**Q.P. Code :**

**(3 Hours)** **[ Total Marks : 80]**

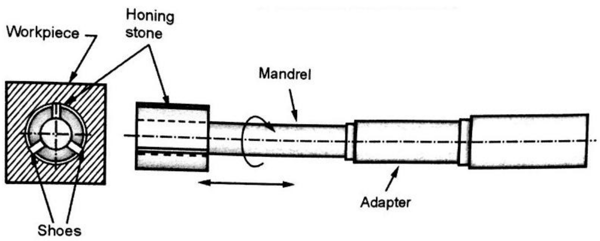
**N.B.** **(1)** Question no. **1** is **compulsory.**
**(2)** Attempt any **three** questions out of remaining **five** questions.
**(3) Illustrate** your answer with **necessary** sketch wherever **necessary**.
**(4) Figures** to the **right** indicate full **marks**.

**1.** **Attempt any FOUR of the following :** **(20)**

**(a)** Write short note on Honing Machine.

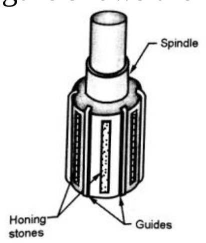
**Ans.** Honing is an abrading process, used for finishing already machined surfaces.

- Mostly, honing is used for finishing internal cylindrical surfaces such as drilled holes.
- The tool used during the process is called as hone which is bonded with abrasive stones and made in the form of a stick.
- Honing can be done by hand or using machines.
- Figure shows a hand honing tool and honing process




**Hand honing tool and honing process**

- The honing stones are held in holder or mandrel and forced outwards hydraulics or mechanical pressure.
- To form the honing stones aluminium oxide, silicon carbide or diamond grains of suitable grit are bonded in resinoid, vitrified or shellac bond.
- In some cases vertical honing machines are also used.
- Figure shows the honing tool used in vertical honing machines.




**Honing tooi head for vertical machines**

- Out of all the surface finishing operations, honing enables maximum stock removal, still it is not a metal removing process..
- Due to this ability, honing is used for correcting slight out of roundness or taper.
- The general amount of stock removed by honing process is from 0.1 mm to 0.25 mm, though it is capable of removing the stock upto 0.75 mm.
- The speed used for honing process is in the range of 10 to 30 m/min.

**(b)** What are the features of a horizontal CNC machine?

**Ans:** involves the replacement of convention hardwired NC controller unit by a small computer which performs some or all of the basic NC functions by storing the programme in its memory.

Control features:

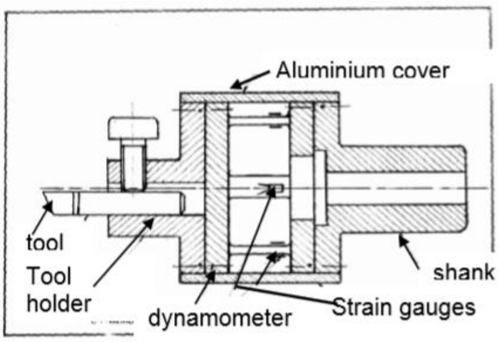
- program editing
- part program storage
- program storage in RAM
- controlled flexibility
- fixed cycles and programming subroutine

constructional features: spindle drives

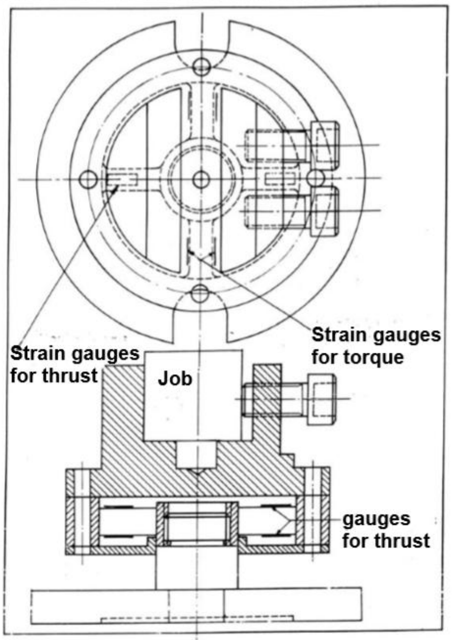
- axes feed drives
- slideways for machine
- recirculating ball screws

**(c)** Explain what is a tool dynamometer with a neat sketch.

**Ans**




*Schematic view of a strain gauge type 2 – D turning dynamometer.*




*Schematic view of construction of a strain gauge type drilling dynamometer.*

**(d)** State the factors for selection of grinding wheel.

**Ans.** The factors on which the selection of grinding wheel depends are as follows

Constant Factors:

- Workpiece material: It affects the selection of abrasive, grain, size, grade, structure and bond.
- Amount of material to be removed.
- Contact area: For small contact area finer and harder wheels are used whereas, for large contact area coarse and softer wheels are used.
- Type of grinding machine

Variable factors:

- Speed of the wheel: It affects the selection of grade and bond.
- Speed of the workpiece: Higher workpiece speed indicates more material is to be ground in given time hence, greater wear on the wheel. For this, harder wheel is selected.
- Machine condition

**(e)** Explain the steps for designing the broach tools.

**Ans** The main elements to be decided in designing a broach are as follows:

- tool pitch
- total rise
- length of cutting portion of broach
- load on broach

Let,

n = total number of teeth in the broach

L = Effective length of a broach in mm

p = tooth pitch in mm

*l* = length to broached in mm

t = rise per tooth in mm

$n_s$ = no. of safety teeth preceding cutting teeth (if any)

$n_f$ = no. of finishing teeth (generally 3 to 6)

(1) Tooth pitch (p):

Pitch is given by $p = 1.75\sqrt{l}$

(2) Rise per tooth (t):

Rise per tooth depends upon:

- Shape and size of hole
- Type of material being broached
- Force available at the machine

Total rise = No. of teeth in the broach x Rise per tooth

Total rise = n x t

(3) Total number of teeth in the broach (n):

Total number of teeth in the broach are given by,

n = Roughing teeth + finishing teeth

$$n = \left(\frac{Depth\ of\ cut}{Cut\ per\ tooth}\right) + \left(n_s + n_f\right)$$

$$n = \left(\frac{Total\ rise}{Rise\ per\ tooth}\right) + (n_s + n_f)$$

(4) Effective length (L):

Effective length of a broach is given by,

L = No. of teeth in the broach x pitch

$$\therefore L = n \times p$$

(5) Tooth load on a broach (F):

Calculation of the load on a broach helps in judging the capability of the machine for pulling or pushing the broach. It also helps in ascertaining whether the broach will stand during the operation or fail. This tooth load is given by,

a. For round holes:

F = Hole circumference x N x t x K

$$\therefore F = \pi d \times N \times t \times K$$

b. For square holes:

F = Hole perimeter x N x t x K

$$\therefore F = 4H \times N \times t \times K$$

Where, d = finished hole diameter in mm

N = maximum number of teeth cutting at a time,

t = rise per tooth in mm

K = force required to cut 1 $mm^2$ of metal at a given rise per tooth

H = finished length of one side of the square hole, in mm

(6) Total Effective length ($L_T$):

$L_T$ = length of roughing teeth + length of finishing teeth

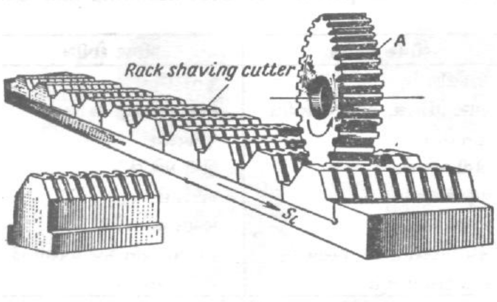
**2. (a)** Explain the different gear finishing methods. **(10)**

**Ans** The shape or surface of gear teeth obtained through shaping or generating process is not too accurate and finished as much desired. Due to this type of surface, there is increase in a lot of noise, excessive wear and backlash within the meshing teeth. Due to these errors, there is chance of failure of the drive. To overcome these defects, some finishing processes are required after gear generation.

**Gear shaving:**

- Rack type
- Rotary type

- In rack type, shaving tool is kept below gear and reciprocated.
- Grooves are made on cutter.
- In rotary type, grooves are made on gear shaped cutter.




GEAR SHAVING PROCESS

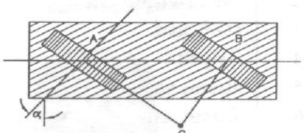



FIG. 2.20 GEAR SHAVING PRINCIPLE

**Gear Grinding:**

1.) Form grinding

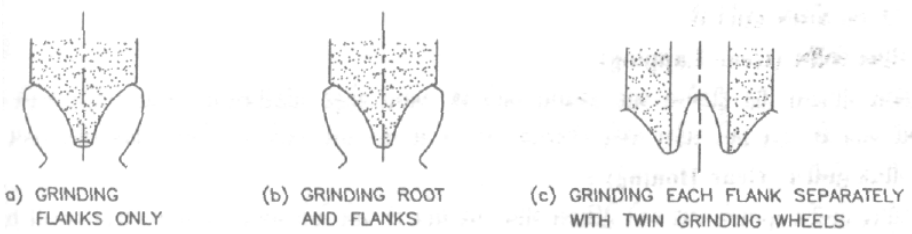
- Involute shaped grinding disk is used to finish each teeth one by one.
- Indexing mechanism is used to rotate blank.
- Sometimes two disk wheels are used to reduce time.

2.) Generation Grinding

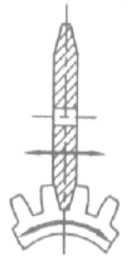
- Spiral, bevel gears are grinded by this method.
- Grinding wheel is also moved in tooth space.

3.) Grinding by threaded wheel

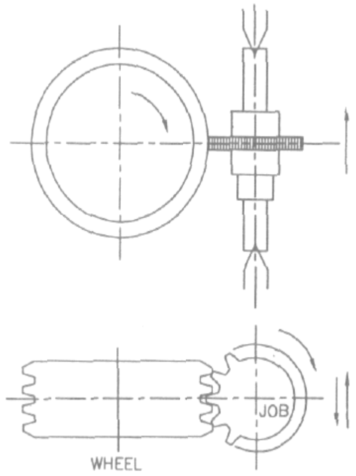
- Similar to hobbing
- Grinding wheel is having helical threads.




GEAR FORM GRINDING PROCESS



GENERATION GRINDING PROCESS




GEAR GRINDING BY THREADED WHEEL

**(b)** Draw and explain the different terms of a twist drill. **(6)**

**Ans.** Axis: The imaginary straight line which forms the longitudinal center line of the drill

Back Taper: A slight decrease in diameter from front to back in the body of the drill

Body: The portion of the drill extending from the shank or neck to the outer corners of the cutting lips

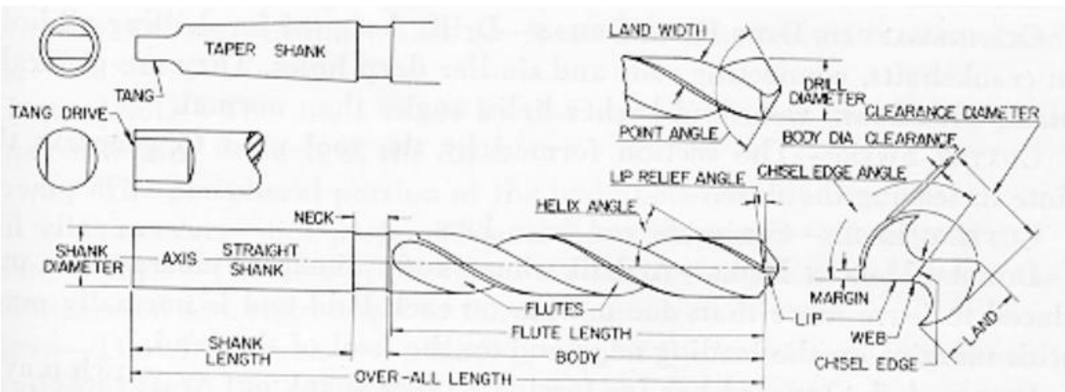
Body Diameter Clearance: That portion of the land that has been cut away so it will not rub against the walls of the hole

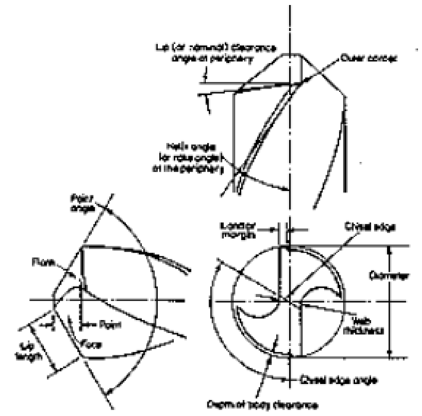
Built-Up Edge: An adhering deposit of nascent material on the cutting lip or the point of the drill

Cam Relief: The relief from the cutting edge to the back of the land, produced by a cam actuated cutting tool or grinding wheel on a relieving machine

Chip Breaker: Nicks or Grooves designed to reduce the size of chips; they may be steps or grooves in the cutting lip or in the leading face of the land at or adjacent to the cutting lips

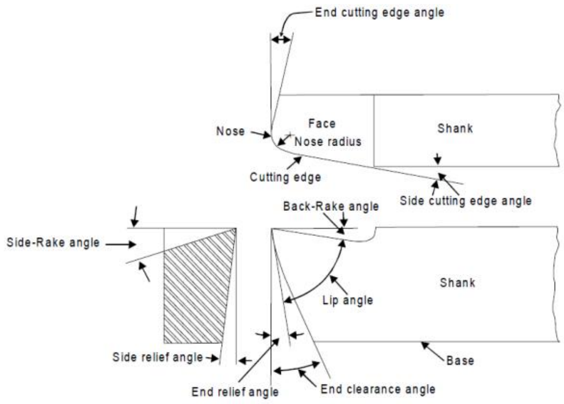
Chip Packing: The failure of chips to pass through the flute during cutting action
Chipping: The breakdown of a cutting lip or margin by loss of fragments broken away during the cutting action
Chisel Edge: The edge at the end of the web that connects the cutting lips
Chisel Edge Angle: The angle included between the chisel edge and the cutting lip, as viewed from the end of the drill
Clearance: The space provided to eliminate undesirable contact between the drill and the workpiece
Clearance Diameter: The diameter over the the cut away portion of the drill lands
Axis: The imaginary straight line which forms the longitudinal center line of the drill
Back Taper: A slight decrease in diameter from front to back in the body of the drill
Body: The portion of the drill extending from the shank or neck to the outer corners of the cutting lips
Body Diameter Clearance: That portion of the land that has been cut away so it will not rub against the walls of the hole
Built-Up Edge: An adhering deposit of nascent material on the cutting lip or the point of the drill
Cam Relief: The relief from the cutting edge to the back of the land, produced by a cam actuated cutting tool or grinding wheel on a relieving machine
Chip Breaker: Nicks or Grooves designed to reduce the size of chips; they may be steps or grooves in the cutting lip or in the leading face of the land at or adjacent to the cutting lips
Chip Packing: The failure of chips to pass through the flute during cutting action
Chipping: The breakdown of a cutting lip or margin by loss of fragments broken away during the cutting action
Chisel Edge: The edge at the end of the web that connects the cutting lips
Chisel Edge Angle: The angle included between the chisel edge and the cutting lip, as viewed from the end of the drill
Clearance: The space provided to eliminate undesirable contact between the drill and the workpiece
Clearance Diameter: The diameter over the the cut away portion of the drill lands





**(c)** Write in brief about tool signature. **(4)**

**Ans** Convenient way to specify tool angles by use of a standardized abbreviated system is known as tool signature. It indicates the angles that a tool utilizes during the cut. It specifies the active angles of the tool normal to the cutting edge. This will always be true as long as the tool shank is mounted at right angles to the workpiece axis.




Elements of tool signature

The seven elements that comprise the signature of a single point cutting tool are always stated in the following order:

1. Back rake angle (0°)
2. Side rake angle (7°)
3. End relief angle (6°)
4. Side relief angle (8°)
5. End cutting edge angle (15°)
6. Side cutting edge angle (16°) and
7. Nose radius (0.8 mm)

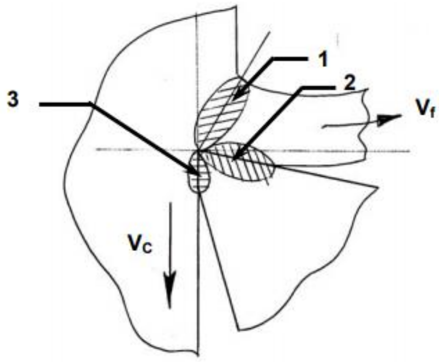
It is usual to omit the symbols for degrees and mm, simply listing the numerical value of each component in single point cutting tool:

**A typical tool signature is 0-7-6-8-15-16-0.8**

**3. (a)** State the different sources of heat in metal cutting. **(10)**

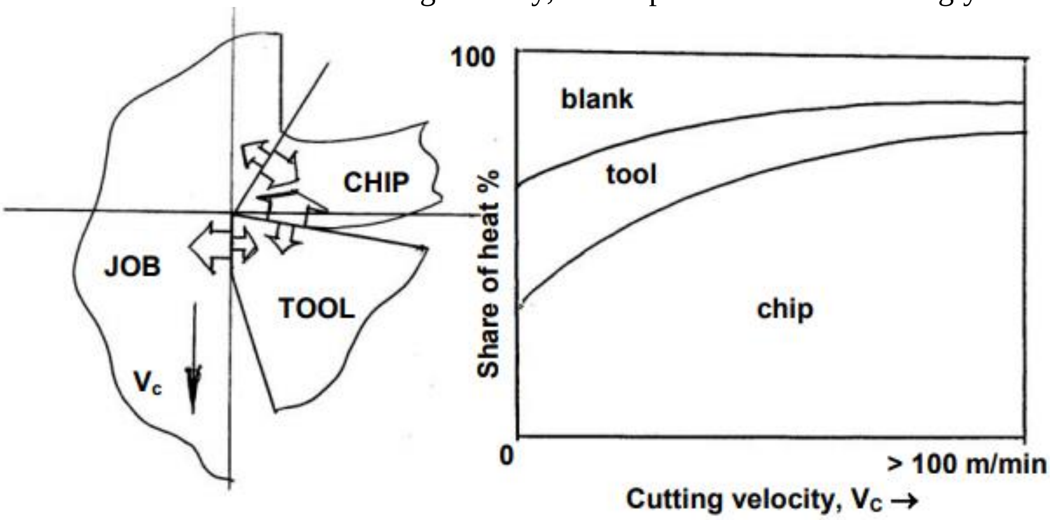
**Ans** During machining heat is generated at the cutting point from three sources, as indicated in Fig.

Those sources and causes of development of cutting temperature are: • Primary shear zone (1) where the major part of the energy is converted into heat • Secondary deformation zone (2) at the chip – tool interface where further heat is generated due to rubbing and / or shear • At the worn out flanks (3) due to rubbing between the tool and the finished surfaces.




Sources of heat generation in machining

The heat generated is shared by the chip, cutting tool and the blank. The apportionment of sharing that heat depends upon the configuration, size and thermal conductivity of the tool – work material and the cutting condition. Fig. visualises that maximum amount of heat is carried away by the flowing chip. From 10 to 20% of the total heat goes into the tool and some heat is absorbed in the blank. With the increase in cutting velocity, the chip shares heat increasingly.




Apportionment of heat amongst chip, tool and blank.

ii) Effects of the high cutting temperature on tool and job. he effect of the cutting temperature, particularly when it is high, is mostly tool • rapid tool wear, which reduces tool life s if the tool material is not • the cutting edges due to t • built-up-edge formation he possible detrimental effects of cutting temperature on the machined job Δ dimensional inaccuracy of the job due to thermal distortion and Δ ing etc. Cutting velocity, VC → Share of heat % 0 100 blank tool chip JOB CHIP TOOL Vc > 100 m/min ( T detrimental to both the tool and the job. The major portion of the heat is taken away by the chips. But it does not matter because chips are thrown out. So attempts should be made such that the chips take away more and more amount of heat leaving small amount of heat to harm the tool and the job.

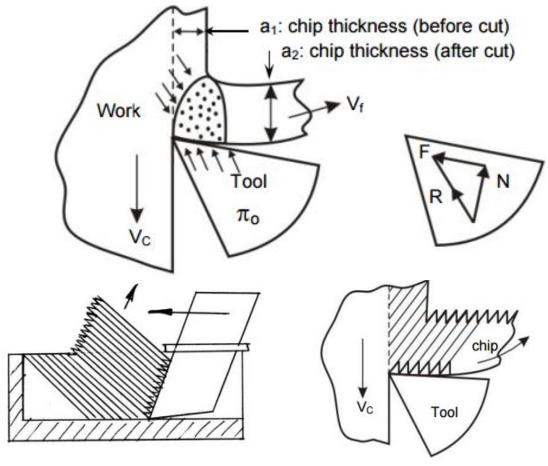
The possible detrimental effects of the high cutting temperature on cutting (edge) are • plastic deformation of the cutting edge enough hot-hard and hot-strong thermal flaking and fracturing of hermal shocks T are: expansion-contraction during and after machining surface damage by oxidation, rapid corrosion, burn Δ induction of tensile residual stresses and microcracks at the surface / subsurface

However, often the high cutting temperature helps in reducing the magnitude of the cutting forces and cutting power consumption to some extent by softening or reducing the shear strength, τs of the work material ahead the cutting edge.

To attain or enhance such benefit the work material ahead the cutting zone is often additionally heated externally. This technique is known as Hot Machining and is beneficially applicable for the work materials which are very hard and hardenable like high manganese steel, Hadfield steel, Nihard, Nimonic etc.

**(b)** Explain the mechanism of chip formation. **(6)**

Machining is a semi-finishing or finishing process essentially done to impart required or stipulated dimensional and form accuracy and surface finish to enable the product to • fulfill its basic functional requirements • provide better or improved performance • render long service life. Machining is a process of gradual removal of excess material from the preformed blanks in the form of chips. The form of the chips is an important index of machining because it directly or indirectly indicates : • Nature and behaviour of the work material under machining condition • Specific energy requirement (amount of energy required to remove unit volume of work material) in machining work • Nature and degree of interaction at the chip-tool interfaces. The form of machined chips depend mainly upon : • Work material • Material and geometry of the cutting tool • Levels of cutting velocity and feed and also to some extent on depth of cut • Machining environment or cutting fluid that affects temperature and friction at the chip-tool and work-tool interfaces.
During continuous machining the uncut layer of the work material just ahead of the cutting tool (edge) is subjected to almost all sided compression as indicated in Fig




(a) Shifting of the postcards by partial sliding against each other

(b) Chip formation by shear in lamella.

*Fig.* *Piispanen model of card analogy to explain chip formation in machining ductile materials*

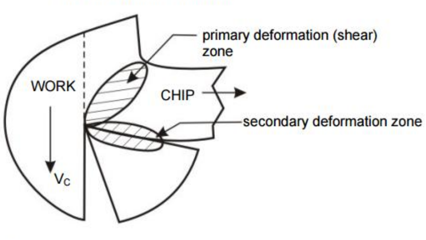



*Fig.* *Primary and secondary deformation zones in the chip.*

The basic two mechanisms involved in chip formation are • Yielding – generally for ductile materials • Brittle fracture – generally for brittle materials During machining, first a small crack develops at the tool tip as shown in Fig

At the sharp crack-tip stress concentration takes place. In case of ductile materials immediately yielding takes place at the crack-tip and reduces the effect of stress concentration and prevents its propagation as crack. But in case of brittle materials the initiated crack quickly propagates, under stressing action, and total separation takes place from the parent workpiece through the minimum resistance path as indicated in Fig.

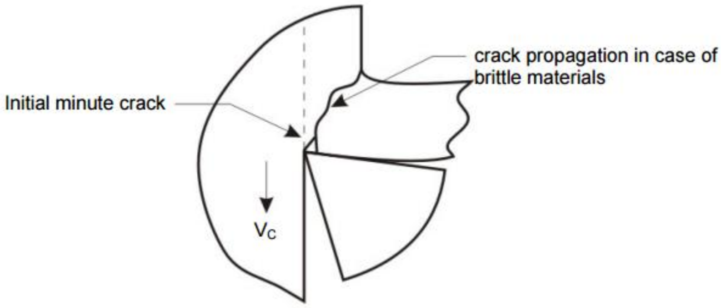



*Fig. Development and propagation of crack causing chip separation.*

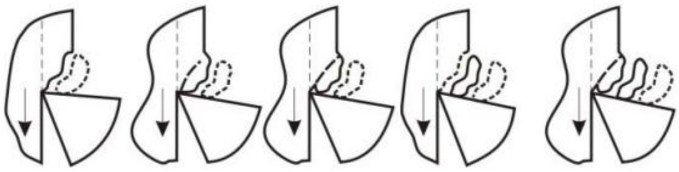



*Fig. Schematic view of chip formation in machining brittle materials.*

**(c)** Compare Shaper and Planer machines. **(4)**

**Ans.**

| | Shaper | Planer |
|---|---|---|
| 1 | It is a light duty machine. | It is a heavy duty machine. |
| 2 | The tool is held on the ram which reciprocates and work mounted on the table is stationary. | The work mounted on the table reciprocates while the tool is rigidly held on the machine frame. |
| 3 | It requires less floor area. | It requires more floor area. |
| 4 | Very heavy cuts and coarse feeds cannot be employed. | Heavier cuts and coarse feeds can be employed. |
| 5 | Usually only one tool is used. | Several tools can be mounted and employed simultaneously facilitating faster rate of production. |
| 6 | Cutting takes place by moving the cutting tool over the job. | Cutting takes place by reciprocating the work under the tool. |
| 7 | Used for machining relatively small surfaces. | Used for machining large flat surfaces. |
| 8 | Indexed feed is given to the work during the idle stroke of the ram. | Indexed feed is given to the tool during the idle stroke of the work table. |

**4.** **(a)** What are the functions of cutting fluid? Explain different types of cutting fluid. **(10)**

Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing workpiece thermal deformation, improving surface finish and flushing away chips from the cutting zone. Practically all cutt ing fluids presently in use fall into one of four categories:
Straight oils
Soluble oils
Semisynthetic fluids
Synthetic fluids
Straight oils are non-emulsifiable and are used in machining operations in an undiluted form. They are composed of a base mineral or petroleum oil and often contains polar lubricants such as fats, vegetable oils and esters as well as extreme pressure additives such as Chlorine, Sulphur and Phosphorus. Straight oils provide the best lubrication and the poorest cooling characteristics among cutting fluids.

Synthetic Fluids contain no petroleum or mineral oil base and instead are formulated from alkaline inorganic and organic compounds along with additives for corrosion inhibition. They are generally used in a diluted form (usual concent ration = 3 to 10%). Synthetic fluids often provide the best cooling performance among all cutting fluids.

Soluble Oil Fluids form an emulsion when mixed with water. The concentrate consists of a base mineral oil and emulsifiers to help produce a stable emulsion. They are used in a diluted form (usual concentration = 3 to 10%) and provide good lubrication and heat transfer performance. They are widely used in industry and are the least expensive among all cutting fluids.

Semi-synthetic fluids are esentially combination of synthetic and soluble oil fluids and have characteristics common to both types. The cost and heat transfer performance of semi-synthetic fluids lie between those of synthetic and sol uble oil fluids.

The principal methods of cutting fluid application include:
Flood Application of Fluid:
a flood of cutting fluid is applied on the workpiece

Jet Application of Fluid:
a jet of cutting fluid is applied on the workpiece directed at the cutting zone

Mist Application of Fluid:
cutting fluid is atomised by a jet of air and the mist is directed at the cutting zone

Cutting Fluid Effects in Machining
The primary functions of cutting fluids in machining are :
Lubricating the cutting process primarily at low cutting speeds
Cooling the workpiece primarily at high cutting speeds
Flushing chips away from the cutting zone
Secondary functions include:
Corossion protection of the machined surface

enabling part handling by cooling the hot surface
Process effects of using cutting fluids in machining include:
Longer Tool Life
Reduced Thermal Deformation of Workpiece
Better Surface Finish (in some applications)
Ease of Chip and Swarf handling

Cutting Fluid Selection Criteria
The principal criteria for selection of a cutting fluid for a given machining operation are:
Process performance :
Heat transfer performance
Lubrication performance
Chip flushing
Fluid mist generation
Fluid carry-off in chips
Corrosion inhibition
Fluid stability (for emulsions)
Cost Performance
Environmental Performance
Health Hazard Performance

**(b)** In an orthogonal cutting with a tool rake angle 10°, the following observations were made: **(6)**
Chip thickness ratio = 0.4
Horizontal component of the cutting force = 1200 N
Vertical component of the cutting force = 1600 N
From Merchant's theory, calculate:
(i) Shear plane angle (ii) Shear force along the rake face (iii) Normal force on the rake face (iv) Coefficient of friction (μ) at the chip tool interface (v) Friction angle.

**Ans.** Given:
α = 10°
r = 0.4
Ft = FH = 1200 N
Fc = FV = 1600 N
(i) Shear plane angle (Φ)

$$tan\varphi = \frac{r\ cos\ \alpha}{1 - r\ sin\ \alpha} = \frac{0.4 \cos 10}{1 - 0.4 \sin 10}$$

Φ = 22.94°

(ii) Shear force along the rake face (Fs):

$$F_s = F_c \cdot \cos\varphi - F_t \cdot \sin\varphi = 1600 \cos 22.94 - 1200 \sin 22.94 = 1005.74\ N$$

(iii) Normal force on the rake face (Fn)

$$F_n = F_t \cdot \cos\varphi + F_c \cdot \sin\varphi = 1200 \cos 22.94 + 1600 \sin 22.94 = 1728.72\ N$$

(iv) Coefficient of friction (μ) at the chip tool interface

$$\mu = \frac{F_c \cdot \sin\alpha - F_t \cdot \cos\alpha}{F_c \cdot \cos\alpha - F_t \cdot \sin\alpha} = \frac{1600 \sin 10 + 1200 \cos 10}{1600 \cos 10 - 1200 \sin 10} = 1.067$$

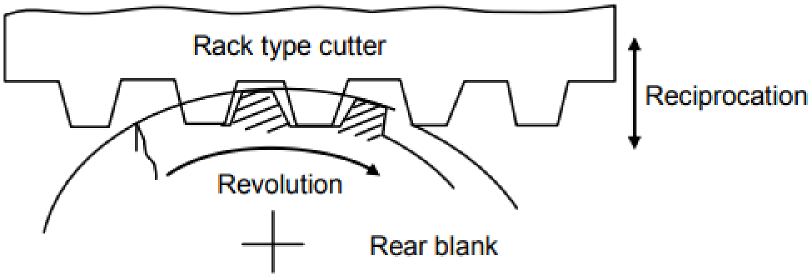
(v) Friction angle (τ):

$$\mu = \tan\tau$$
$$1.067 = \tan\tau$$
$$\tau = 46.87°$$

**(c)** Explain the rack planning process. **(4)**

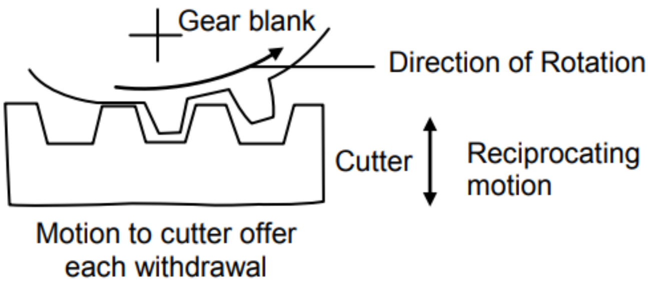
**Ans** Rack Planning Process

This process is used for shaping of spur and helical gear teeth with the help of a rack type cutter. In this process the gear blank is mounted on a horizontal aims and rotated impertinently. At the same time the gear blank is kept in mesh with a reciprocating rack type cutter. The process is shown in Figure .




**Gear Shaping by Rack Type Cutter**

The teeth cutter gradually removes material to cut the teeth and to make the required profile. The whole operation includes some important operations. These are feeding cutter into the blank, rolling the blank intermittently and keeping cutter in mesh with the rolling gear blank. After each mesh the gear blank is rolled by an amount equal to one pitch of gear tooth. After each cutting, the rack is withdrawn and re-meshed after the rotation of gear blank.




**Process of Sunderland Gear Shaping Process**

A few of the initial teeth of rack type cutter perform the cutting action and remaining teeth to very small removal of workpiece material, these are used to maintain dimensional accuracy of the already cut teeth and to provide them a good finishing. The basic principle of gear shaping is same but by slight altering the process some more different methods of gear shaping are discussed below.

Sunderland Process

This process is named after the name of its inventor. In this process the cutter reciprocates in a direction towards and away from the gear blank. The process is illustrated in figure. Cutter is gradually fed into the gear blank to the required depth. As soon as cutting is completed upto the desired depth, the blank rotates through one pitch distance. The cutter also moves along with the blank and then suddenly withdraws, stepped back by an amount equal to one pitch distance and again made to reciprocate in the normal way. The gear blank does not move till the completion of whole cutting upto the required depth. The whole motion and movement control is basically maintained with the help of synchronous motor and gear train.

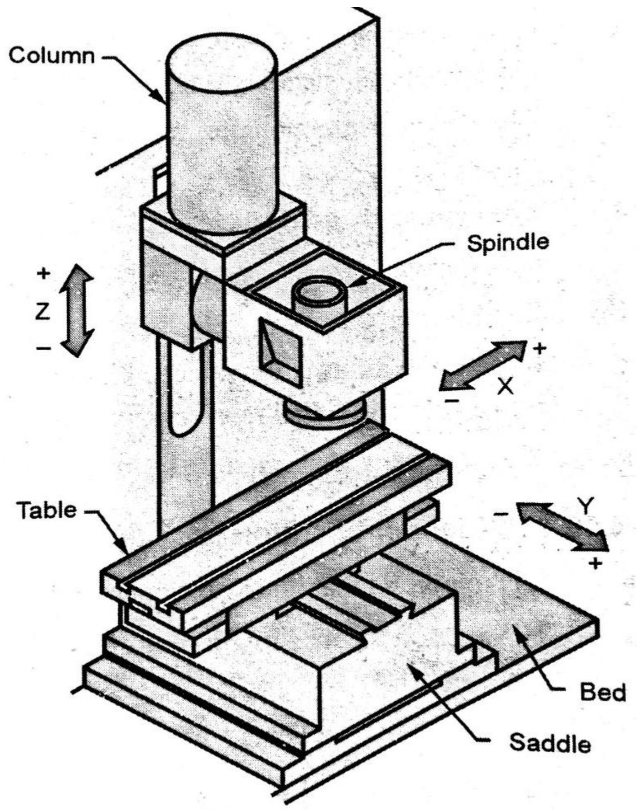
Mang Process

In this process gear blank is mounted on the machine table, keeping its axis in a vertical position. The cutter head, carrying rack type cutter, slides vertically in the sides provided at the front of the machine. The cutter can be set at any angle in a vertical plane. The cutter can also be made reciprocating in any direction. The rest of the process re-samples with other gear shaping processes.

**5.** **(a)** With the help of neat sketch describe vertical machining centers. **(10)**

**Ans.**

- It carries a vertical machining spindle (head) which can slide along vertical guide ways provided on the column.
- The vertical head can be tilted in either direction.
- These machines are suitable for machining flat surfaces with deep cavities like the manufacturing of moulds, dies, etc.
- These machines are also very heavy in construction. Figure shows the principal parts of VMC which are similar to HMC.
  i. Bed: It is a heavy structure which supports the complete machine and carries guide-ways over its top surface. It is generally made of cast iron.
  ii. Saddle: It is mounted over the guide ways on the bed and also carries column over it. It provides y axis movement to the machining center.
  iii. Table: It is mounted over the guide was provided on the saddle. It is made up of cast iron. For mounting the work holding devices, T slots are provided on the tale. It provides X axis movement to the machining centers.
  iv. Column: It is mounted over the saddle. It provides z axis movement to the machining center.
  v. Automatic tool changer: It is used to change the tool from the machine spindle, rapidly.
  vi. Spindle and servo system: Spindle is mounted on the headstock and it provides z axis movement to the machining center. Servo system consists of servo motors and feedback system. It provides accurate and rapid movement along all the axes.




**Vertical machining centre**

**(b)** Write short note on : Cutting tool materials. **(6)**

**Ans.** **1 Carbon Steels**

Carbon steels have been used since the 1880s for cutting tools. However carbon steels start to soften at a temperature of about 180$^{o}$C. This limitation means that such tools are rarely used for metal cutting operations. Plain carbon steel tools, containing about 0.9% carbon and about 1% manganese, hardened to about 62 Rc, are widely used for woodworking and they can be used in a router to machine aluminium sheet up to about 3mm thick.

**2 High Speed Steel (HSS)**

HSS tools are so named because they were developed to cut at higher speeds. Developed around 1900 HSS are the most highly alloyed tool steels. The tungsten (T series) were developed first and typically contain 12 - 18% tungsten, plus about 4% chromium and 1 - 5% vanadium. Most grades contain about 0.5% molybdenum and most grades contain 4 - 12% cobalt.

HSS tools are tough and suitable for interrupted cutting and are used to manufacture tools of complex shape such as drills, reamers, taps, dies and gear cutters. Tools may also be coated to improve wear resistance. HSS accounts for the largest tonnage of tool materials currently used. Typical cutting speeds: 10 - 60 m/min.

**3 Cast Cobalt Alloys**

Introduced in early 1900s these alloys have compositions of about 40 - 55% cobalt, 30% chromium and 10 - 20% tungsten and are not heat treatable. Maximum hardness values of 55 - 64 Rc. They have good wear resistance but are not as tough as HSS but can be used at somewhat higher speeds than HSS. Now only in limited use.

**4 Carbides**
Also known as cemented carbides or sintered carbides were introduced in the 1930s and have high hardness over a wide range of temperatures, high thermal conductivity, high Young's modulus making them effective tool and die materials for a range of applications.
The two groups used for machining are tungsten carbide and titanium carbide, both types may be coated or uncoated.
Tungsten carbide particles (1 to 5 micro-m) are are bonded together in a cobalt matrix using powder metallurgy. The powder is pressed and sintered to the required insert shape. titanium and niobium carbides may also be included to impart special properties.
Titanium carbide has a higher wear resistance than tungsten but is not as tough. With a nickel-molybdenum alloy as the matrix, TiC is suitable for machining at higher speeds than those which can be used for tungsten carbide. Typical cutting speeds are: 30 - 150 m/min or 100 - 250 when coated.

**5 Coatings**
Coatings are frequently applied to carbide tool tips to improve tool life or to enable higher cutting speeds. Coated tips typically have lives 10 times greater than uncoated tips. Common coating materials include titanium nitride, titanium carbide and aluminium oxide, usually 2 - 15 micro-m thick. Often several different layers may be applied, one on top of another, depending upon the intended application of the tip. The techniques used for applying coatings include chemical vapour deposition (CVD) plasma assisted CVD and physical vapour deposition (PVD). Diamond coatings are also in use and being further developed.

**6 Cermets**
Developed in the 1960s, these typically contain 70% aluminium oxide and 30% titanium carbide. Some formulation contain molybdenum carbide, niobium carbide and tantalum carbide. Their performance is between those of carbides and ceramics and coatings seem to offer few benefits. Typical cutting speeds: 150 - 350 m/min.

**7 Ceramics -**
**Alumina**
Introduced in the early 1950s, two classes are used for cutting tools: fine grained high purity aluminium oxide ($Al_2O_3$) and silicon nitride ($Si_3N_4$) are pressed into insert tip shapes and sintered at high temperatures. Additions of titanium carbide and zirconium oxide ($ZrO_2$) may be made to improve properties. But while $ZrO_2$ improves the fracture toughness, it reduces the hardness and thermal conductivity. Silicon carbide (SiC) whiskers may be added to give better toughness and improved thermal shock resistance.
**Silicon Nitride**
In the 1970s a tool material based on silicon nitride was developed, these may also contain aluminium oxide, yttrium oxide and titanium carbide. SiN has an affinity for iron and is not suitable for machining steels. A specific type is 'Sialon', containing the elements: silicon, aluminium, oxygen and nitrogen. This has higher thermal shock resistance than silicon nitride and is recommended for machining

cast irons and nickel based superalloys at intermediate cutting speeds.

**8 Cubic Boron Nitride (cBN)**
Introduced in the early 1960s, this is the second hardest material available after diamond. cBN tools may be used either in the form of small solid tips or or as a 0.5 to 1 mm thick layer of of polycrystalline boron nitride sintered onto a carbide substrate under pressure.

**9 Diamond**
The hardest known substance is diamond. Although single crystal diamond has been used as a tool, they are brittle and need to be mounted at the correct crystal orientation to obtain optimal tool life. Single crystal diamond tools have been mainly replaced by polycrystalline diamond (PCD). This consists of very small synthetic crystals fused by a high temperature high pressure process to a thickness of between 0.5 and 1mm and bonded to a carbide substrate. The result is similar to cBN tools.

**10 Other Materials**
To improve the toughness of tools, developments are being carried out with whisker reinforcement, such as silicon nitride reinforced with silicon carbide whiskers.

**Tool Life Curves**
The Taylor tool life equation can be written as: $v(T)^n = C$, where
v is the cutting speed, m/min, T is the tool life, in minutes, C is the cutting speed for a tool life of 1 minute and n is the Taylor exponent (Do not confuse this use of n with the cold working index n).

| Tool Material | Typical 'n' value |
|---|---|
| High-speed steels | 0.08 - 0.2 |
| Cast Alloys | 0.1 - 0.15 |
| Carbides | 0.2 - 0.5 |
| Ceramics | 0.5 - 0.7 |

**(c)** Write short notes on: Coordinate measuring machine. **(4)**

**Ans.**

- CMM is a 3D device for measuring the physical geometrical characteristics of an object.
- CMM is a machine which takes readings in six degrees of freedom and displays these readings in mathematical form.
- CMM is a specialized form of industrial robot

**Parts**

CMM include three main components:

1.**Main Structure**

which include three axes of motion

2. **Probing system**

3. **Data collection and reduction system**

- Application software
- Machine controller
- Desktop computer

**Cantilever type**

*Advantage:*

Large measuring range

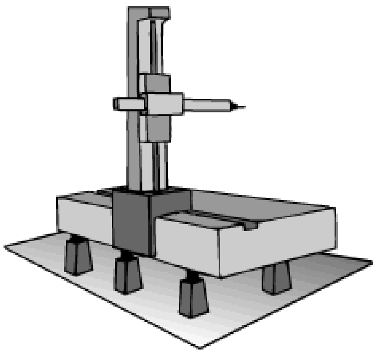
Maximum accessibility

*Disadvantage:*

Bending of the cantilever above the measuring area

*Application:*

For checking sheet metal, cast iron and steel parts in the automotive industry, aircraft construction and shipbuilding.



**Column type**

**(horizontal arm type)**

*Advantage:*

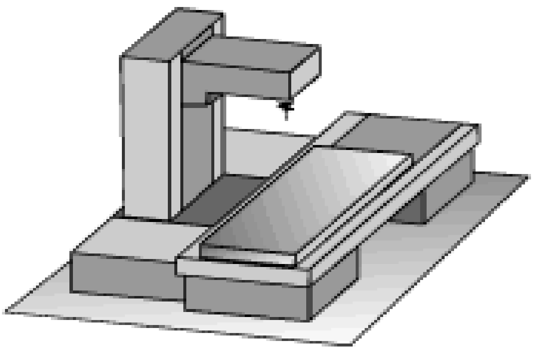
High accelerations and speeds owing to the large supporting base of the column and its low weight

*Disadvantage:*

Suitable for small measuring ranges only since the projecting part of the column must have short length due to its rigidity.

*Application:*

In precision measurements on gages and master parts.



**Bridge type**

*Advantage:*

Most widely used

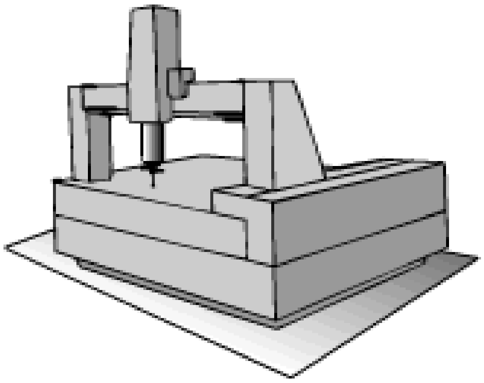
High rigidity owing to compact bridge design and thus small measuring deviations.

*Disadvantage:*

Limited accessibility caused by the bridge.

*Application:*

For medium to large measuring range



**Gantry type**

*Advantage:*

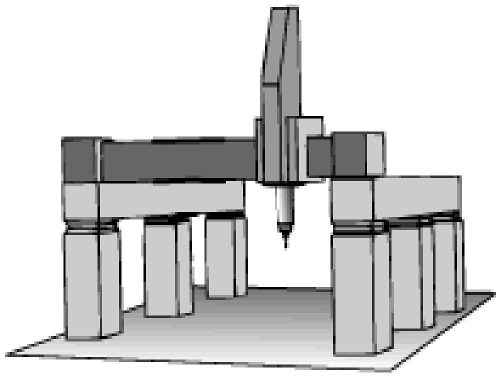
Measurement of large size parts

*Disadvantage:*

Geometric changes caused by non-uniform temperature distribution owing to their large size.

*Application:*

Heavy machine construction,
car body and mold making sectors
of the automotive industry,
measuring wind tunnel models.



**6.** Write short notes on any **FOUR** : **20**

**(a)** Machinability.

**Ans.**

- Machinability of a material indicates how machinable the material is.
- the parameters which affect the machinability of a material are:
  1. physical and mechanical properties of a material
  2. chemical composition and microstructure of a material
  3. cutting conditions
- the general criteria for evaluating machinability are as follows:
  1. Tool life - longer tool life at given cutting speed indicates better machinability
  2. Surface finish - better the surface finish, higher is the machinability
  3. Power consumption - If for metal removal power consumption is low then it indicates better machinability
  4. Cutting Force - Lesser the cutting force for removing the higher volume of metal, higher will be machinability
  5. Shear angle - larger shear angle gives better machinability

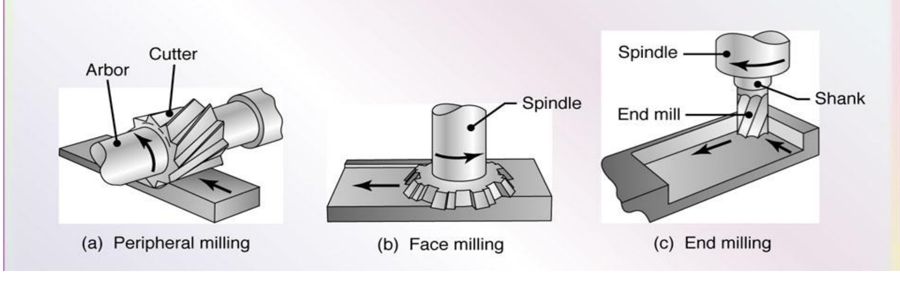
**(b)** Surface Finish in machining.

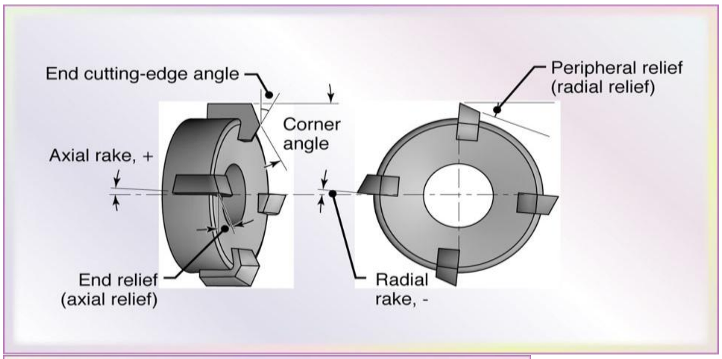
**Ans.** The surface finish produced in machining operation is combination of several factors. The surface finish requirement is as important as the desired dimensional accuracy. Hence, it is necessary to know the factors which affect the surface finish. The resultant roughness produced by a machining operation is categorised as follows:

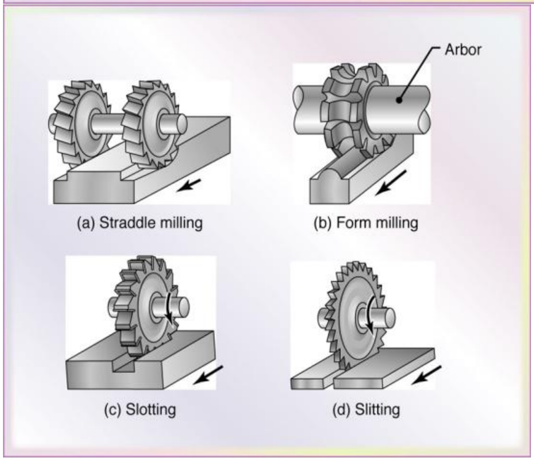
1. Ideal Roughness
   - It is the result of the geometry of the tool and the feed rate.
   - It is a geometric phenomena and is a result of the minimum possible magnitude of unevenness which results from machining operation.
   - It indicates the best possible finish that can be obtained by a given operation.
2. Natural Roughness
   - Practically there are various factors which affect the surface finish. Such roughness is called natural roughness.
   - The important factors are as follows;
     - Formation of build up edge
     - vibration
     - work piece material

**(c)** Geometry of milling cutter.

**Ans.**






**(d)** Carbide inserts.

**Ans.**

- Various types of cemented (sintered) carbides developed to suit different materials and machining operations
  - Good wear resistance
  - Operate at speeds ranging 150 to 1200 sf/min
- Can machine metals at speeds that cause cutting edge to become red hot without loosing harness
- Products of powder metallurgy process
  - Tantalum, titanium, niobium
- Operations
  - Blending
  - Compaction
  - Presintering
  - Sintering

**Types of Carbide Lathe Cutting Tools**

- Blazed-tip type
  - Cemented-carbide tips brazed to steel shanks
  - Wide variety of styles and sizes
- Indexable insert type
  - Throwaway inserts
  - Wide variety of shapes: triangular, square, diamond, and round
    - Triangular: has three cutting edges
  - Inserts held mechanically in special holder

**(e)** GM codes in CNC machines.

G-codes, also called preparatory codes, are any word in a CNC program that begins with the letter G. Generally it is a code telling the machine tool what type of action to perform, such as:

- Rapid movement (transport the tool as quickly as possible through space to the location where it will cut)
- Controlled feed in a straight line or arc
- Series of controlled feed movements that would result in a hole being bored, a workpiece cut (routed) to a specific dimension, or a profile (contour) shape added to the edge of a workpiece
- Set tool information such as offset
- Switch coordinate systems

**CNC G codes**

G00 - Positioning at rapid speed; Mill and Lathe
G01 - Linear interpolation (machining a straight line); Mill and Lathe
G02 - Circular interpolation clockwise (machining arcs); Mill and Lathe
G03 - Circular interpolation, counter clockwise; Mill and Lathe
G04 - Mill and Lathe, Dwell
G09 - Mill and Lathe, Exact stop
G10 - Setting offsets in the program; Mill and Lathe
Lathe
G43 - Tool length compensation; Mill
G44 - Tool length compensation cancel; Mill (sometimes G49)
G50 - Set coordinate system and maximum RPM; Lathe
G52 - Local coordinate system setting; Mill and Lathe
G53 - Machine coordinate system setting; Mill and Lathe
G54~G59 - Workpiece coordinate system settings #1 t0 #6; Mill and Lathe
G61 - Exact stop check; Mill and Lathe
G65 - Custom macro call; Mill and Lathe
G70 - Finish cycle; Lathe
G71 - Rough turning cycle; Lathe
G72 - Rough facing cycle; Lathe
G73 - Irregular rough turning cycle; Lathe

**CNC M Codes**

M00 - Program stop; Mill and Lathe
M01 - Optional program stop; Lathe and Mill
M02 - Program end; Lathe and Mill
M03 - Spindle on clockwise; Lathe and Mill
M04 - Spindle on counterclockwise; Lathe and Mill
M05 - Spindle off; Lathe and Mill
M06 - Toolchange; Mill
M08 - Coolant on; Lathe and Mill

***