LECTURE NOTES

Machining Science and Technology

B. Tech, 6th Semester, ME

Prepared by:

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COURSE CONTENT

Machining Science and Technology

B. Tech, 6th Semester, ME

MODULE – I (13 HOURS)

Geometry of cutting tools in ASA and ORS, Effect of Geometrical parameters on cutting force and surface finish, Mechanics of chip formation, Merchant's theory, Force relationship and velocity relationship, Cutting tool materials, Types of Tool Wear: Flank wear, Crater wear, Wear measurement, Cutting fluid and its effect; Machinability Criteria, Tool life and Taylor's equation, Effect of variables on tool life and surface finish, Measurement of cutting force, Lathe tool dynamometer, Drill tool dynamometer. Economics of machining.

MODULE – II (13 HOURS)

Conventional machining process and machine tools – Turning, Drilling, Shaping, Planning, Milling, Grinding. Machine tools used for these processes, their specifications and various techniques used. Principles of machine tools : Kinematics of machine tools, speed transmission from motor to spindle , speed reversal mechanism, mechanism for feed motion, Tool holding and job holding methods in different Machine tools, Types of surface generated, Indexing mechanism and thread cutting mechanism, Quick return mechanism,.

Production Machine tools – Capstan and turret lathes, single spindle and multi spindle semiautomatics, Gear shaper and Gear hobbing machines, Copying lathe and transfer machine

MODULE – III (10 HOURS)

Non-traditional Machining processes :

Ultrasonic Machining, Laser Beam Machining, Plasma Arc Machining, Electro Chemical Machining, Electro Discharge Machining, Wire EDM, Abrasive Jet Machining

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Machining Science and Technology

B. Tech, 6th Semester, ME

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2. Metal Cutting Principles, M.C.Shaw, Oxford University Press
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Module-1

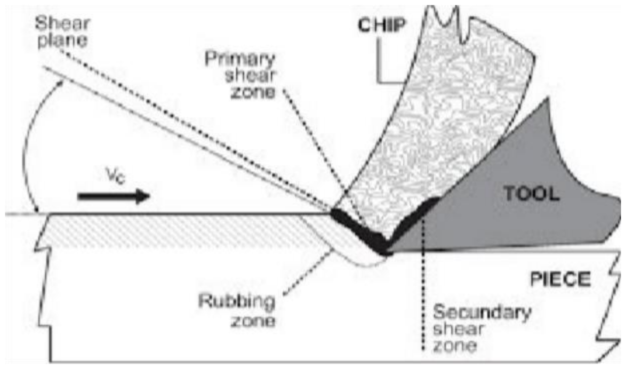
What is Cutting Tool

A cutting tool is a specialized device used in machining processes to remove material from a workpiece by means of shear deformation. It is designed with a sharp cutting edge and specific geometry to ensure efficient material removal, high precision, and extended tool life. Cutting tools can be classified as single-point tools, such as lathe tools used in turning operations, and multi-point tools, such as drills, milling cutters, and broaches. The tool geometry, including rake angle, clearance angle, cutting edge angle, and nose radius, plays a crucial role in determining cutting performance, surface finish, and tool wear. Advanced cutting tools may incorporate coatings (e.g., TiN, TiAlN) or surface texturing to enhance performance by reducing friction, improving chip evacuation, and increasing tool life. In modern manufacturing, tools optimized for hard materials such as AISI 52100 steel and tungsten carbide often feature micro-textures, MQL compatibility, and special edge preparations to withstand high cutting forces and extreme temperatures.

Basic elements of machining.

a) Work piece b) Tool and c) Chip.

The relative motion between the tool and work piece is necessary for effecting the cutting action. The relative motion can be provided by both keeping the work piece stationary and moving the tool or by keeping the tool stationary and moving the work or by moving both in relation to one another. The work piece provides the parent metal, from which unwanted metal is removed by cutting action of tool to obtain shape and size of the component. Chemical composition and physical properties of work piece material will have significant effect in machining. The type and geometry of chip formed are greatly affected by the metal of work piece, geometry of cutting tool and method of cutting. Chemical composition and rate of flow of cutting fluid have considerable influence over the machining operation.



Orthogonal And Oblique Cutting:

The process of metal cutting is divided in to two main classes: Orthogonal and Oblique cutting. In Orthogonal cutting, cutting edge of tool remains normal to the direction of tool feed or work feed. The direction of chip flow velocity is normal to the cutting edge of the tool.

The angle of inclination 'i' of the cutting edge of the tool with normal to the velocity vc is zero. The chip flow angle i.e the angle between the direction of chip flow and normal to the cutting edge of the tool is zero. Cutting edge is longer than the width of the cut.

Oblique cutting:

The cutting edge of the tool always remains inclined at an acute angle to the direction of tool feed or work feed. The direction of chip flow velocity is at an angle with normal to the cutting edge of the tool. The angle is known as chip flow angle. The cutting edge of the tool is inclined at an angle ‘i’ with the normal to the direction of tool feed or work feed. Three mutually perpendicular components of the cutting forces act at the cutting edge of the tool. The cutting edge may or may not be longer than the width of cut. Most of the metal cutting is carried out through oblique method.

Classification of Cutting Tools

Single point tools: Those having only one cutting edge. Ex. Lathe tools, Shaper tools, Planer tools, Boring tools etc**.**

Multi-Pont tools:- Those having more than one cutting edgeEx. Milling cutters, Drills, Broachers, Grinding wheels**.**

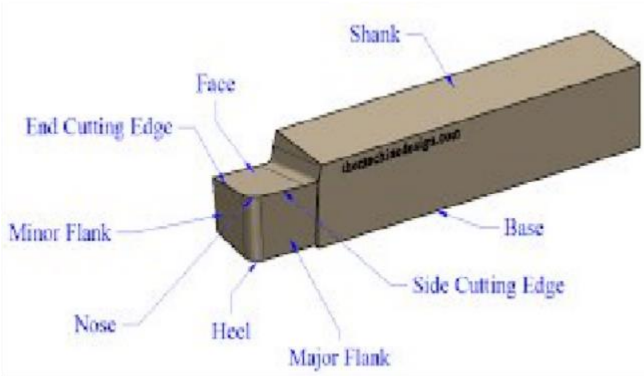
Cutting Tools Can Also Be Classified According To The Motion As:

Linear motion tools: Lathe, Boring, Broaching, Planning and Shaping tools.

Rotary motion tools: Milling cutters, grinding wheels.

Linear And Rotary Tools: Drills, Honing Tools, Boring Heads Etc.

Geometry of Single Point Tools:



1. **Rake angle**: It is the angle formed between face of the tool and plane parallel to its base. If this inclination is towards shank, it is known as back rake or top rake. When it is measured towards side of the tool, it is called side rake. These rake angles guide the chips away from the cutting edge, thereby reducing the chip pressure on the face and increasing the keenness of the tool, so that less power is required for cutting. An increased rake angle will reduce the strength of cutting edge. Therefore tools used for cutting hard materials are given small rake angles, whereas those used for soft metals contain large rake angles.
2. **Negative rake angle**: The above rake angles are called positive rake angles. When no rake is provided on the tool, it is said to have zero rake angle. When the face of the tool is so ground that it slopes upwards from the point, it is said to contain a negative rake. It reduces keenness of the tool and increases the strength of cutting edge. Such rake is usually provided on carbide tipped tools when they are used for machining extra- hard surfaces, hardened steel parts and for taking intermittent cuts. The values of negative rake on these tools normally vary from 5 to 10.
3. **Lip angle**: The angle between the face and flank of the tool is known as Lip angle. It is also called angle of keenness of the tool. Strength of the cutting edge or point of the tool is directly affected by this angle. Larger the lip angle, stronger will be cutting edge and viceversa. This angle varies

inversely as the rake angle. It is only for this reason that when harder metals are to be machined a stronger tool is required, the rake angle is reduced and consequently the lip angle is increased. This calls for reduced cutting speeds, which is disadvantage. The lip angle is therefore kept as low as possible without making the cutting edge so weak that it becomes unsuitable for cutting.

4. **Clearance angle:** It is the angle formed by the front or side surface of the tool which are adjacent and below the cutting edge when the tool is held in a horizontal position. It is the angle between one of these surfaces and a plane normal to the base of the tool. When the front surface is considered, it is called front clearance and when the surface below cutting edge is considered, the angle formed is known as side clearance angle. The purpose of providing front clearance is to allow the tool to cut freely without rubbing against the surface of the job. The side clearance is to direct the cutting thrust to the metal area adjacent to the cutting edge.
5. **Relief angle**: It is the angle formed between flank of the tool and a perpendicular drawn from the cutting point to the base of the tool.
6. **Cutting angle**: The total cutting angle of the tool is the angle formed between the tool face and a line drawn through the point, which is a tangent to the machined surface of the work at that point. Its correct value depends upon the position of the tool in which it is held in relation to the axis of the job.
7. **Nose radius**: If the cutting tip of a single point tool carries a sharp cutting point, the cutting tip is weak. It is therefore highly stressed during the operation, may fail or loose its cutting ability soon and produces marks on the machined surface. In order to prevent these harmful effects, the nose is provided with a radius, called Nose radius. It enables greater strength to cutting tip, a prolonged tool life and superior surface finish on the work piece. As the value of this radius increases, a higher cutting speed can be used. If it is too large, it may lead to chatter. So, a balance has to be maintained. Its value normally varies from 0.4mm to 1.6mm depending upon several factors like depth of cut, amount of feed, type of cutting and type of tool.

Chip Formation:

Chips are formed due to tearing and shearing. In the chip formation by tear, the work piece material adjacent to the tool face is compressed and crack runs ahead of the cutting tool and towards body of the work-piece. The chip is highly deformed and the workpiece material is relatively under formed. Cutting takes place intermittently and there is no movement of the work piece material over the tool face. In chip formation by shear, there is a general movement of the chip over tool face.

The grains of metal ahead of cutting edge of tool start elongating along line AB and continue to do so until they are completely deformed along line CD. The region between the lines AB and CD is called shear zone. After passing over shear zone, the deformed metal slides along the tool face due to the velocity of the cutting tool.

The angle made by plane of shear with the direction of tool travel is known as shear angle. Its value depends on the material being cut and the cutting conditions. If is small, path of shear will be long, chips will be thick and the force required to remove the layer of metal of given thickness will be high and vice-versa.

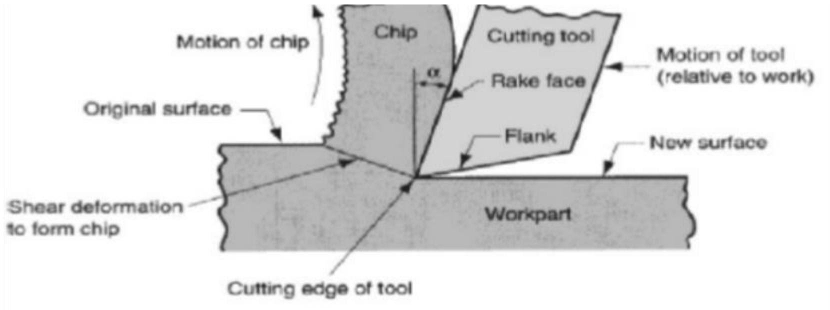


Figure :- Mechanism of chip formation

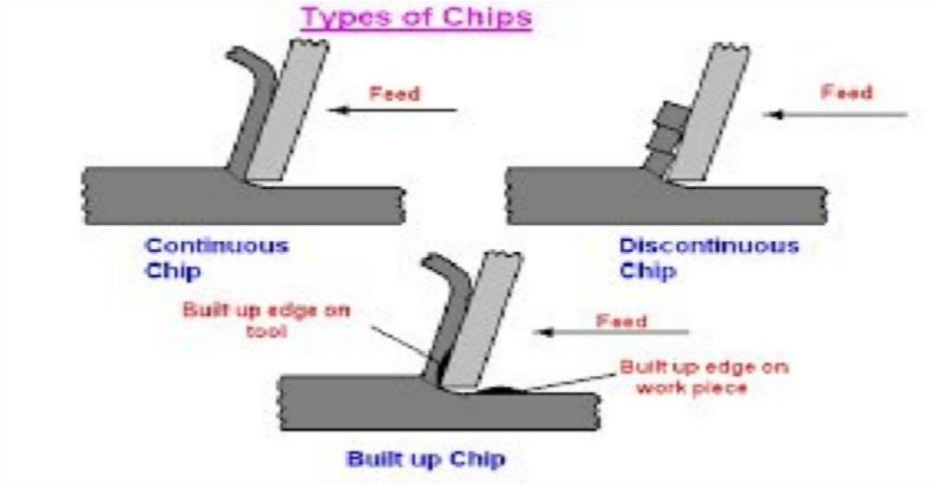
Types of chips:

Every machining operation involves the formation of chips, the nature of chips differs from operation to operation, properties of work-piece material and cutting condition.

Chips are formed due to cutting tool, which is harder and more wear resistant than the workpiece material, relative motion between tool and work-piece, sufficient force and power to overcome the resistance of work-piece material. The chips are formed by the deformation of the metal lying ahead of cutting tool edge by a process of shear. Basically, there are three types of chips.

1. **Discontinuous chips:** This type of chips is produced during machining of brittle materials like cast-iron and bronze. These chips are produced in the form of small segments. In machining of such materials, as the tool advances forward, the shear-plane angle gradually reduces until the value of compressive stress acting on the shear plane becomes too low to prevent rupture. At this stage, any further advancement of the tool results in the fracture of the metal ahead of it, thus producing a chip. With further advancement of the tool, the processes of metal fracture and production of chips goes on repeatedly producing discontinuous chips. Such chips are also sometimes produced in machining of ductile materials, when low cutting speeds are used and adequate lubrication is not provided. This causes excessive friction between the chip and tool face, leading to fracture of chip in small segments. This will also result in excessive wear on the tool and poor surface finish on the work-piece. Other factors responsible for production of discontinuous chips are smaller rake angle on the tool and too much depth of cut.
2. **Continuous chip:** This type of chip is produced while machining a ductile material, like mild steel and copper at very high cutting speed and minimum friction between the chip and the tool face. The friction at the chip-tool inter face can be minimized by polishing the tool face and adequate use of coolant. The basis of production of a continuous chip is the continuous plastic deformation of the metal ahead of the cutting tool, the chip moving smoothly up the tool face. Other factors responsible are bigger rake angle, finer feed and keen cutting edge of the tool.
3. **Continuous chip with built-up edge**: It is very similar to the continuous type and not as smooth as continuous chip. It has a built-up edge adhering on nose of the tool, which changes the effective geometry of cutting. It is obtained by machining ductile metals with high speed tools at ordinary cutting speeds, thus introducing high friction between the chip and tool face. The form and size of such an edge depends largely on the cutting speed, being absent at very low and very high cutting speeds. This type of chip results in poor surface finish. The normal reaction of the chip on the tool face is quite high, and is maximum at the cutting edge or nose of the tool. This gives rise to an excessively high temperature and the compressed metal adjacent to tool nose gets welded to it. The chip is also sufficiently hot and gets oxidized as it comes off the tool and turns blue in colour. The extra metal welded to tool nose or point of the tool is called built-up edge.

   This metal is highly strain hardened and brittle. With the result, as the chip flows up the tool, the built-up edge is broken and carried away with the chip while the rest of it adheres to the surface of the work-piece, making it rough. Due to the built-up edge the rake angle is also altered and so is the cutting force. The common factors responsible for formation of built-up edge are low cutting speed, excessive feed, small rake angle and lack of lubricant.

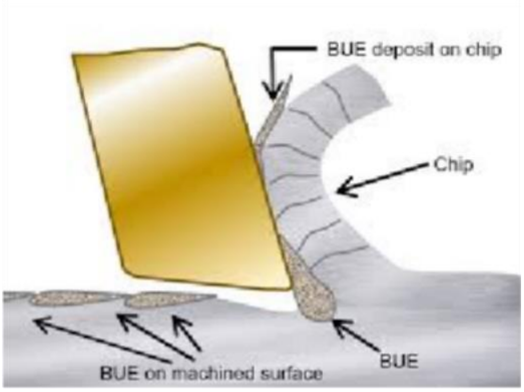


Adverse effects of built-up edge formation:

a) Rough surface finish on the work-piece.

b) Fluctuating cutting force, causing vibrations in cutting tool.

c) Chances of carrying away some material from the tool by the built-up surface, producing crater on the tool face and causing tool wear.



Chip-Breakers:

The chips produced during machining at higher speeds in machining of high tensile strength materials, need to be effectively controlled. Carbide tipped tools are used in case of higher speeds and due to high temperature, the chip will be continuous of blue color and take the shape of coil. Such a chip, if not broken in to parts and removed from the surroundings of the metal cutting area, will adversely affect the machining in the fallowing way.

a) Adversely affect tool life by spoiling the cutting edge, creating crater and raising the temperature.

b) Lead to poor surface finish on the work-piece.

c) The chips get curled around the rotating work-piece and cutting tool, it may be hazardous to the machine operator.

d) If large and continuous coil is allowed to be formed it may endanger the machine and even the work place.

e) Very large coils offer a lot of difficulty in their removal. While machining materials like brass and cast-iron continuous chips of above type are not produced. But in case of continuous chips, by using chip breakers, we can overcome the above difficulties and adverse effects. The chip breakers break the produced chips in to small pieces. The work hardening of the material of the chip makes the work of the chip breakers easy.

Cutting Speed, Feed And Depth Of Cut:

Cutting speed of a tool can be defined as the rate at which its cutting edge passes over the surface of the work-piece in unit time. It is normally expressed in terms of surface speed in meters per minute.

In machining it is important as it considerably affects the tool life and efficiency of machining. Selection of proper cutting speed has to be made very judiciously. If it is too high, the tool gets over heated and its cutting edge may fail, needing regrinding. If it is too low, too much time is consumed in machining and full cutting capacities of the tool and machine are not utilized, resulting in lowering of productivity and increasing the production cost.

Feed of the cutting tool can be defined as the distance it travels along or in to the work-piece for each pass of its point through a perpendicular position in unit time. In turning operation of lathe, it is equal to the advancement of the tool corresponding to each revolution of work. In planning it is the work, which is fed and not the tool. In milling work, the feed is considered per tooth of the cutter.

The cutting speed and feed of a cutting tool is largely influenced by the following factors:

1. Material being machined.
2. Material of the cutting tool.
3. Geometry of the cutting tool.
4. Required degree of surface finish.
5. Rigidity of the machine tool being used
6. Type of coolant being used

Depth of cut: It is indicative of the penetration of the cutting edge of the tool in to the workpiece material in each pass, measured perpendicular to the machined surface i.e. it determines the thickness of metal layer removed by the cutting tool in one pass.

Example: In turning operation on a lathe it is given by

$$D-d/2$$

Where D = Original diameter of the work-piece in mm

d = Diameter obtained after turning in mm in one pass.

Coolants: coolants are used in metal machining to perform the following main functions.

1. They cool the tool and the work piece.
2. They provide lubrication between the tool and work piece and tool and chips.
3. They prevent the adhesion of chips to the tool or work piece or both.

Cooling of the tool and work piece in required in order to dissipate the heat generated during machining. The sources of heat generation during metal cutting are the following.

1 Friction: A lot of friction always takes place between the cutting tool and the work piece and between the tool face and the chips passing over it. The total amount of heat generated depends upon many factors viz. cutting speed, feed, tool material, depth of cut and metal being machined. The heat so generated is known as heat of friction.

2. Plastic deformation of metal: Cutting tool exerts high pressure on the adjacent metal grains which due to this pressure start slipping along their planes of weakness. This causes deformation of all of them. The action of slipping of these grains in contact with one another causes friction, leading to the generation of the heat of deformation. The total amount of heat generated again depends upon the cutting speed, feed, depth of cut and the metal being machined. Higher speeds, feeds, more depth of cut, tougher materials contribute to greater heat generation.

3. Chip distortion: In machining, as the cut proceeds and the chips curl out, the inside and the outside grain of the chip metal are subjected to compression and tension respectively. This causes distortion of the chip grains are the chips leading to a sort of internal friction amongst the grains and consequently generation of heat of chip distortion. The amount of heat generated depends on feeds and depth of cut. Heavier the feed and deeper the cut, the longer will be the area of cross-section of the chip and more distortion amongst the grains, resulting in higher amount of heat generation.

Machinability: Gives the idea of ease with which it can be machined. The parameters influencing the machinability of a material are:

1. Physical Properties of material.

2. Mechanical Properties of material.

3. Chemical composition of material.

4. Micro-Structure of material

5. Cutting conditions. Machinability of the material depends on various variable factors such as

1. Tool Life: Longer tool life, it enables at a given cutting speed on the speed the better is the machinability.

2. Surface finish: It indirectly proportional, i.e. better surface finish the higher in machinability.

3. Power Consumption: Lower power consumption per unit of metal removal-better machinability.

4. Cutting Forces: Lesser amount of cutting force required for removal of higher volume of metal under standard conditions, the higher will be the machinability.

5. Shear angle: Larger shear angle denotes better machinability.

Tool Life:

Tool life can be defined on the time interval for each tool works satisfactorily between into successive grindings. These are three common ways of expressing Tool life.

1. As time period in minutes between two successive grindings.

2. In terms of no. of components machined between two successive grindings.

3. In terms of the volume of the material removed between two successive grindings.

The method of assessing tool life in terms of the volume material removed per unit of time in a practical one.

Volume of metal removed/min = ∏ D t f N mm3 / min

Where D = Dia of work piece in mm

t = depth of cut in mm

f = feed rate mm/rev

N = no. of revolutions of work per min.

If T be the times in minutes to tool failure = ∏ D t f N T mm3

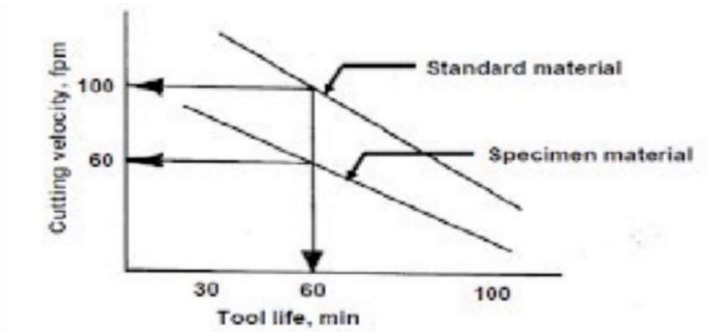
Total Volume of metal removed to tool life = V 1000 t f T mm3

Therefore Tool life TL = V X 1000 X t X f X T (mm3)

Factors affecting Tool Life:

1. Cutting Speed.

2. Feed and Depth of cut.
3. Tool Geometry.
4. Tool Material.
5. Work Material.
6. Nature of Cutting.
7. Rigidity Machine tool and work.
8. Use of cutting fluids**.**



Machinability rating in terms of cutting velocity giving 60 min tool life.

Merchant's Theory:

Merchant's theory, also known as Merchant's Circle Diagram, is a fundamental theory in metal cutting that explains the relationship between forces, tool geometry, and cutting conditions. It was proposed by Eugene Merchant in 1945 to analyze orthogonal cutting, where the cutting edge is perpendicular to the direction of tool movement.

Merchant's theory is based on the shear plane model of metal cutting, which assumes that plastic deformation occurs along a single shear plane. The goal of the derivation is to determine the optimum shear angle (ϕ) that minimizes cutting force and energy consumption.

According to this theory, the relation between rake angle (α), shear angle (β) and friction angle (γ) is given by

$$\beta = \frac{\pi}{4} - \frac{\gamma}{2} + \frac{\alpha}{2}$$

The following conclusions are made by Merchant

1. Shear will take place in the direction in which the energy required for shearing is minimum.
2. Shear stress is maximum at the shear plane and it remains constant.

We know that
$$F_z = \frac{F_s \cos(\gamma-\alpha)}{\cos(\beta+\gamma-\alpha)}$$

$$f_s = \frac{F_s}{A_s}$$

$$A_s = \text{Area of shear plane} = \frac{b_1 t_1}{\sin\beta}$$

$$\therefore \quad F_s = f_s A_s = f_s \times \frac{b_1 t_1}{\sin\beta}$$

Substituting F_s value in F_z,

$$F_z = f_s \times \frac{b_1 t_1}{\sin\beta} \times \frac{\cos(\gamma-\alpha)}{\cos(\beta+\gamma-\alpha)}$$

Since, the Merchant's model is based on the minimized rate of energy consumption which is equal to $F_z \times r$. For optimum value of β,

$$\frac{dF_z}{d\beta} = 0$$

Differentiating the above equation F_z with respect to β and equating it to zero.

$\frac{dF_z}{d\beta}$ is given by

$$f_s b_1 t_1 \cos(\gamma-\alpha) \times \frac{\cos\beta\cos(\beta+\gamma-\alpha)-\sin\beta[-\sin(\beta+\gamma-\alpha)]}{\sin^2\beta\cos^2(\beta+\gamma-\alpha)} = 0$$

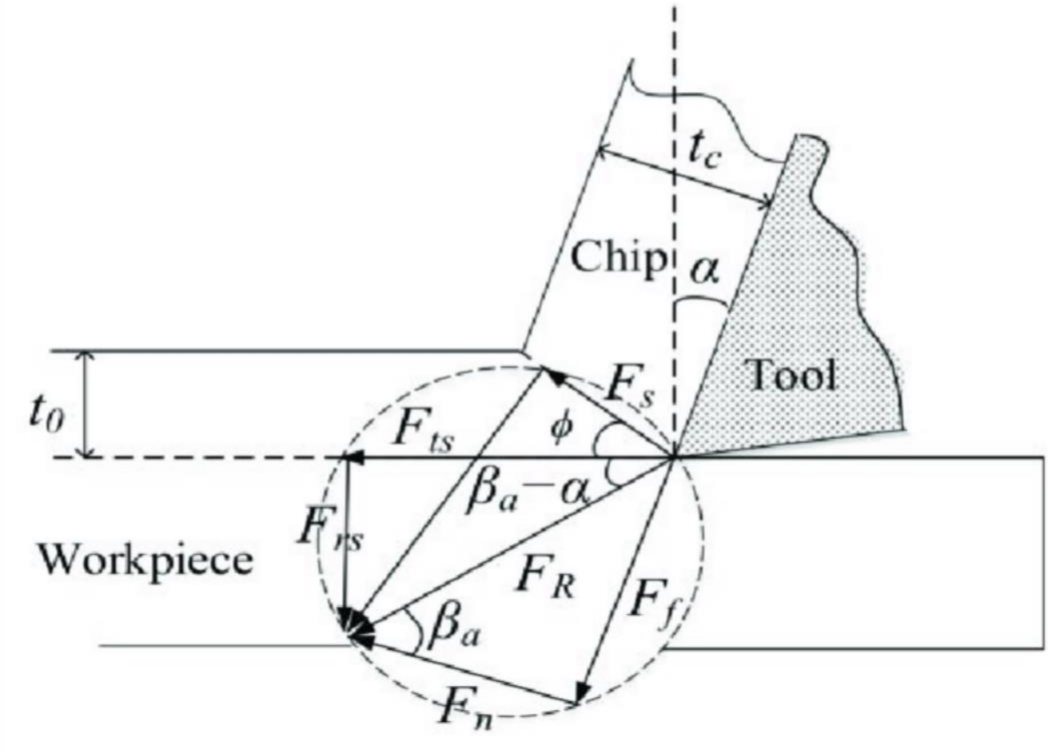
$$\therefore \quad \cos\beta\cos(\beta+\gamma-\alpha)-\sin\beta\sin(\beta+\gamma-\alpha) = 0$$

$$\cos(\beta+\beta+\gamma-\alpha) = 0$$

$$\cos(2\beta+\gamma-\alpha) = 0$$

$$2\beta+\gamma-\alpha = \frac{\pi}{2}$$

$$\beta = \frac{\pi}{4}-\frac{\gamma}{2}+\frac{\alpha}{2}$$

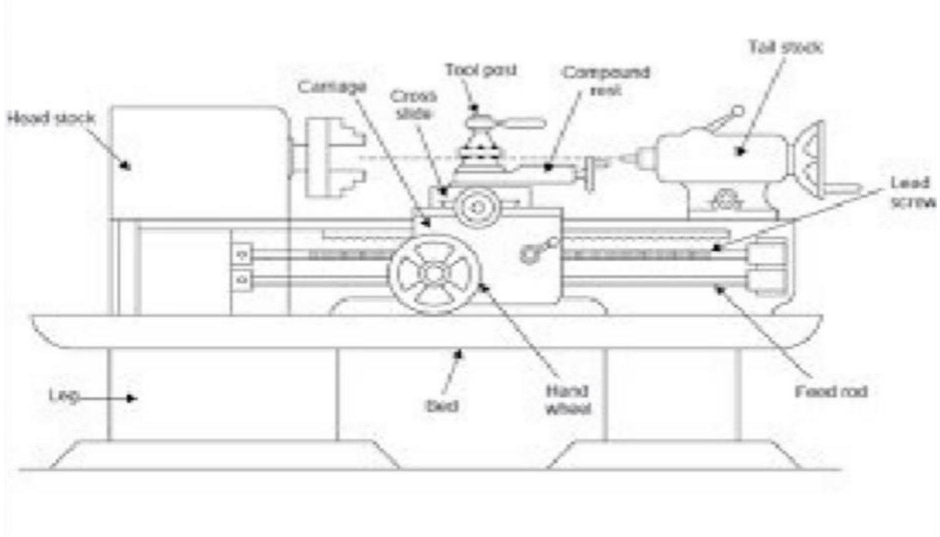


t_c
Chip
α
Tool
t_0
F_s
F_{ts}
ϕ
$\beta_a - \alpha$
F_{rs}
Workpiece
F_R
F_f
β_a
F_n

Module-II

Introduction:

Lathe removes undesired material from a rotating work piece in the form of chips with the help of a tool which in traversed across the work and can be fed deep in work. The tool material should be harder than the work piece. The work piece in held securely and rigidly on the machine. The cutting tool is rigidly held and supported in a tool post and is fed against the revolving work while the work revolves about its own axis the tool is made to move either parallel to it or at an inclination with their axis to cut the desired material. It produces cylindrical surface if it is fed at an inclination.



Specification of a Lathe:

A lathe is generally designed by

a) Swing i.e. the largest work diameter that can be swing over the lathe bed.

b) Distance between head stock centers.

Classification of a Lathe:

According to size, design, method of drive, arrangement of gears, different precision classes and purpose.

i) **Speed Lathe**: It is so named because of the very high speed of head stock spindle. It is a simplest form of lathe and consists a simple head stock, a tail stock and tool post. It has no gear box, lead screw and carriage. Tools are hand operated. Cone-pulley is the only source provided for the speed variation of the spindle. Mainly used for wood turnig, metal spinning and polishing operations.

ii) **Engine Lathe or Centre Lathe**: It is most widely used one. Its name is derived from the fact that early machine tools were driven by a separate engine or from a central engine with over head belts and shafts. The stepped cone- pulley or geared head are often used for varying the speed of lathe spindle. A tail stock is provided to facilitate holding the work between the centers and permit the use of tools like drills and taps etc. The cutting tools are controlled either by hand or by power and can be fed both in cross and longitudinal directions with ref to lathe axis with the help of a carriage feed rod and lead screw. A wide range of attachments can be fitted on it to increase its utility. These are available in sizes to handle up to 1 m dia jobs and 1 to 4 m long.

iii) **Turret Lathe**: It is a production machine used to perform a large number of operations simultaneously. Several tools are set on a revolving turret to facilitate doing large number of operations on a job in minimum time. An index able square tool post is provided on the cross slide for mounting the turning and parting off tools. The turret usually accommodates six tools for different operations like drilling counter sinking, reaming, tapping etc, which can be successively brought in to working positions by indexing the turret. Some special tool holders to perform simultaneous multi tool operations are also available. They are widely used be repetitive batch production.

iv) **Capstan Lathe**: It is similar to turret lathe and incorporate capstan slide which moves on an auxiliary slide and can be clamped in any position. It is best suited for fast production of small parts because of its light weight and short stroke of capstan slide.

v) **Tool room Lathe**: It is the modern engine lathe which is equipped with all necessary accessories for accurate tool room work. It is a geared head driven machine with considerable range in spindle speeds and feeds. It is suited for production of small tools, dies, gauges etc.

vi) **Bench Lathe**: It is a small lathe which can be mounted on the work bench for doing small precision and light jobs.

vii) **Gap bed Lathe**: In these lathes, a gap is provided on the bed near the head stock with a view to handle jobs having flanges or some other producing parts. Very often q removable portion is provided in the bed so that when not required, it can be inserted.

Taper Turning

Taper turning with a lathe involves gradually altering the diameter of a cylindrical workpiece to create a conical surface. This precision machining technique is essential in various industries, including manufacturing and engineering, where components with tapered profiles are frequently required. By skillfully manipulating the lathe's cutting tools and adjusting the workpiece's position, operators can achieve the desired taper with accuracy and control, making it a crucial process in the world of machining and metalworking. To sum up, the function of taper turning process is to create a gradually decreasing or increasing diameter along the length of a cylindrical workpiece, allowing for the formation of tapered shapes or components.

Taper Turning Methods in Lathe Machine

1. Form Tool Method

The form tool method is a straightforward approach for creating short tapers. It involves using a broad form tool with a straight cutting edge set at a half taper angle, which is then fed directly into the workpiece. This tool, known as the taper turning form tool, is specially shaped to produce a tapered workpiece. It's important to note that the length of the taper should be shorter than the tool's cutting edge to avoid excessive vibrations and the need for substantial force.

2. Tail Stock Set Over Method

The tail stock set over method is commonly employed when dealing with very slight taper angles. Here, the workpiece's rotation axis is shifted by half the taper angle to the lathe's axis. The workpiece is positioned between the live center and the dead center, with the tailstock adjusted accordingly in a crosswise direction, allowing the workpiece to tilt and achieve the desired taper.

The amount of offset is calculated in the following way,

O = (Taper × L)/2000

Where,

0 = Offset, in mm.

Taper = millimetre/meter

L = Length of the workpiece in mm

3. Compound Rest Method

The compound rest method is primarily used to create short and steep cones. It involves rotating the compound rest to the required angle and locking it in place. The workpiece is held in the chuck and rotated along the axis of the lathe machine.

Compound rest angle can be calculated by the formula,

Tan θ = D-d/2L

θ=tan−1(D−d/2L) θ=tan−1(D−d/2L)

Where,

D = Larger diameter of the taper

d = Smaller diameter of the taper

L = Length of the taper

4. Taper Turning Attachment Method

In the taper turning attachment method, a specialised attachment is used to perform taper turning. This attachment includes a guide bar, typically centered, which can swing to the necessary taper angles. The tool moves in parallel to the guide bar, and the guide bar can be rotated to achieve the desired taper angle. This method allows for versatile taper turning and can accommodate various workpiece sizes.

5. Combining Feed Method

The combining feed method is an advanced taper turning technique found in some lathe machines. It allows both longitudinal and cross feed to be engaged simultaneously, causing the tool to move in a diagonal path, creating a tapered shape. By adjusting the feed rates of longitudinal and crossfeed, the direction of the tool can be controlled. However, this method requires skilled operators due to its complexity and potential for errors.

Taper Turning Applications

- Achieving conical shapes for components.
- Creating wedges and tapered pins.
- Forming tool profiles with gradual variation in diameter.
- Crafting candle holders and lampshades.
- Machining aerospace and automotive parts.
- Designing stairs and railings with a taper.

SHAPER

WORKING PRINCIPLE:

The job is rigidly held in a vice or clamped on a machine table. The tool is held in tool post mounted on the ram of the machine. The ram reciprocates to and for and in doing so, makes the tool to cut the material in the forward stroke. No cutting of material takes place, during the return stroke of the ram. Hence it is called idle stroke. In case of draw-cut shaper, the cutting takes place in the return stroke and forward stroke is idle stroke. The job is given an indexed feed in a direction normal to the line of action of the cutting tool.

PRINCIPAL PARTS

1. Base: It is a heavy and robust cast iron body which acts as a support for all other parts of the machine, which are mounted over it.

2. Column: It is a box type cast Iron body, mounted on the base and acts as housing for the operating mechanism of the machine, and the electricals. It also acts as a support for other parts of the machine such as cross rail and ram, etc. On its top it carries a machined way, in which ram reciprocates and vertical guide ways at its front.

3. Cross-rail: It is a heavy cast Iron construction, attached to the column at its front on the vertical guide ways. It carries two mechanisms, one for elevating the table and the other for across traverse of the table.
4. Table: It is made of cast Iron and has a box type construction. It holds and supports the work during the operation and slides along the cross-rail to provide feed to the work. T-slots are provided on its top and sides for securing the work to it.

5. Ram: It is also an Iron casting, semicircular in shape and provided with a ribbed construction inside for rigidity and strength. It carries the tool head and travels in dove tail guide ways to provide a straight-line motion to the tool. It carries the mechanism for adjustment of ram position inside it.

6. Tool head: It is the device to hold the tool. It can slide up and down and can be swung to a desired angle to set the tool at a desired position for the operation.

7. Vice: It is a job holding device and is mounted on the table. It holds and supports the work during the operation. Alternatively, the job can be directly clamped to the machine table.

SIZE AND SPECIFICATIONS

The size of the shaper is determined by the maximum length of cut or stroke it can make. A standard shaper is usually capable of holding and machining a cube of the same dimensions as the length of stroke. The length of stroke is always the principal dimension, but a number of other details are also required to specify a shaper fully. Complete specifications of a 300 mm stroke shaper are as follows.

1. Length of stroke 300 mm
2. Max. Horizontal travel of table 350 mm
3. Max. Vertical travel of table 365 mm
4. Max. Distance from table to ram 12 mm
5. Max. Vertical travel of tool slide 117 mm
6. Length and width to table top 300 250 mm
7. Length and depth of table side 241 317 mm
8. Power of Motor 2/2 HP OR 1.5/1.5kw
9. No. of ram cycles per minimum 6
10. Range of ram cycle per minimum 21 to 22 mm
11. Tool box takes tool of size 16 22 mm
12. Max. Vice opening 152 mm
13. Approximate Weight 700 kg
14. Floor space 1350 790 mm

CLASSIFICATION OF SHAPERS

Shapers are classified in many ways, i.e. according to length of stroke, type of driving mechanism, direction of travel of ram, the type of work they do, the type of design of table etc. The main classification is as follows:

1. Standard Shaper:

It consists of a plain table, may or may not have the vertical supports at its front. In some machines there is a provision for the table to swivel around horizontal axis, parallel to ram. This enables machining of inclined flat surfaces. Material is cut in the forward stroke of the tool and the return stroke is idle. It is also known as plain shaper.

2. Draw-cut Shaper: it is similar to standard shaper, but is comparatively much heavier and the metal cutting operation takes place during the return stroke of the ram i.e. in moving towards the column. Its heavy construction enables heavier cuts with less vibration.

3. Horizontal Shaper: It is a very popular shaper in which the ram and tool reciprocates in horizontal plane. Normally used to machine flat surfaces.

4. Universal Shaper: It is a horizontal type shaper but its table can be swung about a horizontal axis parallel to ram ways. The top of this table can be tilted about another horizontal axis which is normal to the former axis. If a swivel vice is fitted to this table the work can be rotated about three possible axes. Machining of surfaces can be taken up in different planes and the machine is very useful for tool- room work.

5. Vertical Shaper: This shaper has its ram reciprocating in a vertical direction. The table is of circular, rotary type. The ram of vertical shaper can be adjusted 10 on either side of vertical, enabling machining of inclined surfaces also.

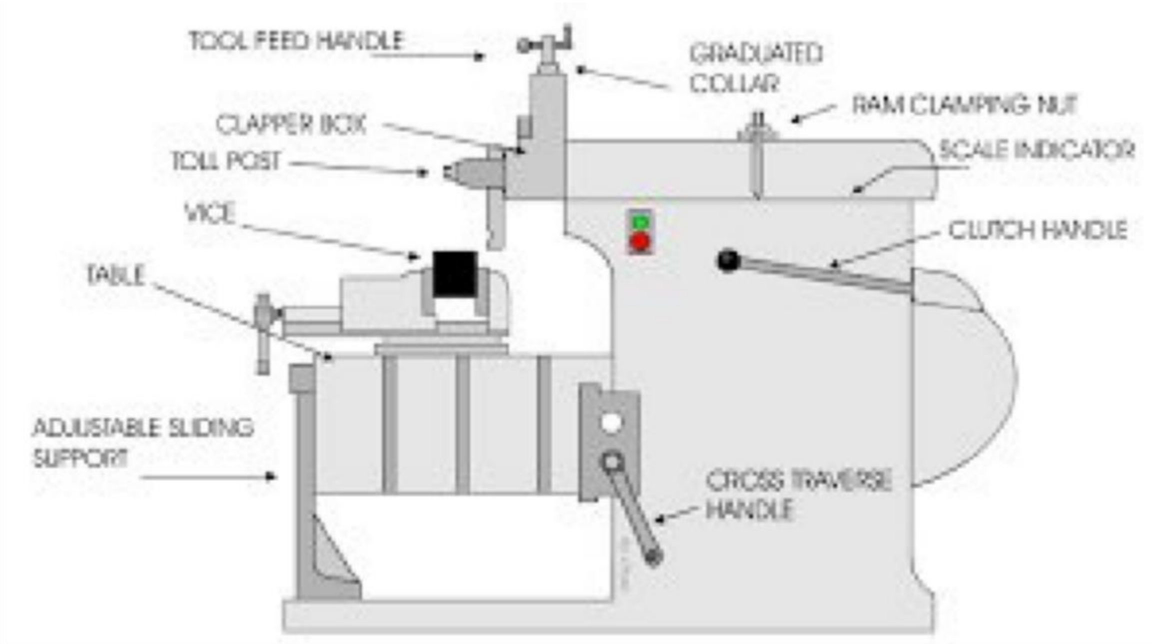
6. Geared Shaper: This classification is according to the type of driving mechanism. This type of shaper carries a rake under its arm which is driven by super gear (pinion). This has become obsolete.

7. Crank Shaper: These shapers carry a crank and slotted link mechanism for the ram movement. Large no. of shapers uses this mechanism.

8. Hydraulic Shaper: In this hydraulic pressure is used for driving the ram. It is more efficient as it enables constant speed and force from the start to the end of the cut.

9. Contour Shaper: In this a standard shaper is fitted with an additional tracer mechanism, a template and a follower is used to reproduce the contours of the template. This facilitates machining of those shapes which would have been impossible on any other type of shaper.

10. Travelling head Shaper: It is a specially designed shaper for machining heavy and large work pieces which can't be held on the table. Such jobs are loaded on the base of the shaper or on the floor and then machined. In these machines, the ram is so designed that, in addition to reciprocation for machining, it also gets a cross movement to provide necessary feed.



PLANING MACHINES

Planning is machining of large flat surfaces. These surfaces may be horizontal, vertical or inclined. The function of a planning machine is similar to that of a shaper except that the planer is basically designed to undertake machining of large and heavy jobs which are impracticable to be machined on shaper or milling machine etc. Planning machine is the most economical for machining large flat surfaces. Planning machine is differ from a shaper in that for machining, the work, loaded on the table, reciprocates past the stationery tool in a planer, where as in shaper the tool reciprocates past the stationery work.

WORKING PRINCIPLE:

It is almost a reverse case to that of a shaper. The work is rigidly held on the work table of the machine. The tool is held vertically in tool head mounted on the cross-rail. The work table, together with the job is made to reciprocate past the vertically head tool. The indexed feed, after each cut, is given to the tool during the idle stroke of the table.

PRINCIPAL PARTS:

1. Bed: It is a very large and heavy cast iron structure with cross ribs for additional strength and stiffness as it supports the whole structure of the machine over it. It is about two times longer than the table it carries over it. At its top it carries either v-ways or flat ways to support and guide the table. All the ways are straight, parallel and constantly lubricated with pressure lubrication at several points along the ways.
2. Table: it is made of Cast Iron with accurately machined top. It is a box type construction with ribs under it to make it strong to support heavy work over it. At its top, it carries longitudinal T-slots and holes to accommodate the clamping bolts and other devices to hold the work. Under the table, chip pockets are cast integral with it for collecting and removing the chips.

3. Housings or Columns: The columns are vertical members, situated on both sides in case of a double housing planer and on one side only in case of an open side planner. Inside them, they carry the different mechanisms for transmission of power to the upper parts of machine, from the main drive, viz. cross-rail elevating screws, vertical feed shaft and cross feed bar etc.

4. Cross-rail: It is a horizontal member of a heavy structure connecting the two vertical columns of the machine. It provides additional rigidity to the machine. By means of elevating screws it can be moved up and down along the ways on the columns. Clamps are provided to lock the cross-rail in any desired position along the columns. A suitable device is incorporated to ensure that the cross-rail is perfectly horizontal before clamping. The cross rail is moved up or down uniformly on both ends, both the elevating screws are rotated simultaneously by horizontal shaft, mounted on the top of the machine through bevel gears. Ways are provided at the front of the cross-rail for the two vertical tool heads. Inside the rail are provided the feed rods for vertical power feed and cross feed to the tools. The rail is made sufficiently long, to project on both sides of columns, so that, one of the two tools heads can be pushed out to one end. This will enable other tool head to travel freely crosswise from one end of the table to the other, covering entire width of the job.

5. Tool Heads: The planer tool heads, both in construction and operation resembles the shaper tool heads. Four tool heads can be fitted in a planer and any or all of them can be used at a time. Two tool heads can be fitted in vertical position on the cross-rail and the other two on the vertical columns. Each column carries one side tool head. The method of mounting is similar for all the tool heads. First the saddles are mounted on the horizontal ways of the cross-rail (for vertical tool heads) and vertical ways of the columns (for side tool heads) these saddles further carry machined ways at their front, on which tool heads are mounted. All the four tool heads work independently, simultaneously. The tools heads on the cross-rail can travel horizontally, along the rail. They can also be raised or lowered by moving cross-rail up or down. The tools can be fed down wards by rotating the down feed screw. Similarly, the side tool heads can move up and down along the vertical column ways. Their tools can be fed horizontally in to the job or at desired inclination. A swivel plate incorporated between the slide and saddle. This enables the tool head swivel through an angle of 700 on either side from its normal position. Both hand feeds and power feeds can be used, but power feeds are commonly used.

6. Controls: Various controls for starting, operating and stopping the various mechanisms, automatic cutting off speed and regulation and similar other functions are provided with in quick approach of the operator of the machine.

TYPES OF PLANERS:

A large variety of planers of different designs and sizes are available and they are broadly classified in to the following types:

1. Standard or Double housing planer
2. Open side planer
3. Planer Miller
4. Plate planer
5. Pit planer

1. STANDARD OR DOUBLE HOUSING PLANER:

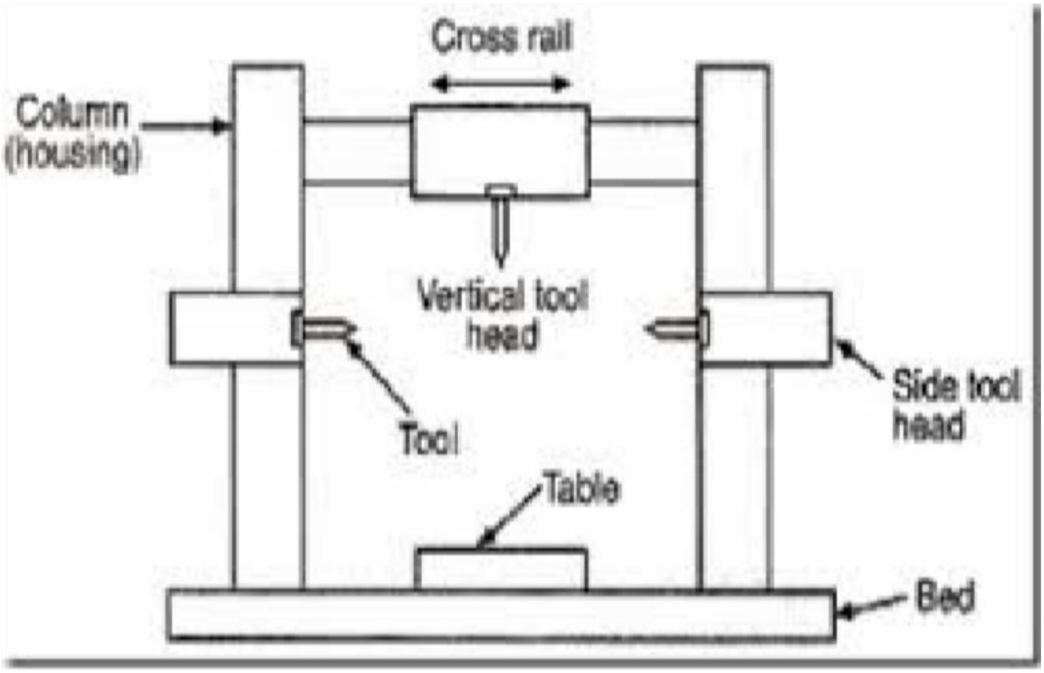
This is most commonly used type of planer. It consists of two vertical housings or columns, one on each side of bed. The housings carry vertical machined and scraped ways. The cross rail is fitted between the two housings and carries one or two vertical tool heads. The work table is mounted over the bed. Side tool heads are fitted on the vertical housings. These machines are heavy duty type and have very rigid construction. They use high cutting speeds but the size of the work is limited to width table i.e. the horizontal distance between the two columns. Extremely large and heavy casting, like machine beds, tables, plates, slides of columns, it is possible to hold a number of work pieces in a series over the bed length and machine them together. This will effect in saving machining time. Because of four tool heads a number of surfaces can be machined simultaneously. Because of high rigidity of machine, robust design of cutting tools, heavier cuts can be taken, which leads to quickes metal removal and reduced machining time and hence to economical machining**.**

2. OPEN SIDE PLANER: This type of planer consists of only one housing, situated vertically on one side of the bed and the other side is left open without any obstruction. The cross-rail is of cantilever type and is wholly supported on the single column. Only three tool heads can be used maximum. The other features are same as double housing planer. The main advantage of an open side planer is its adoptability for machining components which are much wider than could pass between the housings.

3. PLANER MILLER: It is actually a combination of the two machines, and hence the name planer miller. It resembles a double housing planer but the conventional revolving cutters.

4. PLATE PLANER: This is completely different from the conventional type both in construction and operation. The bed and the table of the plate planer are a fixed unit and the work is mounted on the table. The tool head is mounted on a movable carriage, which can travel longitudinally along the bed. The operator also stands on a flat form attached to the carriage and travels along it during machining. The work remains stationary while the tool moves to and for. The tool holder can hold one or more tools at a time and can also be tilted for machining slant surfaces. It is a single purpose machine for a special work. Ex: machining edges of boiler plates, ships plates, for pipe lines and for welding.

5. PIT PLANER: This machine is specially designed for machining long, heavy and tall work, that can’t be machined on the conventional type of planers. The job is mounted either on stationary table or on the floor inside a pit. The machine is provided with two short vertical housing which carry cross-rail. One or two tool heads are mounted on the cross rail and two side tool posts on the housings. This whole unit travels along the horizontal ways to and fro and thus the tool moves past the work for machining the surface. The horizontal and inclined surfaces of the work piece are machined on these planers.



DRILLING

Drilling is an operation to produce holes in a solid metal by means of a revolving tool called drill. The drilling is followed by reaming for dimensional accuracy and fine surface finish by means of a multi-tooth revolving tool called reamer. Boring is the operation for enlarging an existing hole previously produced through drill, cast, punched or by any other suitable operation. The operations of drilling, boring and reaming can be performed both by hand feed as well as power feed on a large number of machines such as centre lathe, drilling machine, boring machine, turning mill(vertical lathe) Capstan and Turret Lathes, Automatic Lathes etc.

DRILL SIZE AND SPECIFICATIIONS: According to the Indian standards the drills are specified by their diameters, series they belong to, the material they are made of and the IS number. These data are mainly based on the material for which the drill is to be normally used. They are made in 3 types:

1. Type-N → For normal low Carbon Steel.
2. Type-H → For hard materials.
3. Type -S → For soft and tough materials.

Example: A twist drill specified as "9.50 IS: 5101 HS" means a twist drill of 9.50mm dia. Confirming to IS: 5101 made of high-speed steel unless otherwise mentioned in the tool designation the type should be taken as 'N' and the point angle as 1180. In metric sizes the drills are normally manufactured in diameters ranging from 0.2mm to 10mm.

TYPES OF DRILLING MACHINES:

Drilling machines are manufactured in various sizes and varieties to suit the different types of work. They are broadly classified as:

1. Portable drilling Machine.
2. Sensitive or Bench drill.
3. Upright drilling Machine (Single Spindle)
4. Upright drilling Machine (Turret Type)

5. Radial drilling Machine

6. Multiple spindles drilling Machine.

7. Deep hole drilling Machine

8. Gang drilling Machine.

9. Horizontal drilling Machine

10. Automatic drilling Machine.

1. PORTABLE DRILLING MACHINE:

It is a very small, compact and self-contained unit carrying a small electric motor inside it. It is very commonly used for drilling holes in such components that can't be transported to the shop due to their size or weight. On account of the high speeds available considerable time is saved. Another advantage is that the holes can be drilled at any desired inclination. Portable drills have a capacity to drill holes up to max. of 18mm dia.

2. SENSITIVE OR BENCH DRILL:

This type of drill machine is used for very light work. Its construction is very simple and so is the operation. No gears are used in the drive. It can be swung to any desired position. Vertical movement to the spindle is given by the feed handle through a rack and pinion arrangement. The max. dia. it can drill is 20mm dia steel.

3. UPRIGHT DRILLING MACHINE (SINGLE SPINDLE):

It is used for heavier work and has a back gearing arrangement. It differs from sensitive drill in its weight, rigidity, application of power feed and wide range of spindle speeds. The drilling capacity is up to 75mm in steel. The table can swing to any position with rotary movement. It enables any part of the surface to come under the tool without disturbing work.

4. **UPRIGHT DRILLING MACHINE (TURRET TYPE):** It is a production drilling machine and is very useful when a series of different size holes are to be drilled repeatedly or number of different operations like drilling, reaming, counter boring, counter sinking, spot facing etc are to be performed in sequence repeatedly. The turret head which carries six, eight or ten different tool mounting positions is mounted on a ram. It can be easily indexed to bring the proper tool in operating position over the work and can be raised or lowered by moving the ram upwards or down wards. The required tools are mounted in sequence in the turret head so that they automatically come in operating position when the head is indexed. This type of machine eliminates tool changing time and a single machine can be used to perform no. of different operations one after the other.

5. **RADIAL DRILLING MACHINE**: This machine is very useful because of its wider range of action. Its principal use is in drilling holes on such work which is difficult to be handled frequently. In this the tool is moved to the desired position instead of moving the work for drilling.

6. **MULTIPLE SPINDLES DRILLING MACHINE:**

   These machines are mostly used in production work and are so designed that several holes of different sizes can be drilled simultaneously increasing the production with sufficient accuracy. In these two or more spindles are driven from a common driving shaft through worm and worm gears or belts. Drill heads with a capacity to drive up to 50 spindles simultaneously are available. In these heads it is possible to adjust the spindles to several different positions to enable drilling of holes at any location within the area covered by the head.

7. **DEEP HOLE DRILLING MACHINE:** Where very long holes of relatively smaller diameter are required to be drilled these machines are used, such as in rifle barrels and long spindles. These machines can be horizontal as well as vertical types, according to the requirements. These machines

are provided with head stock and a carriage. The work is mounted between these two and the carriage carries the drill. On the head stock side, the work is supported on a spindle which also rotates the same as the drill is fed slowly. In deep hole drilling operation, the work rotates at high speed, while the drill is fed in to the work at low speed and feed. Since the drill is quite long it is required to be supported, so is the case with the work piece, for which steady rests are used. Coolant is simultaneously fed to the cutting edges through the passages and it will cool the cutting edges and takes away the chips along with it. The drill is withdrawn each time it has cut through a length equal to its diameter. This helps in easy removal of the chips from the hole. Horizontal designs are used for longer jobs and vertical designs are used for relatively shorter jobs.

8. GANG DRILLING MACHINE:

It is a multiple spindle drilling machine and all the spindles are arranged in a row. These spindles are driven either separately or collectively. This machine is very useful when the nature of work is such that a number of operations like drilling, reaming, counter boring and tapping etc are to be performed in succession on it. The work moves from one spindle to the other, after each operation. The number of spindles depends upon the type of production. Four spindles are very common. One operator can perform all the operations.

9. HORIZONTAL DRILLING MACHINE:

All drilling machines, except one variety of deep hole drilling machines, are of vertical type. In these machines the spindle and the tool are in horizontal position and are mainly used for long jobs, such as columns pipes and barrels etc which are difficult to be drilled in vertical position. The horizontal drilling is also used for jobs of excessive weight and extraordinary large size jobs which can’t be handled easily. The operation of drilling performed by keeping the job stationery and moving the machine.

10. AUTOMATIC DRILLING MACHINE:

These are production machines arranged in series to perform a number of different operations in sequence at successive work stations. The work pieces, after completion of an operation at one station, are automatically transferred to the next station for another operation. The operation sequence, related cutting speeds, feeds, start and finish of the operation at each station etc are so arranged and synchronized that once the work piece is loaded at the first station, it automatically switches on to the next operation and unloaded. Several different operations like drilling. boring, tapping, milling, honing etc can be performed on a job is succession on these machines**.**

MILLING MACHINE:

Milling is a machining process of metal removal due to cutting action of a revolving cutter, when the work is fed past it. The revolving cutter is held on a spindle or arbor and the work clamped on the machine table, fed past the revolving cutter. In doing so, the teeth of the cutter remove the metal, in the form of chips, from the surface of the work to produce the desired shape.

It has a capability to perform large number of operations, which no other single machine tool can perform. It gives high production rate, with in very close limits of dimensions. that is why it has largely replaced other machine tools like shaper, planer, slotter etc. for small and medium size jobs only. It is too slow for machining very long jobs. For small and medium jobs, the milling machine gives the fastest production with a very high accuracy. It has very wide application in mass production work.

Working Principle:

The metal removing operation on a milling machine, the work is rigidly clamped on the table of the machine and the revolving multi teeth cutter mounted on a spindle or an arbor. The cutter revolves at a high speed and the work fed slowly past the cutter. The work can be fed in a vertical, longitudinal or cross direction. As the work advantages, the cutter teeth remove the metal from the work surface to produce the desired shape.

Size and Specification:

Size of the milling machine is usually denoted by the dimensions (length and breadth) of the table of the machine. Different manufactures, denote these sizes by different numbers 0,1,2,3,4,5,6 etc. each of these numbers indicates a particular standard size. Other main specifications are the Horse power of driving motor, number of spindle speeds, feeds, drive, taper of spindle nose, required floor area etc.

Types of Milling Machines:

A large variety of different types of milling machines are available, the broad classification of these machines is as follows:

1. Column and knee type milling machines.
2. Fixed bed type or manufacturing type milling machines.
3. Planer type milling machines.
4. Production milling machines.
5. Special purpose machines.

1. Column and knee type Milling Machines:

These machines are all general purpose machines and have a single spindle only. They derive their name "column and knee" type from the fact that the work table is supported on a knee like casting, which can slide in vertical direction a long a vertical column. These machines depending up on the spindle position and table movements are further classified as follows:

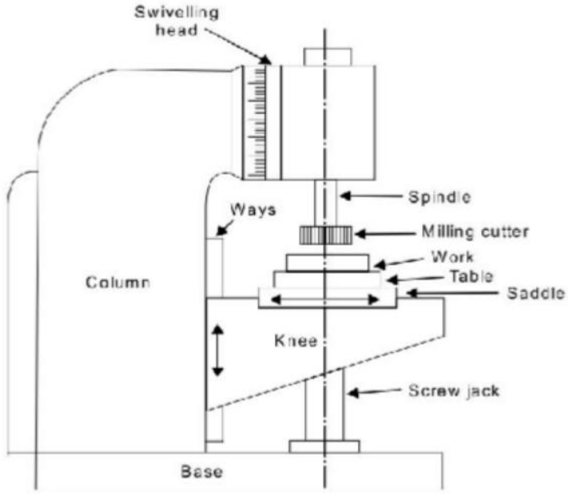
a) Hand Milling Machine.

b) Plain or Horizontal Milling Machine.

c) Vertical Milling Machine

d) Universal Milling Machine.

e) Omniverse Milling Machine.



A column and knee type milling machine

2. Fixed bed type or manufacturing type Milling Machines:

These machines, in comparison to the column and knee type, are more sturdy and rigid, heavier in weight and larger in size. They are not suitable for tool room work. Most of these machines are either automatic or semi-automatic in operation. They may carry single or multiple spindles. The common operations performed on these machines are slot cutting, grooving, gang milling and facing. They facilitate machining of many jobs together, called multi-piece milling. Their further classification is as follows:

a) Plain type (having single horizontal spindle)

b) Duplex head (having double horizontal spindles)

c) Triplex head (having two horizontal and one vertical spindle)

d) Rise and fall type (for profile milling)

3. Planer type Milling Machines: They are used for heavy work. Up to a maximum of four tool heads can be mounted over it, which can be adjusted vertically and transverse directions. It has robust and massive construction like a planer.

4. Production Milling Machines: These are also manufacturing machines, but differ from the above machines in that they do not have fixed bed. They include the following machines.

a) Rotary table or Continuous type.

b) Drum type.

c) Tracer controlled.

5. Special purpose machines:

These machines are designed to perform specific type of operation only

a) Thread Milling Machine

b) Profile Milling Machine

c) Gear Milling or Gear hobbling Machine

d) Cam Milling Machine

e) Planetary type Milling Machine

f) Double end Milling Machine

g) Skin Milling Machine

h) Spar Milling Machine.

a) Hand Milling Machine:

It is the simplest of all the milling machines and smallest in size. All the operations, except the rotation of arbor, are performed by hand. The table carrying the work over it is moved by hand to feed the work. This machine is especially useful in producing small components like hexagonal or square heads on bolts, cutting slots on screw heads, cutting key ways etc.

b) Plain or Horizontal Milling Machine:

The vertical column serves as a housing for electricals, the main drive, spindle bearing etc. The knee acts as a support for the saddle, work table and other accessories like indexing head etc. Over arm provides support for the yoke which in turn supports the free end of the arbor. The arbor carrying the cutter rotates about a horizontal axis. The table can be given straight motions in three directions, longitudinal, cross and vertical (up and down) but can't be swivelled. For giving vertical movement to the table the knee itself, together with the whole unit above it, slide up and down along the ways provided in front of the column. For giving cross movement to the table the saddle is moved towards or away from the column along with the whole unit above it. A brase is employed to provide additional support and rigidity to the arbor, when a long arbor is used. Both hand and power feeds can be used for the work.

c) Vertical Milling Machine: It derives its name from the vertical position of the spindle. This machine is available in both types, the fixed bed type as well as column and knee type. It carries a vertical column on a heavy base. The over arm in this machine is made integral with the column and carries a housing at its front. This housing called head can be fixed type or swiveling type. In fixed type, the spindle always remains vertical and can be adjusted up and down. In swiveling type, the head can be swiveled to any desired angle to machine the inclined surfaces. The knee carries an enclosed screw jack, by means of which it is moved up and down along the parallel vertical guide ways provided on the front side of the column.

The saddle is mounted on the knee and can be moved, along the horizontal guide ways provided on the knee, towards or away from the column. This enables the table to move in cross-direction. The table is mounted on guide ways, provided on the saddle, which are in a direction normal to the direction of the guide ways on the knee. By means of the lead-screw, provided under the table, the table can be moved in the longitudinal direction. Thus the work gets up and down movement by the knee, cross movement by saddle and longitudinal movement by the table. Power feeds can be used to both the saddle and the table. Mostly face milling cutters and shell-end type cutters are used on these machines.

d) Universal Milling Machine: It is the most versatile of all the milling machines and after lathe it is the most useful machine tool as it is capable of performing most of the machining operations. With its application the use of a large number of other machine tools can be avoided. It differs from the plain milling machine only in that, the tool can be given one more additional movement. Its table can be swilled on the saddle in a horizontal plane. For this circular guide ways are provided on the saddle along which it can be swilled. A graduated circular base is incorporated under the table, with a datum-mark on the saddle, to read directly the angle through which the table has been swiveled. This special feature enables the work to be set at an angle with the cutter for milling helical and spiral flutes and grooves. It's over arm can be pushed back or moved and a vertical milling head can be fitted in place of the arbor to use it as a vertical milling machine.

e) Omniversal Milling Machine:

This is a modified form of plain milling machine and is provided with two spindles, of which one is horizontal, as in plain milling and the other is carried by a universal swiveling head and can be fixed in vertical position or can be set any desired angle up to 900 on both sides of vertical i.e. in a plane parallel to the front face of the column, and up to 450 in a plane perpendicular to the former direction i.e. towards or away from the column. Another special feature of this machine is that it carries, in addition to all the possible adjustments provided in a universal milling machine, two more adjustments. These adjustments are of the knee which can be swiveled about a horizontal axis to tilt the table and can be moved horizontally also. These special features make it a very useful machine tool for tool room work as it facilitates various operations to be carried out in different planes and at different angles in a single setting of the work.

PRINCIPAL PARTS OF COLUMN AND KNEE TYPE MILLING MACHINES Main parts of all the column and knee type milling machines are similar, the movements of the moving parts differ in then. All these machines essentially consist the following main parts:

1. BASE: It is heavy casting provided at the bottom of the machine. It is accurately machined on both the top and bottom surfaces. It actually acts as a load bearing member for all other parts of the machine. Column of the machine is secured to it carries the screw jack, which supports and moves the knee. It also serves as a reservoir for the coolant.

2. COLUMN: It a very prominent part of a milling machine and is produced with enough care. Various parts and controls are fitted to this. On the front face of the column are made the vertical parallel ways in which the knee slides up and down. At its rear side, it carries the enclosed motor

drive. A cover is provided on this side, which can be opened to enable accessibility to the drive. Top of the column carries dove-tail horizontal ways for the over arm.

3. KNEE: It is a rigid casting, which is capable of sliding up and down along the vertical ways on the front face of the column. This enables the adjustment of the table height. The adjustment is provided by operating the elevating jack provided below the knee, by means of a hand wheel or application of power feed. Machined horizontal ways are provided on the top surface of the knee for the cross traverse of the saddle and hence the table. For efficient operation of the machine, rigidity of the knee and accuracy of its ways play an important role. On the front face of the knee two bolts are usually provided for securing the braces to it to ensure greater rigidity under heavy loads.

4. SADDLE: it is the intermediate part between the knee and the table and acts as a support for the table. It can be adjusted cross wise, along the ways provided on the top of the knee, to provide cross feed to the table. At its top, it carries horizontal ways along which table moves during longitudinal traverse.

5. TABLE: It acts as a support for the work. The work is mounted on it either directly or held in the dividing head. It is made of Cast Iron, with its top surface accurately machined and carries longitudinal T-slots to accommodate the clamping bolts for fixing the work. Longitudinal feed is provided to it by means of a hand wheel fitted on one side of the feed screw. Cross feed is provided by moving the saddle and vertical feed by raising or lowering the knee. Both hand feed and power feed can be employed the adjustable stops should be used to trip out the same at the correct movement. Modern milling machines provide rapid traverse in all the three directions to effect saving in time. In universal milling machines, the table can be swiveled in horizontal plane and the graduations on circular base help in adjusting required swivel.

6. OVER ARM: It is the heavy support provided on the top of both plain and universal milling machines it can slide horizontally, along the ways provided on the top of the column, and adjusted to a desired position in order to provide support to the projecting arbor, by accommodating its free end in yoke. If further support is needed, to have additional rigidity, braces can be employed to connect these when many cutters are used simultaneously.

INDEXING METHODS

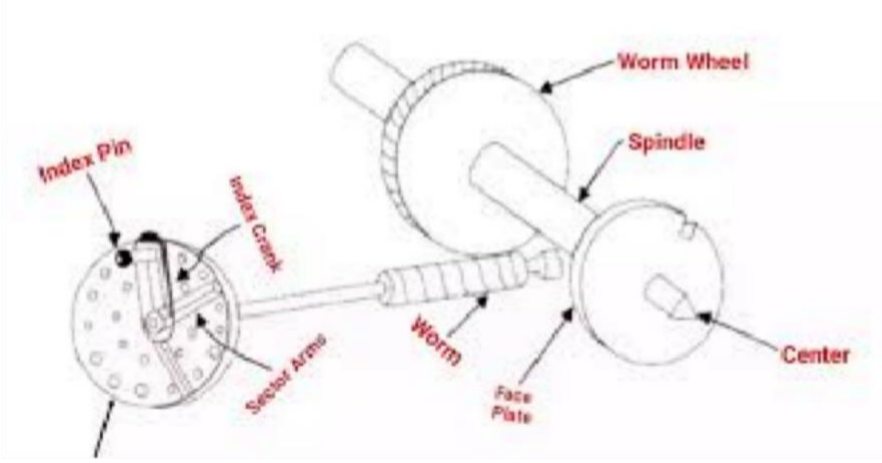
Indexing is dividing the job periphery in to a desired number of equal divisions. It is accomplished by a controlled movement of the crank such that the job rotates through a definite angle after each cut is over. The following methods of indexing are commonly used.

1. Direct Indexing
2. Plain or Simple Indexing
3. Compound Indexing
4. Differential Indexing

Direct Indexing: It is the simplest case of indexing in which a plain dividing head is used. The index plate is directly mounted on the spindle and rotated by hand. It can be used only when the number of divisions to be obtained is such that the number of slots on the periphery of the index plate is a multiple of the number of divisions.

2. Plain or Simple Indexing: This method of indexing is used when the direct method of indexing cannot be used for obtaining the required number of divisions on the work. For example: if the work required to be divided in to 22 equal divisions the direct indexing cannot be used, because 22 is not divisible in to any of the hole circles on the direct indexing plate. For such cases, simple indexing can easily be used.

For this, either a plain indexing head or a universal dividing head can be used. This method of indexing involves the use of the crank, worm, worm wheel and index plate. As already described, the worm wheel carries 40 teeth and the worm is single start. The worm wheel indirectly mounted on the spindle.



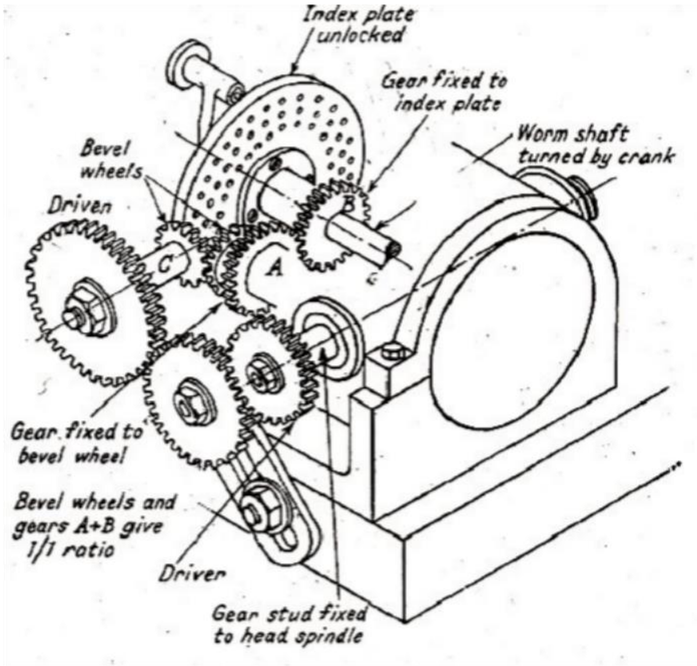
(Index Head)

4. **Compound Indexing**:

   This method of indexing is used when the number of divisions required is outside the range that can be obtained by simple indexing. It involves the use of two separate simple indexing movements and is performed in two stages; 1. By turning the crank a definite amount in one direction in the same way as in simple indexing. 2. By turning the index plate and the crank both either in the same or reverse direction, thus adding further movement or subtracting from that obtained in the first stage.

4 Differential indexing:

In principle it is not much different from compound indexing. It is also carried out in two stages. First the crank is moved in a certain direction. In the second operation that follows either some movement is added to the above crank movement or subtracted from the same. However, the said loss or gain in the movement is obtained by moving the plate by means of a train of gears, connecting the dividing head spindle to the worm spindle. The said motion is gained by rotating the index plate in the same direction as crank and it is lost by rotating the plate in the opposite direction to that of the crank. During differential indexing the index plate locking pin should be taken out to make the plate free to rotate. The dividing heads are supplied with standard set of change gears. Change gears supplied with Brown &Sharp dividing heads are the following: 24 (2 No s) 28, 32, 40, 44, 48, 56, 64, 72, 86, 100 In addition to this, some dividing heads are provided with following set of gears 46, 47, 52, 58, 68, 76, 84 German made universal dividing heads are provided with following set of gears 24 (2 No s) 28, 32, 40, 44, 48(2), 56, 64, 72, 86, 96, 100. Both simple and compound gear train is used in differential indexing. In these gear trains, the first driver is always mounted on the main spindle of the dividing head, i.e. the same spindle on which is mounted the worm wheel inside and the job at the other end. The last driven is mounted on the worm spindle, which drives the index plate. The simple train consists of only one driver and one driven, connected together through one or two idle gears. The compound train consists of two drivers and two driven wheels. The first driven and 2nd driver gears are mounted on a stud, incorporated between the dividing head spindle and the worm spindle. Idle gear may or may not be used. If it is used, it should be incorporated between the 2nd driver and 2nd driven. The motion in indexing is so transferred that, when the crank is rotated the worm wheel, and hence the spindle, is rotated in the usual way. This, in turn rotates, the first driver. The motion is transferred to the last driven gear. This through the worm spindle is ultimately transferred to the index plate. the direction of rotation of index plate depends upon the type of gear train employed and the number of idle gears used there in. the index plate is required to be rotated in the same direction as the crank if motion is to be gained and in reverse direction if the same is to be lost.



(Differential indexing)

BROACHING MACHINES:

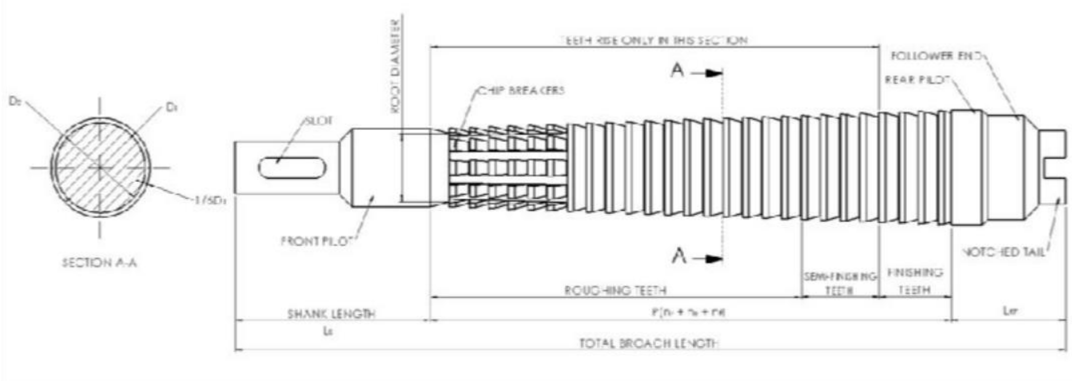
Types of Broaches:

There is large variety of broaches and they are classified.

1. According to the method of operation: Push, Pull or Stationary.
2. According to the kind of operations they perform: Internal and external.
3. According to their construction: Solid, built up, rotor cut, inserted tooth, over lapping tooth, progressive etc.
4. According their use: Single purpose or Combination.
5. According to the functions: Key way, spline, burnishing, roughing, sizing, serration, rifling, surface, spiral etc.

Push broaches are shorter in length than the pull broaches, of the same cross-section in order to ensure adequate stiffness to resist bending. Push broacher is used where a shorter length is to be broached and less material is to be removed. Where a considerable amount of metal is to be removed and a longer surface is to be broached a pull type broach, which carries more number of teeth and is longer, and hence removes more material is preferred. Internal broaches are generally made of solid construction, but where chances of wear are MACHINE TOOLS III B.

Tech I Sem (Mech)-R17 Dept. Of Mechanical Engineering MRCET 87 more and high accuracy is desired a shell type construction is always preferred, which consists of several replaceable shells mounted on a bar. They are known as built-up broaches. External or surface broaches are generally of built-up type having replaceable sections or teeth. The broaches used to produce single surface such as a round hole, are known as single purpose. Against this, many broaches, called combination broaches are designed to take two types of cuts simultaneously and produce two different surfaces or perform two different operations such as sizing and burnishing a hole or sizing a hole and cutting splines in it. Both the operations are done in a single pass of the tool. A burnishing broach is used for producing a highly finished and glazed surface. It is the tool (broach) which moves, while the work is stationary, but in certain cases the broach remains stationary, where as work pieces are moved past it as in continuous broaching machine. A broach made in single piece is known as solid broach.



Tool materials and Heat treatment:

For light work broaches made of high carbon steel are used. High speed steel is the most commonly used material for the manufacture of broaches and they give satisfactory performance in mass-production, and heavy-duty work. They give fine surface finish and have long life. Broaches having their teeth tipped with sintered carbides used for hard materials and abrasive materials. Their use is mostly confined to mass production work in surface broaching. Proper heat treatment and subsequent grinding are two very important aspects in manufacturing a broach. Long broaches are heated in vertical type of electric furnace, so that there is a uniform distribution of heat throughout the entire length of the tool and the distortion is minimum. This is followed by cooling in air under pressure. The broach is hung vertically during air cooling also in order to avoid war page. Short broaches are heat treated in horizontal furnaces. Specially designed grinders are used to grind and finish the teeth of the broach.

Broach Construction:

The front pilot enters the hole to keep proper alignment. The cutting teeth follows the front pilot, gradually increase in size. The first set of cutting teeth, called roughing teeth, does most of the cutting. They are fallowed by semi-finished teeth, which remove comparatively less stock. The variation in their sizes will be smaller than the roughing teeth. They bring the size of the hole to the required size. The finishing teeth which follow after semi finish teeth do not practically remove any stock but they smooth finish the hole. When the first finishing teeth are worn out, those behind them start doing the sizing operation. The rear pilot supports the broach and keeps it aligned after the cut is over.

PRINCIPLE OF BROACHING:

The operation of broaching involves the use of a multi tooth cutter, called broach. The teeth of the broach are so designed that the height of the cutting edge of the following cutting tooth is slightly more, equal to the feed per tooth, than that of the preceding tooth. Thus when the broach is fed in a straight line, either, over an external surface or through an internal surface, the metal is cut in several successive layers by successive teeth of the broach. The thickness of each layer is same and is known as feed per tooth. The sum of thickness of all the layers taken together is called the depth of cut. During the operation either the broaching fed past the stationary work piece or the work piece past a stationary broach, the former practice being more common. The surface produced carries an inverse profile to that of the broach teeth. A specific point regarding broaching is that out of all the basic machining processes, it is the only process in which the feed is in built in the tool (broach). This feed is equal to the chip the thickness. A push type broach is fed past the stationary work on a horizontal broaching machine, to machine an external surface on the work piece. A pull type broach is fed in to the hallow work piece on a vertical pull-down type machine, to machine an internal surface of the work piece. In this case also, the work piece will remain stationary. Both the operations are performed in a single linear stroke of the broach. After end of the stroke in both the above operations, the broach is retraced to the original starting position, the finished part is replaced by a new work piece and the operation repeated as usual**.**

GRINDING MACHINE:

Grinding is a process of removing material by the abrasive action of a revolving wheel on the surface of a work piece, in order to bring it to the required shape and size. Grinding is similar to other machining operations since the material is removed in the form of very small chips, similar to those obtained in other machining operations. The wheel used for performing the grinding operation is known as “Grinding Wheel”. It consists of sharp crystals, called abrasives, held together by a binding material or bond. It may be a single piece type or several segments joined together. In most of the cases, it is a finishing operation and a very small amount of material is removed from the surface during the operation.

ABRASIVES:

It is the material of the grinding wheel, which does cutting action. These are extremely hard materials, consisting of very small particles, called grains, which carry a number of sharp cutting edges and corners. They are two types.

1). Natural

2). Artificial

Natural Abrasives: They are obtained directly from mines. The common natural abrasives are sand stone, emery, corundum, Quartz and diamond

All the natural abrasives, except diamond are now obsolete. Sand stone is used only for sharpening wood working tools. All other natural abrasives are almost replaced by artificial abrasives. Diamond, still retains its place even in modern grinding processes. It is largely used for dressing grinding wheels and for grinding hard materials.

Artificial Abrasives:

They are manufactured under controlled conditions in closed electric furnaces to avoid impurities and to achieve necessary temperature for the chemical reaction to take place. The main artificial abrasives are:

1. Silicon Carbide (Sic):

It is made from Silicon dioxide, coke, sawdust and salt. These constituents are mixed together and piled up around carbon electrical conductor of a resistance type electric furnace. A heavy current is switched on and temperature of about 26000C generated. The mass, under the action of intense heat, fuses. The outer shell is removed and the Silicon Carbide Crystals are broken in to grains.

2. Aluminum Oxide: This abrasive is very hard and tough grains having sharp cutting edges. It is obtained by fusing impure Aluminum Oxide (Bauxite) in an electric arc furnace. Dry bauxite is mixed with ground coke and Iron chips. This mixture is heated in the furnace with a heavy current. It is then crushed and the powdered grains are formed are screened through standard meshes. These grains are not as hard as Silicon Carbide but less brittle preferred for grinding metals of high tensile strength like hardened tool steel components.

3. Artificial Diamonds: The diamonds produced through artificial means are quite comparable to the natural diamonds in their grinding characteristics and give normally better results than the natural diamonds.

Advantages and uses of artificial abrasives

The manufactured or artificial abrasives superseded the natural abrasives for the following reasons:

1. The controlled conditions in the electric furnace enable uniformity in the product.
2. The quantity of production and supply can easily be varied according to the demands.
3. They have largely abolished the dependence on natural means to meet the growing demand in the modern manufacturing processes. The selection of a particular abrasive is governed by many factors, like hardness, toughness and other properties of work material.

BOND MATERIALS:

In order to give an effective and continuous cutting action, it is necessary that the grains of abrasive material should be held firmly together to form a series of cutting edges. The material used for holding them is known as bond. The principal bonds are:

1. Vitrified
2. Silicate
3. Oxychloride
4. Resinoid
5. Shellac
6. Rubber

1. Vitrified bond:

It is a clay bond, reddish brown color. The base material is “Felspar” which is fusible clay. Proper proportions of Felspar, refractories and flux mixed thoroughly with abrasive grains to form a paste. The paste is placed is moulds to get the shape of a wheel and air dried. The wheels become enough hard are fed in to kiln at 12600C and allowed to remain there for few days. This process is known as fusing and it provides uniform distribution of bond through and the wheel. After this, the wheels are trimmed to the required size. For obtaining very hard and close grained wheels, the paste after being place in the moulds, is pressed under hydraulic pressure.

Advantages:

1. It is made porous and enables quicker metal removes.
2. It is not affected by water, oil, acids, temperature or climatic conditions.
3. The bond itself is very hard and acts as an abrasive.
4. On account of excessive heat in the kiln the impurities are burnt and only bond and abrasive left.

Disadvantages:

1. The process of manufacture is very slow.

2. Cracks may develop in large size wheels during fusing.

3. Wheels over 750mm dia can't be easily produced.

4. Proper control during fusing becomes difficult.

2. Silicate bond:

It s base material is Silicate of soda. The process of mixing, moulding, packing or ramming, drying etc are done in the same way as vitrified bond, but the oven carries a temperature of about 2600C only. The application of lower temperature results in high tensile strength. As usual, the paste mixture after moulding is subjected to hydraulic pressure if hard and close grained wheels are needed. They are light grey in color. These wheels are used where a cool cutting action with less wear is needed as in grinding the edges of the heat treated steel cutting tools. The cool cutting action is due to the bond releases the abrasive grains more quickly than vitrified bond.

Advantages:

1. It is more rapid process than vitrified bond.
2. Because of the moderate temperature in kiln, there is no tendency to weaken the grains.
3. Fusing is better controlled, results in more reliable bond.
4. When wet grinding is performed, the soda acts as a lubricant.
5. Large wheels up to 1500mm dia can be easily produced.
6. The cutting action of the wheel is smoother and cooler.
7. Because of low fusing temperature the wheel can be moulded on Iron backs, which is not possible in case of vitrified bond.

Disadvantages:

1. Extra hard wheels cannot be produced with this bond.
2. Harder grades of this bond do not provide a free cutting action

Oxychloride bond:

It is a mixture of Oxide and Chloride of Magnesium and setting takes place in cold state. The process of wheel manufacture is similar to the above two, but no heating and subsequent cooling is required on account of the cold setting property. Ageing is necessary so that the bonded wheel gets adequate hardness. This bond provided a cool cutting action, but grinding is usually done dry as it is very susceptible to the action of conventional coolants and therefore, the full use of the cutting capability of the wheel cannot be taken.

5. Resinoid bond:

It is a synthetic organic compound, which is enough strong and flexible. It provides a sharp cutting action and enables a high rate of stock removal at high speeds. Mainly used for cutting bar stocks, fine grinding of cams, precision grinding of rolls etc. These wheels are manufactured from a mixture of abrasive grains, synthetic resins and some compounds. This mixture is filled in moulds and then fed in to the furnace for heating. A constant temperature of about 2000 c is maintained in the furnace. Due to heat, the resin sets and binds the abrasive grains together. The shape and size of the bonded wheels will depend upon the shape and size of the mould.

SELECTION OF GRINDING WHEELS

Selection of proper grinding wheel is a vital necessity to obtain the best results in grinding work. A wheel may be required to perform various different functions like quick removal of stock material, give a high grade surface finish, maintain close dimensional tolerances and a single wheel will fail to meet all the requirements. It is necessary therefore, that proper grain size, bond, grade, strength, shape and size of the wheel should be selected to meet the specific requirements of a job. The factors up on which the above selection will depend are as follows:

1. Properties of the material to be machined i.e. its hardness, toughness, strength etc.

2. Quality of surface finish required.

3. Grinding allowance provided on the work piece i.e. the amount of the stock material to be removed.

4. Dimensional accuracy required.

5. Method of grinding i.e. wet or dry.

6. Rigidity, size and type of machine.

TYPES OF GRINDING MACHINES

Different types of grinding machines have been designed and are being used. Some of these are for roughing work, some for-precision work and some for special purpose i.e. to perform a specific type of operation only. There are many varieties of grinding machines; the most commonly used types can be classified as:

1. Roughing or non-precision grinders.

2. Precision grinders

1. Roughing or non-Precision grinders:

The main purpose of these grinders is to remove more stock than can be removed by other types of grinders. The quality of surface finish is of secondary importance are as follows:

1. Bench, pedestal or floor grinders.

2. Swing frame grinders.

3. Portable and flexible shaft grinders.

4. Belt grinders.

1. Bench, pedestal or floor grinders:

These grinders are commonly used for grinding various materials and cutting tools in tool rooms, foundries and general repair shops etc. They carry horizontal spindle, having grinding wheels mounted on both ends. It can be suitably bolted on a bench. The floor stand or pedestal grinder is bench grinder of above type mounted on a steel stand or pedestal of suitable height. The horizontal spindle carrying the grinding wheels is normally an extension on both sides of the armature shaft of the motor.

2. Swing frame grinders:

It consists of a 2 to 4 meters long horizontal frame, freely suspended at its centre. The frame carries a grinding wheel at its one end and motor at the other. The motor drives the grinding wheel by means of a belt. In operation, the motor is started to revolve the wheel and the frame swung by the operator about its point of suspension (centre point) to cover up the desired grinding area.

3. Portable and flexible shaft grinders:

These grinders resemble very much with the portable electric drills, both in construction, as well as operation, with only difference that the spindle carrying the drill chuck is replaced by a spindle on which a small grinding wheel is mounted. A safety guard is also provided over the wheel. These grinders are vastly used in finishing casting, forgings, welded joints in structural work, removing burrs and sharp edges. Flexible shaft grinders consist of a flexible shaft driven by an electric motor. The shaft carries a chuck or collet at its end to receive small grinding tools, mounted wheels and points and small grinding discs. The electric motor is mounted on a fixed stand.

Module-III

INTRODUCTION

Unconventional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes. Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Nontraditional machining processes, also called advanced manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons as outlined below. Very hard fragile materials difficult to clamp for traditional machining When the work piece is too flexible or slender When the shape of the part is too complex.

Manufacturing processes can be broadly divided into two groups

a) Primary manufacturing processes: Provide basic shape and size

b) Secondary manufacturing processes: Provide final shape and size with tighter control on dimension, surface characteristics Material Removal Processes Once Again Can Be Divided Into Two Groups.

1. Conventional Machining Processes
2. Non-Traditional Manufacturing Processes or Unconventional Machining processes
3. Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge-shaped cutting tool that is harder than the work material under machining condition.
4. **CHARACTERISTICS OF CONVENTIONAL MACHINING ARE:**

- Generally macroscopic chip formation by shear deformation
- Material removal takes place due to application of cutting forces – energy domain can be Classified as mechanical
- Cutting tool is harder than work piece at room temperature as well as under machining Conditions.

Non-conventional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes. Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.

NEED FOR UNCONVENTIONAL MACHINING PROCESSES

- Extremely hard and brittle materials or Difficult to machine material are difficult to Machine by traditional machining processes.
- When the work piece is too flexible or slender to support the cutting orgrinding Forces Extremely hard and brittle materials or Difficult to machine material are difficult to Machine by traditional machining processes. • When the work piece is too flexible or slender to support the cutting or grinding Forces when the shape of the part is too complex. when the shape of the part is too complex.

CLASSIFICATION OF UCM PROCESSES:

1. Mechanical Processes

Abrasive Jet Machining (AJM)

Abrasive Water Jet Machining (AWJM)

Water Jet Machining (WJM)

Ultrasonic Machining (USM)

2. Electrochemical Processes

Electrochemical Machining (ECM)

Electro Chemical Grinding (ECG)

Electro Jet Drilling (EJD)

3. Electro-Thermal Processes

Electro-discharge machining (EDM)

Laser Jet Machining (LJM)

Electron Beam Machining (EBM)

4. Chemical Processes

5. Chemical Milling (CHM)

Photochemical Milling (PCM)

BRIEF OVERVIEW

1. **ULTRA SONIC MACHINING**

   USM is a mechanical material removal process in which the material is removed by repetitive impact of abrasive particles carried in liquid medium on to the work surface, by a shaped tool, vibrating at ultrasonic frequency.

2. **ABRASIVE JET MACHINING**

   It is the material removal process where the material is removed or machined by the impact erosion of the high velocity stream of air or gas and abrasive mixture, which is focused on to the work piece.

3. **. LASER BEAM MACHINING**

   Laser-beam machining is a thermal material-removal process that utilizes a high- Energy, Coherent light beam to melt and vaporize particles on the surface of metallic and nonMetallic work pieces. Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes.

4. **ELECTRON EAM MACHINING**

   It is the thermo-electrical material removal process on which the material is removed by the high velocity electron beam emitted from the tungsten filament made to impinge on the work surface, where kinetic energy of the beam is transferred to the work piece material, producing intense heat, which makes the material to melt or vaporize it locally.

5. **ELECTRO CHEMICAL MACHINING**

   It is the controlled removal of metals by the anodic dissolution in an electrolytic medium, where the work piece (anode) and the tool (cathode) are connected to the electrolytic circuit, which is kept, immersed in the electrolytic medium.

6. **ELECTO CHEMICAL GRINDING**

   ECG is the material removal process in which the material is removed by the combination of Electro- Chemical decomposition as in ECM process and abrasive due to grinding.

7. **PLASMA ARC MACHINING**

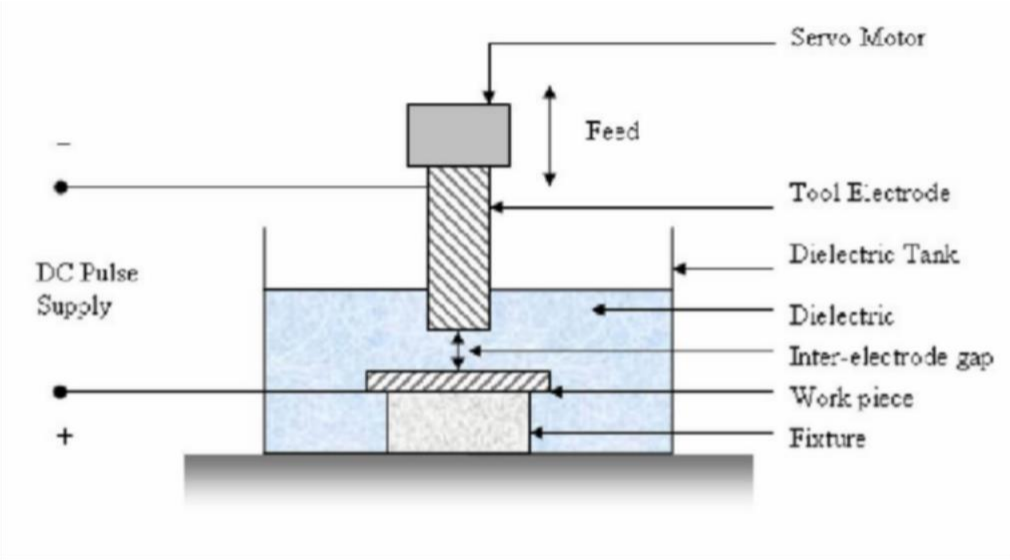
   Plasma is defined as the gas, which has been heated to a sufficiently high temperature to Become ionized.

8. **WATER JET MACHINING**

   Water jet cutting can reduce the costs and speed up the processes by eliminating or reducing expensive secondary machining process. Since no heat is applied on the materials, cut edges are clean with minimal burr. Problems such as cracked edge defects, crystallization, hardening, reduced weldability and machinability are reduced in this process.

   1. **EDM (ELECTRO DISCHARGE MACHINING PROCESS)**

      Electrical discharge machining (EDM) is one of the most widely used non-traditional machining processes. The main attraction of EDM over traditional machining processes such as metal cutting using different tools and grinding is that this technique utilizes thermoelectric process to erode undesired materials from the work piece by a series of discrete electrical sparks between the work piece and the electrode. A picture of EDM machine in operation The traditional machining processes rely on harder tool or abrasive material to remove the softer material whereas non-traditional machining processes such as EDM uses electrical spark or thermal energy to erode unwanted material in order to create desired shape. So, the hardness of the material is no longer a dominating factor for EDM process. A schematic of an EDM process is shown in Figure where the tool and the work piece are Immersed in a dielectric fluid.



Electro discharge machining (EDM)

EDM removes material by discharging an electrical current, normally stored in a capacitor bank, across a small gap between the tool (cathode) and the work piece (anode) typically in order

Application of EDM

The EDM process has the ability to machine hard, difficult-to-machine materials. Parts with complex, precise and irregular shapes for forging, press tools, extrusion dies, difficult internal shapes for aerospace and medical applications can be made by EDM process. Some of the shapes made by EDM process are shown in Figure**.**

Figure: Difficult internal parts made by EDM process

Working principle of EDM

Electrical Discharge Machining (EDM) works on the principle of controlled electrical discharges (sparks) to remove material from a conductive workpiece. The process involves a tool electrode and a workpiece, both submerged in a dielectric fluid (such as deionized water or oil). A pulsed DC voltage is applied, creating an electric field across a small gap between the tool and the workpiece. When the voltage exceeds the dielectric breakdown strength, a spark discharge occurs, generating intense heat (8,000–12,000°C) that melts and vaporizes a small portion of the workpiece. The dielectric fluid cools the surface and flushes away the debris, ensuring a clean machining environment. This process repeats thousands of times per second, gradually shaping the workpiece into the desired form. EDM is widely used for machining hard metals, complex shapes, and delicate components where conventional machining is difficult, such as in aerospace, tool and die making, and medical applications.

Advantages of EDM

• By this process, materials of any hardness can be machined;

• No burrs are left in machined surface;

• One of the main advantages of this process is that thin and fragile/brittle components can be machined without distortion;

• Complex internal shapes can be machined

Limitations of EDM

• This process can only be employed in electrically conductive materials;

• Material removal rate is low and the process overall is slow compared to conventional machining processes;

• Unwanted erosion and over cutting of material can occur;

• Rough surface finish when at high rates of material removal.

Dielectric fluids:

Dielectric fluids used in EDM process are hydrocarbon oils, kerosene and deionised water. The functions of the dielectric fluid are to:

• Act as an insulator between the tool and the workpiece.

• Act as coolant.

• Act as a flushing medium for the removal of the chips. The electrodes for EDM process usually are made of graphite, brass, copper and copper tungsten alloys.

Design considerations for EDM process are as follows:

Deep slots and narrow openings should be avoided.

• The surface smoothness value should not be specified too fine.

• Rough cut should be done by other machining process. Only finishing operation should be done in this process as MRR for this process is low.

WIRE CUT ELECTRICAL DISCHARGE MACHINING (WCEDM)

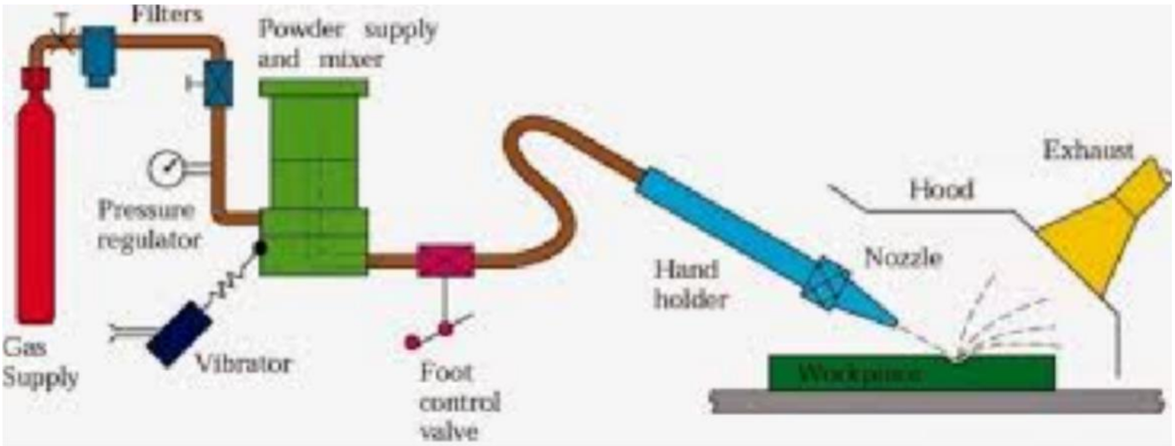
EDM, primarily, exists commercially in the form of die-sinking machines and wire- process, a slowly moving wire travels along a prescribed path and removes material from the workpiece. Wire EDM uses electro-thermal mechanisms to cut electrically conductive materials. The material is removed by a series of discrete discharges between the wire electrode and the workpiece in the presence of dielectric fluid, which creates a path for each discharge as the fluid becomes ionized in the gap. The area where discharge takes place is heated to extremely high temperature, so that the surface is melted and removed. The removed particles are flushed away by the flowing dielectric fluids. The wire EDM process can cut intricate components for the electric and aerospace industries. This non-traditional machining process is widely used to pattern tool steel for die manufacturing cutting machines (Wire EDM). The concept of wire EDM is shown in Figure. In this

Figure: Wire erosion of an extrusion die

The wires for wire EDM is made of brass, copper, tungsten, molybdenum. Zinc or brass coated wires are also used extensively in this process. The wire used in this process should posse's high tensile strength and good electrical conductivity. Wire EDM can also employ to cut cylindrical objects with high precision. This process is usually used in conjunction with CNC and will only work when a part is to be cut completely through. The melting temperature of the parts to be machined is an important parameter for this process rather than strength or hardness. The surface quality and MRR of the machined surface by wire EDM will depend on different machining parameters such as applied peak current, and wire materials.

ABRASIVE JET MACHINING (AJM)

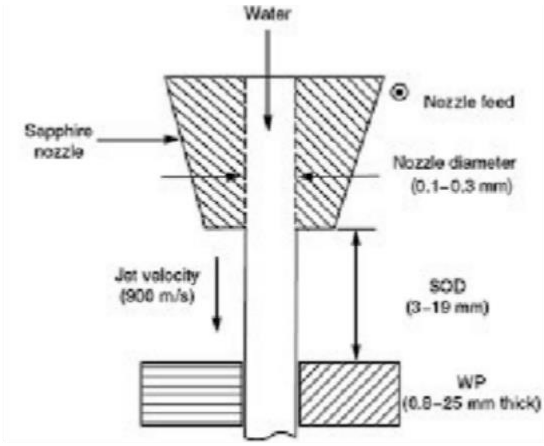
In Abrasive Jet Machining (AJM), abrasive particles are made to impinge on the work material at a high velocity. The high velocity abrasive particles remove the material by micro- cutting action as well as brittle fracture of the work material. In AJM, generally, the abrasive particles of around 50 μm grit size would impinge on the work material at velocity of 200 m/s from a nozzle of I.D. of 0.5 mm with a standoff distance of around 2 mm. The kinetic energy of the abrasive particles would be sufficient to provide material removal due to brittle fracture of the work piece or even micro cutting by the abrasives.



Abrasive Jet Machining

WATER JET MACHINING (WJM)

Water jet cutting can reduce the costs and speed up the processes by eliminating or reducing expensive secondary machining process. Since no heat is applied on the materials, cut edges are clean with minimal burr. Problems such as cracked edge defects, crystallization, hardening, reduced weald ability and machinability are reduced in this process. Water jet technology uses the principle of pressurizing water to extremely high pressures, and allowing the water to escape through a very small opening called "orifice" or "jewel". Water jet cutting uses the beam of water exiting the orifice to cut soft materials. This method is not suitable for cutting hard materials. The inlet water is typically pressurized between1300 – 4000 bars. This high pressure is forced through a tiny hole in the je el, hich is typically 0.18 to 0.4 mm in diameter. Picture of water jet chining process**.**



Applications

Water jet cutting is mostly used to cut lower strength materials such as wood, plastics and aluminum. When abrasives are added, (abrasive water jet cutting) stronger materials such as steel and tool steel.

Advantages Of Water Jet Cutting

1. There is no heat generated in water jet cutting; which is especially useful for cutting tool steel and other metals where excessive heat may change the properties of the material.

2. Unlike machining or grinding, water jet cutting does not produce any dust or particles that are harmful if inhaled.

3. Other advantages are similar to abrasive water jet cutting

Disadvantages of water jet cutting

1. One of the main disadvantages of water jet cutting is that a limited number of materials can be cut economically.

2. Thick parts cannot be cut by this process economically and accurately

3. Taper is also a problem with water jet cutting in very thick materials. Taper is when the jet exits the part at different angle than it enters the part, and cause dimensional inaccuracy.

ABRASIVE WATER-JET MACHINING (AWJM)

Abrasive water jet cutting is an extended version of water jet cutting; in which the water jet contains abrasive particles such as silicon carbide or aluminium oxide in order to increase the material removal rate above that of water jet machining. Almost any type of material ranging from hard brittle materials such as ceramics, metals and glass to extremely soft materials such as foam and rubbers can be cut by abrasive water jet cutting. The narrow cutting stream and computer controlled movement enables this process to produce parts accurately and efficiently. This machining process is especially ideal for cutting materials that cannot be cut by laser or thermal cut. Metallic, non-metallic and advanced composite materials of various thicknesses can be cut by this process. This process is particularly suitable for heat sensitive materials that cannot be machined by processes that produce heat while machining. The schematic of abrasive water jet cutting is shown in Figure 15 which is similar to water jet cutting apart from some more features underneath the jewel; namely abrasive, guard and mixing tube. In this process, high velocity water exiting the jewel creates a vacuum which sucks abrasive from the abrasive line, which mixes with the water in the mixing tube to form a high velocity beam of abrasives.

Applications

Abrasive water jet cutting is highly used in aerospace, automotive and electronics industries. In aerospace industries, parts such as titanium bodies for military aircrafts, engine components (aluminum, titanium, and heat-resistant alloys), aluminum body parts and interior cabin parts are made using abrasive water jet cutting. In automotive industries, parts like interior trim (head liners, trunk liners, and door panels) and fiber glass body components and bumpers are made by this process. Similarly, in electronics industries, circuit boards and cable stripping are made by abrasive water jet cutting.

Advantages of abrasive water jet cutting

In most of the cases, no secondary finishing required

• No cutter induced distortion

• Low cutting forces on work pieces

• Limited tooling requirements

• Little to no cutting burr

• Typical finish 125-250 microns

• Smaller kerf size reduces material wastages

• No heat affected zone

• Localizes structural changes

• No cutter induced metal contamination

• Eliminates thermal distortion

• No slag or cutting dross

Limitations of abrasive water jet cutting

1. Cannot drill flat bottom
2. Cannot cut materials that degrades quickly with moisture Surface finish degrades at higher cut speeds which are frequently used

PLASMA ARC MACHINING

The plasma welding process was introduced to the welding industry in 1964 as a method of bringing better control to the arc welding process in lower current ranges. Today, plasma retains the original advantages it brought to industry by providing an advanced level of control and accuracy to produce high quality welds in miniature or precision applications and to provide long electrode life for high production requirements Principles of Operation:The plasma arc welding process is normally compared to the gas tungsten arc process. But in the TIG-process, the arc is burning free and unhandled, whereas in the plasma-arc system, the arc is necked by an additional water-cooled plasma-nozzle. A plasma gas – almost always 100 % argon –flows between the tungsten electrode and the plasma nozzle.The welding process involves heating a gas called plasma to an extremely high temperature and then ionizing it such that it becomes electrically conductive. The plasma is used to transfer an electric arc called pilot arc to a work piece which burns between the tungsten electrode and the plasma nozzle. By forcing the plasma gas and arc through a constricted orifice the metal, which is to be welded is melted by the extreme heat of the arc. The weld pool is protected by the shielding gas, flowing between the outer shielding gas nozzle and the plasma nozzle. As shielding gas pure argon-rich gas-mixtures with hydrogen or helium are used. The high temperature of the plasma or constricted arc and the high velocity plasma jet provide an increased heat transfer rate over gas tungsten arc welding when using the same current. This results in faster welding speeds and deeper weld penetration. This method of operation is use. The high temperature of the plasma or constricted arc and the high velocity plasma jet provide an increased heat transfer rate over gas tungsten arc welding when using the same current. This results in faster welding speeds and deeper weld penetration. This method of operation is used for welding extremely thin material and for welding multi pass groove and welds and fillet welds.

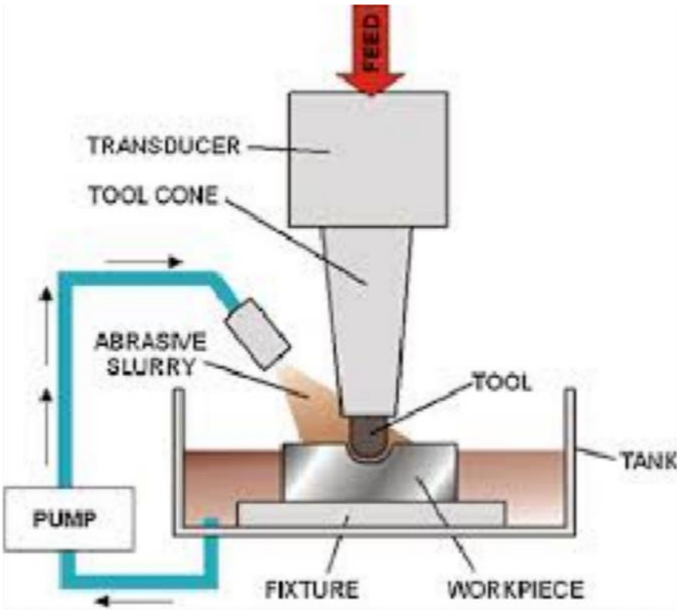
Uses & Applications:

Plasma arc welding machine is used for several purposes and in various fields. The common application areas of the machine are

1. Single runs autogenous and multi-run circumferential pipe welding
2. . In tube mill applications.
3. Welding cryogenic, aerospace and high temperature corrosion resistant alloys
4. Nuclear submarine pipe system (non-nuclear sections, sub-assemblies)

ULTRASONIC MACHINING (USM)

USM is mechanical material removal process or an abrasive process used to erode holes or cavities on hard or brittle work piece by using shaped tools, high frequency mechanical motion and an abrasive slurry. USM offers a solution to the expanding need for machining brittle materials such as single crystals, glasses and polycrystalline ceramics, and increasing complex operations to provide intricate shapes and work piece profiles. It is therefore used extensively in machining hard and brittle materials that are difficult to machine by traditional manufacturing processes. The hard particles in slurry are accelerated toward the surface of the work piece by a tool oscillating at a frequency up to 100 KHz - through repeated abrasions, the tool machines a cavity of a cross section identical to its own**.** USM is primarily targeted for the machining of hard and brittle materials (dielectric or conductive) such as boron carbide, ceramics, titanium carbides, rubies, quartz etc. USM is a versatile machining process as far as properties of materials are concerned. This process is able to effectively machine all materials whether they are electrically conductive or insulator. For an effective cutting operation, the following parameters need to be carefully considered The machining tool must be selected to be highly wear resistant, such as high-carbon steels. The abrasives (25-60 µm in dia.) in the (water-based, up to 40% solid volume) slurry Includes: Boron carbide, silicon carbide and aluminum oxide.



Advantage of USM

1. USM process is a non-thermal, non-chemical, creates no changes in the microstructures, chemical or physical properties of the work piece and offers virtually stress free machined surfaces.
2. Any materials can be machined regardless of their electrical conductivity Especially suitable for machining of brittle materials
3. Machined parts by USM possess better surface finish and higher structural integrity. USM does not produce thermal, electrical and chemical abnormal surface.

Disadvantages of USM

1. USM has higher power consumption and lower material-removal rates than traditional Fabrication processes.
2. Tool wears fast in USM
3. Machining area and depth is restraint in USM

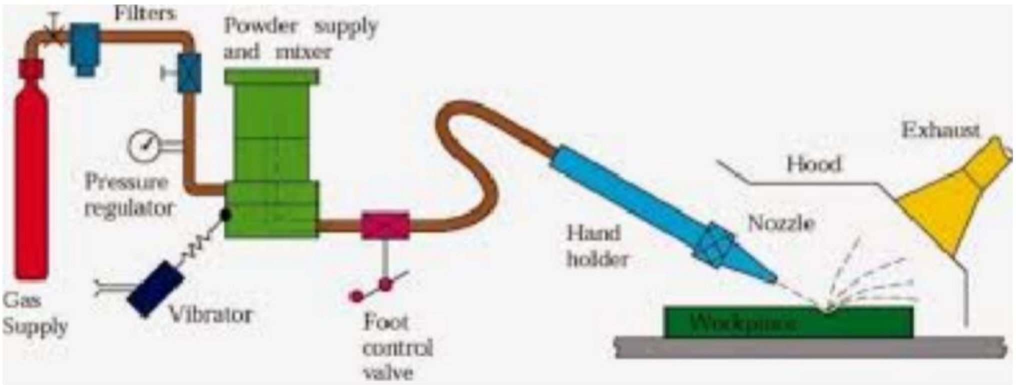
ABRASIVE JET MACHINING

Abrasive jet machining is mechanical energy based unconventional machining process used to remove unwanted material from a given work piece.

CONSTRUCTION

It consist of Compressor (To pressurize the gas), Filter, mixing chamber, Hopper, Vibrator, Nozzle, Pressure gauge and flow regulator. The nozzle is made of a hard material like tungsten carbide. Abrasive used are aluminum oxide, Silicon carbide, or Sodium bicarbonate. The gases commonly used are air, N2, CO2. Hopper is placed above mixing chamber for feeding purpose.

Vibrating device placed below mixing chamber to vibrate mixture of abrasive and gas.



WORKING

First dry air or gas is filtered and then it compressed by compressor. A pressure gauge and flow regulator control the pressure and regulate the flow of the compressed air. Compressed air entered into the mixing chamber where it mixed with abrasive particles. Then mixture passes through nozzle where high velocity fine abrasive jet is produced. The nozzle increases velocity about 200 to 400 m/s at the expense of its pressure.

APPLICATIONS:

Drilling, Cleaning, and polishing of hard surface. To machine intricate shapes which is difficult to machine. Aircraft fuel system, medical appliances and Hydraulic valves.

Advantage of Abrasive Jet Machining:

No heat is generated in work.

So, it is suitable for heat sensitive materials.

No physical contact between tool and work.

Thin and fragile materials also machined.

Low investment. Smooth surface finish.

Disadvantage:

Low MRR.

Abrasive powder cannot be reused.

Nozzle life is less and maintenance of nozzle required.

Factors affecting performance of AJM:

Abrasive grain size and It's mass flow rate Mixing ratio.

Velocity of abrasive particles.