops can be preset depending on the requirement. While setting the tool, each stop is adjusted to control the length of travel of the turret. These preset stops are getting indexed when the turret is indexed.

The tool post can move both in perpendicular and parallel directions to the spindle axis. Mostly, the power feed is used for the movement of the tool post. In the rear tool post, the parting-off tool is clamped in inverted position to make the direction of rotation of workpiece anticlockwise with respect to tool movement.

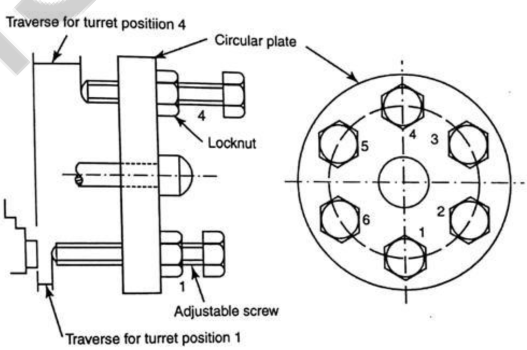


Figure 2.65 Adjustable stop for turret

4. Cross slide:

The two types of cross sliders are as follows.

Reach over type

Side hung type

11.Describe various types of multi spindle automats.

REFER MAY/JUNE 2014

12.Enumerate the various methods of producing taper.

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 Figure 2.48. The form tool is ground to the required angle. When the work piece rotates, the tool is fed perpendicular to the lathe axis.

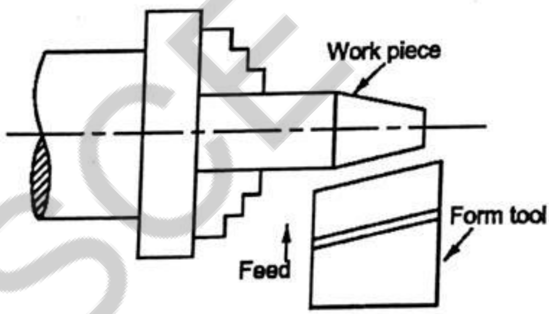


Figure 2.48 Form tool method

The taper length should be less than the tool cutting edge length. As the entire cutting edge removes the 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.

Set over, $h = \frac{D - d}{2l} \times L \tan \alpha$ [$\because$ 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.

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

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

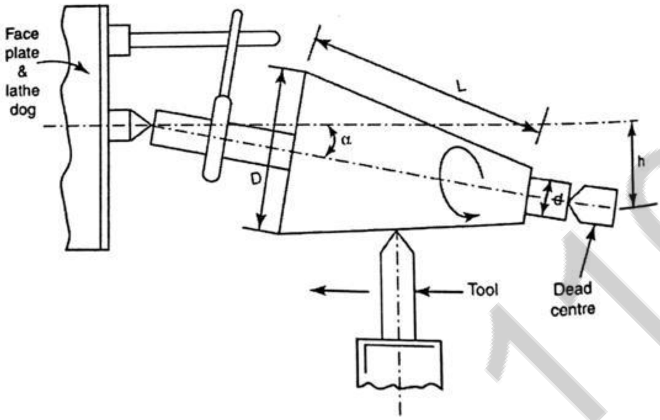


Figure 2.49 Tailstock set over method

The method is employed when the angle of taper is very small (less than 8°). The work piece is held between live centre and dead centre. Now, the tailstock is moved cross i.e., perpendicular to the lathe axis by turning the set-over screw. This process is called 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

The method is used to produce a short and steep taper. In this method, the work is held in a chuck and it is rotated about the lathe axis. The compound rest is swiveled to the required angle and clamped in position.

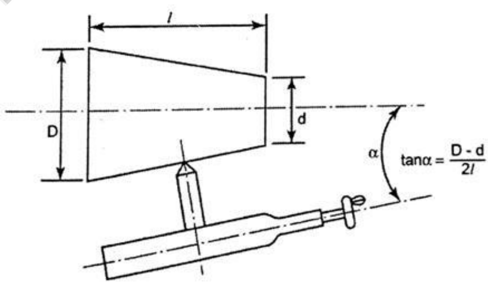


Figure 2.50 Compound rest method

The angle is determinded by using the formula, $\tan \alpha = \frac{D - d}{2l}$. Then, the toll is fed by the compound rest hand wheel. This method is used for producing both internal and external tapers. 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 a 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 it 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.

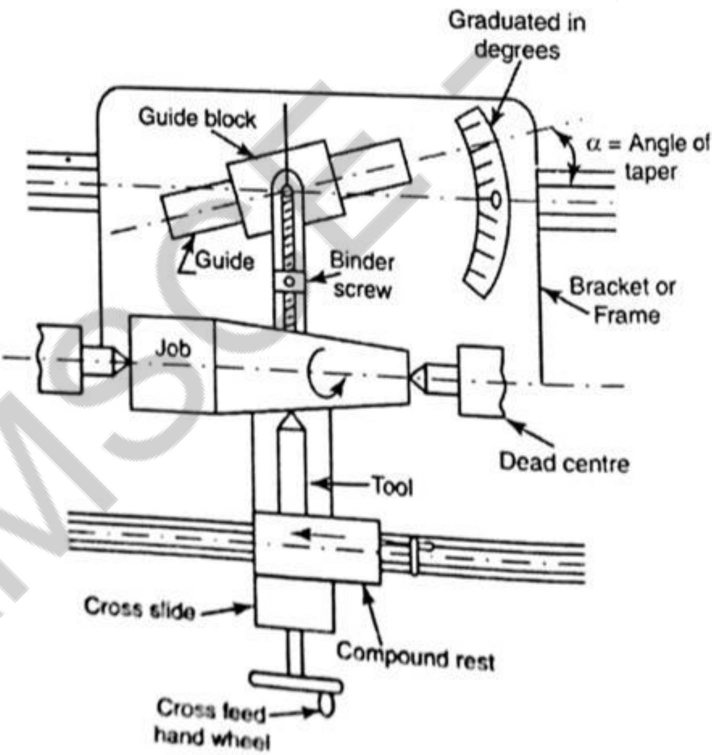


Figure 2.51 Taper Turning Attachment Method

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

The angle is calculated using the formula, $\tan \alpha = \frac{D-d}{2l}$.

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

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

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. The compound rest hand wheel is used to give the depth of cut. The guide is set at half taper angle. By this method, any type of taper can be turned.

13.Write step by step procedure for preparing tool layout of turret and capstan lathe.

Tool Layout

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

- Selection of tools
- Designing of special tools
- Selection of speed
- Selection of feed
- Setting the required length of workpiece 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 the product are largely dependent on an efficient tool layout.

The tool layout mainly consist of three stages.

- Planning and scheduling stage: preparation of operation sheet with the order of operation.
- Detailed sketching of various stages of machining operation in a sequence of operations.
- Sketching the plan showing the various tools into the hexagonal turret faces and on the cross slides in a proper sequence.

Rules for Preparing Tool Layout of Turret and Capstan Lathe

The following rules should be kept in mind and followed in laying out the sequence of operations necessary to produce a workpiece on the turret lathe.

- For small batch production, simple tool layout should be used with standard tools. For mass production, it will be more economical to use special tools to minimize the machining time.
- Different machining operations should be done simultaneously as far as possible.
- Similarly, the handling operations can be combined with the machining operations such that the total machining time is reduced.
- During simultaneous multiple cutting operations the cutting tools should be arranged in such a way that the cutting forces by various cutting tools get balanced.
- The finishing cut should be done full length of the workpiece involving multiple rough cuts with different tools.
- The contoured surface should be machined in two steps rather than single step to improve quality.
- It is important to drill a centre hole before final drilling in the case of small diameter holes.
- Large bores should start with drilling small holes and then extended using boring tools.
- To drill long holes having length > 3 times the diameter, special care should be taken. Frequent withdrawal of the tool from the hole for flushing the chip form the drill flutes with cutting fluid is essential.
- The operations involving heavy forces and it reduces of the workpiece such as deep grooves or large bores should not be carried out in early stages.
- In the case of stepped holes, large diameter hole should be drilled first and them the smaller hole should be drilled.

Step By Step Procedure for Preparing Tool Layout of Turret and Capstan Lathe

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 operation, the proper operation sequence is decided.
4. Various tool according to the sequence of operations are selected.
5. The selected tools are fitted either on a hexagonal turret or on cross-slide according to the operation sequence.
6. The proper cutting speed, feed 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.
8. Total machining time of each and every operation
9. Idle time between successive operations and
10. Time required for loading and unloading the components.
11. The detailed drawing of the workpiece is drawn along with the turret tools and cross-slide tools in a 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 lathe tools and operations.

14. Explain about Sliding head automatic lathe.

Swiss Type Automatic Lathes(Siding Head Automatic Lathes)

This type of automatic lathe is suitable for small, long and slender parts such as parts of wristwatches. There is a distinct difference between 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 automatic lathe is also called a sliding head automatic lathe. This machine is used for producing long accurate parts of small diameter (2 ot 25 mm). In this, the parts can be machined to an accuracy of 0.005 mm to 0.00125 mm.

There may be five cross slides in the case of automatic lathe. However, the productivity-wise, the conventional automatic lathes are superior for short workpieces. The advantage of a sliding head automatic lathe is that the long slender workpieces can be machined with a very good surface finish, accuracy and concentricity in sliding head automatic lathes. Further, Swiss type automatic lathes are capable of completely machining certain types of parts which may require second and third operations in conventional automatic machines. Figure 2.96 shows a Swiss type screw cutting machine.

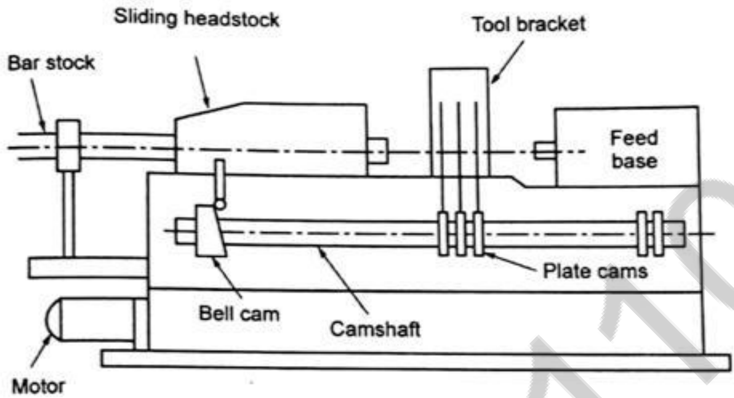


Figure 2.96 Swiss type screw type screw cutting machine It consists of four major parts.

The sliding headstock through which the bar stock is passed and gripped by a carbide-lined guide bush.

The camshaft which controls the bar stock and cutting tool movements.

The tool bracket which supports five tool slides and a bush for stock.

Auxiliary attachments for performing various operations such as knurling, drilling, tapping, screwing, slotting, recessing etc.

The description of various parts is given below.

1. Sliding headstock:

This headstock has a collet. The bar stock is held in the collet. The headstock slides along the guide ways of the bed. A bell cam connected to the camshaft controls this sliding motion.

2. Tool bracket:

The tool bracket is mounted on the bed way near the head stock. The tool bracket supports 4 or 5 tool slides. It also has a bush for supporting and guiding the bar stock. Two slides are horizontally positioned i.e. one at the front and the other at the rear. The other slides are arranged above these slides. All slides can move back and forth. These slides are independently actuated by sets of rocker arms and plate cams. Plate cams are fitted to the camshaft. Figure 2.97 shows the schematic of tool bracket.

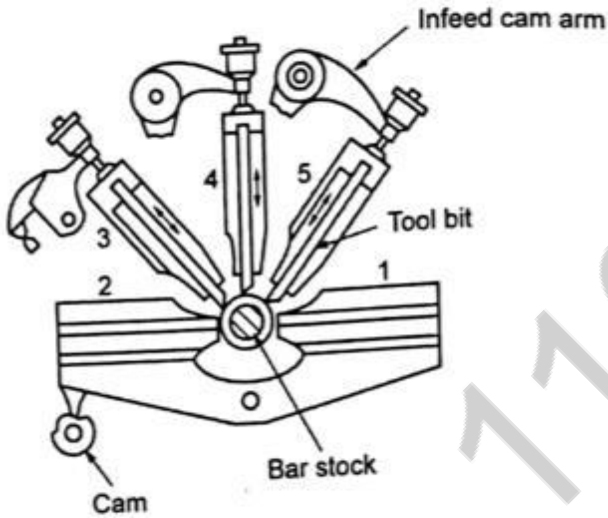


Figure 2.97 Tool bracket

3. Feed base:

The feed base is mounted at the right-hand side of the headstock. It can move along the bed. Using this attachment, operations such as drilling, boring, thread cutting etc., are done. The movement of the feed base is controlled by the plate cam fitted to the camshaft.

4. Camshaft:

The camshaft is mounted at the front of the machine. It has a bell cam at the left end which controls the sliding movement of the headstock. Plate cams fitted at the centre of the shaft controls the movement of the tool slides. A plate cam at the right end of the camshaft controls the movement of the feed base. The parts produced in this machine are shown in Figure 2.98

Working principle:

The bar stock is held in the rotating spindle by a collet chuck. Headstock slides along the bed ways with the rotating bar stock. This headstock movement gives a longitudinal feed to the work. All tools in the tool slides remove material from the workpiece at the same time. The tool in the feed base attachment may also do operations such as drilling. After the workpiece is machined, the headstock slides back to the original position. One revolution of the camshaft produces one component.

Most of the turning and forming operations are done by the tools held on the (horizontal) front and rear tool slides. The vertical tool slides are mainly used for undercutting chamfering, knurling and cutting off.

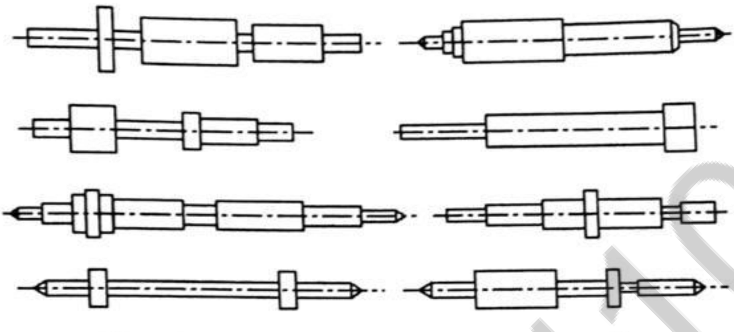


Figure 2.98 Parts produced by Swiss type screw machine

Advantages of Swiss type screw machine:

It is used to manufacture precision turning of small parts.

It has five tool slides.

A wide range of speeds is available.

It is rigid in construction.

Micrometer tool setting is possible.

Interchageability of cams is possible.

Simple design of cams is enough.

Tolerance of 0.005 to 0.0125 mm is obtained.

Numerous working stations are available.

15.A shaft of 150 mm diameter is to be reduced to 40 mm diameter by turning. The turning operation is carried out with rough machining of speed 25 m/ min and finish machining of speed 50m/min. The feed for rough machining is 0.2 mm/rev while that for finishing is 0.1 mm/rev. The maximum depth of cut for rough machining is 2 mm. Finish allowance maybe taken as 1 mm. Calculate the machining time required for this operation. Also, estimate the power required for rough machining and finishing passes if the constant K= 1200 N/mm$_2$.

Given data:

L=150mm

D_1=50mm

D_2=40mm

For rough machining,

V=25m/min

f=0.2mm/rev

d=2 mm

For finishing,

V=25m/min

F=0.1mm/rev

Finishing allowance = 1mm

K=1200N/mm2

Solution:

Since the machining operation is done by using rough machining first and then finish machining, the calculations are done first for rough machining and then for finishing.

Total depth of cut, $d = \frac{D_1 - D_2}{2} = \frac{50 - 40}{2} = 5 \text{ mm}$

Time required for rough machining operation:

Material to be removed using rough machining,

=5-1=4 mm

Since maximum depth of cut for rough machining is given as 2 mm,

Number of passes required, $n = \frac{\text{Material to be removed}}{\text{Maximum depth of cut per pass}} = \frac{4}{2} = 2$

Average diameter,

$$D = \frac{D_1 - D_2}{2} = \frac{50 + 40}{2} = 45 \text{ mm}$$

Cutting speed, $V = \frac{\pi DN}{1000}$

$\therefore$

$$= \frac{1000 \times 25}{\times 45} = 176.84\text{rpm}$$

$$\text{Machining time for roughing} = \frac{L}{fN} \times n = \frac{150}{0.2 \times 176.84} \times 2 = 8.48 \text{ min}$$

Time required for finish machining operation:

Finish machining is carried out in single pass usually. Hence, n=1.

Cutting speed, $V = \frac{\pi DN}{1000}$

$\therefore$

$$N = \frac{1000 \times 50}{\pi \times 40} = 397.89 \text{ rpm}$$

Machining time for finishing $= \frac{L}{fN} \times n = \frac{150}{0.1 \times 397.89} \times 1 = 3177 \text{ min}$

Total time required for machining = Rough machining time+Finishing time

=8.48+3.77=12.25 min Ans.

Power estimation:

For rough machining operation,

Power required, P = K×d×f×V

=1200×2×0.2×25/60=200W

For finishing operation,

Power required, P=1200×1×0.1×50/60=100W

16.Explain the method of thread cutting operation on a lathe (Nov/Dec 2019) refer question no :1

17. What is the profile of the threads in the lead screw a central lathe. (Apr/may 2019) refer question no :1

18. Name the important and widely used tool holding devices used in a turret lathe. (Nov/Dec 2019)

<u>Tool holding devices</u>

For mass production of variety of work in turret and capstan lathe, many different types of tool holders for holding various tools are used for typical operations.

Tool holders may be fitted in hexagonal turret, front tool post or in rear tool post.

The various tool holders are

Straight cutter holder
Adjustable angle tool holder
Multiple tool holder
Offset cutter holder
Slide tool holder
Knee tool holder
Drill holder
boring bar holder
Knuring tool holder
Form tool holder
Die holder etc.

19. Explain the significance of operation facing and turning performed in the lathe with reference to the change in the geometry of the work place. (Apr/may 2019) refer q.no: 08

20.Enumerate the purpose of various attachments used on a centre lathe. (Apr/may 2019) refer q.no: 05

21.A shaft of 150 mm long. 12.5 mm diameter 304 stainless steel rod is being reduced to 12 mm diameter by turning. The spindle rotes at N=400 rpm, and the tool is travelling at an axial speed of 200 mm/min. Calculate the cutting speed, material-removal rate, cutting time,power dissipated, and cutting force. (Apr/may 2019) refer q. no: 15

22. Explain about Sliding head automatic lathe. (Apr/may 2019) refer q. no: 14

23. With the help of suitable sketches describe the following:
(i) Taper turning by using taper turning attachment.
(ii) Taper turning by combining longitudinal feed and cross feed.
(Apr/may 2018) refer q. no: 12

24. Enumerate the constructional details and working principle of turret indexing mechanism in capstan and turret lathes.
(Apr/may 2018)

3 SHAPER, MILLING AND GEAR CUTTING MACHINES

PART A

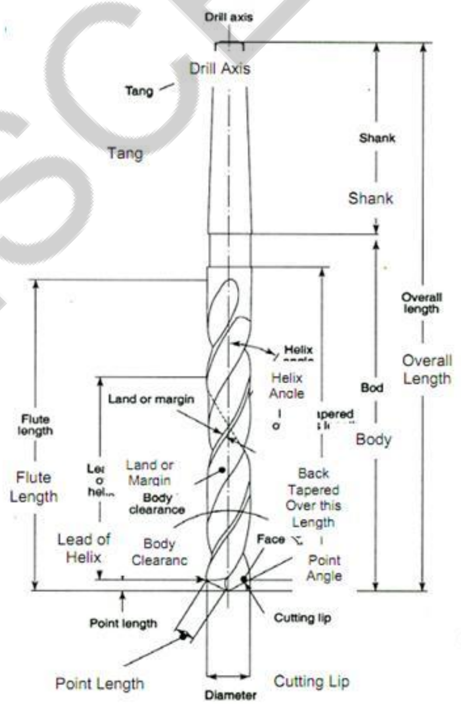
1. Distinguish between up milling and down milling. **(Nov/Dec 2017) (apr/may 2019)**

Up milling	Down milling
The cutter rotates against the direction of travel of workpiece	The cutter rotates in the same direction of travel of workpiece
Chip thickness minimum at the beginning of cut reaches maximum when the cut terminates	Chip thickness maximum at the beginning reaches minimum to end.

2. Why gear finishing is required?

Gear finishing is required because the rough surface gear teeth occur due to vibration causing nose, excessive wear, play and backlash between meshing pair of gears. Rough surface gears produced by gear generating process leads to low power transmission.

3. Sketch the nomenclature of a drill bit



4. What do you mean by differential indexing?

A method in which the difference between simultaneous movements of index plate and index crank is used to drive circle into subdivisions is called differential indexing. First, the crank is moved in a certain direction. Next, the movement is added or subtracted by moving the plate by means of a gear train.

5. Why is milling a versatile machining process?

Metal removal is performed through the relative motions of a rotating, multi-edge cutter and multi-axis movement of the workpiece. Milling is a form of interrupted cutting where repeated cycles of entry and exit motions of the cutting tool accomplish the actual metal removal and discontinuous chip generation.

6.Give the functions of flutes on taps.

The flutes perform three functions, they are

(i) It provides cutting edges

(ii) To conduct the cutting fluid to the cutting region

(iii) To act as a channel to carry away the chips formed by cutting action.

7.What are the various types of gear generating process?

- Gear shaping process
- Gear planing process
- Gear hobbing process

8.What is straddle milling?

It is operation of producing a flat vertical surface on both side of a workpiece by using two side milling cutter mounted on the same arbor.

9.Give any three differences between gear hobbing and gear milling?

Gear Hobbing:

- Hob operates on several teeth at a time.
- It is not necessary to disengage cutter and work before indexing.
- Gear hobbing is faster process than gear milling.

Gear Milling:

- Milling machine can cut only one tooth at a time.
- It requires cutter and work to get disengaged before indexing can occur.
- It is slower process compared to gear hobbing process.

10.Distinguish between gear shaping and gear planning?

Gear shaping:

The job is indexed and tool reciprocates

Gear can be generated by using form tool as well as pinion cutter.

Gear planning:

Job is indexed and reciprocated but the tool is fixed.

Gear can be produced by means of form tool and Rack cutters.

11.What are the advantages of gear shaping over the other methods?

The advantages are:

The finished gear has a generated profile

It is suitable for cutting internal gears

Only one cutter is used for cutting all spur gears of the same pitch.

12.What do you understand by gear generating?

Gear generating process is based on the fact that any two motives gear of the some module will mesh exactly. In this process one of the gears act as cutter. Due to relative rolling motion of the cutter and blank, gear teeth are generated.

13.What are the parts used in the column and knee type milling machine?

Base 2. Column 3. Knee 4.Table 5.Over hanging arm 6.Front brace 7.Arbour

14. What is counter boring?

It is used to enlarge the end of the hole cylindrically and the enlarge hole forms the square shoulders with original hole.

15. What is tapping?

It is the operation to produce internal threads by using tap tool.

16. What is sensitive drilling machine?

It is a small machine designed for drilling small holes at high speed in light jobs. The feed should be manual .It is used to produce the up to 1.5 to 15mm.

17. What is the use of deep hole drilling machines?

It is used to produce deep holes in rifle barrels, cranks shaft, long shafts.

18. What is reaming?

It is the secondary operation after the drilling operation has been performed to produce the accurate hole or finish the hole.

19.What are the different types of mechanism used in shaper?

Crank and slotted Mechanism

Whit worth mechanism

Hydraulic shaper mechanism

20.What do you understand by Gang milling? (Apr/May 2017)

Gang milling is the process of producing many surfaces of a job simultaneously by feeding the table against a number of required cutters.

21.What is gear finishing? Why is it done? (Apr/May 2017)

The rough surface gear teeth occur due to vibration causing noise, excessive wear, play and backlash between meshing pair of gears. So, the gear produced by generating process leads to low power transmission and produces poor surface finish gears get hardened due to dimensional inaccuracy. Therefore the gear finishing is carried at last in gear manufacturing to produce accurate and good quality surface.

22.Why reaming operations is performed? (Nov/Dec 2017)

It is performed when a very high grade of surface finish and dimensional accuracy is required.

23.What are the work holding devices used in shaper. (apr/may 2018)

Clamping the vice
Clamping on the table
Clamped to the angular plate.

24.What are the different methods of indexing ? (Nov/Dec 2019)

- Direct or rapid indexing
- Plain or simple indexing
- Differential indexing
- Compound indexing
- Angular indexing

25.Explain the principle of quick return motion. (Nov/Dec 2019)

To convert the rotary motion of a motor into reciprocating motion of the tool, the various types of drives are provided in the shaper because the metal is removed during forward stroke. But no metal is cut during return stroke. Due to this,the time taken for the return stroke should be reduced by making the return stroke faster than the cutting stroke. It is achieved by quick return mechanisms.

26.How do shaping and planning differ? (Apr/may 2019)

shaping:

The job is indexed and tool reciprocates

Gear can be generated by using form tool as well as pinion cutter.

planning:

Job is indexed and reciprocated but the tool is fixed.

Gear can be produced by means of form tool and Rack cutters.

27.Explain the difference between generation and forming operations. (Apr/may 2019)

S.no	Generation	Forming
1	A single point cutting tool is used.	A multi-point cutting tool is used.
2	The cutting edge of the tool is made to the shape of gear tooth.	Gear cutters are used
3	The work is mounted between two centers.	The work is held between more than two gears
4	The work or tool reciprocates to perform cutting task	Gear cutters rotes.

28.How do you classify milling cutters ? (Nov/Dec 2018)

According to the shape of the tooth
According to the way of mounting on the machine
According to the type of operation

29.List the applications of gear hobbing. (Apr/may 2018)

Hobbing is used for generating spur, helical and worm gears.

Perfect tooth profile can be obtained.

It can be used in mass production.

Several gear blanks mounted on the same arbor can be processed simultaneously.

PART – B

1.Explain the hydraulic drive mechanism of a horizontal shaper with Neat sketch

<u>Hydraulic Drive</u>

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

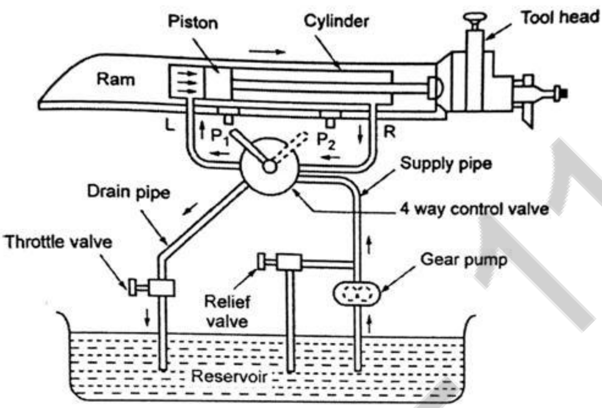


Figure 3.3 Hydraulic Drive

The supply pipe is again connected to the reservoir by a pump and relief valve. The valve is actuated by the lever and trip dog fitted to the ram. Oil is sucked by a gear pump from the reservoir at a particular pressure. This high-pressure oil goes to the cylinder through a four-way valve. The oil is allowed from the pump to the left side of the piston which forces the piston to move the ram towards right (R). It is called as forward or cutting stroke. In this stroke, oil flows out on the right side entry to the reservoir through the four way valve and drain pipe. The lever hits one trip dog (P_1) at the end of this stroke. Now, the lever position is changed. Due to this, the supply pipe supplies the oil on the right side of the piston which moves the ram towards left (L) called as return stroke or non-cutting stroke. In this stroke, the high-pressure oil covers less area on the cylinder. Due to this, the pressure force will increase. Hence, this return stroke is faster by supplying the same quantity of oil.
Advantages of hydraulic Drive:

Smooth cutting operation can be obtained by uniform speed

Changing of cutting speed is easier.

Higher cutting to return ratio can be obtained.

Infinite range of cutting speeds is available.

The operation is more safety due to the relief valve fitted.

Stroke length can easily be adjusted without stoping the machine.

2.What is ‘deep hole drilling’? List the measures that are taken to avoid drill run off and to drill straight holes.

Holes with a length to diameter ratio over 5 are called as deep holes.
It is impossible to obtain accurately straight holes using twist drill by using ordinary drill presses.
The straightness of the holds depends upon the rigidity of the twist drill and guiding action of margins adjacent to flutes, which slides on the drilled portion.
Deep hole drilling machine is used to drill deep holes in rifle barrels, crank shafts, long shafts etc.
The deep hole drilling machine is operated at high speed and low feed.
Mostly deep hole drilling machines are built in horizontal construction and it is used for center-cut gun drill which has a single cutting edge with straight flute running throughout its length.

In deep hole drilling machines, normally sufficient quantity of lubricant is pumped to the cutting points for removal of chips and for colling the cutting edges of the drill. For drilling long jobs they are supported at several points to prevent any deflection.

If the drill lips are unequal (or) it become dull unequally it will begin to deviate from the centre of the hole which leads to run off.

The amount of drill run off depends upon drill operation at initial stage of drilling when only the chisel edge cuts the metal at the square of drill axis.

The other factors influencing run off are checking due to large elastic deformation of the drill, excess play of spindle bearings and non-uniform adhering of chips.

The main difficulty encountered in deep hole drilling is the removal of chips and supply of cooling water to cutting edges.

Measures required to avoid drill runoff and to drill straight holes

Holes should be drilled at low rates of feed.

The drills should be carefully sharpen to maintain both lips at same angle.

Proper cutting fluid should be provided to avoid excessive wear of drill and removal of chips.

The hold is first spotted with a short starting drill of large diameter, with a point angle of 90°. This case is beneficial in drilling holes with small diameter in turret lathes and automatics.

Twist drill should be guided with a jig bushing in drilling holes with a comparatively low length to diameter ratio.

> It is better to drill hole with workpiece (i.e) drill bit is kept station-ary (or) rotating the drill bit in opposite direction to that of work-piece and then workpiece is rotated which keeps the drill in centre position and also reduces run-off.

3.Explain the indexing mechanism for a dividing head on milling machine?

<u>Indexing and dividing heads</u>

Indexing is the operation of dividing the periphery of the workpiece into any number of equal parts. In gear cutting, equal spacing of teeth on a gear blank is performed by indexing. Indexing is done by special attachment called indexing head or dividing head.

A working mechanism of an universal indexing/dividing head is shown in the Fig. 4.42

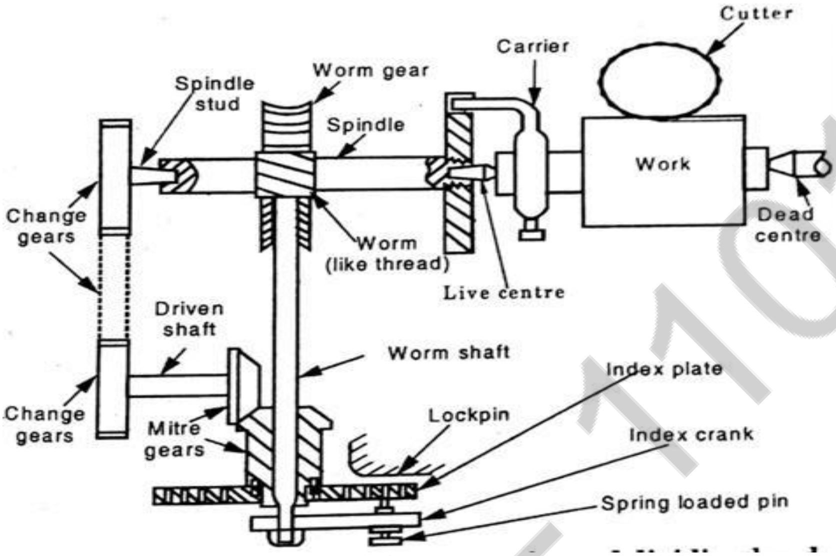


Fig 4.42 (a) Working mechaism of a universal dividing head

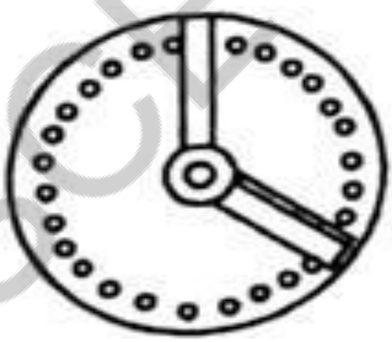


Fig 4.42 (b) Sector arm

- The main spindle housed on two bearings carries a worm gear. Worm is mounted on a worm shaft and at the other end a index crank is fitted.
- The worm gear has 40 teeth and worm is single threaded. Thus 40 turns of the crank will rotate the spindle through one complete revolution or one turn of the crank will causes the spindle to be rotated by 1/40 of a revolution.

In order to turn the index crank a fraction of revolution, an index plate is used. An index plate is a circular disc having a different number of equally spaced holes arranged in concentric circles.

The index plate is screwed on a sleeve which is loosely mounted on the worm shaft. Index plate remains stationary by a lock pin connected with the frame. A spring loaded pin fixed to the crank fits into the holes in the index plate.

If the pin is moved from one hole to the next hole in a 16 hole circle of the index plate, the spindle will revolve $\frac{1}{40} \times \frac{1}{16} = \frac{1}{640}$ of a turn.

Sector arm is used to eliminate the necessity of counting holes on the index plate each time the index crank is moved. Live centre is accommodated in the taper hole of the spindle.

The nose is threaded on the outside for mounting a chuck or a face plate. The work is supported between two centres or on a chuck.

The dividing spindle head may be connected with the table feed screw through a gear train to impart a continuous rotary motion to workpiece for helical milling.

4.Write short note on reaming operation

<u>Reaming Tools</u>

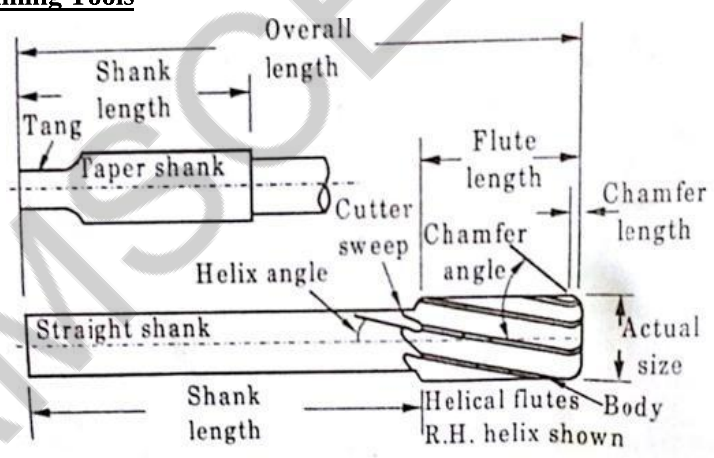


Fig. 3.66 (a) Reamer with Helical flutes

A reamer is a tool used for enlarging (or) finishing a hole previously drilled (or) bored to give a good finish and an accurate dimension. It has multi tooth cutter which removes relatively small amount of material.

Reamers may be for hand use by holding in a tap wrench (or) have taper shanks for use in machines like the tail stock of the lathe (or) in a drill press.

Reamers can be made up of

- Carbon tool steel
- High Speed Steel (HSS)
- Carbon tool steel with carbide tipped cutting edges
- High Speed steel with carbide tipped cutting edges

5.Why is gear finishing required? Discuss the various types of gear finishing operations.

Gear finishing are required to have accurate tooth profile, in order to operate most efficiently and render satisfactory life.

If gears want to operate quitely at high speed, it is essential to have smooth and hard forces of teeth.

When gears are produced rapidly and economically by most of the process except cold rolling, the tooth profiles may not be accurate as desired and if surfaces are rough, it will lead to rapid wear.

To obtain greater hardness of gears, it is heat treated, which may lead to slight distortion and surface roughness.

Hence, after the production of gears, it is essential to undergo gear finishing operations.

- Gear shaving
- Gear grinding
- Gear burnishing
- Gear lapping
- Gear honing
- Gear tooth rounding

The bottom drum is connected to a driving motor. Work pieces may feed against the abrasive cloth by hand. There is a platen supporting the belt at its backside. This grinder is used for rough grinding the work piece. The accuracy in this grinder cannot be expected. The accuracy depends upon the skill of the operator. Small and irregular shaped work piece can safely be ground on this grinder.

Gear Shaving

Gear shaving is process of finishing of gear tooth by rotating at very high rpm through meshing a gear shaving tool. It follows the principle of rack and pinion mechanism. In this case, the tool with serrations acts as a rack and the gear which is intended for finishing acts a pinion. When the tool moves, the serrations will act as cutting edges to remove rough surfaces on the pinion gear by scrapping process shown in Figure 3.120.

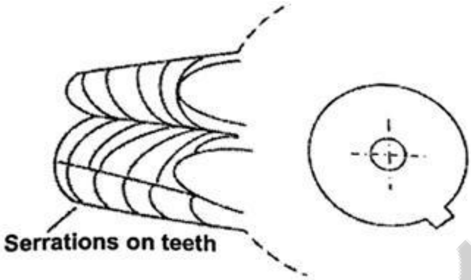


Figure 3.120 Gear shaving tool

Roll finishing of gear tooth

Two hardned rolling dies are used to remove the rough surface in the gear to be finished. The dies have very accurate tooth profile of the gear to be finished. The gear to be finished is held between these dies.

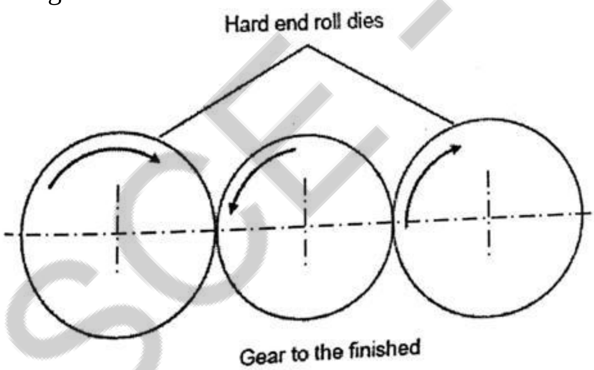


Figure 3.121 Roll finishing

Next, all three dies are rotating about their axis in meshing. During rotation, the pressure is applied by both dies on the gear to be finished. At the same time, the material of the dies should be harder than the gear in the process to permit the plastic formation of high points and burrs on the profile of gear tooth which results the smooth surface gear tooth.

Gear Burnishing

First, the gear to be finished is mounted on a vertical reciprocating shaft which is a type of mandrel. Next, the mandrel is held between three hardened rotating gears called burnishing gears. The burnishing gears are slowly moved towards the axis of gear to be finished. The rotations of all gears are permitted for a few minutes or atleast few revolutions to allow the plastic formation. The plastic formation of irregularities in cold state allows the flow of plastic liquid to form the smooth surface to the gear. The reciprocating motion of forward and backward passes of the gear to be finished is carried in order to obtain the smooth surface throughout the gear teeth surface. The quality of gear teeth can be ensured by maintaining the speed of burnishing and gear to be finished.

Gear Teeth Grinding

The abrasive grinding wheel of a required shape and geometry is used to finish of gear teeth. In addition, the abrasive grinding wheel should highly be heat treated to increase its hardness to perform and enhance the grinding action on the gear teeth to be finished. In this case, the gear to be finished is mounted in a shaft and reciprocated under the grinding wheel. The grinding action is carried out of each of the gear teeth.

In some cases, medium-hardened grinding wheels are used to save the cost of gear hobbing and gear shaving processes.

There are two methods by which the gear is generated

Gear generating process

Gear forming process

The generting grinding method uses two saucers shaped grinding wheels as shown in Figure 3.122. These grinding wheels are set so that their active faces are in planes tangent to the involutes curvatures of two teeth on the gear. This is accomplished by turning the wheels to an angle equal to the pressure angle of the gear being ground.

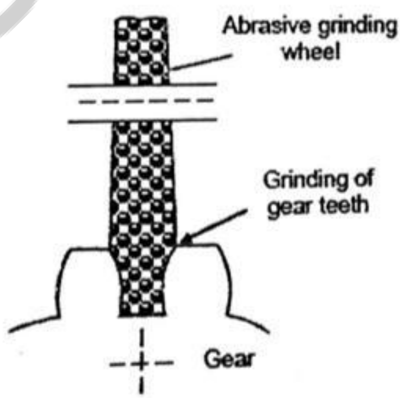


Figure 3.122 Abrasive grind wheel for teeth grinding

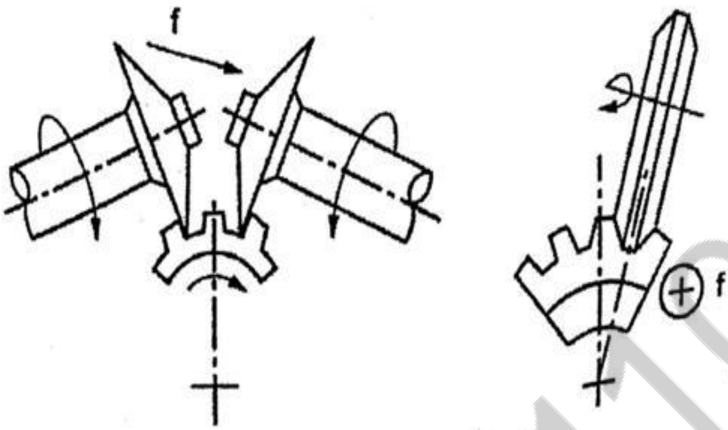


Figure 3.123 Gear teeth grinding

In forming method, the contour of the wheel is trued by a special fixture so that it coincides with the profiled of gear tooth. The adjacent flanks of two teeth are simultaneously ground.

Advantage:

Gears which cannot be finished by other methods can be ground.

Disadvantage:

Grinding gears are costly.

Gear Lapping

Lapping is a surface finishing process used for producing geometrically accurate flat, cylindrical and spherical surfaces. The removal of metal takes place by abrasive action.

The lapping process is used for:

removing small amounts of material from the surfaces of tools.

removing small defects and surface cracks left during previous operations.

eliminating small distortion

Machine Lapping

Machine lapping is performed for obtaining a highly finished surface on many articles such as races of ball and roller bearings, gears, crankshafts, machine bearings, pistons, pins and gauges etc. Hand lapping is used in lapping a few components only. For batch production lapping work, lapping machines are used.

In maching lapping operation process, the two surfaces are rubbed under a load. A fine abrasive suspended in oil is fed in between surfaces while the operation is in progress. During the operation in progress, the direction of rubbing is constantly changed. Three types of lapping media are used in lapping machines. These are: (a) metal laps and abrasive powders, (b) bonded abrasive and (c) abrasive paper or cloth. Metal laps are used on components requiring extremely high accuracy. Bonded abrasives are used for commercial production.

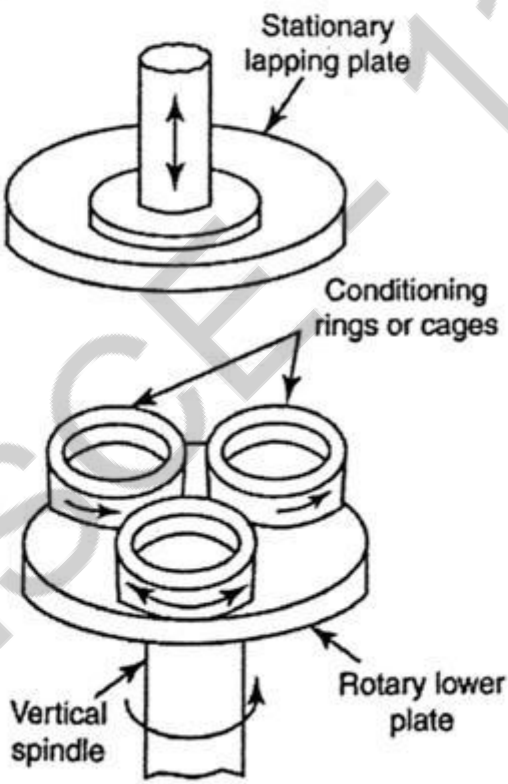


Figure 3.124

The following three types of lapping machines are commonly used.

Bonded abrasive circular plate lapping machines. These machines are used for lapping flat and circular work pieces.

Bonded abrasive or cast iron wheel machines. It works on the principle of centreless lapping and is used for lapping circular surfaces.

Internal cylindrical lapping machines. These machines are similar to honing machines.

The working principle of typical vertical spindle lapping machine is shown in Figure 3.124. The work pieces are loaded in conditioning rings or cages on the rotary lower plate which rotates about a vertical axis. At the same time, the conditioning rings also rotate along with the work pieces in their own positions. The combination of these two rotary motions provides a gyratory motion to the work pieces due to which the entire surface of the two plates is covered. It results an even wear of the plate surface and therefore, its flatness is maintained. The upper plate just provides a floating action and it helps in maintaining parallelism.

6.Write short note on super finishing.

<u>Super finishing</u>

Super finishing is micro finishing operation that is used for surface refining of cylindrical, flat, spherical and core shaped parts.

Super finishing is fine honing operation that obtaines high surface finish on component.

Removes chatter marks and removes fragmented or smear metal from the surface of dimensionally finished part.

It produces the ultimate in refinement of metal surfaces.

Stock removal in super finishing is of order of 0.005 to 0.025 mm on diameter with a surface finish of order 0.05 to 0.2 μ m.

It cannot correct the geometrical shape & surface but can impart high degree of geometric accuracy to work piece.

It is used both for internal and external surfaces of both cylindrical and plane surfaces.

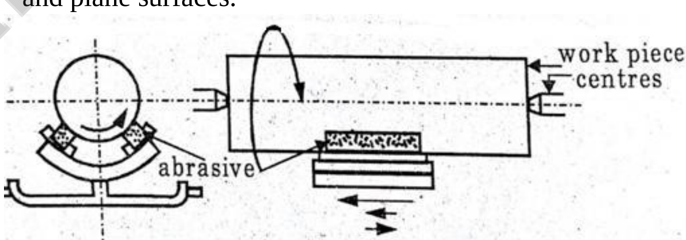


Fig 4.38. Shaft super finishing

7.Describe a Universal type milling machine.

Universal Milling machine:

It is the most versatile of all milling machines with its applications. The use of large of number of other machine tools can be avoided.

In appearance, a universal milling machine is similar to a horizontal milling machine the worktable of this machine is provided with another extra swivel movement with an index or dividing head located at the end of the table.

Thus, the universal milling machine table has the following movements.

- vertical movement-through the knee
- Cross wise movement-through the saddle
- Longitudinal movement of the table
- Angular movement of the table by swiveling the table on the swivel base.

The swiveling attachments provided on these machines help in cutting spirals, gear and cams in addition to normal milling operations. These machines are very accurate and used mainly for tool room work.

The various controls of a universal milling machine are shown in Figure 3.66.

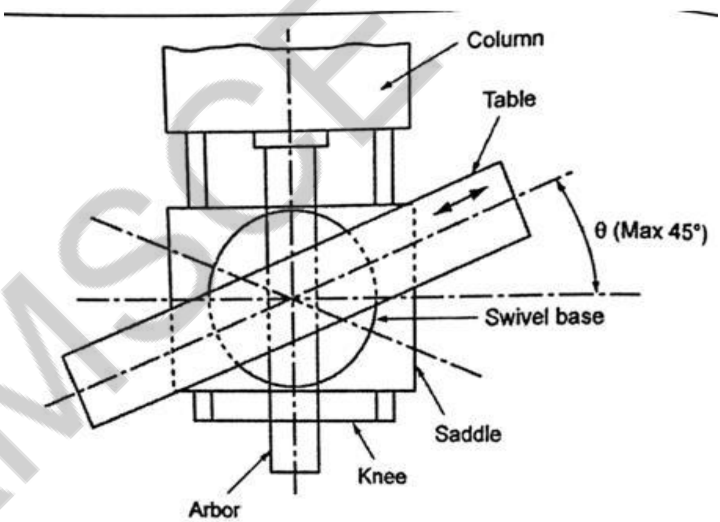


Figure 3.66

Comparison between pain and universal milling machine:

In a plain milling machine, the table is provided with three movements such as longitudinal, cross and vertical. In universal

milling machines. There is a fourth movement to the table in addition to these three movements. The table can horizontally be swiveled and can be fed at angle to the milling machine spindle.
The universal milling machine is provided with auxiliaries such as dividing head, vertical milling attachment, rotary table etc. Hence it is possible to make spiral, bevel gears, twist drills, reamers etc on universal milling machine.
The plain milling machine is more rigid and heavier in construction than a universal milling machine.
The plain milling machine is used for manufacturing operations whereas universal milling machine is used for tool room work and special machining operations. Hence, generally, universal milling machine is used in tool room work.

8.Explain with neat sketches the procedure for carrying out the following operations on a shaper. Horizontal cutting, vertical cutting, concave surface keyway cutting.

Shaping Operations:

The following operations can be performed on a shaper.

- Machining horizontal surface
- Machining vertical surface
- Machining angular surface
- Machining slots, grooves and keyways
- Machining irregular surfaces.

Machining Horizontal Surface

The work is held on a table and the tool is fitted on the tool post with minimum overhung. It should prevent the rubbing of tool on the work while returning

The tool is vertically adjusted by some clearance and the stroke length is set longer than work piece. i.e. 12mm tool approach and 8mm tool over run are added to the length of the work. Then the proper cutting speed and feed are chosen. During starting of the shaper to machine the work, the tool is just made to touch the job, Afterwards, the depth of cut is given at each end of the return stroke by rotating the down feed screw

In any machines, the roughing cut is performed by giving more depth of cut with slow cutting speed and faster feed. Similarly, the finishing cut is performed by giving less depth of cut with faster cutting speed and slow feed.

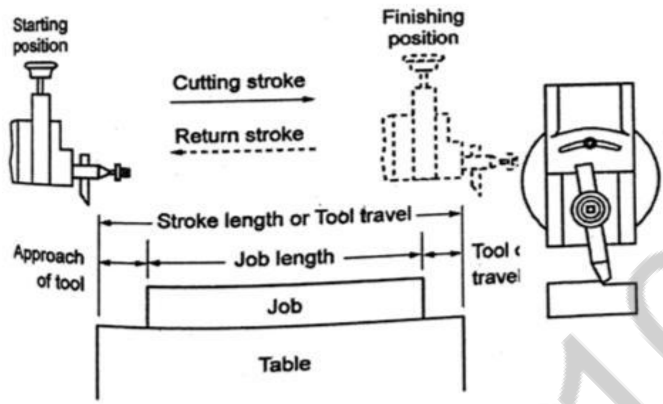


Figure 3.15 Machining horizontal surface

Machining Vertical Surface

The job is held on the table and the tool is set on the tool holder. The tool position and the stroke length are adjusted to a required dimension then the value on the vertical slide dial is set at zero. The apron is swiveled to avoid the rubbing of tool on the work surface during return stroke.

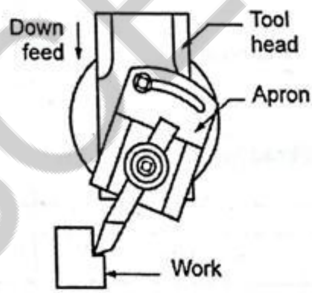


Figure 3.16 Machining vertical surface

The depth of cut is given by raising or elevation the table. Feed is given by rotating the down feed screws of tool head at the end of return stroke.

Machining Slots, Grooves and Keyways

The work is held in a vice using 'V' blocks and parallels. First a hole is drilled to a required keyway depth at the end of the work piece. The diameter of the hole should greater than the width of keyway. Then, the position and stroke length are adjusted. The keyway-cutting tool is set on the tool head. Finally, the external keyway is machined with reduced speed.

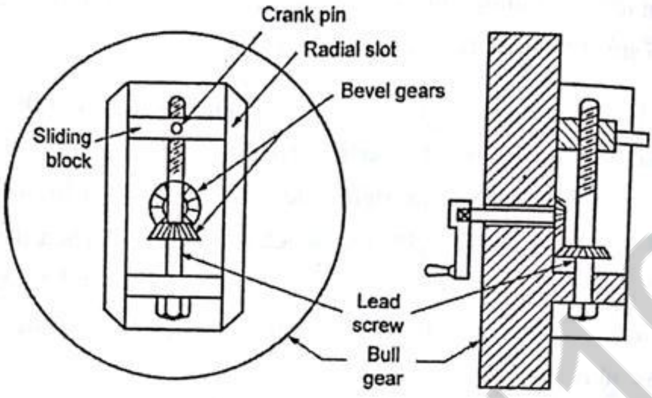


Figure 3.18 Machining grooves and slots

Machining Irregular Surface

For machining the irregular surface, a round nose tool is set on the tool head. By giving both the cross feed and vertical feed at the same time, the irregular surface is obtained.

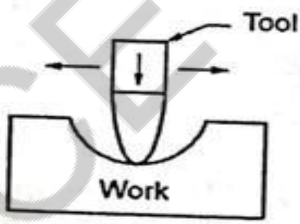


Figure 3.19

The cross feed is given through the table and the vertical feed is given by the tool head. The apron is fitted to some angle away from the machined surface to avoid the rubbing of tool on the work during return stroke.

9.List out the gear finishing processes. Explain any two with neat sketches.

Finishing of gears

Generally, the gear teeth are produced by any one of the generating processes. But, the gear does not be more accurate with good quality surface. The rough surface gear teeth occur due to vibrations causing noise, excessive wear, play and backlash between meshing pair of gears. So, the gear produced by generation process leads low power transmission

and produces incorrect velocity ratio because poor surface finish gears get hardened due to dimensional inaccuracies. Therefore, the gear finishing is carried at last in gear manufacturing.
The following gear finishing processes are described below.

Gear Shaving

Gear shaving is a process of finishing of gear tooth by rotating at very high rpm through meshing a gear shaving tool. It follows the principle of rack and pinion mechanism. In this case, the tool with serrations acts as a rack and the gear which is intended for finishing acts a pinion. When the tool moves, the serrations will act as cutting edges to remove rough surfaces on the pinion gear by scrapping process shown in Figure 3.120.

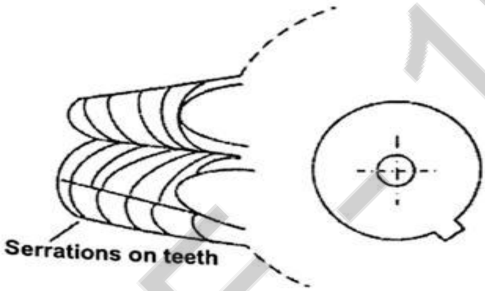


Figure 3.120 Gear shaving tool

Roll Finishing of Gear tooth

Two hardened rolling dies are used to remove the rough surface in the gear to be finished. The dies have very accurate tooth profile of the gear to be finished. The gear to finished is held between these dies.

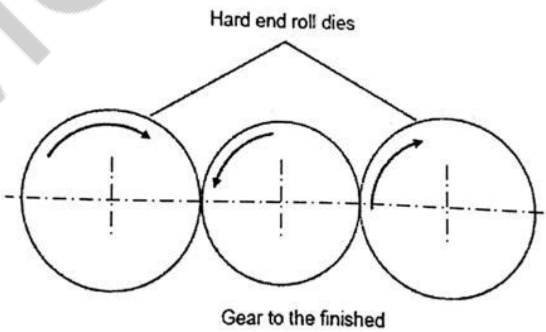


Figure 3.121 Roll finishing

Next, all three dies are rotating about their axis in meshing. During rotation, the pressure is applied by both dies on the gear to be finished. At the same time, the material of the dies should be harder than the gear in the process to permit the plastic formation of high points and burrs on the profile of gear tooth which results the smooth surface gear tooth.

10.Enumerate with a neat sketch gear shaping.

<u>Gear shaping</u>

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 types of cutters are used such as disc type and shank type cutters. Both axes of cutter and blank are parallel. After loading the work, the cutter is radially fed into the blank to give the depth of cut.

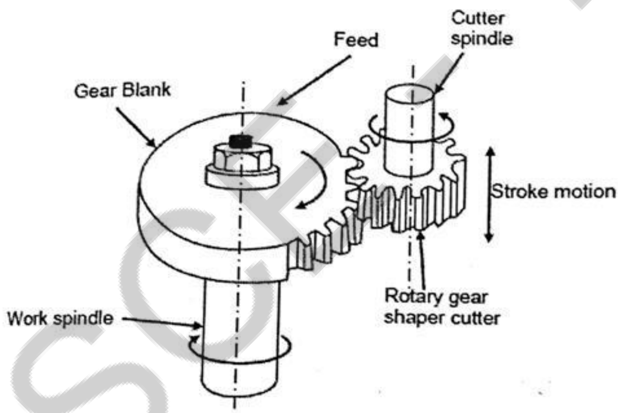


Figure 3.114 Gear shaping

The cutter and work spindle are separately connected with gear trains. 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 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.

Rotary motion of the cutter and blank.

Radial feed of the cutter towards the blank

Vertical reciprocating motion of cutter.

Withdrawal motion of the blank away from the cutter during re-turn stroke.

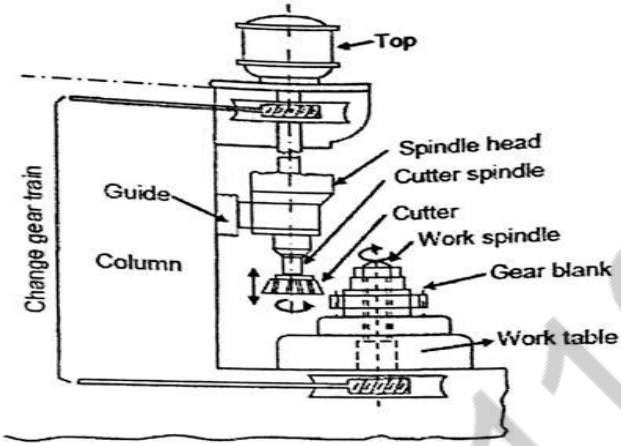


Figure 3.115 Gear shaping machine

Applications:

Gear shaping is used for generating both internal and external spur gears.

Helical gears can also be generated using special attachments.

Advantages:

Both internal and external gears can be generated.

Various sizes of gears can be generated using a single cuter.

Special gears of non-conventional type gears such as elliptical gear, face gear, cluster gear can be cut.

Very high degree of accuracy can be obtained due to removal of uniform size of chips.

As the cutting action is continuous, the rate of production will be high.

The mechanism is simple.

Limitation:

Worm gears of cluster gears cannot be produced.

11.List out various operations carried out on drilling machine. Explain any three.

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.

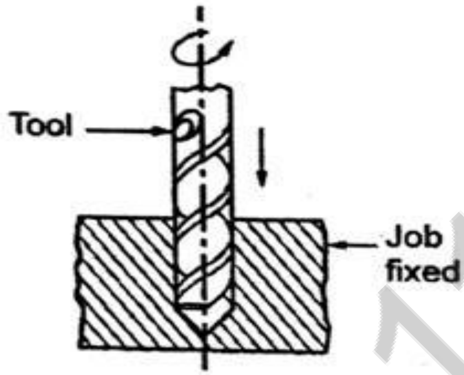


Figure 3.27 Drilling

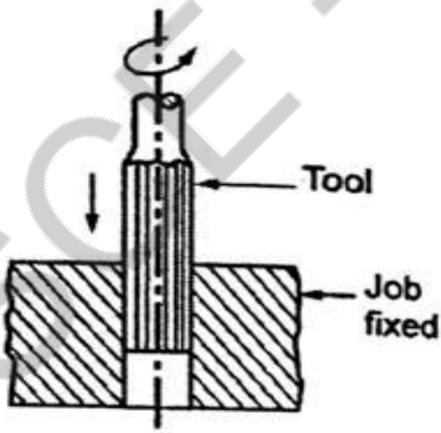


Figure 3.28 Reaming

Reaming

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

Boring

Boring is an operation of enlarging a hole by a single point cutting tool. Boring is done where the 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 accurately finished to the required size. The internal surface of a hole in a casting is machined by boring process. Boring corrects out the roundness of a hole. The cutter is held in a boring bar. The boring bar has a tapped shank to fit into a spindle hole. Boring is a slow process.

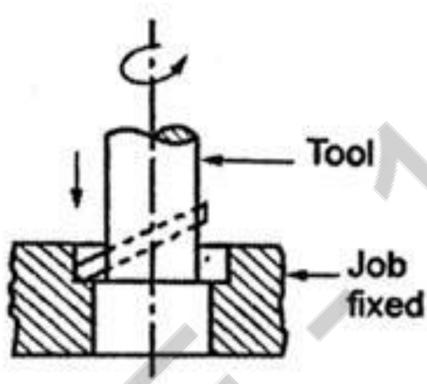


Figure 3.29 Boring

Counter Boring

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

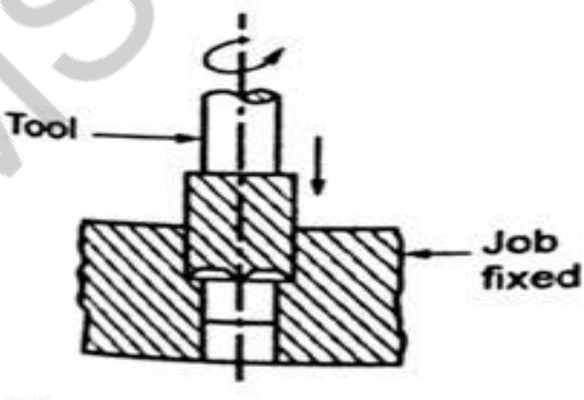


Figure 3.30 Counter boring

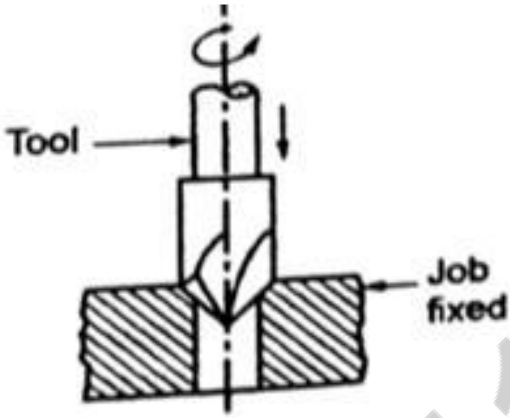


Figure 3.31 Counter sinking

12.What are various types of milling cutters that are used in milling?

Milling Cutters

Classification of Milling Cutters

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

According to the shape of the tooth

- Milled tooth cutters.
- Form relieved cutters.

According to the type of operation

- Plain milling cutters
- Side milling cutters
- End mill cutters
- Angle milling cutters
- T-slot milling cutters
- Slitting saws
- Form milling cutters
- Fly cutters
- Wood ruff key slot milling cutter.

According to the way of mounting on the machine

- Arbor cutters

Shank cutters

Face cutters

1. Plain milling cutter:

It 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 the flat surface parallel to its axis. There are two types of plain milling cutters commonly used.

Plain straight teeth cutter

Plain milling helical teeth cutter.

The plain milling cutters having the width more than its diameter as shown in Figure 3.83 is called slab mill cutter. It is used for rough machining with coarse feed. The cutter has less number of teeth.

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.

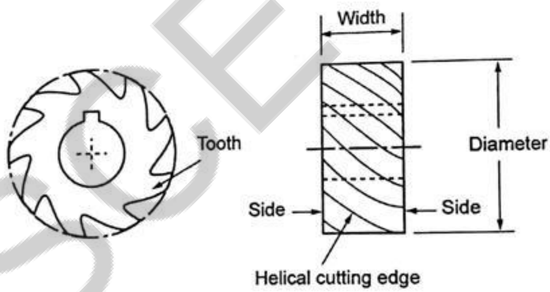


Figure 3.82 Plain milling cutter

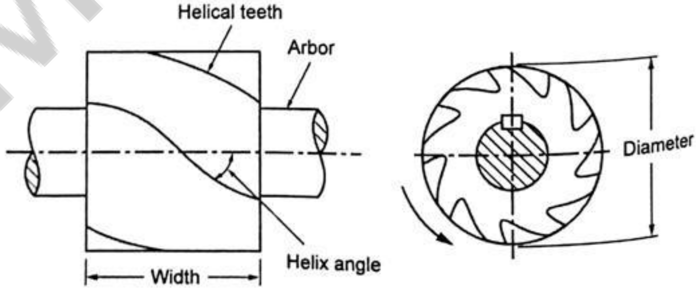


Figure 3.83 Slab milling cutter

2. Side milling cutter:

It has cutting edges on its periphery and also on sides. This cutter is used for removing metal from the side of the workpieces. It is also used for cutting slots. These cutters may have plain, helical or staggered teeth. Among these three, helical cutters are preferred on milling machines since they require less power for machining. Also, it provides smoother operation as more than one tooth performed a milling operation at a time.

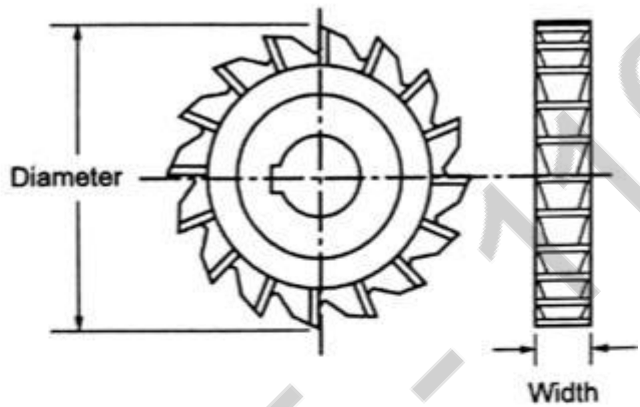


Figure 3.84 Side milling cutter

3. End milling cutter:

The end milling cutters have cutting teeth on the end as well as on the periphery of the cutter as shown in Figure 3.85. 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.

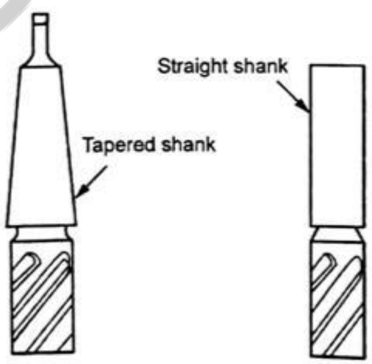


Figure 3.85 End milling cutter

Tapered shank cutters are fitted to the spindle using adapters. Straight shank cutters are fitted to the spindle using collets. End mills are commonly used for vertical milling operations. They are used for light milling operations such as 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 uses are in milling V-grooves, notches, dovetail slots, reamer teeth and other angular surface. Angular cutters are classified into single angle cutters and double angle cutters.

A single angle cutter may have their teeth either only on the angular face or on both, angular face and side as shown in Figure 3.86. The latter type enables simultaneously milling both the flanks of the incined angular groove. Their teeth may have an included angle of 45_0 to 60_0.

Double angle cutters differ from single angle cutters in such a way that have two angular faces which join together to form V-shaped tooth as shown in Figure 3.87. The included angle of this ‘V’ is either 45_0, 60_0, or 90_0. The angle of both sides should be equal.

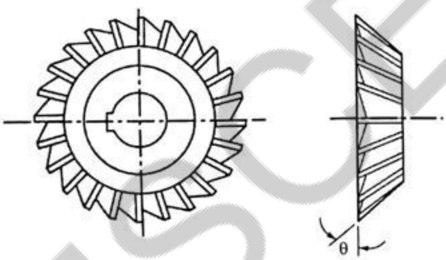


Figure 3.86 Single angle milling cutter

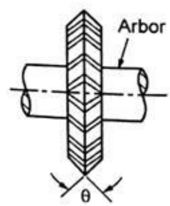


Figure 3.87 Double angle milling cutter

5. T-slot milling cutter:

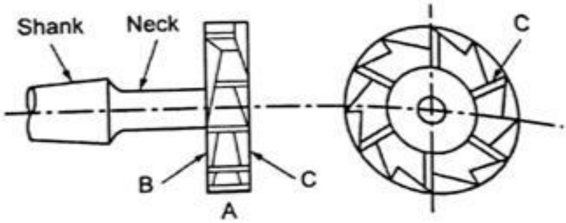


Figure 3.88 T-slot milling cutter

It is a single operation cutter which is used only for cutting T-shots. The arrangement of cutting teeth is similar to a side milling cutter. But this cutter has a tapered shank. A neck is formed between cutting face and shank as shown in Figure 3.88. The cutter has cutting edges on its periphery and sides as mentioned A, B and C in Figure 3.88.

6. Slitting saws:

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

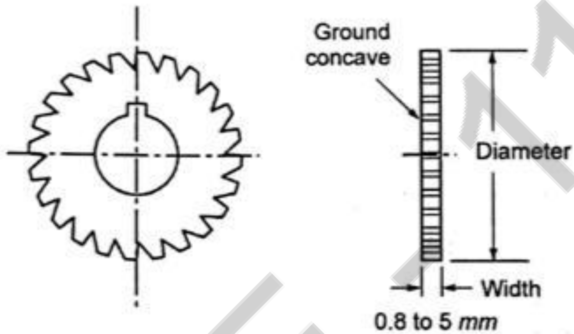
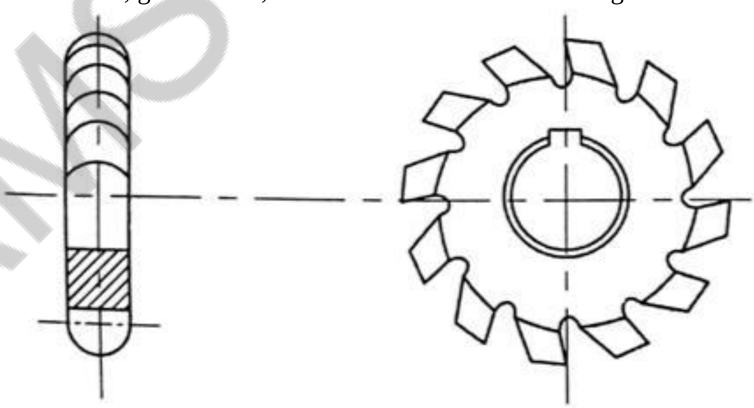


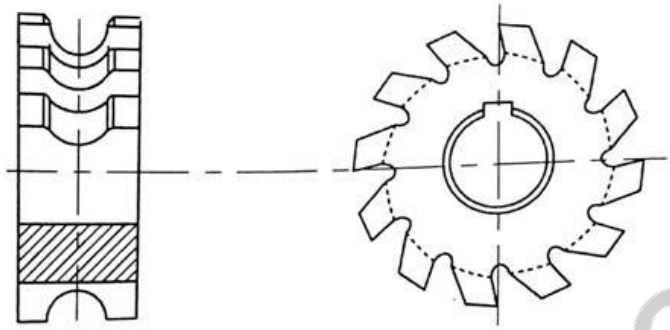
Figure 3.89 Slitting saw

7. Form milling cutter:

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.



(a) Convex milling



(b) Concave milling

Figure 3.90 Form milling cutter

Convex milling cutter has teeth curved outward on its periphery as shown in Figure 3.90 (a). The cutter will produce a concave semi-circular surface on the workpiece. Concave milling cutter has teeth curved inwards on its periphery as shown in Figure 3.90 (b). The cutter will produce a convex semicircular surface on the workpiece. 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 with the same module, different cutters are required. The corner rounding cutters are used for milling the edges and corners of jobs to required radius.

8. Fly cutters:

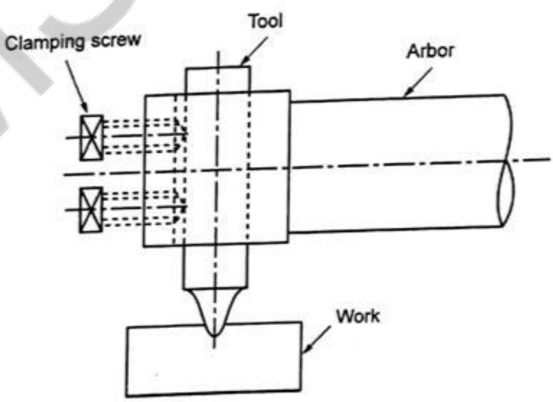


Figure 3.91 Fly cutter

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 bar. Clamping screws are used for tightly holding the tool in above holders as shown in Figure 3.91. The cutting edge of the tool is ground to the required shape. The cutter removes metal when it rotates.

9. 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 neck. The cutter may have straight or staggered teeth. The sides of the cutter are ground concave as shown in Figure 3.92. It provides a clearance for the cutter movement. It is used to cut woodruff key slot in a shaft.

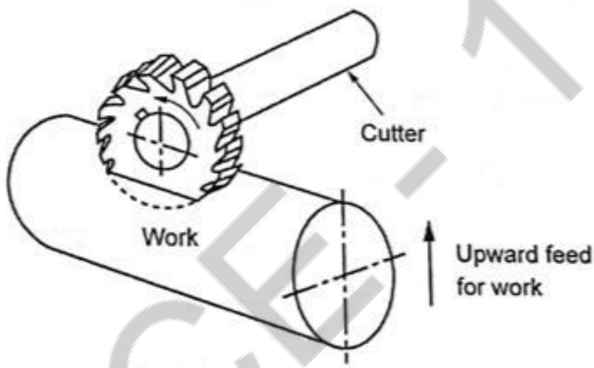


Figure 3.92 Woodruff key slot milling cutter

13. Describe with neat sketch the quick return mechanism used in shaper.

Quick Return Principle

From Figure 3.5, A_1 and A_2 are rear and forward extreme positions of link. S_1 and S_2 are two extreme positions of a crank pin. During forward stroke, the link moves from A_1 to A_2 as the sliding block moves from S_1 to S_2 in the clockwise direction at an angle of α.

During return stroke, the sliding block goes from S_2 to S_1 in clockwise direction through an angle of β. But, the speed of bull gear is constant throughout. Therefore, the time taken during these two strokes is directly proportional to these angles α and β. But the angle β is smaller than α. So, the time taken by the return stroke will be reduced.

$$\therefore m = \frac{\text{Cutting time}}{\text{Return time}} = \frac{\alpha}{\beta} = \frac{\text{Cutting angle}}{\text{Return angle}}$$

m varies from 2.1 to 3.2.

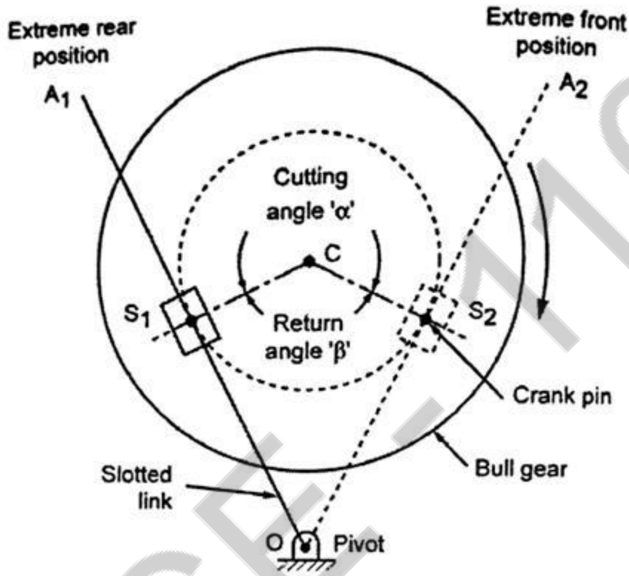


Figure 3.5 Quick return motion

Whitworth quick return mechanism:

The shaft of an electric motor drives the pinion which rotates the bull gear. The bull gear has a crank pin. A sliding block slides over this crankpin and it slides inside the slot of a crank plate.

The crank plate is eccentrically pivoted at point S. A connecting rod connects the pin at P at one end ram at the other end M. When the pinion rotates, the bull is also rotated along with the crank pin. At the same time, the sliding block slides on the slot provided on the crank plate. It makes the ram to move up and down (reciprocating motion) by the connecting rod.

The two important cases are discussed below.

When the pin A is at X, the ram is in forward stroke. At that time, the bull gear rotates in anticlockwise direction at angle of α.

When the bull gear rotates further in the same direction from Y to X at an angle of β, the return stroke will take place. Here, the angle β is lesser than α. So, the time taken for the return stroke is reduced.

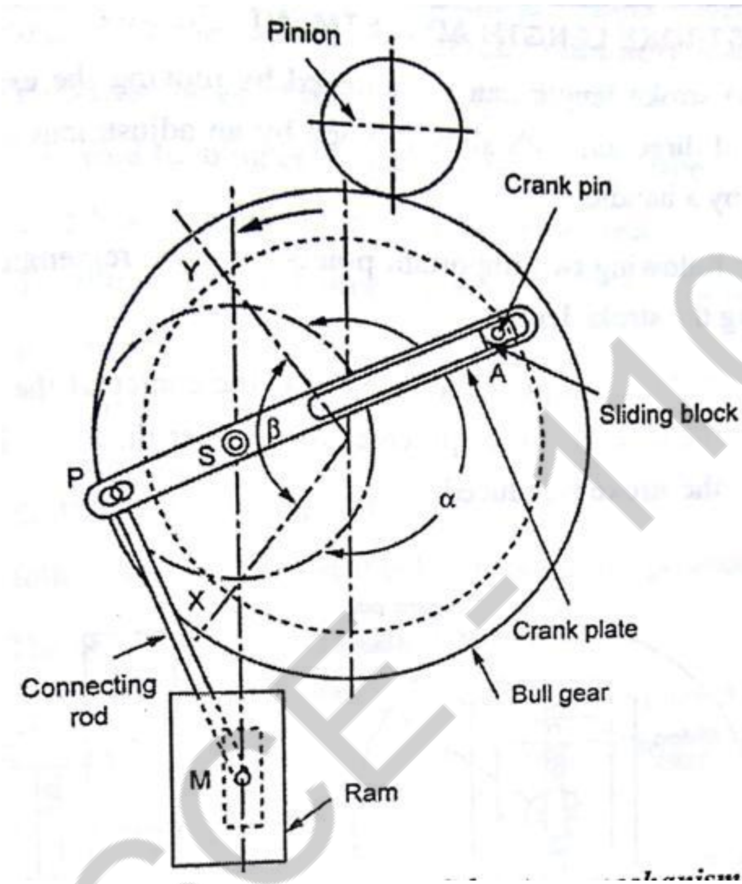


Figure 3.6 Whitworth quick return mechanism

$$\therefore m = \frac{\text{Cutting time}}{\text{Return time}} = \frac{\text{Angle } \alpha}{\text{Angle } \beta}$$

14.What are the various types of milling cutters that are used in milling? Discuss any three

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

Milled tooth cutters

Form relieved cutters According

to the type of operation.

Plain milling cutters

Side milling cutters

End mill cutters
Angle milling cutters
T-slot milling cutters
Slitting saws
Form milling cutters
Fly cutters
Wood ruff key slot milling cutter.

According to the way of mounting on the machine
Arbor cutters
Shank cutters
Face cutters

1. Plain milling cutter
It 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 the flat surface parallel to its axis. There are two types of plain milling cutters commonly used.
Plain straight teeth cutter
Plain milling helical teeth cutter
The plain milling cutters having the width more than its diameter is called slab mill cutter. It is used for rough machining with coarse feed. The cutter has less number of teeth.

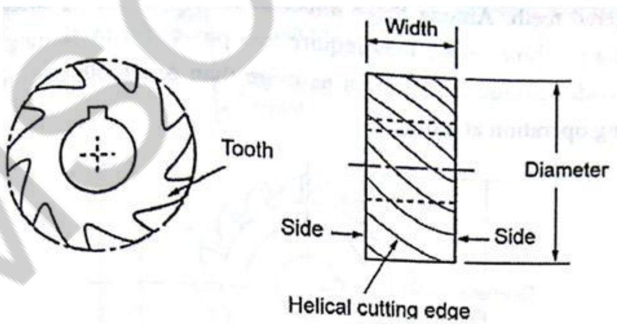


Figure 3.81 Plain Milling Cutter

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.

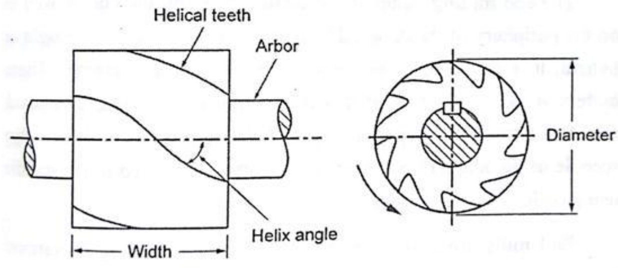


Figure 3.82 Slab Milling

Cutter 2. Side milling cutter:

It has cutting edges on its periphery and also on sides. This cutter is used for removing metal from the side of work pieces. It is also used for cutting slots. These cutters may have plain, helical or staggered teeth. Among these three, helical cutters are preferred on milling machines since they require less power for machining. Also it provides smoother operation as more than one tooth performed a milling operation at a time.

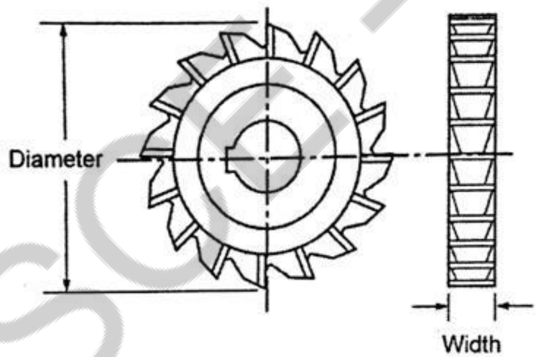


Figure 3.83 Side milling cutter

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

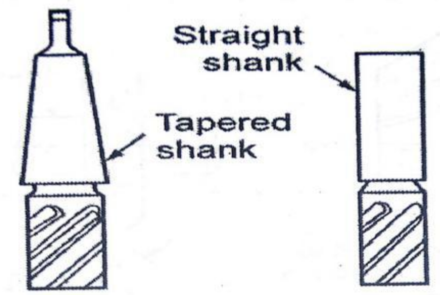


Figure 3.84 End milling cutter

15.What are the various methods used for gear finishing? Discuss any two methods.
REFER MAY/ JUNE 2015

16.Enumerate with neat sketch kinematics of gear shaping machine.
REFER MAY/JUNE 2015

17. Discuss in detail about the features of hydraulic drive of a horizontal shaper and list its advantages also.
(Apr/May 2018) Refer Q.No: 01

18. Write short notes on gear shaping. List the advantages and disadvantages of gear shaping process. (Apr/May 2018)
Refer Q.No: 10

19. Classify the different types of milling cutters and outline each with illustrative sketch. Explain form milling, Gang milling
(Nov/Dec 2018) Refer Q.No: 12

20. Explain the working principles of gear shaving process.
(Apr/May 2019) Refer Q.No: 05

21. With simple line diagram explain various operations performed in a drilling machine. Also give salient features to explain reasons why a radial drilling machine is called as a versatile machine.
(Apr/May 2019) Refer Q.No: 11

22. With the help of a neat sketch explain a vertical milling machine.
(Nov/Dec 2019)

23. Describe a gear hobbing machine with a neat sketch.
(Nov/Dec 2019)

ABRASIVE PROCESS AND BROACHING 4

PART A

1.What are the advantages and disadvantages of using centreless grinding?

Advantages:

The work is supported throughout its entire length. So, there is no deflection
The process is best suited for mass production
An excellent accuracy and fine surface finish

Disadvantages:

Work with flats and key ways cannot be ground.
Work pieces with step and multiple diameters cannot be ground.

2.What are the three methods of external cylindrical centreless grinding?

Through feed
In feed
End feed

3.What is the principle of a broaching process?

Broaching 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. Each tooth removes a predetermined amount of material. The job is completed in one stroke of the machine.

4.List some of the materials of broaching tools.

High speed steel (HSS) are mostly used as material for broaches
Brazed carbides are used for cutting edges for machining cast iron parts with close tolerances.

5.What are grinding points? Sketch the various grinding points?

Small grinding wheels of about 50mm and less diameter are mounted securely and permanently to steel spindle or mandrel by cementing or other means called as grinding points.

6.What is a tool post grinder?

Tool post grinders is used for miscellaneous and small grinding works on a lathe.

The grinding wheel is held on the tool post of a lathe and fed across the work, the regular longitudinal or compound rest feed being used

A common application of tool post grinders is the truing of lathe centres.

7.How does loading differ from glazing in grinding process?

A glazed wheel has cutting particles which are dull worn out bond. It will not allow the dulled particles to be turn of the wheel. A glazed wheel increased the smoothness of the wheel face and it decreases its cutting capacity.

The loaded wheel has particles of the metal being ground adhering to it. They prevent the wheel from cutting freely due to openings and pore of the wheel face filled up with metal.

8.What are the principal types of broaching machines?

The broaching machine may be classified as follows.

According to the nature and direction of primary cutting motion – horizontal, vertical, and continuous

According to the purpose – internal, and external surface

According to method of operation – pull and push

According to construction of the broach tool – solid, inserted tooth, progressive cut, built-up

According to the function – keyway, burnishing, spline, round-hole, surface

According to number of main slides or stations – single, double, multiple slides

According to motion of broach tool relative to work – straight line motion, stationary broach tool.

9.Why is grinding called finishing process?

Grinding is called finishing process, because the grinding process removes metal usually in the order of 0.25 to 0.50 mm. It produces very high quality surface finish.

10.What are the types of precision grinders?

Cylindrical grinders b) Internal grinders c) Surface grinders d) Tool and cutter grinders e)

Special grinding machines

11. What is the use of internal grinders?

Internal grinders are used to finish straight, tapered, or formed holes to correct size, shape and finishing.

12. How does the centre less grinding operate?

The centre less grinding operates with two wheels as the cutting or grinding wheel, to remove excess stock and a regulating wheel is used to control the speed of rotation of work and rate of feed.

13. How are the non-ferrous metals held in magnetic chuck?

Non-ferrous metals may be held on a magnetic chuck by clamping them in suitable fixtures made of iron or steel by exhausting air from a vaccum chuck

14. What is meant by measuring and sizing devices?

The measuring and sizing devices range from simple measuring devices to continuous reading gauge, which actually control the feeding of the machine.

15. What are natural and artificial abrasives?

Natural abrasives are available in the earth. They have more impurities. In artificial abrasives we can easily control the quality.

16.What do you mean by duplex broach?(Apr/May 2017)

Surface broaching machines have their broaching tools attached to a ram or rams forced in a straight path along guideways past the work-piece. On some machines the ram moves horizontally, On others vertically, when two rams are used the machine is called a Duplex broach.

17.Define the terms 'Glazing ' and 'Loading' with respect to grinding wheels. (Apr/May 2017)

Glazing of the wheel is a condition in which the face or cutting edge takes a glass-like appearance. i.e. the cutting points of the abrasives have become dull and worn down to the bond.

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

18.Define grinding Ratio? (Nov/Dec 2017)

Grinding efficiency $E = \frac{G}{U}$ in this equation

'G' is grinding ratio which is defined as the volume of material removed per unit volume of wheel wear

$$G = \frac{\text{Volume of material removed}}{\text{Volume of wheel wear}}$$

19.Why broaching process is long and laborious? (Nov/Dec 2017)

Broaching process is long and laborious because it the cut is performed in one pass of the broach, which makes it very efficient.

- ❼ Broaching is used when precision machining is required, especially for odd shapes. i.e. circular, non – circular holes, spliner, keyways, and flat surfaces
- ❼ It used in high – Quantity production runs.

20.What are the specifications of grinding wheel? (Apr/may 2018)

- Type of abrasives
- Grain size or grit number
- Structure
- Type of bond
- Manufacturer's code

21.Why is the centre less grinders called specialized machine for cylindrical parts ? (Apr/may 2018)

Centre less grinders called specialized machine for cylindrical parts because centre less grinding differs from centred grinding operations in such a way no spindle or fixture is used to locate and secure the workpiece. The workpiece is secured between two rotary grinding wheels and the speed of their rotation relative to each other determines the rate at which material is removed from the workpiece.

Centreless grinding is performed on cylindrical workpieces such as pistons, valves, rings, tubes, balls, wrist pins, drills, bushings, shafts etc.

22.What is broaching operation? (Nov/Dec 2018)

Broaching is a process of removing metal from a work piece by a cutting tool called Broach.

Broach is a tool having multiple cutting edges arranged along its length. The tool may be pulled (or) pushed over a surface on the work piece. As the height of the tooth is gradually increasing, the metal will be removed progressively by each tooth. The work will be machined in a single pass of the broach.

23.Mention the factors involved in the selection of a grinding wheel? (Nov/Dec 2018)

Constant factors

Variable factors

24.Compare push broaching and pull broaching ? (Apr/May 2019)

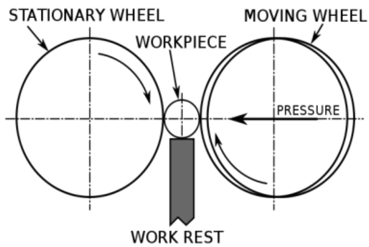
A push broach is pushed through the work during cutting. During broaching the broach comes under compressive load. To avoid bending, the push broach is made short. Because of this, only less amount of material is removed by the broach.

A pull broach cuts the material while it is pulled through the work piece. During pulling the broach comes under tensile load. So it is not bend during machining. So the broach can be made longer. So more amount of material can be easily removed by the broach.

25.What is dressing, in reference to grinding wheel ? (Apr/May 2019)

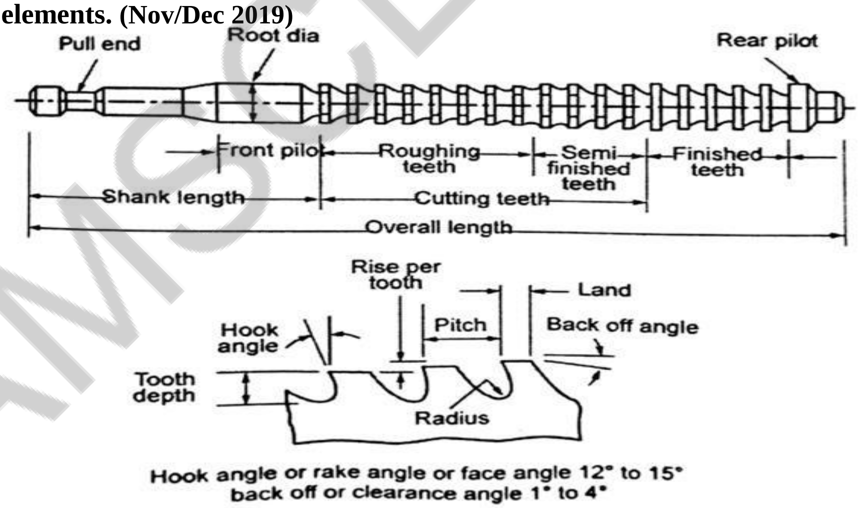
It is the process of loading and breaking away the glazed surface so that new sharp abrasive particles are again present to work for efficient cutting is called dressing. The dressing is done using the tool called dresser.

26.With the help of a neat figure explain a centerless grinders. (Nov/Dec 2019)



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.

27.Draw a neat diagram of a broaching tool and label its important elements. (Nov/Dec 2019)



PART B

1.Discuss the various types of bonding materials generally used for making Grinding Wheels.

<u>Type of Bonds</u>

Bond is an adhesive substance which holds the abrasive grains together to form the grinding wheel. The bonds must sufficiently be strong to withstand the stresses of high speed rotating grinding wheel. There are various types of bonds used and their choice depends on operating conditions of the abrasive tool such as grinding speed, pressure on the tool, heat formation in the grinding zone etc.

Bonds are classified into two types.

- Organic
- Non-Organic

Metallic, vitrified and silicate bonds are non-organic. Resinoid, rubber, shellac and oxychloride bonds are organic. The various bonding procedures are discussed below.

Vitrified bond:

Vitrified bond is made of clay and water. The abrasive grains and fusible clay (also called as 'felspar') are thoroughly mixed together with sufficient water to make the mixture uniform. This mixture is placed in moulds to get the shape of grinding wheel and air is dried at room temperature.

These wheels are then fed into a kiln and allowed to remain for few days at a temperature of about 1260°C. This process is known as fusing and it provides for uniform distribution of the bond throughout the wheel. Then, these wheels are trimmed to the required size. Vitrified bonds are used most extensively.

Advantages:

- It is made porous and enables a quicker stock removal.
- It is not affected by water, oil, acids and alkaline.
- The bond itself is very hard and acts as an abrasive.
- The structure of the wheel is uniform due to wet mixing of the different constituents.

Disadvantages:

- The Process of manufacture is very slow.
- Cracks may develop in large wheels during fusing.
- Wheels over 750mm diameter cannot easily be produced.
- High temperature in the kiln tends to make the abrasive grains weak.
- A proper control during fusion becomes difficult.

Silicate bond:

Silicate wheels are made by mixing abrasive grains with silicate of soda. The mixture is moulded in a mould and dried for several hours. After drying, the moulded material is kept in a furnace at about 260°C for 20 to

80 hrs. Silicate bonded wheels are light grey in colour. These wheels are having a fairly high tensile strength. The specific purpose of these wheels is that where a coal cutting action with less wear is needed in grinding the edges of the heat-treated steel cutting tools.

Advantages:

It is more rapid process than vitrified bond.

There is no tendency to weaken the grains because of low temperature.

Fusing is better controlled and hence, it results a more reliable bond.

Large wheels up to 1500mm diameter can easily be produced.

The cutting action of the wheel is smoother and cooler.

Disadvantages:

Extra hard wheels cannot be produced with this bond.

Wear of the wheel is high

Harder grades of this bond do not provide a free cutting action.

Resinoid Bond:

Resinoid bonding is produced by mixing abrasive grains with synthetic resins. The mixture is rolled to the desired shape and baked at a temperature of 210°C to 250°C for few hours. At this temperature, the resin sets to hold the abrasive grains in a wheel form. Resinoid bonded wheels are strong, elastic and permet high peripheral speeds but they are destroyed by alkaline cooling fluids. It can be avoided by impregnating the wheel with paraffin.

These wheels normally operate at surface speeds in the region of 300m/ min. They are particulary suitable for the use in grinding steel, cast iron and malleable iron castings.

Rubber bond:

The abrasive grains are mixed with liquid rubber and sulphur. The mixture is rolled into sheets of required thickness. The wheels are then cut and placed in preheated moulds and vulcanized under pressure. These wheels are quite strong, close-grained and can be made in very thin sections. They are mainly used where a very high-class surface finish is primary requirement. The rubber-bonded wheels are also used as regulating wheels in centreless grinding. During the operation, water can safely be used as a coolant but caustic soda and oil should not be used.

Shellac Bond:

Shellac bonded wheels are made by mixing the abrasive grains with shellac in a mixture. Then, the mixture has been rolled or pressed into a desired wheel shape. They are hardened by baking for several hours at about 160°C. Shellac bond wheels are strong but it posses some elasticity as rubber wheels. These wheels produce high surface finish and are used for grinding parts such as camshafts and mill rolls. A very thin wheels are used fro cutting off operations.

<u>Oxy Chloride bond:</u>

This bond is produced by mixing abrasive grains with oxide and chloride of magnesium. This mixture is pressed into moulds and dried. It is heated in a furnace. These wheels are less brittle and less sensitive to side loads as compared to vitrified bond wheels. The type of wheel ensures a cool cutting action. So, grinding is done dry condition. These wheels are affected by acidic solutions, dampness and sudden changes in temperature. This bond is used for making disc shaped wheels.

Different types of bonds used in grinding are represented by different symbol as shown below:

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

2.Write short note on abrasive belt grinding.

<u>Abrasive Belt Grinder</u>

The line diagram of this grinder is shown figure 4.11. A belt has an endless abrasive belt running over two drums. The abrasive belt has small abrasive grains pasted to one of its side.

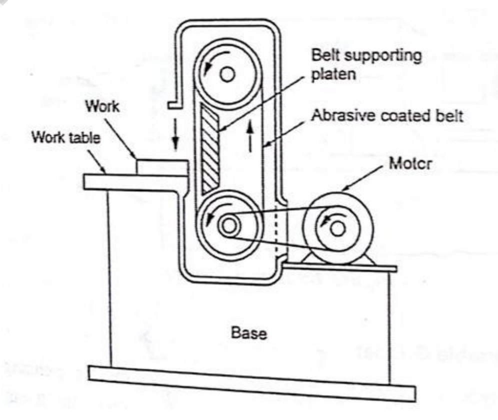


Figure 4.11 Abrasive belt grinder

3.Enumerate the advantages and disadvantages of centreless grinding. Advantages:

The work is supported throughout its entire length. So, there is no chatter or deflection.

Size of the job can easily be controlled by a regulating wheel.

This process is best suited for mass production since the process is continuous and rapid.

An excellent accuracy and fine surface finish can be achieved as there is no distortion of work piece during grinding.

Work holding devices such as chucks, dogs, centres, mandrels are not required.

A wide range of components can be ground.

A very little skill is required for the operator.

Large grinding wheels can be used so that the wheel wear is minimized.

Disadvantages:

Work with flats and key ways cannot be ground.

Work pieces with step and multiple diameters cannot be ground easily.

In hollow work pieces, there is no certainty that the outside diameter will be concentric with the inside diameter.

3.Explain the following in grinding (1) Dressing and Truing.

<u>Dressing</u>

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. The dressing is done using the tool called dresser.

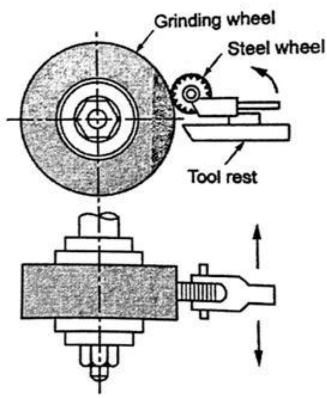


Figure 4.2 Star wheel dresser

There are various types of dressing tools available

- Star dressing tool
- Round abrasive stick
- Diamond dressing tool.

Figure 4.2 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.

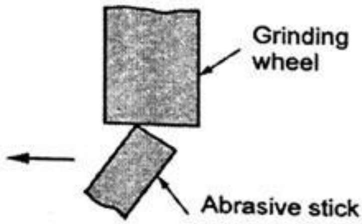


Figure 4.3 Abrasive stick dresser

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. A round abrasive stick type of dressing tool consists of steel filled with a bonded abrasive. The end of the tube is held against the wheel and it moves across the face.

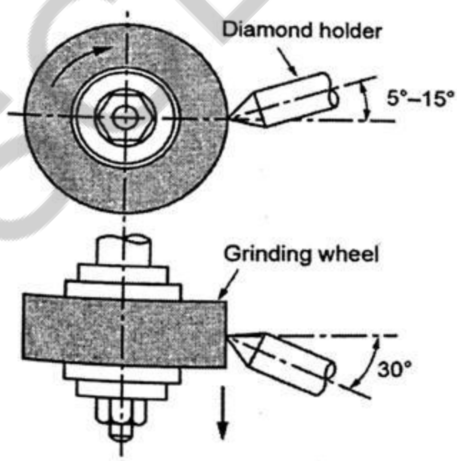


Figure 4.4 Diamond tip dresser

The grinding wheel used for precision and high finish grinding is dressed by a dresser having a 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 Figure 4.4. A 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.

4.The performance of a grinding wheel depends upon type of abrasive, grain size, grade, structure and bonding material. Discuss the effect of each.

Grinding Wheel Abrasives

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

Natural abrasives

Artificial abrasives.

1. Natural abrasives:

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

Sandstone or solid quartz.

Emery (50 to 60% crystalline Al_2O_3 + Iron oxide).

Corundum (75 to 90% crystalline Al_2O_3 + Iron oxide)

Diamond.

Natural abrasives lack the uniformly of properties and the reliability has largely been replaced by manufactured or artificial abrasives.

Artificial abrasives:

These are manufactured under controlled conditions in closed electric furnace in order to avoid the introduction of impurities and to achieve the 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:

Aluminium oxide

Silicon carbide

Artificial Diamond

Boron carbide

Cubic boron nitride.

a)Aluminium Oxide (Al_2O_3):

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.

Aluminium oxide is tough and less brittle. It is used for grinding materials of high tensil strength such as high speed steel, malleable iron, wrought iron etc.

The common trade name for this abrasive is 'Alundum' 'Aluminium Oxide', 'Aloxide' and 'Borolon'. Aluminium oxide is represented by a letter A.

b) Silicon carbide:

It is made from Silicon dioxide, coke, sawdust and salt. The ingredients are thoroughly mixed and heated in an electric furnace about 2000° for 34 hrs. The mass under the action of intense heat fuses and the following chemical reaction takes place.

$$SiO_2 + 3C = SiC + 2CO$$

The silicon carbide mass is crushed, washed and treated with alkalis. It is again washed and finely ground into small particles. Silicon carbide is hard and brittle. It is used for grinding materials of low tensile strength such as grey cast iron, brass, copper, aluminium etc. The common trade name for this abrasive is 'Silicon carbide' 'Carborundum', 'Crystolon' and 'Electron' etc. It is represented by a letter C.

In general, the physical properties of aluminium oxide are compared with silicon carbide as follows:

Silicon carbide is harder than aluminium oxide.

Aluminium oxide can withstand greater stresses than silicon carbide.

Aluminium oxide is tougher than silicon carbide.

(c) Artificial Diamond

Artificial diamond is a form of pure carbon which is mainly used for truing and dressing other grinding wheels for sharpening carbide tools, and for processing glass, ceramics and stone.

(d) Boron carbide (B_4C)

It is harder than silicon carbide but not as hard as diamond. It is produced from coke and boric acid at tremendously high temperature in an electric furnace. Boron carbide is mainly used for grinding and lapping very hard metals hard alloys, glass and Jewels.

(e) Cubic boron nitride:

It is a never synthetic abrasive that is harder than either aluminium oxide of silicon oxide. It is a combination of boron and nitrogen. Boron nitride is the second hardest substance even developed by man or nature. It is used for grinding HSS cutters, grinding tool-steel, punch-press dies, grinding some hardenable stainless steels and for internal grinding of all ferrous metals.

Types of Bonds

Bond is an adhesive substance which holds the abrasive grains together to form the grinding wheel. The bonds must sufficiently be strong to withstand the stresses of high speed rotating grinding wheel. There are various types of bonds used and their choice depends on operating conditions of the abrasive tool such as grinding speed, pressure on the tool, heat formation in the grinding zone etc.

Bonds are classified into two types.

Organic

Non-organic

Metallic, vitrified and silicate bonds are non-organic. Resinoid, rubber, shellac and oxychloride bonds are organic. The various bonding procedures are discussed below.

1. Vitrified bond:

Vitrified bond is made of clay and water. The abrasive grains and fusible clay (also called as 'felspar') are thoroughly mixed together with sufficient water to make the mixture uniform. This mixture is placed in moulds to get the shape of grinding wheel and air is dried at room temperature. These wheels are then fed into a kiln and allowed to remain for few days at a temperature of about 1260°C. This process is known as fusing and it provides for uniform distribution of the bond throughout the wheel. Then, these wheels are trimmed to the required size. Vitrified bonds are used most extensively.

Advantages:

It is made porous and enables a quicker stock removal.

It is not affected by water, oil, acids and alkaline.

The bond itself is very hard and acts as an abrasive.

The structure of the wheel is uniform due to wet mixing of the different constituents.

Disadvantages:

The process of manufacture is very slow.

Cracks may develop in large wheels during fusing.

Wheels over 750mm diameter cannot easily be produced.

High temperature in the kiln tends to make the abrasive grains weak.

A proper control during fusion becomes difficult.

Silicate bond:

Silicate wheels are made by mixing abrasive grains with silicate of soda. The mixture is moulded in a mould and dried for several bours. After drying, the moulded material is kept in a furnace at about 260°C for 20 to 80 hrs. Silicate bonded wheels are light grey in colour. These wheels are having a fairly high tensile strength. The specific purpose of these wheels is that where a coal cutting action with less wear is needed in grinding the edges of the heat-treated steel cutting tools.

Advantages:

It is more rapid process than vitrified bond.

There is no tendency to weaken the grains because of low temperature.

Fusing is better controlled and hence, it results a more reliable bond.

Large wheels up to 1500mm diameter can easily be produced.

The cutting action of the wheel is smoother and cooler.

Disadvantages:

Extra hard wheels cannot be produced with this bond.

Wear of the wheel is high.

Harder grades of this bond do not provide a free cutting action.

Resinoid bond:

Resinoid bonding is produced by mixing abrasive grains with synthetic resins. The mixture is rolled to the desired shape and baked at a temperature of 210°C for few hours. At this temperature, the resin sets to hold the abrasive grains in a wheel form. Resinoid bonded wheels are strongs, elastic and permit high peripheral speeds but they are destroyed by alkaline cooling fluids. It can be avoided by impregnating the wheel with paraffin.

These wheels normally operate at surface speeds in the region of 300m/ min. They are particularly suitable for the use in grinding steel, cast iron and malleable iron castings.

Rubber bond:

The abrasive grains are mixed with liquid rubber and sulphur. The mixture is rolled into sheets of required thickness. The wheels are then cut and placed in preheated moulds and vulcanized under pressure. These wheels are quite strong, close-grained and can be made in very thin sections. They are mainly used where a very high-class surface finish is primary requirement. The rubber-bonded wheels are also used as regulating wheels in centreless grinding. During the operation, water can safely be used as a coolant but caustic soda and oil should not be used.

Shellac bond:

Shellac bonded wheels are made by mixing the abrasive grains with shellac in a mixture. Then, the mixture has been rolled or pressed into a desired wheel shape. They are hardened by baking for several hours at about 160°C.

Shellac bond wheels are strong but it posses some elasticity as rubber wheels. These wheels produce high surface finish and are used wheels. These wheels produce high surface finish and are used for grinding parts such as camshaft and mill rolls. A very thin wheels are used for cutting off operations.

Oxy chloride bond:

This bond is produced by mixing abrasive grains with oxide and chloride of magnesium. This mixture is pressed into moulds and dried. It is heated in a furnace.

These wheels are less brittle and less sensitive to slide loads as compared to vitrified bond wheels. The type of wheel ensures a cool cutting action. So, grinding is done dry condition. These wheels are affected by acidic solutions, dampness and sudden changes in temperature. This bond is used for making disc shaped wheels.

Different types of bonds used in grinding are represented by different symbol as shown below:

Vitrified bond – V

Silicate bond – S

Resinoid bond – B

Rubber bond – R

Shellac bond – E

Oxychloride bond – O

5.Specification of Grinding Wheel

<u>Grit or Grain Size</u>

It refers to the actual size of the abrasive particles. The grain size is denoted by the number. This number is equal to the number of meshes in 254cm of a sieve through which the grains can pass through. Larger is the grit number, smaller will be the grain size (fine grit) and vice-versa.

For rough grinding, coarse grained wheels (smaller grit number) are used. For finish grinding, fine-grained wheels (large grit number) are used. Table 4.1 shows the grain size used for coarse grinding to very fine grinding operations.

Table 4.1

Grinding Operation	Grit or grain size						
Coarse	10	12	14	16	20	24	-
Medium	30	36	46	54	60	-	-

Fine	80	100	120	150	180	-	-
Very Fine	220	240	280	320	400	500	600

Grade

Grade or hardness indicates the strength with which the bonding material holds the abrasive grains in the grinding wheel. It does not refer the hardness of abrasive grains. So, the grade of the wheel has nothing to do with the hardness of abrasive particles.

The degree of hardness are specified by the use of letters of the alphabet. ‘A’ indicates the softest grade whereas ‘Z’ indicates the hardest grade. A soft graded wheel will readily release the abrasive particles. When the hard metal is grinding, the abrasive grains will be blunt quickly. When the soft grade wheels are used here, the blunt grains are readily released. New sharp grains will project from the wheel surface. There grains will effectively cut the hard material. Therefore, for grinding hard material, soft wheels are used. For grinding hard material, soft grade wheels are used. The different grades of grinding wheels are shown in table 4.2.

Table 4.2

Soft	A	B	C	D	E	F	G	H		
Medium	I	J	K	L	M	N	O	P		
Hard	Q	R	S	T	U	V	W	X	Y	Z

Structure of Wheels

This term denotes the spacing between abrasive grains or in other words the density of the wheel. The structure of grinding wheel is designated by a number. The higher is the number, wider will be spacing. When the spacing is small, the structure is called dense structure. When the spacing is wide, the structure is called open structure. The numbers are given in an ascending order from dense to wider structure.

Table 4.3

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

Table 4.3 indicates the two types of structure with their numbers.

6.Discuss with neat sketch vertical broaching machine.

Vertical Broaching Machine

The vertical broaching machines are generally classified as follows.

1.Pull up type
2.Pull down type
3.Push down type

Among these three, pull down type is the most popular.

Push Down Type Vertical Broaching Machine

The push type vertical broaching machine is used in surface broaching operation. It consists of a box shape column, slide and drive mechanism. Figure 4.36 shows the vertical push down type surface broaching machine.

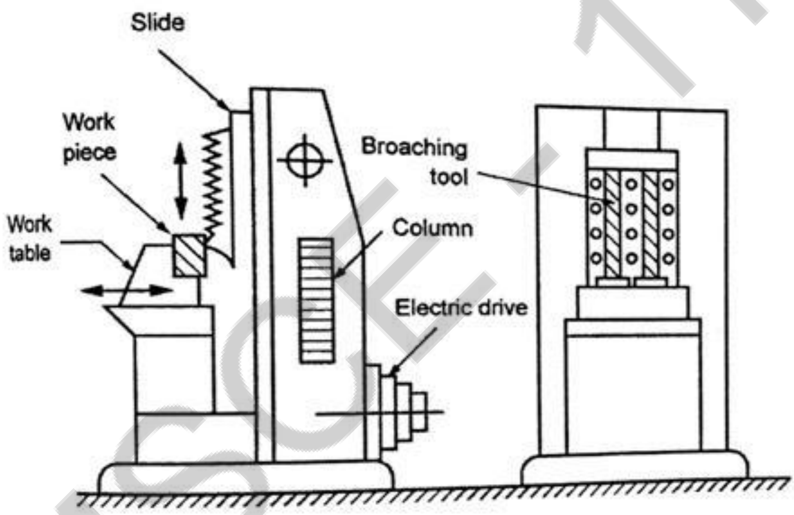


Figure 4.36 Push down type vertical broaching machine

Broaching tools are mounted on slide which is hydraulically operated and accurately guided on column ways. The slide with the broaches travels at various speeds which are controlled by the hydraulic drive. Its stroke 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.

7.List out various abrasives used in grinding wheel. Explain any three. REFER MAY/JUNE 2015

8.Explain with neat sketches the three methods of external cylindrical centreless grinding.

<u>Centreless Grinders</u>

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 Figure 4.22. The grinder has two wheels. A larger grinding wheel is revolving at a high speed and a small regulating wheel is revolving at a slow speed.

<u>Methods of external centreless grinding</u>

Basically, there are three different methods by which centreless grinding can be done. They are

Through feed

In feed

End feed

<u>1. Through feed:</u>

It is used for straight cylindrical work piece such as long shafts or bars, roller pins etc. In this method, the regulating wheel is tilted at a small angle. It makes the work to move axially through the space between grinding wheel and regulating wheel. The guides are provided at both ends of wheel and guide the movement of work piece. The machine usually removes 0.2mm of stock in one pass on the diameter of work.

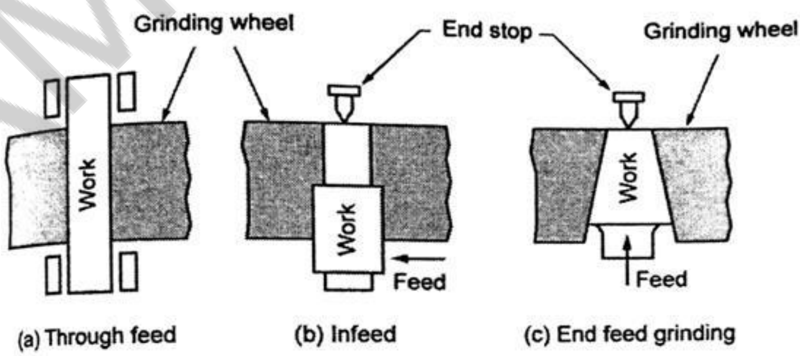


Figure 4.24 Methods of centreless grinding

<u>2. In-feed grinding:</u>

It is smilar to plunge grinding. The work is placed on the work rest against an end stop. It prevents the axial movement of work piece. The regulating wheel and work rest with the work pieces are moved towards the grinding wheel by hand feed shown in Figure 4.24 (b). This method is useful to grind shoulders and formed surfaces.

3. End feed grinding:

In this method, both grinding and regulating wheels are tapered and thus, it produces tapered work pieces. The work piece is fed lengthwise between wheels and it is ground as it advances until it reaches the end stop shown in Figure 4.24 (c).

9.Explain with neat sketches horizontal pull broaching operation and vertical push broaching operation.

Horizontal Type Internal Broaching Machine

Figure 4.34 shows the horizontal internal broaching machine. This machine has a box type bed. The length of bed is twice the length of stroke. Most of the modern horizontal broaching machines are provided with either a hydraulic or an electric drive. It is housed in the bed. The job is located in the adopter as shown in Figure 4.34.

The adopter is fitted in the front vertical face of the machine. The small end of the broach is inserted through the hole of the job and connected to the pulling head. The pulling head is mounted on the front end of the ram. The ram is connected to the hydraulic drive mechanism.

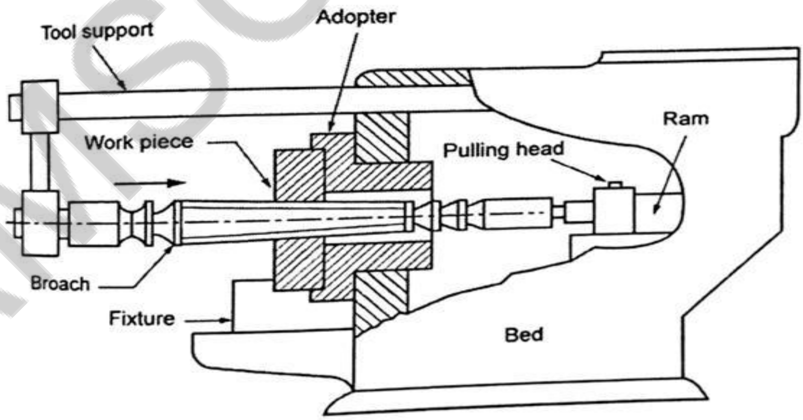


Figure 4.34 Horizontal Type Internal broaching machine

The rear end of the broach is supported by a guide. The broach is moved along guide ways. Broaching machines are generally operated at low speed of 2 to 15m per min. These machines are provided with automatic stops to control the length of stroke of ram. These machines may be fully automatic or semi automatic type.

Horizontal type internal broaching machine is used for small and medium sized works. It is used for machining keyways, splines, serrations, internal gears, etc.

Among these three, pull down type is the most popular.

Push Down Type Vertical Broaching Machine

The push type vertical broaching machine is used in surface broaching operation. It consists of a box shape column, slide and drive mechanism. Figure 4.36 shows the vertical push down type surface broaching machine.

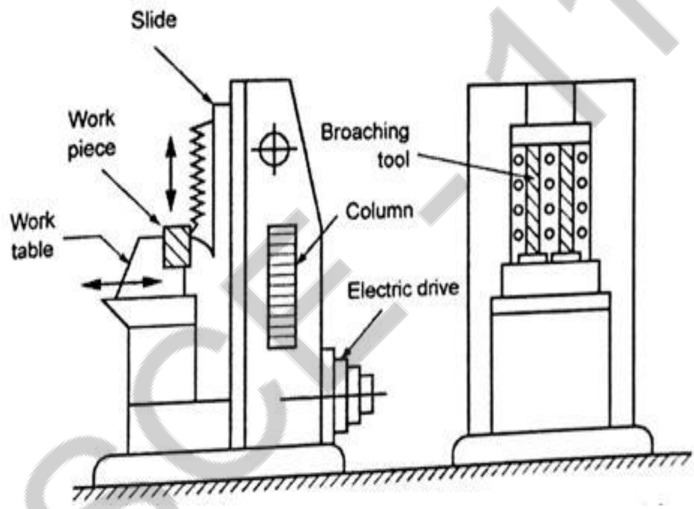


Figure 4.36 Push Down Type Vertical Broaching Machine

Broaching tools are mounted on slide which is hydraulically operated and accurately guided on column ways. The 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.

10.List out various types of bonding materials used in grinding wheel. Explain any three.

REFER MAY/JUNE 2015

11.explain how a wheel is balanced and mounted?

<u>Shapes of Grinding Wheel</u>

Grinding wheels are manufactured in various standard shapes. The different shapes of grinding wheels are as shown in Figure 4.5. A straight, recessed on one side and recessed on both sides of wheels are used primarily for grinding external or internal cylindrical surface and for plain surface grinding. The cylinder shaped wheel is used for producing flat surfaces the grinding being done with the end face of the wheel.

Straight cup wheel is used for grinding flat surfaces by traversing the work fast the end or face of the wheel. A flaring cup wheel is used for tool sharpening. Grinding wheels tapered on two sides are used for grinding the gear teeth and threads. Dish types are used for grinding tool saws. The straight grinding wheels can be obtained with a variety of standard faces. Some of these are shown in Figure 4.6.

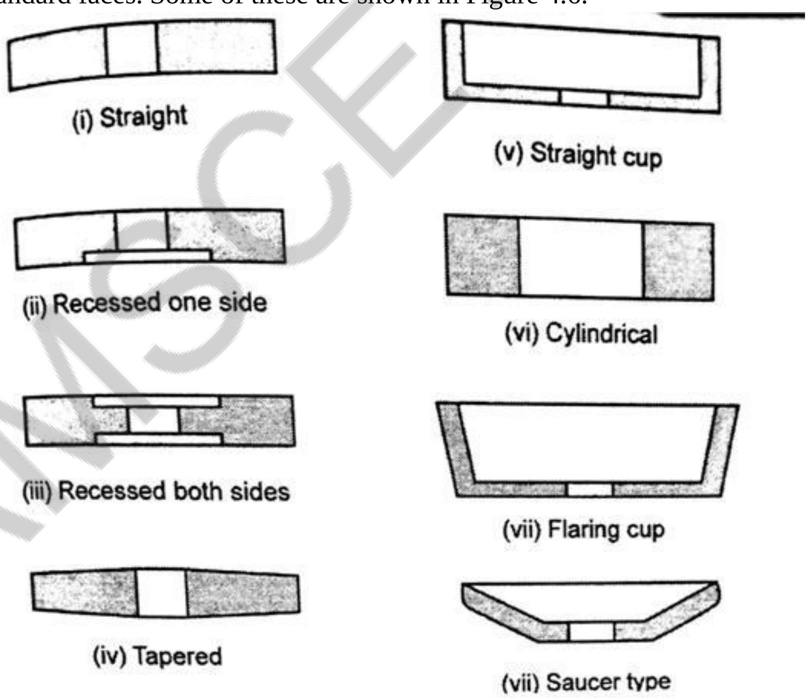


Figure 4.5 Standard grinding wheel shapes

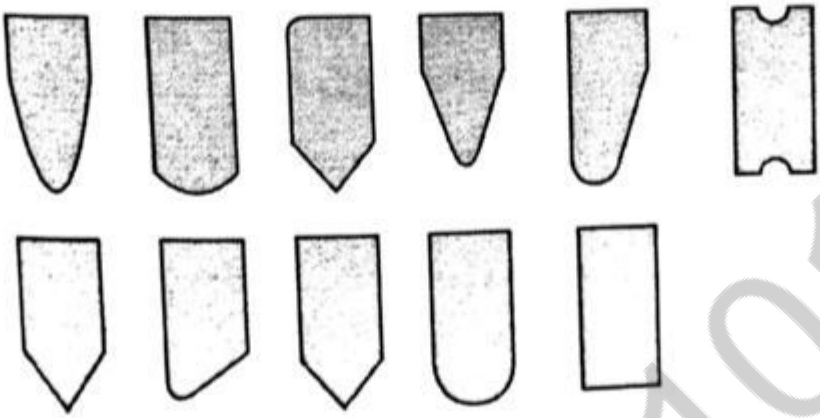


Figure 4.6 Standard shapes of grinding wheel faces

<u>Mounting Wheels and Points</u>

They are small grinding wheels of different shapes. They are attached to metal shanks which can be inserted in the chucks of portable high-speed electric motors. Figure 4.7 shows some mounted wheels and points.

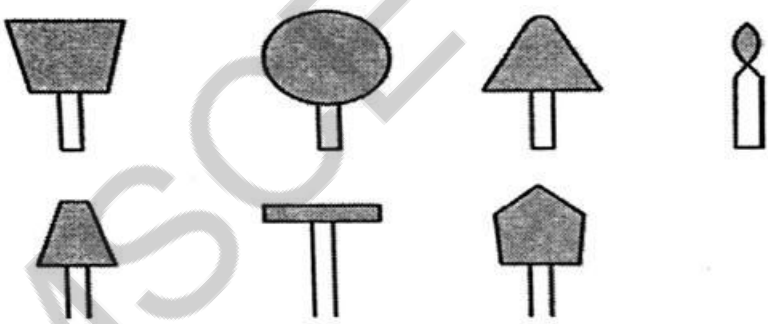


Figure 4.7 Mounting wheels and points

12.Describe the construction and operation of a vertical broaching machine with neat sketch and also sketch broach tool nomenclature

<u>Vertical Broaching Machine</u>

The vertical broaching machines are generally classified as follows.

1.Pull up type

2.Pull down type

3.Push down type

Among these three, pull down type is the most popular.

Push Down Type Vertical Broaching Machine

The push type vertical broaching machine is used in surface broaching operation. It consists of a box shape column, slide and drive mechanism. Figure 4.36 shows the vertical push down type surface broaching machine.

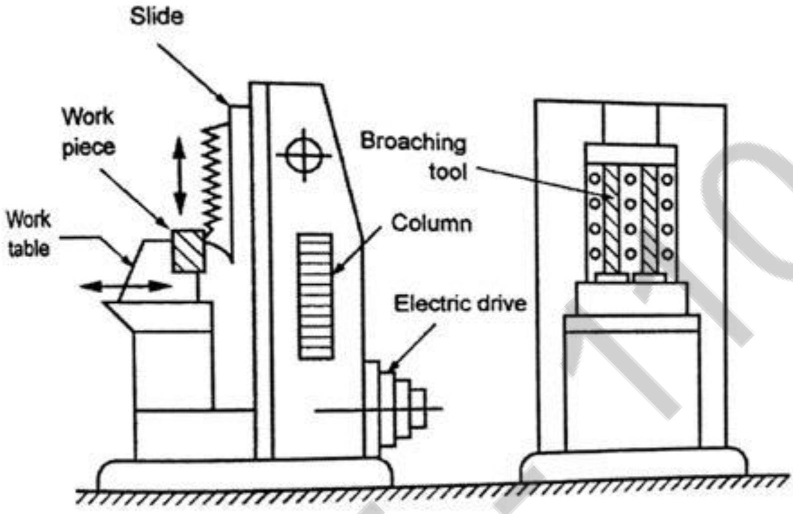


Figure 4.36 Push down type vertical broaching machine

Broaching tools are mounted on slide which is hydraulically operated and accurately guided on column ways. The slide with the broaches travels at various speeds which are controlled by the hydraulic drive. Its stroke 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

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

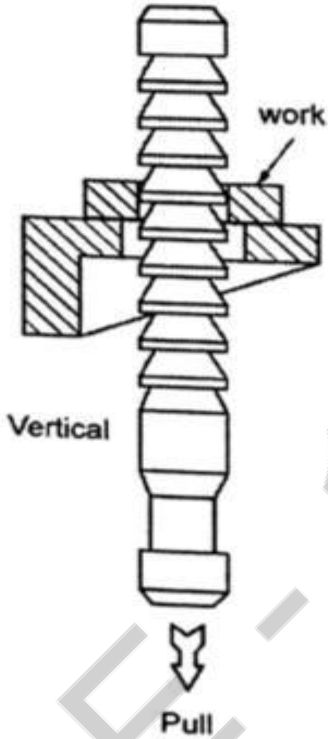


Figure 4.37 Pull down type vertical broaching machine

The pulling mechanism is enclosed in the base of the machine. The work piece is mounted on the table by means of a 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 a 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 Figure 4.37.

Pull Up Type Vertical Broaching Machine

In this type, the ram slides on the vertical column of the machine. The ram carries the pulling head at its bottom. The pulling mechanism is above the worktable and the broach is one the base of the machine. The broach enters the job held against the underside of the table and is pulled upward. At the end of the operation, the work is free and falls down into a container.

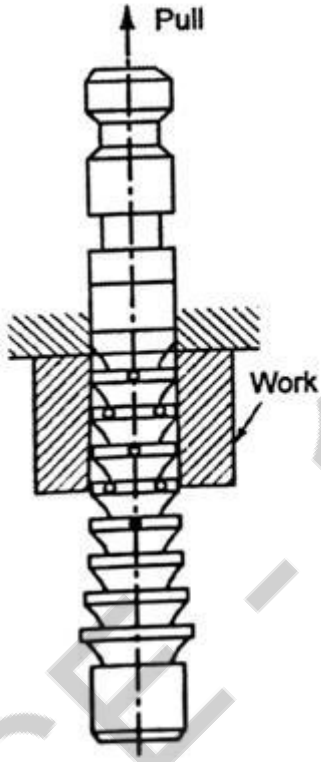


Figure 4.38 Pull up type vertical broaching machine

Broach Nomenclature

The broach is composed of a series of teeth. Each tooth is standing slightly higher than the previous one. This rise per tooth is the feed per tooth and it determines the material removed by the tooth. There are basically three sets of teeth present in a broach as shown in Figure 4.41.

(i) Roughing teeth:

These teeth have the highest rise per tooth and remove the bulk material.

(ii) Semi-finishing teeth:

These teeth have slightly smaller rise per tooth than the previous one. Hence, they remove relatively smaller amount of material when compared to the roughing teeth.

(iii) Finishing teeth:

The last set of teeth is called finishing or sizing teeth. Less amount of material is removed by these teeth. The necessary size is achieved by these teeth and hence, all teeth are of the same size which is finally required. The various other nomenclatures are given as follows.

(iv) Pull end:

Pull end of the broach is to engage with the broaching machine through a puller head.

(v) Front pilot:

It ensures the alignment of broach in the hole before machining.

(vi) Rear pilot and follower grip:

It supports the broach and keeps it in correct alignment after the cut is over.

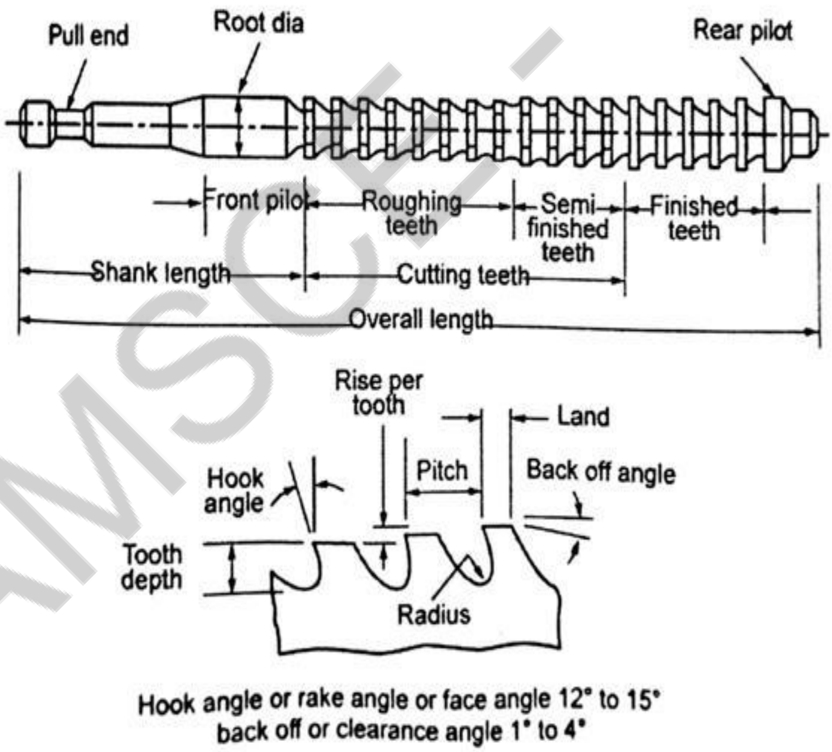


Figure 4.41 Broach Tool Nomenclature

(vii) Land:

The top portion of teeth is called land. It determines its strength. It is usually less for light cut. The land is ground to give a small clearance.

(viii) Pitch:

It is the linear distance from the cutting edge of one tooth to the same point on the next tooth. The pitch may differ for roughing, semi finishing and finishing teeth.

(ix) Back off or clearance angle:

It is the relief angle on the land. This angle is usually 1° to 4° for roughing teeth and 0° to 1.5° for semi finishing teeth when it is used for cast iron and steel. No clearance angle for finishing teeth is provided.

(x) Rack or hook or face angle:

This angle is ground back on the face. Its value depends upon the material to be cut. In general, it will increase face angle as the ductility increases. This angle may vary from 12° to 15°.

13.Explain with neat sketches the four different types of surface grinding operations.

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

The line diagram of this type of grinder is shown in Figure 4.18. It consists of a horizontal spindle carrying the grinding wheel and rectangular worktable. The table is mounted on a base. The horizontal guide ways of base is a rectangular box such as a casting. The driving mechanisms are housed inside the base.

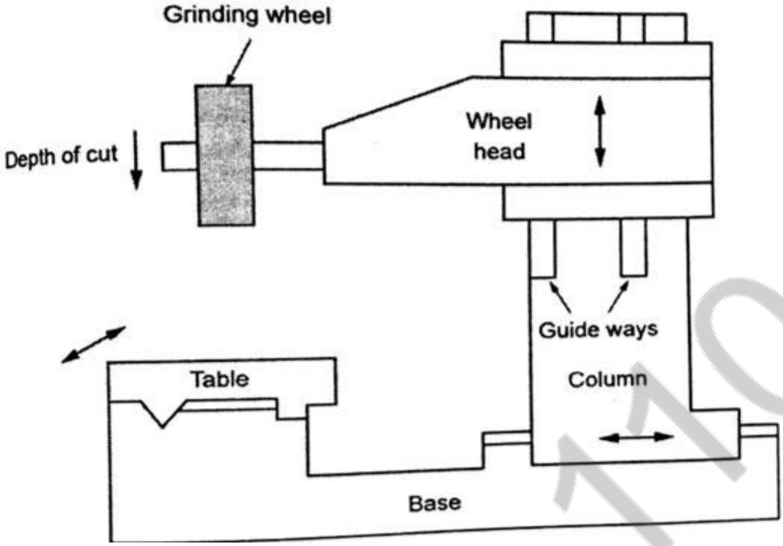


Figure 4.18 Horizontal spindle reciprocating table surface grinder

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 Figure 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 bottom. The depth of cut is given by the foresaid arrangement.

Working:
The workpiece is clamped on the table. The trip dogs are suitably adjusted 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. The cross feed 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.

<u>**Horizontal Spindle Rotary Table Surface Grinder**</u>

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

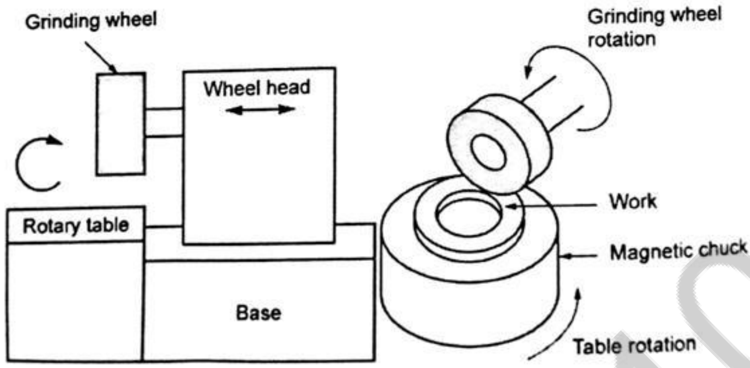


Figure 4.19 Horizontal spindle rotary table surface grinder

The circular table rotates at specific speed and the wheel can axially feed (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.

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 a cup or cylindrical types for faster stock removal. It is used where the 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.

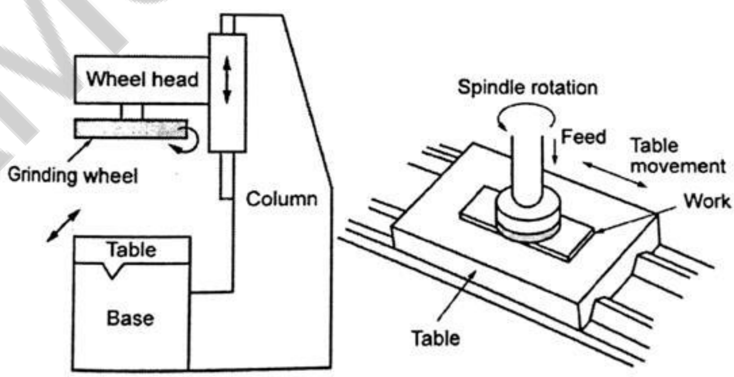


Figure 4.20 Vertical spindle reciprocating table surface grinder

Vertical Spindle Rotary Table Surface Grinder

This machine has all parts similar to a horizontal type machine except that the grinding wheel rotates about a vertical axis as shown in Figure 4.21. The grinding spindle is vertically mounted on the face of a column and rotates in a fixed position. The vertical spindle carries a cup type-grinding wheel. The grinding wheel is lowered for giving the depth of cut. The rotary table rotates with the work piece. The work piece is clamped on the table using a magnetic chuck.

This grinding machine is used for grinding large quantity of small work piece.

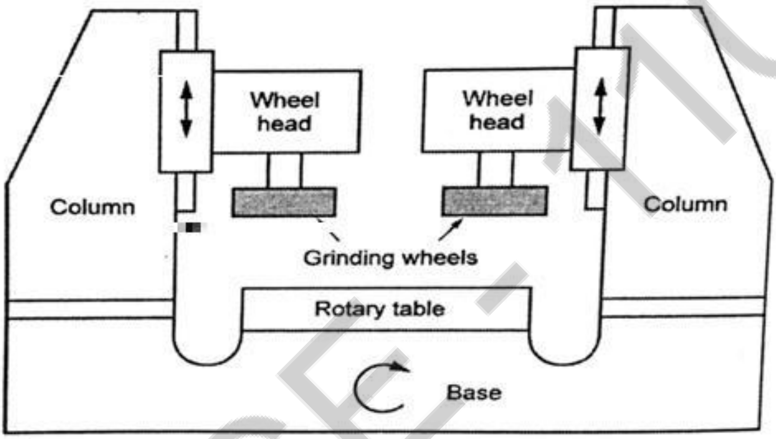


Figure 4.21 Vertical Spindle Rotary Table Surface Grinder

14.Sketch and indicate various elements of a pull broach
Describe various types of broaching machine used in industry

Pull Down Type Vertical Broaching Machine

These machines are mostly used for internal broaching operations. 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 a 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 a 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 Figure 4.37.

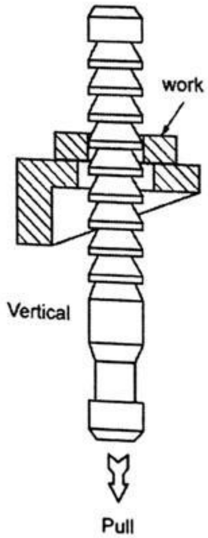


Figure 4.37 Pull down type vertical broaching machine

Pull Up Type Vertical Broaching Machine

In this type, the ram slides on the vertical column of the machine. The ram carries the pulling head at its bottom. The pulling mechanism is above the worktable and the broach is one the base of the machine. The broach enters the job held against the underside of the table and is pulled upward. At the end of the operation, the work is free and falls down into a container.

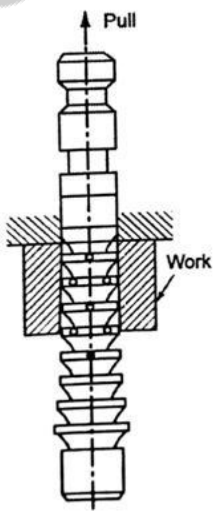


Figure 4.38 Pull up type vertical broaching machine

Continuous Broaching Machine

Continuous broaching machines are used for high production rates of small parts. Three types of continuous broaching machines are

Horizontal

Vertical, and

Rotary type

Horizontal Type Continuous Broaching Machine

This is one type of surface broaching machine. The broaching machine has a driving unit which consists of two sprockets. They are connected by an endless chain. Fixtures are mounted at intervals on the chain for locating and holding work pieces.

The broach tool is horizontally fixed in the frame of the machine. The rigid guiding member is arranged under the chain in the zone where the work piece passes under the broach.

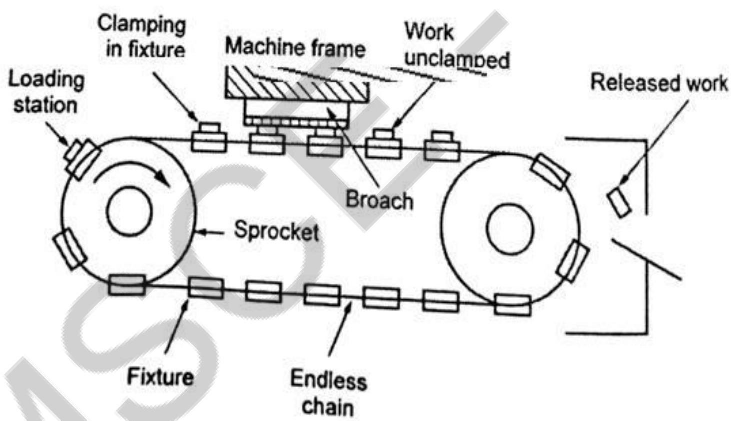


Figure 4.39 Horizontal Type Continuous Broaching Machine

When the fixture passes the loading station, the operator will drop the part in the fixture. The work is automatically clamped before it reaches the tunnel. The broaching takes place when the work piece will move under the broach. The work piece is then automatically released by a cam. At the unloading point, the work piece falls out the fixture. A continuous broaching machine increases the productivity and hence, it is used for mass production.

Vertical Continuous Broaching Machine

When the axes of two sprockets are vertical, it is called as vertical broaching machining. The fixtures are mounted on the chain according to its movement. The operating principle is similar to previous case. Here, the broach is vertically placed on the frame of the machine.

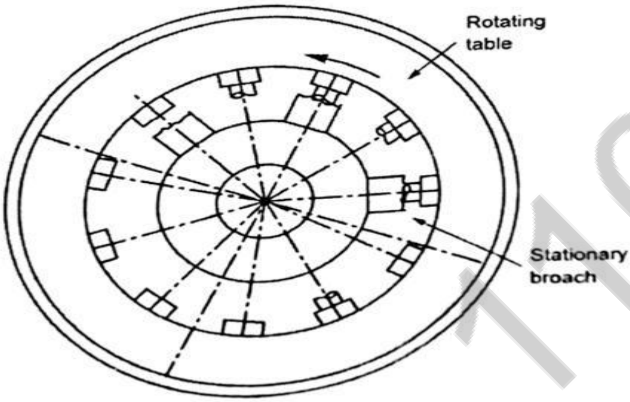


Figure 4.40 Rotary Table Continuous Broaching Machine

Rotary Table Continuous Broaching Machine

The machine has a rotary table and a vertical column. In the vertical column, the broach horizontally fitted above the table as shown in figure 4.40. A series of fixtures are mounted on the rotary table for locating and holding work pieces. They move past the stationary broaches. The rotary broaching machines are limited to small parts. They are used for squaring distributor shaft, slotting and the facing of small parts.

15. Explain the working mechanism of the following grinding process briefly (i) Cylindrical surface (ii) Centerless grinding (Apr/May 2018) Refer Q.no: 3,8

16. Explain the working mechanism of the following broaching process briefly (i) Surface broaching (ii) Continuous Broaching (Apr/May 2018)Refer Q.no: 14

17. Discuss in detail any two types of surface grinding process with neat sketches. (Nov/Dec 2018) Refer Q.no: 13

18. Classify the types of broaching machine and spell in detail about each process. (Nov/Dec 2018) Refer Q.No: 09

19.(i)Why is aluminium oxide preferred to silicon carbide in grinding wheel? Refer Q.no: 04

(ii) Why is coarse grain and open structured wheel is preferred for stock removal grinding? Refer Q.no: 05

(iii) Explain with simple sketches explain the working of a broaching operation also differentiate between the push and pull type broaching. (Apr/May 2019) Refer Q.no: 06

20.(i)Define the term grinding ratio, G, and discuss the parameters which influence the grinding ratio.

Grinding efficiency $E = \frac{G}{U}$ in this equation

'G' is grinding ratio which is defined as the volume of material removed per unit volume of wheel wear

$$G = \frac{\text{Volume of material removed}}{\text{Volume of wheel wear}}$$

(ii) With simple sketch explain the working of a centre less external grinding operation. (Apr/May 2019) Refer Q.no: 3,8

21.Explain the applications of various type of abrasives. (Nov/Dec 2019) Refer Q.no: 04

22. With the help of a block diagram describe a vertical spindle rotary-table grinder. (Nov/Dec 2019) Refer Q.no: 13

5 CNC MACHINING

PART A

1.State the following of the following G and M codes G01, G04, M04, M30

G01 – Linear interpolation
G04 – Dwell
M04 – Spindle anticlockwise
M30 – End of programme

2.Compare bulk and surface micromachining process

Bulk micromachining	Surface micromachining
In this process, structures by selectively etching inside a substrate	In this process, structures are created on top of a substrate
Itisusedtoproducemicroelectromechanical systems (MEMS)	It is used t o produce MEMS products such as surface micromachined accelerometas and 3D flexible multi channel neural probe array

3.State the functions of the following G and M codes

G00 – Point to point positioning
G03 – Circular interpolation, anticlockwise
M06 – Tool change
M03 – Spindle clockwise

4.How are various functions timed in NC machines?

Machine tool – manual, semiautomatic, automatic
Main functions to be performed by the machine tool
Slide displacement
Relative motion between tool and workpiece
X, Y, Z directions, Rotation about X, Y, Z axes
Final component

5.Distinguish between a fixed zero and floating zero?

Fixed Zero	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 define by positive X and Y coordinates	In floating zero, the machine operator sets zero point at any positions on the machine table. The part programmer decides the zero point to be located. It is also known as reference point

6.Define CNC and DNC

CNC:

Computer Numerical Control (CNC) is a machine which controls the functions and motions of a machine tool by means of a prepared program containing coded alphanumeric data.

DNC:

Direct Numerical Control is also called Distribute Numerical Control. It is a technology that permits a single computer to be networked with one or more machines that use computer numerical control (CNC)

7. What a adaptive control?

The automatic monitoring and adjustment of machining conditions in response to variations in the operation performance is called adaptive control.

8.List the main elements of a NC machine tool

The main elements of a NC machine tool are

- Work table
- Motors for driving spindle speed
- Machine control unit
- Part program
- Punched tape and reader
- Cutting tools

9.What do you understand by 'canned cycle' in manual part programming?

A canned cycle is a combination of machine moves that performs anyone particular machining function drilling, milling, boring, tapping etc.
The preparatory functions for canned cycle
are G81 to G89 are used for canned cycle
G80 is used for cancelling the canned cycle.

10. Define subroutine.

If the same machining operation which was carried out already is to be performed at many different positions on the work piece, it can be executed by means of a programme called as subroutines.

11.State any 4 advantages of N.C machines.

It provides greater accuracy.
Improved product quality.
Less operator skill is required.
Tooling cost is less.

12.What is preparatory function?

It is word address format represented by the letter G ,followed by a numerical code for the operation of the control unit to instruct the machine tool.

13. What is tool length offset?

When tools with different length are used, then the difference in their lengths with respect to datum is known as offset of each tool.

14. What is meant by manual part programming?

Manual part programming is a process of writing programs which consist of a set of instructions to carry out the machining of the work

15. What is post processing?

Post processing is a computer program that takes a generalized part program output and adopts it to a particular machine control unit/machine tool combination. It is the basic intelligence required to change the program into computer language.

17. What do you mean by machining centre?

The machining centre in a control machines is an automatic tool changing arrangement that is designed to perform a variety of machining operations, with large number of cutting tools and provided with a continuous path CNC system.

18.List out any 3 merits of CNC.

Part program tape and tape reader are used only once
Tape editing at machine site

Greater flexibility

19.What is APT language?

APT is not only a NC language it is also the computer program that performs the calculations to generate cutter positions based on APT statement.

20. Classify statements in APT.

Geometry statement 2. Motion statement 3.Post processor statement 4. Auxilary Statement

21.Distinguish mechanization and automation. (Apr/May 2017)

Mechanisation	Automation
Introduce a machine into the process instead of manual work. But it performed with human assistance	Technology by which a process or procedure is performed without human assistance

22.What is the need for micromachining? Mention the four catego-ries of micromachining techniques. (Apr/May 2017)

Micromachining techniques have been developed on the basis of the microelectronic fabrication technology.

Four categories of micromachining techniques.

- Bulk micromachining
- Surface micromachining
- Micro-molding process
- Non-Lithography based localized micromachining

23.What are G – codes and M – codes? (Nov/Dec 2017)

G – codes:

‘G’ is a preparatory function which changes the control mode of the machine and called as G – codes.

M – codes:

M is a miscellaneous function which is generally called as M – codes. By specifying m – codes other auxiliary operations are performed.

24.State the limitations of CNC machine tools? (Nov/Dec 2017)

i) High initral cost

ii) High maintenance cost

iii) Costly control system

iv) Skilled operations is required

v) Unemployment.

25.Write the disadvantages of manual part programming. (Apr/May 2018)

(i)Time required is more to actually develop a fully functioning CNC program such as manual calculations, verification and related activities.

(ii)There is a chance of large percentage of errors, a lack of tool path verification and difficulty in making changes in a part program.

26.What are the challenges in wafer machining ? (Apr/May 2018)

- When wafers are this thin , an external means of mechanical support is always required.
- During wafer machining , fiber failure may happen.

27.Compare NC with CNC in machining process. (Nov/Dec 2018)

NC System	CNC System
It requires less manual works	It requires less manual works.
Less skill is enough	Less skill is enough
More accuracy is obtained	More accuracy is obtained
The system is medium flexible	The system is more flexible

28.Define 'micromachining' with the help of an example. (Nov/Dec 2018)

Micromachining refers a technique for the fabrication of 3D structures on the micrometer scale. Micromachining refers the superfinishing, a metal working process for producing very fine surface finishes. It mainly involves the microelectromechanical systems (MEMS) to perform micromachining.

Example:

MEMS devices, airbag sensor, medical devices, micro-dies, and molds

29.What is the difference between absolute and incremental programming ? (Apr/May 2019)

In absolute programming, the tool locations are always defined in relation to zero point.

In Incremental programming , the next tool location must be defined with reference to the previous tool location.

30.What is the difference between a closed-loop control system and an open-loop control system ? (Apr/May 2019)

S.no	Open-loop system	Closed-loop system
1	There is no feedback about the result produced due to open loop	Instantaneous feedback is obtained about the result produced
2	There is no reference for the results	It has definite reference for the results.
3.	This system is used where the accuracy is least considered.	This system is used where the accuracy is more importance.

31.Brief on the term Numerical control. (Nov/Dec2019)

If various functions of machine tools are controlled by means of prepared program, which consists of letters, numbers and symbols, then the machine tools are called Numerical Control machine tools.

32.What is NC part programming ? (Nov/Dec2019)

The part programme is a set of instructions proposed to get the machined part starting with the desired blank and NC machine tool. Each line of instruction is capable of specifying dimensional and non-dimensional data and it is written in a specific format.

PART B

1.Explain the working of NC machine tool with the help of a diagram.

Numerical control (NC) Machine tools

If various functions of machine tools are controlled by means of prepared program, which consists of letters, numbers and symbols, then the machine tools are called Numerical Control machine tools.

The NC program consists of the following criteria

1.Methodology of manufacture
2.The movement of machine tools
3.What tool is to be used?
4.At what speed?
5.At what feed?
6.To move from which point to which point in what path?

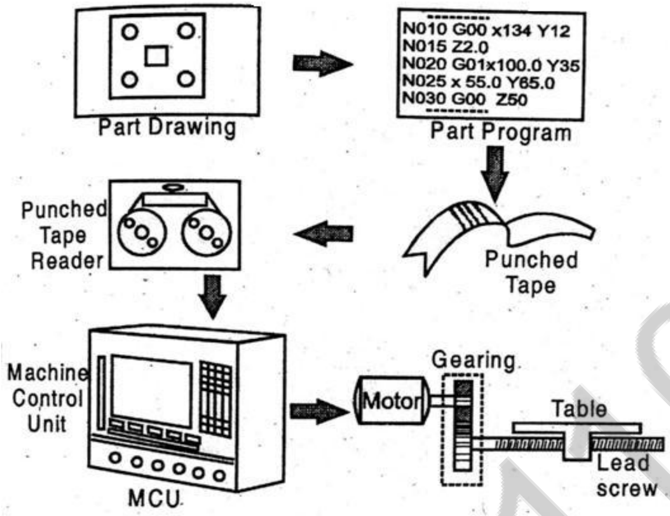


Fig 5.1 Elements of NC Machine tool operation

The basic informations are given to the NC System in the form of part drawing along with the cutting process parameters and the cutting tools used.

By using these, the part programs are written in the form of letters, nunbers and symbols.

This part program is entered in the punched tape.

The program is then read by the punched tape reader. These numerical codes are translated by the Machine Control Unit (MCU) into a from so that the machine can understand and the motion of the machine tool is controlled.

(ii)List the advantages of CNC systems over conventional NC Systems.

To manufacture complicated and accurate parts in less time, CNC is used.

The following are advantages of CNC machines over conventional machines.

Accuracy is more and it is repeatable. i.e. accuracy is kept in all ranges of speeds and feeds.

Production time is less.

Complicated part can be manufactured

Highly skilled and experienced operator is not necessary.

Since the operator can have more free time, he can look after other machine operations also.

2.Explain the various steps to be followed while developing the CNC Part programs.

Part Programming Fundamentals for CNC Machines

A part program is a set of instruction providing x,y and z coordinates and other details to perform the desired machining operations.

It directs how the tool should move with respect to workpiece (or) vice versa. A part program consists of all information necessary to complete the machining of a component.

In olden days, the part programs were coded on a punched tape. Nowadays, the punched tapes are replaced by USB device (Pen drive) and CDs. (The punched tape is prepared according to the part program manuscript). The punched tapes are 1 inch wide (25.4 mm). It was standardised by the Electronics Industries Association (EIA). The sample punched tape is shown in Fig. 5.67. The punched tape is fed through the tape reader once for each component.

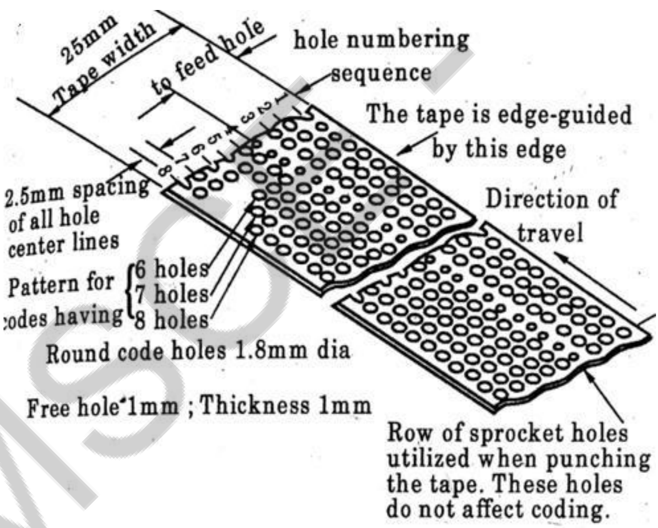


Fig 5.67 Numerical Control punched tape format as standardized by Electronics Industries Association (EIA)

- There are eight columns of holes as shown in Fig. 5.67. There is one column of sprocket holes in between 3rd and 4th columns to feed the tape.
- The coding of the tape is obtained by either the presence (or) absence of a hole in the various positions.
- This coding system uses the binary digit.

A binary digit is called a bit. It has a value 0 (or) 1 to represent absence (or) presence of a hole in a particular row and column position of the tape.

The columns of holes run lengthwise along the tape. Row positions run across the tape.

In the row of bits, a character is formed. A character is a combination of bits representing a letter, number and symbol.

A word is a collection of characters forming part of instruction. The collection of words from a block. A block of words gives one set of instruction. Each block of information is separated by End-of-block (EOB) symbol in the 8_{th} column.

The part program is denoted by the symbol %. It defines, the sequence of CNC maching operation.

Each block contains the following types of words to perform movements and functions.

1.Sequence Number (N-word (or) N Codes)

2.Preparatory functions (G-words (or) G Code)

3.Coordinate words (X, Y, Z words) (or) Dimension words

4.Feed rate (F word (or) F Code)

5.Speed rate (S word (or) S Code)

6.Tool selection (T word (or) T code)

7.Miscellaneous function (M word (or) M code)

End of Block (EOB/*)

Types of words (or) Codes in CNC

i.Block Number (or) Sequence Number (N words (or) N Codes)

This sequence number is used to identify the sequence of a block of data. It is usually given in ascending order. This is useful for the operator to know which sequence of block is performed by the tool. It consists of alphabet N followed by ‘0’ to ‘999’.

(Eg) N5, N10, N150,…..

ii.Preparatory functions (G-words (or) G Codes)

G words are used to prepare the MCU to be ready to perform a specific operations.

These words are used to prepare the machine to perform a particular function like

Positioning

Contouring

Thread cutring and

Machining

The following are the codes of various preparatory functions

iii.Dimension words (X, Y, & Z words) (or) coordinate words (i)Linear dimension words.

X, Y, and Z are used for primary motion.

U, V, W are used for secondary motion parallel to X, Y and Z axes respectively.

p, q, r are used for another type of motion parallel to X, Y and Z respectively.

(ii)Angular Dimension words:

a, b, and c (or A, B, and C) are used for rotary motion about X, Y, and Z axes respectively.

I, J, K is used for position of arc centre, thread lead parallel to X, Y, Z axes in case of thread cutting.

The decimal point is not allowed in this word. So 5.675 mm in X direction will be represented as X05675. The last three digits of X05675 are used for decimal part of the number. Some machines accept X5675 by omitting leading Zeros.

iv.Feed Rate Word (F word (or) F Code)

The rate at which the cutting tool (or) cutter travels through the material is expressed in mm/min (or) mm/rev.

The F word is used to program the proper Feed rate.

This word is mostly used for contouring system (or) straight line system

F200 means a feed rate of 200 mm/min.

v.Spindle Speed (or) Cutting speed word (S word (or) S code)

This word indicates the spindle rpm (or) the constant cutting speed in m/min.

S1000 indicates that spindle rotates at 1000 rpm.

Thus this code is represented by S followed by the three digit number.

vi. Tool selection word (T word (or) T Code)

This code is represented by 'T' followed by maximum five digit number. Different cutting tools are indicated by different numbers.

The Automatic Tool Changers (or) turrets select the appropriate tool when 'T' word calls out a particular tool thate has to be used for cutting.

This word is used for cutter nose radius compensation and cutter length compensation.

vii. Miscellaneous (or) Auxiliary Function (M Code)

The functions like coolant on (or) off, spindle rotation start etc are known as miscellaneous functions.

3.What is 'Adaptive control'?

Adaptive control denotes a control system that measures one or more process variables (i.e) force, temperatures, horse power etc., and manipulates feed and speed to compensate undesirable changes in the process variables.

It uses information about machining process to improve the efficiency of the process.

It determines proper speed and feed required during machining as a function of variations in factors such as hard-work material, depth of penetration, etc.

It has capacity to componesate the variables during the process.

The main objective of Adaptive control is to optimize the machining process.

4.Discuss the programming of NC Machines.

Part programming fundamentals

The conversion of engineering blueprint to a part programme can manually be performed or with the assistance of high-level computer language. In both, part programmers determine the cutting parameters, spindle speed and feed, based upon characteristics of the workpiece, tool material and limitations of the machine tool. Therefore, they must have extensive knowledge of machining process and machine tool.

Part Program

The part programme is a set of instructions proposed to get the machined part starting with the desired blank and NC machine tool. Each line of instruction is capable of specifying dimensional and non-dimensional data and it is written in a specific format. This format is known as NC block.

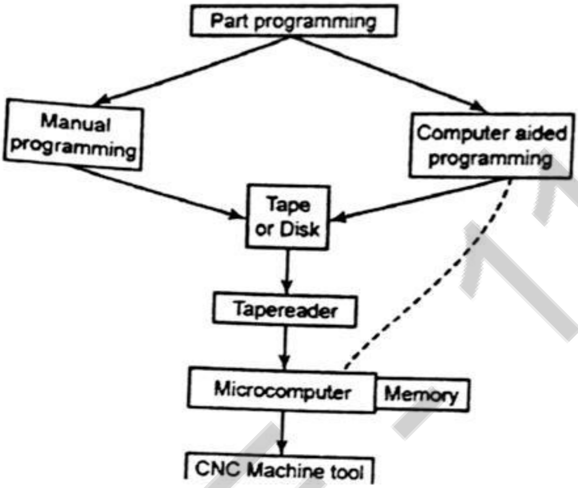


Figure 5.25 Layout of part programme procedure

Figure 5.25 shows the part programme procedure. This work is carried out by a part programmer. He prepares the planning sheet and writes the instructions in a coded form which is acceptable to the controller of the machine tool.

Methods of Creating Part Programming

The following are various methods of creating part programming.

- Manual part programming.
- Computer-assisted part programming (CAD/CAM based programming system)
- Manual data input
- Computer automated part programming

5.Discuss the constructional features of a NC Machine tool and explain their functions.

Basic Components of NC Machines

Software

The software refers the set of instructions, languages, punched cards, magnetic tape, punched pater tape and other information processing items. The software is the sole element to control the sequence of movement of NC machines. Hence, it is also called software controlled machines. The programmer plans the entire operations and their sequence by referring the product drawing supplied to him. Then the instructions in the form of programme are prepared known as part programme. The part programme is prepared on a programme manuscript. Then these instruction are punched on the control tape. According to the instructions punched in tapes, tape reader feeds the codes to machine control unit (MCU). Finally MCU converts the supplied instructions into the machine movements connected with the machine tool.

Machine Control Unit (MCU)

NC Machine tool has a main unit known as machine control unit (MCU) having some electronic hardware elements to read NC programme, interprets it and equally translates it for mechanical actions of the machine tool.

Machine Controller is the automatic control unit which provides information for manual intervention of the operator. It converts the information from the tape programme into the desired command signals. It is also called as Machine Control Unit (MCU). The actuation systems come into the desired action on receiving the command signal from MCU. MCU may be housed in a separate body or on the machine itself. It controls the path of cutting tool, speeds and feeds, tool change and several other functions. Figure 5.4 shows a machine tool and control unit, and machine mounted MCU respectively.

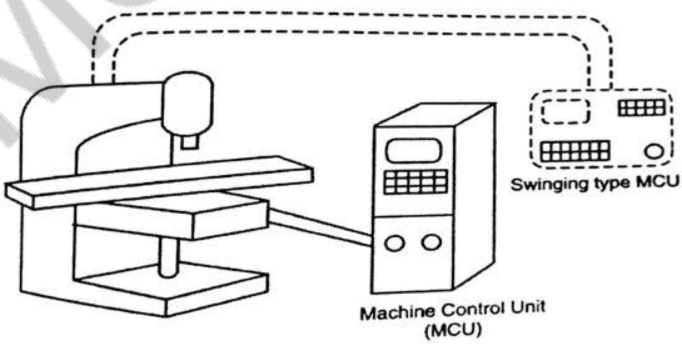


Figure 5.4 Machine Control Unit (MCU)

Capabilities of MCU:

MCU should capable of doing the following functions.

1. Machine tool spindle start and stop.
2. Varying the spindle speed.
3. Changing the direction of rotation of the spindle.
4. Start and stop coolant supply.
5. Changing the desired tool.
6. Changing to the desired workpiece
7. Lock and unlock fixtures and workpieces
8. Guiding the cutting tool tip along the desired path.
9. Controlling the feed rate of movement of the tip.

A typical MCU consists of the following units.

(i) Input or Reader Unit:

This input unit consists of electro-mechanical devices used to collect the input from punched tape, cards, magnetic tape and disk. Then the system is driven under a reading head, interpreted the coded information and collected it again for reuse.

(ii) Memory:

A set of information consists of words which is read from tape and stored into temporary memory called buffer. One block may contain one complete set of instruction words in a particular sequence. The memory helps to keep on storing the next block of words when the machine is processed the previous block.

(iii) Processor:

The unit which coordinates and controls the functions of other units by sending ready signals to the machine at appropriate point of time is called processor.

(iv) Output channels:

The channels which convert the stored data in the memory into actuation signal and supply the output channels as pulses.

(v) Control Panel:

The control panel consists of switches, indicators, manual data input (MDI) and dials for supplying the information about the process to the operator.

(vi) Feedback Channels:

A feedback channel is to check the process whether it goes right or not by sending signals to the operator.

Machine Tool

Machine tool is the main component of numerical control system which executes the operations. It consists of worktable, cutting tools, jigs and fixtures, motors for driving spindle are coolant and lubricating systems. It is a single machine capable of performing operations such as milling, boring, drilling, reaming, and tapping by Automatic Tool Changer (ATC) under the control of tool selection instruction.

6.List and explain the advantages of CNC Systems over continuous path type numerically controlled machine tools

Advantages and Disadvantages of NC

Machines Advantages:

- It provides greater accuracy
- Less production cost per piece is possible due to reduction in lead time and also setup time.
- Improved product quality and provision of high order of repeatability are achieved.
- High production rates as the machining conditions are optimized and the non-machining time is reduced to a minimum.
- Less scrap is due to consistent accuracy and the absence of human errors.
- The reduced inventory in work-in-process (WIP) is possible.
- Less operator skill is required.
- Machine utilization is better.
- Tooling cost is less.
- Cycle time is reduced thereby increasing the tool life.

Disadvantages:

- The major disadvantages of NC machines are their costs and requirements of highly knowledgeable person in this field.
- Long preparation time is required for each production series.
- Flexibility is not there since the machine is only for fixed cycle of operations.

Advantages of CNC Machines

It increases the memory for part programme processing.
It increases in capacity for storing large part programs.
It is easy to edit the part programs on the control console.
CNC is more compatible.
The realization of control logic through software is easy.
Significant improvement is obtained the reliability of operation of the machines.
The integration of NC Machines in the manufacturing systems as a whole is easy.
The possibilities are incorporated to improve for correcting errors in part programming.
The possibility of using the computer's peripheral equipment is provided.
Tape and Tape reader are used only once for resulting the improved reliability.
CNC can accommodate conversion of tapes prepared in units of inches to the international units system.

7.Enumerate constructional features of CNC machining centre.

CNC Machine Constructional Details

Production equipment with computer numerical control is a major component of CAD/CAM Technology. For flexible automation on the shop floor, CNC Machines play a major role. This technology is applied for large scale industries of material processing equipment. For manufacturing a component, CAD/ CAM process generates a NC programme which can run the CNC machines. The integration of CNC machines in the Computer Integrated Machines (CIM) technology is the today's concept of many industries.

Some of the important parts of CNC machines are machine structure, guide ways, feed drives, spindle and spindle bearings, measuring systems, controls, software and operator interface, gauging, tool monitoring.

The information stored in the computer can automatically be read and converted into electrical signals. The electrical signals operate the servo systems. Electrically controlled servo systems allow the slides of a machine tool simultaneously to be driven at the appropriate feeds and direction to machine complex shapes. CNC machines are used in milling machines, lathe machines, grinding machines, boring machines, flame cutters, drilling machines etc.

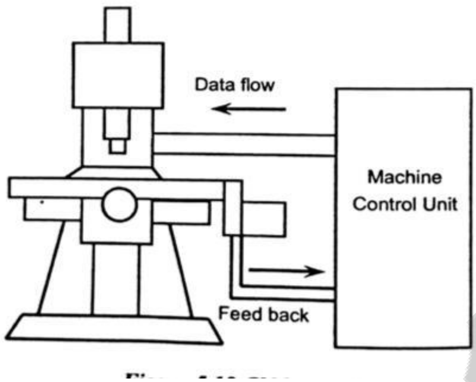


Figure 5.18 CNC Machine

Special Features of CNC Machines

CNC Drive systems

Cutting spindles:

A spindle drive is a primitive type of transmission. A rod, referred to as a spindle, is attached to the output of an engine. This rod then comes in direct contact with a tired. A spindle tooling provides an objective connection between cutting tool and spindle of the machine tool. The spindle is employed to perform variety of cutting operations.

Requirements of spindles for CNC machines:

- High stiffness – both static and dynamic
- Running accuracy
- Axial load carrying capacity
- Thermal stability
- Axis freedom for thermal expansion
- High speeds of operation

Spindle heads:

The following are the various types of spindle heads.

- Inclinable head
- Robot-head
- Horizontal spindle head
- Vertical spindle head
- Universal head

In Robot-heads, nine axes are available in the machines and six axes are controlled simultaneously. In universal-head, pitch and roll are also offered on a large floor type machine. In horizontal and vertical heads, a long beam is available to rotate the orientation of a spindle through 90°. It is similar to right angle spindle attachments.

Feed Drive

Requirements of feed drive:

- 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 such as 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 feedback devices

Work holding system

To locate and hold the workpiece, in CNC machine tools, work holding system is used. The work holding devices used in CNC machines are given below.

- Fixtures
- Hydraulic chuck
- Collect attachment
- Bar holding system
- Steadies

Fixtures are mostly used as a work holding device in CNC machines.

The following are the features for CNC machine tools.

- Fixture length compensation
- Quick loading and unloading of fixtures on pallets
- Better accuracy of the fixture
- Rigidity to withstand cutting force

Work holding devices:

In order to keep the setup time to minimum, the work holding devices should be accurate, easy and quick to operate, ensure rigidity against heavy cuts. A commonly used work holding devices are given below.

- Collect chucks

Jaw chucks
Arbors
Fixtures

8.Describe various type of CNC machine based on tool motion.

REFER NOV/DEC 2016

9.Discuss the salient features of CNC Machining centre.

Machining Centres

Machining Centres are one of the important types of CNC machine tools.
Automatic Tool Changer (ATC) is used here.
The following operations can be carried out here.

1.Milling
2.Drilling
3.Reaming
4.Boring
5.Tapping

Indexable tool magazine is an important character for machining center carrying (16-100) tools. The machining center has two or more table named as pallets. An automatic pallet changer (APC) centre is used and time will be reduced. It means, Work-In-Progress (WIP) will be reduced.

Classification of machining centres:

According to the spindle configuration, machining centres are classified as

Horizontal spindle machining centre
Vertical spindle machining centre
Universal machining centre

Horizontal Spindle Machining Centre

A typical horizontal spindle machining centre configuration is shown is Figure 5.20. The features of the horizontal spindle machine are given below.

Single spindle machines
Automatic tool changer (ATC)
Bed type machine
Axis X $\Rightarrow$ Table or column Y $\Rightarrow$ Spindle head
Z $\Rightarrow$ Saddle or column or head stock or spindle head

(v)Rotary indexing table

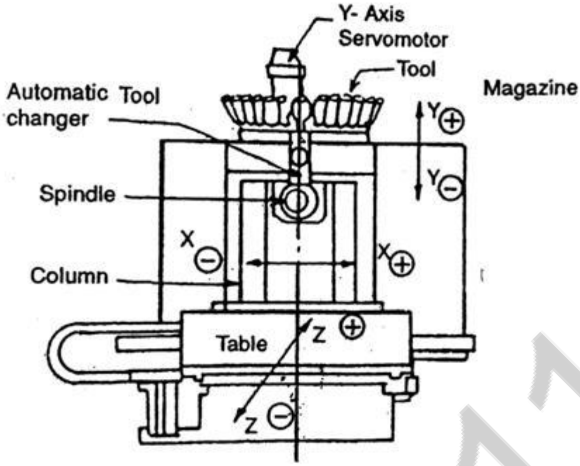


Figure 5.20 Horizontal Machining Centre

<u>Vertical Spindle Machining Centre</u>

A Typical vertical spindle machining centre configuration is shown in figure 5.21

The features of the vertical spindle machine are:

Single or Multi spindle

ATC or Turret head (Automatic Tool Changer)

Axis X $\Rightarrow$ Table or column

$\Rightarrow$ Saddle or column or ram

Z $\Rightarrow$ head stock

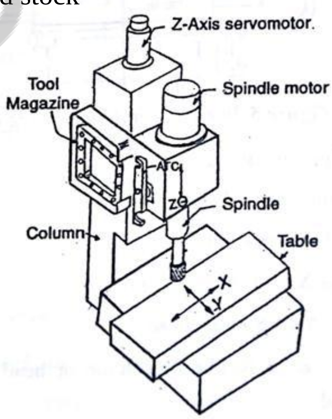


Figure 5.21 Vertical Machining Centre

Universal Machining Centre

The features of the universal machining centre are listed below.

It has a single spindle.

Spindle is capable of fitting horizontal to vertical
It has five axis of machine
Table also can be fitted
The flexibility is more than other two types
Tool breakage detection is possible.
Automatic loading and unloading of workpiece are possible.

10.Enumerate various steps involved in Wafer preparation.

Wafer Machining

Wafer machining is the primary process used in manufacturing of microelectronic devices.
After purifying the silicon used for fabrication, a single crystal silicon is obtained through the process known as Czochralski process.
This process utilizes a seed crystal that is dipped into a silicon melt and then slowly pulling out while being rotated.
This results in silicon crystal of 150mm – 300mm in diameter and over 1m in length
This crystal is then slicated into individual waftes by using a inner diameter blade known as wafer machining. (Refer Fig. 7.60)

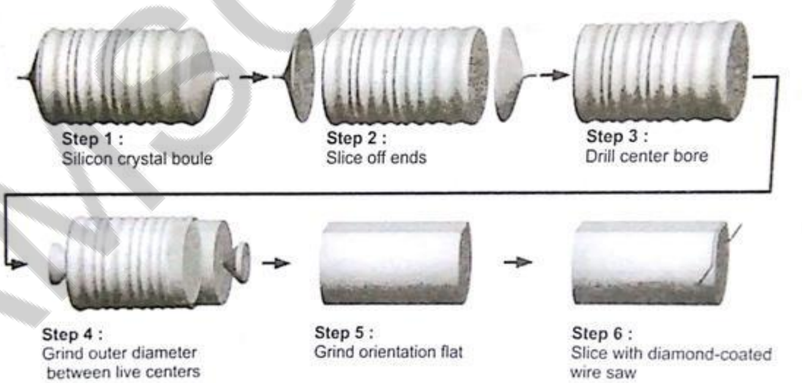


Fig. 7.60 Wafer Machining

- In this method, rotating blade with inner diameter is used for cutting and then the wafers are cut to a thickness of required microns (upto $0.5 \times 10_3$ µm).
- This thickness provides necessary physical and mechanical support for temperature absorption and fabrication.
- Finally, these wafers are cleaned and polished to get surface without damage.
- The fabrication of whole microelectronic device takes place over this wafer surface.

11. explain the advantages and limitation of NC machine

Advantages and Disadvantages of NC Machines

Advantages:

- It provides greater accuracy
- Less production cost per piece is possible due to reduction in lead time and also setup time.
- Improved product quality and provision of high order of repeatability are achieved.
- High production rates as the machining conditions are optimized and the non-machining time is reduced to a minimum.
- Less scrap is due to consistent accuracy and the absence of human errors.
- The reduced inventory in work-in-process (WIP) is possible.
- Less operator skill is required.
- Machine utilization is better.
- Tooling cost is less.
- Cycle time is reduced thereby increasing the tool life.

Disadvantages:

The major disadvantages of NC machines are their costs and requirements of highly knowledgeable person in this field. Long preparation time is required for each production series. Flexibility is not there since the machine is only for fixed cycle of operations.

describe four main features of CNC machine and distinguish them from convectional machine

Comparison of NC and CNC with conventional systems

S.No.	Conventional System	NC System	CNC System
1.	It requires more manual works.	It requires less manual works	It requires less manual works.
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 is less flexible	The system is medium flexible	The system is 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.	More suitable for mass production.
8.	It is more suitable for less production rate.	It is more suitable in medium production rate.	More suitable for mass production.

12.Explain the various types of statement used in APT languages with suitable example

APT Statements

There are four types of statements in APT Language.

(i)Geometric statements
(ii)Motion statements
(iii)Postprocessor statements
(iv)Special control or Auxiliary statements

<u>1.Geometric statements:</u>

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 given

by 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 given

by 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. They are called postprocessor statements. The postprocessor allows the transformation of a postprocessor control statement into an appropriate code of the control.
Examples of post-processor statements are given below

COOLNT/ON

SPINDL/ON

FEDRAT/20

SPINDL/ISOO, CCW

END

4.Auxiliary statements:

Auxiliary statements are used for cutter size definition, part identification and so on. These statements control the output listing, translation, rotation and repetitive programming techniques. Examples of auxiliary statement are:

CLPRNT	Cutter location print
OUTTOL	Outside tolerance
INTOL	Inside tolerance
FINI	Termination of the program

13.Write CNC part for the component shown in Figure 5.82 Mention the assumptions made. [May 2016]

Solution:

First, the billet is reduced from 110 mm to 100 mm to avoid applying more depth of cut. So, the part program is prepared for reducing is diameter by turning for 150+3=153 mm length (3 mm is given as allowance for parting-off). The tool positions are 1-2-3.

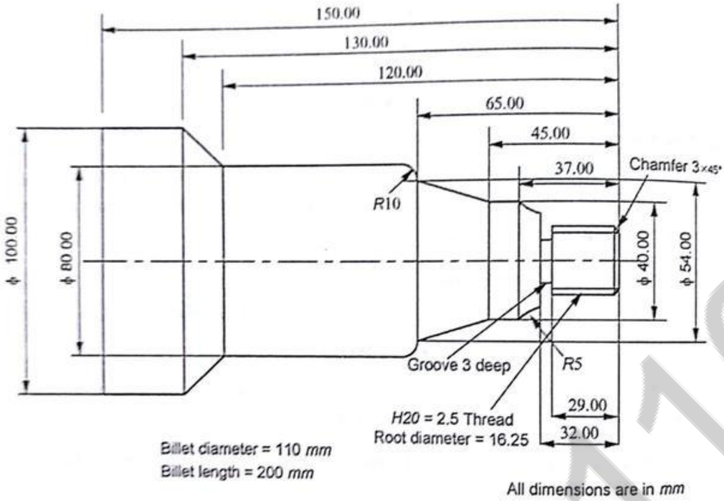


Figure 5.82 Component drawing for AU Problem 5.5

Then the program is continued for manufacturing the given component as per the given dimensions. The tool positions are A-B-C-D-E-F-G-I-H-J-K to manufacture the given component. Same sign conventions and codes as mentioned in **problem 5.1** are followed to prepare the part program.

Figure 5.83 Tool positions for turning the billet to 100 mm diameter The depth of cut peroplace

$$=\frac{\text{Depth of cut}}{\text{Number of passes}} = \frac{0.65 \times 2.5}{10} = 0.1625 \text{ mm}$$ is given by x cut

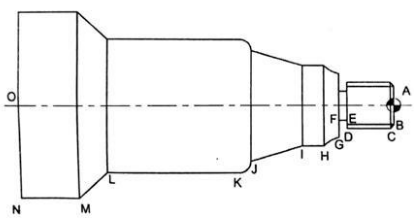


Figure 5.84 Tool positions for the component

Programming in incremental mode:

O0024

(Program number)

N01 G28 T00 U00 W00

N02 M06 T01 (Place tool number one in the spindle)

N03 G54 G91 S1500 M03 T01

(Select coordinate system, incremental mode, start spindle CW at 1500 RPM, get tool number one ready)

N04	M08					(Turn ON coolant)
N05	G00	X00	Y00			Rapid movement to position 1
N06	G01	X00	Y-50	F80		Facing the edge 1-2 & feed 80
N07	G01	X-153	Y00			Turning from 2 to 3
N08	G00	X00	Y00			Rapid movement to position 1 or A
N09	G01	X00	Y-7			Facing the edge AB up to position B
N10	G01	X-3	Y-3			Chamfering from B to C
N11	G01	X-26	Y00			Turning from C to D
N12	G01	X00	Y3			Facing the DE up to position E
N13	G01	X-3	Y00			Turning from E to F
N14	G01	X00	Y-8			Facing from F to G
N15	G03	X-5	Y-5			Filleting from G to H
N16	G01	X-8	Y00			Turning from H to I
N17	G01	X-20	Y-7			Tapering from I to J
N18	G02	X-10	Y-10			Filleting from J to K
N19	G01	X-45	Y00			Tuning from K to L
N20	G01	X-10	Y-10			Taper turning from L to M
N21	G01	X-20	Y00			Turning from M to N
N22	G01	X00	Y50			Parting off from N to O
N23	G00	X150	Y00			Rapid movement to A
N24	G54	G91	S100	M03	T02	

(Select coordinate system, incremental mode, start spindle CW at 100 RPM, get tool number two ready for thread cutting)

```
N25   G74   Y0.123  L10
N26   G84   X-19.0  Y16.25  K2.0  D1.23  F0.08  A60
            (G84    = Canned cycle
            Y23.74  = Minor diameter
            X-33.0  =Thread length
            K2.0    = Height of thread
            D0.13   = Depth of cut
            F0.08   = Feed
            A60     = Included angle)
N27   G80
(Cancelling Canned cycle)
N28   G00   X00   Y00   Z00
            (Rapid traversing of the tool 2 to starting position)
N29   M09
      (Coolant OFF)
N30   M05
      (Spindle OFF)
N31   M02
(End of the program)
N32   G28   X00   M19         (Return to tool change position,
                                orient spindle)
```

14. Surface Micromachining or Wafer Machining

In the surface micromachining process, the structures are created on top of a substrate. In this case, a silicon substrate (wafer) is selectively etched to produce structures. In this machining, the microstructures are built by deposition and etching of different structural layers on top of the substrate. These layers are selectively etched by photolithography and either a wet etch involving an acid or a dry etch involving an ioized gas, or plasma. Dry etching can combine the chemical etching with physical etching, or ion bombardment of the material. Generally, poly-silicon is used as one of the layers and silicon dioxide is used as a sacrificial layer. The purpose is to remove or etch voids.

It offers the advantage of the possibility of realizing monolithic Microsystems to build structures on the same substrate. The limitation of this machining is that only smaller components can be machined. This type of micromachining is mainly preferred for the manufacture of thin film solar cells. The complicated components such as movable parts are built using a sacrificial layer.

In addition, the surface micromachining processes are used in action in the following MEMS products such as surface micromachined accelerometers and 3D flexible multichannel neural probe array.

Micromachining Processes

Micromachining techniques use several techniques of microelectronic fabrication. Micromachining to create micron-sized structures came into existence with microelectronic fabrication (photolithography, in particular as the basis. But many researchers are exploring non-lithography alternatives. A big advantage of photolithography is batch-processing and economical when the volume of products is very large. For exploratory purposes, especially in the academic and industrial research labs, the non-lithography processes are very attractive. A few important lithography and non-lithography processes are described here.

Lithography Based Micromachining

1. Photolithography process:

A photo-polymer called photoresist(PR) is the basis for photolithography. If a layer needs to be partterned i.e., if we want to remove the material from a layer selectively, we need to create a masking layer to define the windows through which to each. The mask is usually a glass plate with a chromium pattern or quartz. Emulsion masks can also be used. They are pouring a small amount of the liquid photoresist on top of the masking layer. It is called spin-casting. It is then baked in an oven to harden it.

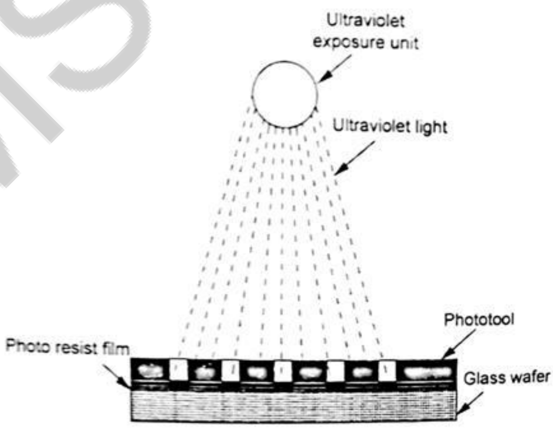


Figure 5.88 Photolithography process

The photoresist layer is then exposed to ultraviolet (UV) light through a mask. The UV-exposed regions of the photoresist change properties via depolymerization. Then, the photoresist layer is developed. It is done by spraying a solution called photoresist developer development process. If it is of the negative type, the UV-exposed regions will remain while the unexposed regions will get dissolved. It means, how a masking layer is patterned using the photolithography technique. It is mainly used in machining glass wafer parts.

The etching is done using a nozzle to inject etchant at a higher velocity. Mostly etchants are abrasives materials. Then the photoresist film placed where the surface need not be carried out. The surface is exposed to ultraviolet light.

Soft lithography: It is akin to imprinting, embossing and rubber-stamping. A stamping mold is made of a plastic material which is then used to create patterns on various substrates, including the curved ones. As the name implies, it is suitable for soft materials.

2. Etching:

After covering the layer to be etched with a masking layer and opening the windows in the masking layer using photolithography, the next step is to remove the material through the windows in the masking layer.
There are two broad types of etching as follows:

Wet etching

Dry etching

Wet etching process:

Wet etching typically implies immersing the masked wafer in a liquid bath of a chemical etchant. It can be isotropic or anisotropic.

Isotropic etch: It etches uniformly in all directions at more or less the same rate.

Anisotropic etch: It etches at different rates in different directions leading to somewhat complicated patterns which are exploited to define the shapes for micromechanical and microelectronic structures.

(ii) Dry etching:

Dry etching is carried out where there is no immersion of the masked wafer into a solution to affect the etch. This type of etching is carried in two ways such as

Plasma based etching, and

Non-plasma based etching.

In plasma based etching, the external energy in the form of radio frequency (RF) power drives chemical reactions. Ions are accelerated towards the material to be etched for enhancing the etching reaction in the direction of travel of ions. It is anisotropic but it is not limited by crystal planes. Up to 10-15 microns of depth can be etched this way.

Non-plasma based etching is a vapor-phase dry etching where XeF_2 (xenon fluoride) vapor etches Silicon under a pressure of 0.13 kPa.

3. LIGA:

It refers LI thographie, Galvanoformung, Abformung (LIGA). It involves lithography, electroplating and molding processes. The five basic steps of LIGA are resist development, X-ray radiation and masking, electroforming, resist removal and molding.

(a) Resist development:

The resist material is applied on the surface of the part. The surface is allowed for few minutes to dissolve the resist material using a wet-etching process.

(b) X-ray radiation and masking:

Next, the deep X-ray is penetrated to break the chemical bonds of the resist material.

(c) Electroforming:

The space generated by the removal of the irradiated plastic material are filled with the metal using an electro-deposition process. The precision grinding process with the diamond slurry-based metal plate is used to remove the substrate layer.

(d) Resist removal:

PolyMethyl MethAcrylate (PMMA) resist exposed to X-ray and to remove oxygen plasma or through a wet-etching process.

(e) Plastic molding:

The metal mold from LIGA is used for injection molding of MEMS.

4. Thin film deposition:

There are a number of techniques for creating a thin layer of deposit over the entire wager as follows.

(a) Physical vapor deposition (PVD):

The material is evaporated or vaporized and ii is made to cover the wafer uniformly such that the thickness can be controlled too. Filament evaporation, electron beam (E-beam) evaporation, and flash evaporation are some examples.

(b) Sputtering:

Sputtering is achieved by bombarding a target with energetic ions and knocking off the atoms from a target material and transporting them to the wafer where they get deposited.

(c) Chemical Vapor Deposition (CVD):

In this process, thin films are formed by depositing the gaseous phase material directly on the surface. The gaseous phase is created through a thermal decomposition and/or chemical reaction.

(d) Electroplating:

It is commonly used for depositing metal films. Metal ions from an electroplating solution get attracted to the base that is maintained at a negative potential.

4. Planarization:

Multi-layered structures, especially when surface micromachining is used, lead to complicated topographies. So, an intermediate planarization step is often needed to flatten the top layer. It simplifies the geometry of the subsequent layers. Planarization can be done in many ways. Three methods are described below.

(a) Chemical Mechanical Polishing (CMP):

It is basically a micro equivalent of the grinding process. As the name implies, a polishing abrasive slurry is applied and the wafer is rotated at the required speed similar to grinding.

(b) Resist etch back:

Here, a dummy layer of etchable photoresist is applied to achieve a flat surface and it is etched along with the layer beneath at the same rate.

(c) Polymer filling:

In this process, similar to varnishing a floor with multiple coats, a plymer is applied first to fill all the troughs and then it is again applied to ensure a flat layer. It is not suitable if further process steps are done at high temperatures.

15.Write CNC part program for the component shown in Figure Q 0 Mention the assumptions made. (Apr/May 2018)

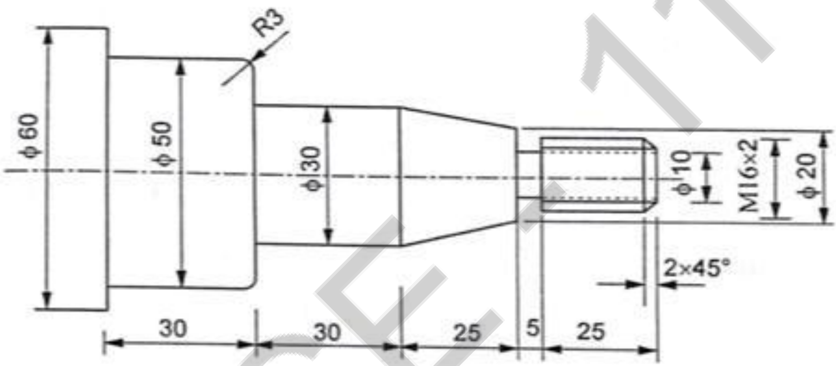


Figure Q 15(b)

Solution:

Depth of cut per pass = $\dfrac{\text{Depth of cut}}{\text{Number of passes}} = \dfrac{0.65 \times 2}{10} = 0.13$ mm is given by x cut

Programming in incremental mode:

O0001

(Program number)

N01 G28 T00 U00 W00

N02 M06 T01 (Place tool number one in the spindle)

N03 G54 G91 S1500 M03 T01

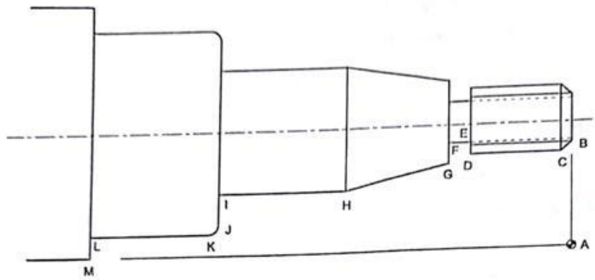


Figure Q 15 (b) Tool positions for the component

(Select coordinate system, incremental mode, start spindle CW at 1500 RPM, get tool number one ready)

N04 M08 (Turn ON coolant)

N05 G00 X00 Y00 Rapid movement to position 1

N06 G01 X00 Y24 F80 Facing the edge B& feed 80

N07 G01 X-2 Y-2 Chamfering from B to C

N08 G01 X-23 Y00 Turning from B to C

N09 G01 X00 Y-3 Facing the edge DE up to position E

N10 G01 X-5 Y00 Turning from E to F

N11 G01 X00 Y-3 Facing the FG up to position G

N12 G01 X00 Y-5 Tapering from G to H

N13 G01 X-30 Y00 Turning from H to I

N14 G01 X00 Y-7 Facing from I to J

N15 G02 X-3 Y-3 Filleting from J to K

N16 G01 X-27 Y00 Turning from K to L

N17 G01 X00 Y-5 Facing the edge LM up to position M

N18 G00 X105 Y00 Rapid movement to A

N19 G54 G91 S100 M03 T02

(Select coordinate system, incremental mode, start spindle CW at 100 RPM, get tool number two ready for thread cutting)

N20 G74 Y0.13 L10

N21 G84 X-25 Y12 K2.0 D0.13 F0.08 A60

(G84 = Canned cycle

Y12 = Minor diameter

X-25 =Thread length

K2.0 = Height of thread

D0.13 = Depth of cut

F0.08 = Feed
A60 = Included angle)

N22 G80 (Cancelling Canned cycle)
N23 G00 X00 Y00 Z00
(Rapid traversing of the tool 2 to starting position)
N24 G28 T00 U00 W00
N25 M06 T03 (Place tool number 3 in the spindle)
N26 G54 G90 S1500 M03 T03
(Select coordinate system, absolute mode, start spindle CW at 1500 RPM, get tool number 3 ready)

%EXE1
N27 G00 G90 T0 X0 Z0
N28 TO101 M06
N29 X2 Y-30 G95 F0.3 M03

N30 G83;25; 10; 75; 4; 0; 1
(Total hole depth; First depth cut; Reduction(%); Min, peak; Dwell Part retract)
N31 G00 G90 T0 X0 Y0 M05
N32 M30
%
N33 M09
(Coolant OFF)
N34 M05
(Spindle OFF)
N35 M02 (End of the program)
N36 G28 X00 M19 (Return to tool change position, orient spindle)

16. Describe the drive systems used in CNC machine tools.
(Apr/May 2018) Refer Q.no:01

17. Describe the following:
(i) With a neat sketch, explain the working of ATC.
(ii) Write short notes on APT language.
(Apr/May 2018) Refer Q.no:03

APT is not only a NC language it is also the computer program that performs the calculations to generate cutter positions based on APT statement

Geometry statement 2. Motion statement 3.Post processor statement 4. Auxilary Statement

18. Describe in brief the basic components of a tape operated NC machine tool. (Nov/Dec 2018) Refer Q.no:02

19. Narrate the design considerations of CNC machine. (Nov/Dec 2018) Refer Q.no:04

20.Discuss the characteristics and capabilities of NC machines which makes it more versatile than the conventional machine
What is the difference between point to point and continuous path in a motion control system? (Apr/May 2019) Refer Q.no:05

21.Explain the architecture of NC system. (Nov/Dec 2019) Refer Q.no:09

22. Explain in detail Machining Centre and its application. (Nov/Dec 2019) Refer Q.no:09