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Diploma in Mechanical Engineering

Course Code: 1020

M – Scheme

e-TEXTBOOK
on
SPECIAL MACHINES
for
IV Semester DME

Convener for ME Discipline:

Dr. M. ISAKKIMUTHU, M.E., Ph.D.,
PRINCIPAL,
Dr. Dharmambal Government Polytechnic College for Women,
Tharamani, Chennai - 600 113.

Team Members for Special Machines:

Mr. K. Sundararaj,
WS /Mechanical Engineering,
226, PAC Ramasamy Raja Polytechnic College,
Rajapalayam – 626 108

Mr. K. Rajendran,
Lecturer /Mechanical Engineering,
226, PAC Ramasamy Raja Polytechnic College,
Rajapalayam – 626 108

Validated By

Thiru M. SUGUMARAN, M.E.,
PRINCIPAL,
Ramakrishna Mission Polytechnic College,
Mylapore, Chennai - 600 004.

32042 - SPECIAL MACHINES

DETAILED SYLLABUS

Unit	Name of the Topic	Pages
I	**MANUFACTURING OF PLASTIC COMPONENTS** **Plastic Components:** Types of plastics - Engineering plastics – thermosets – composite - structural foam, elastomers - polymer alloys and liquid crystal polymers. Factors Influencing the Selection of Plastics - Mechanical properties – degradation - wear resistance - frictional properties - special properties – processing – cost **Processing of Plastics:** Extrusion-general features of single screw extrusion - twin screw extruders. Injection moulding types: Plunger type - Reciprocating screw injection - details of injection mould - structural foam injection mould - sandwich moulding - gas injection moulding - injection moulding of thermosetting materials - calendaring and rotational moulding. Design consideration for plastic components. **Composite manufacturing:** Introduction – characteristics of composite manufacturing - constituents – Glass fibers manufacturing process – hand laminating process – autoclave processing – filament winding – pultrusion process – liquid composite process – working principles by schematic diagram only – advantages – disadvantages.	1-23
II	**RECIPROCATING MACHINES** **Planer:** Introduction - description of double housing planer – specifications - principles of operation – drives - quick return mechanism - feed mechanism - work holding devices and special fixtures - types of tools - operations. **Shaper:** Introduction – specifications – principles of operations standard shaper – quick return mechanism - crank and slotted link – hydraulic shaper - feed mechanism - work holding devices – fixture - operations. **Slotter:** Introduction – specifications - method of operation - Whitworth quick return mechanism - feed mechanism - work holding devices - types of tools. **Broaching:** Types of broaching machine - horizontal, vertical and continuous broaching - principles of operation - types of broaches – classification - broach tool nomenclature - broaching operations.	24-65
III	**MILLING MACHINES AND GEAR GENERATING PROCESSES** **Milling Machines:** Types - column and knee type – plain - universal milling machine - vertical milling machine - principles of operation - specification of milling machines - work holding devices - tool holding devices - arbor - stub arbor - spring collet – adapter. Milling cutters: cylindrical milling cutter - slitting cutter -side milling cutter - angle milling cutter - T-slot milling cutter - woodruff milling cutter - fly cutter - nomenclature of cylindrical milling cutter. Milling operations: straddle milling - gang milling - vertical milling attachment. Indexing plate – differential indexing - simple indexing – compound indexing – simple problems.	66-104

	Generating Process: gear shaper - gear hobbing - principle of operation only. Gear finishing processes: burnishing – shaving - grinding and lapping - gear materials.	
IV	**ABRASIVE PROCESS AND NON- CONVENTIONAL MACHINING PROCESSES** **Abrasive Process:** Types and classification – specifications - rough grinding – pedestal grinders - portable grinders - belt grinders - precision grinding - cylindrical grinder - centerless grinders – surface grinder - tool and cutter grinder - planetary grinders - principles of operations - grinding wheels – abrasives - natural and artificial diamond wheels - types of bonds - grit, grade and structure of wheels - wheel shapes and sizes - standard marking systems of grinding wheels - selection of grinding wheel - mounting of grinding wheels - Dressing and Truing of wheels - Balancing of grinding wheels. **Non-Conventional Machining Processes:** Construction, working and applications of Ultrasonic machining - chemical machining - electro chemical grinding - electrical discharge machining - plasma arc machining - LASER machining - Advantages – Disadvantages.	**105-145**
V	**CNC MACHINE AND ITS COMPONENTS** **CNC Machines:** Numerical control – definition – working principle of a CNC system – Features of CNC machines - advantage of CNC machines – difference between NC and CNC – Construction and working principle of turning centre – Construction and working principle of machining centre – machine axes conventions turning centre and machining centre – Coordinate measuring machine – construction and working principle. **Components of CNC machine:** Slide ways – requirement – types – friction slide ways and antifriction slide ways - linear motion bearings – recirculation ball screw – ATC – tool magazine – feedback devices – linear and rotary transducers – Encoders - in process probing - tool material – tool inserts.	**146-165**

Text Book:

1. Elements of Workshop Technology- Vol. I & II, Hajra Choudry & Battacharya, Edn. 11, published by Media Promoters and Publishers Pvt. Ltd., Seervai Buildings `B’, 20-G, Noshir Bharucha Marg, Mumbai 400 007 – 2007.
2. Production Technology, Jain & Gupta, Khanna Publishers, 2-B, North Market, Naisarak, New Delhi – 110 006 – 2006.

Reference Book:

1. Production Technology, HMT, Edn. 18, published by Tata McGraw Hill Publishing Co. Ltd., 7, West Patel Nagar, New Delhi 110 008.
2. Manufacturing process, Myro N Begman, , Edn. 5, Tata McGraw Hill Publishing Co. Ltd., 7, West Patel Nagar, New Delhi 110 008.
3. Workshop Tech Vol I,II, III, WAJ. Chapman, published by Viva Books Pvt. Ltd., 4262/3, Ansari Road, Daryaganj, New Delhi 110 002.
4. Production processes, NITTTR, published by 5, Tata McGraw Hill Publishing Co. Ltd., West Patel Nagar, New Delhi 110 008.
5. Principles of the manufacturing of Composite materials – Suong V Hoa, DES tech publication. Inc, 439, North Duke street, Lancaster, Pennsylvania – 17602 U.S.A.

UNIT I – MANUFACTURING OF PLASTIC COMPONENTS

PLASTIC COMPONENTS

Introduction

Plastic is an organic resin or synthetic resin which can be moulded to any required shape. Generally, the plastic is of organic nature which contains hydrogen, oxygen, carbon and nitrogen.

Types of plastics

Plastics are classified as given below

1. Thermo plastic 2. Thermosetting plastic

Engineering plastics

Plastics are used in engineering applications are called engineering plastics. These plastics are having high strength and good physical properties. These plastics are costlier than commodity plastics.

Thermosets

These type of plastic require heat and pressure to mould to the required shape. Once it is hardened cannot be softened again. This plastic is formed by condensation. The plastic has three molecular structure and high molecular weights. This is hard, tough, no swelling and brittle. So it cannot be softened or re moulded.

Composite

A material which is produced by combining two dissimilar materials for a better application is called composite material. This material is the most common one used in household goods and in many industrial applications. This material has more strength and stiffness than the normal plastic. E.g., Fibre glass-rein forced plastic.

Structural foam or foamed plastics

Foamed plastics have the properties of discrete porosity. This increases the buoyancy and elasticity and acoustical, heat and electrical insulating properties. Porosity is induced with foaming agents which may be chemical or physical. These can be added to both thermoplastic and thermosetting plastic compounds. Polystyrene and polyurethane are the plastics used in the foam form. Polypropylene, phenolic, silicone and are also used.

Uses of Foamed plastics

1. Used in marking mattresses.
2. Used in making automobile dash boards and seat cushions, boards, sheets and rods etc.

Elastomers

Elastomer is nothing but a rubber. It is a polymeric material. It has large and reversible elastic deformations. The elastomer can be stretched more than plastics.

Characteristics of Elastomers

1. It has non crystalline structure.
2. It does not conduct electricity.
3. It is a low heat conductor.
4. It is not corroded by chemical and corrosive environment.
5. It has low softening temperature.

Polymer

Polymer is the combination of a large number of repeating units called monomers. A polymer is made by the thousands of monomers joined together to form a large molecule of colloidal dimension. Each molecule of a polymer is being either a long chain or a network beating units all covalently bonded together. Mostly, The Polymers are made of carbon compounds but also those can be made from inorganic chemicals such as silicates and silicones.

Polymer Alloys

The properties of polymer are improved by the addition of agents called additives various additives are explained below.

1. Plasticizers 2. Fillers 3. Catalysts 4. Initiators
5. Dyes and pigments 6. Lubricants 7. Solvents

Liquid crystal polymers

These polymers are belonging to a group of chemically complex and structurally distinct materials and possess special properties. These polymers are composed or extended, rod shaped and right molecules. Some of the liquid crystal polymers are rigid solids at room temperature and having the following properties.

1. High impact strength
2. Excellent thermal stability
3. Stiff and strong
4. Chemically inert to wide variety of acids, solvents etc.
5. Inherent flame resistance.
6. Combustion product are relatively non-toxic.

Uses:

1. Liquid crystal polymers mostly used in liquid crystal displays (LCD), on digital watches.
2. Inter connect devices, relays and capacitor housings etc.
3. Photocopiers and fibre optic components.

FACTORS AFFECTING THE SELECTION OF PLASTICS

Factors affecting the selection of plastics:

The following factors are to be considered while selecting the plastics.

1. Mechanical properties
2. Degradation
3. Wear resistance
4. Frictional properties
5. Special properties
6. Processing method
7. Cost

Mechanical properties

- The mechanical properties such as elasticity, plasticity, toughness etc. are very essential for a plastic material to when it is subjected to forces and loads.

- Thermosetting plastics are having higher load carrying capacity than thermoplastics.
- Elastomers are added to increase the elastic properties.

Degradation

Brake down of chemical structure of plastics caused by heat stress and radiation.

Wear resistance

Wear occurs between the two bearing surfaces or moving parts one over another. In such a places, suitable plastic material should be selected. It means the plastic components should be made of plastic material with sufficient wear resistance property.

Frictional properties

Plastics are widely used as bearings, bushings, slides, etc. So, such parts are to be made by the plastics which are not easily affected by any frictional movement.

Special properties

Plastic material can be moulded to any required shape with the help of pressure of heat. Plastic material are having less weight and high strength and toughness when comparing to the metals. So, these factors also influence the selection plastics for manufacturing the components.

Processing cost

- The selection of suitable plastic material is for manufacturing the components also depends on the processing cost.
- There are various processing methods are available for manufacturing the plastic components and suitable processing cost.

PROCESSING OF PLASTICS

A few types of processes are available for processing either thermoplastic or thermosetting plastics. Each process makes some desired form to the plastic. Common production processes for making plastics are given below.

1. Extrusion
2. Moulding Processes
    a) Compression moulding
    b) Injection moulding

c) Roto moulding

d) Expandable-bead moulding

e) Blow moulding

3. Thermoforming
4. Calendaring
5. Casting

Extrusion

It is also called as extrusion moulding. All the thermoplastic materials can be extruded into various shapes.

Common types of extruders are

1. Single screw   2. Cast film   3. Pipe and profiles

Single screw extruder

Working principle

- Extrusions are produced by forcing a material through the opening of a die to produce the required shape.
- In this, the powdered raw material, usually thermoplastic is fed into a hopper and carried along by a screw conveyor through the heating chamber. The raw material becomes viscous fluid in the heating chamber.

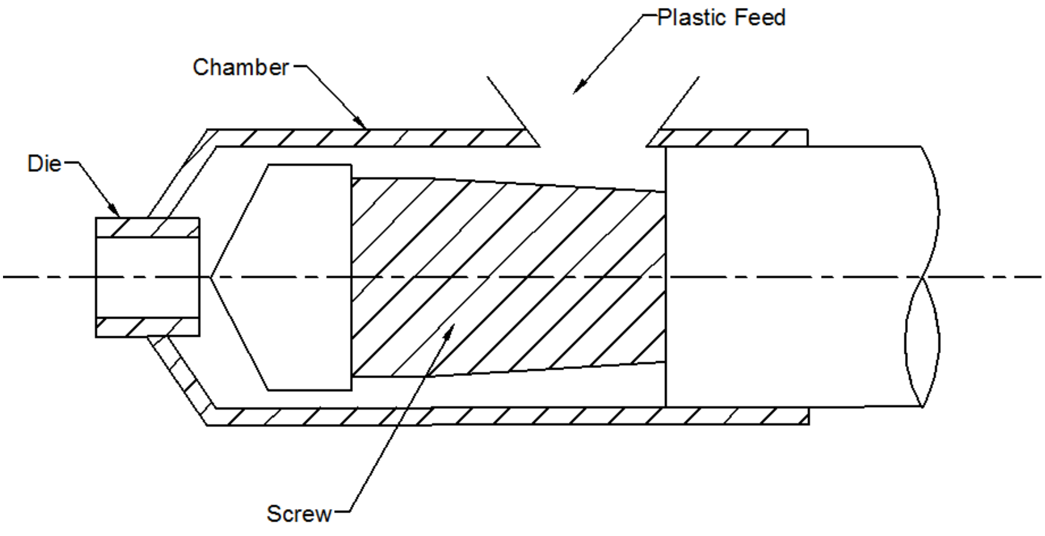


Fig. 1.1 Single screw extruder

- Then, the fluid material is forced through the heated die.
- The material leaving the die rests on a moving conveyor and is cooled by water, air spray to obtain the shape of the die opening.
- Heavy plastics materials are cut to required shape and the flexible plastics are coiled.

Advantages

- Less cost
- High production rate

Disadvantages

- Long uniform sections are only can be formed
- Suitable for mass production only
- Less dimensional accuracy

Applications

- This process is suitable for making the parts like tubes, rods, sheets, films, pipes, ropes and profiles.

Twin screw extruder

The method of processing of plastics using twin screw extruders is similar as that of single screw extruders. But they have two screws rotating in a heated barrel. The output of a twin screw extruder can be typically three times that of a single screw extruder of same diameter and speed.

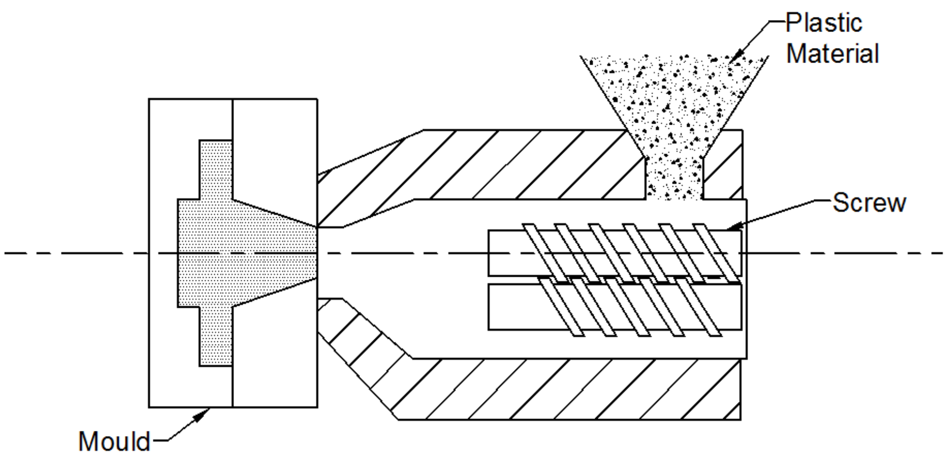


Fig. 1.2. Twin screw extruder

The following screw configurations are available.

a. Intermeshing counter-rotating
b. Intermeshing co rotating
c. Non - Intermeshing counter-rotating
d. Non- Intermeshing co rotating

In a counter rotating twin screw extruder, the material is effectively squeezed between counter rotating rolls. In a co rotating system, the material is transferred from one screw on the other in a figure of eight pattern. This arrangement is particularly suitable for heat sensitive materials because the material is conveyed through the extruder quickly with little possibility of entrapment. The movement around the screw is slower if the screws are intermeshed but the propulsive action is greater.

Advantages:

- Output rate is high.
- Mixing efficiency is more.
- High heat is generated for melting the plastic material fastly.

Injection Moulding

This is the most common method used for moulding thermoplastics In this, Granulated material is fed from a hopper, in measured amounts, to the heating zone chamber where it becomes as a fluid. The softened plastic is then injected into the dies by means of a plunger to make desired shape.

Ram or plunger type Injection Moulding Machine

Working principle

In this, granulated material is fed from a hopper, in measured amounts, to the heating zone chamber where it becomes as a fluid. Then, the softened plastic is injected into the dies by means of a plunger. Injection moulding dies are water cooled to solidify the molten plastic material until the material reaches solid stage. The injection pressure force the fluid to the die. After the cooling period, the dies are opened and ejected the completed solidified piece.

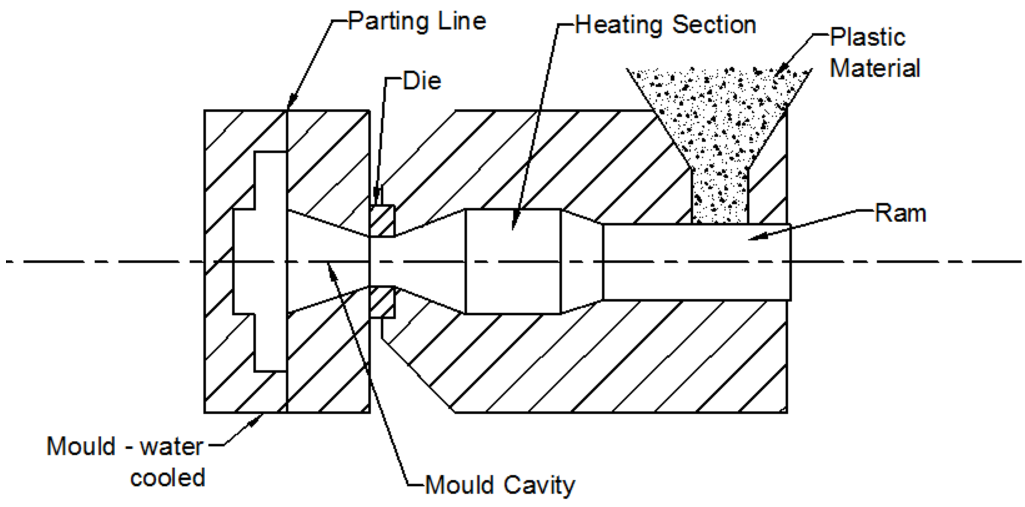


Fig. 1.3. Ram or plunger type Injection Moulding

Advantages

- Complicated shapes of various sizes of products can be produced
- Good dimensional accuracy

Disadvantages

- High tooling cost
- Suitable for mass production only
- High production rate

Reciprocating screw Injection Moulding

This process is similar to the hot chamber casting of metals. The following diagram shows a screw injection moulding process.

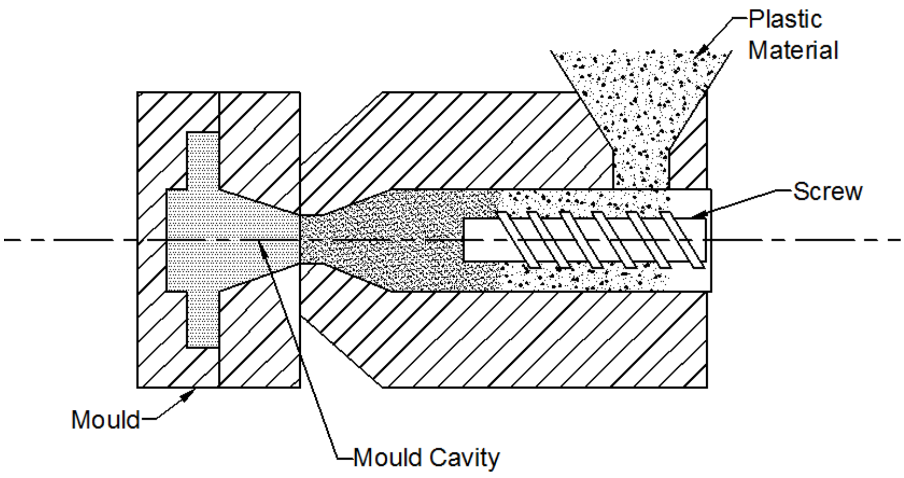


Fig. 1.4. Reciprocating screw Injection Moulding

Working principle

In this, the granulated material is fed through a hopper in a measured amount, to the heating zone chamber where the raw material becomes fluid.

- Then the resins fall into and pushed along the heated tube by reciprocating screw (feeder) till a sufficient volume of melted plastic is available at the injection nozzle end.
- The screw is fully plunged forward to force the plastic into the mould.
- For every plunging action, one or several parts are produced depending on the die used.
- The ram is held under pressure for a certain period till the part can solidify.
- Then the mould is opened and the knockout pins ejects the moulded piece.

Advantages

1. High production rate.
2. Low cost.

Details of injection mould:

Injection mould contains two halves which is to be impression part of mould. The mating surfaces of the mould halves are accurately machined so that no leakage of plastic can occur at the splitting portion. To guide mounting of the mould in the machine, cooling and ejection of the moulding several additions are made to the basic mould halves.

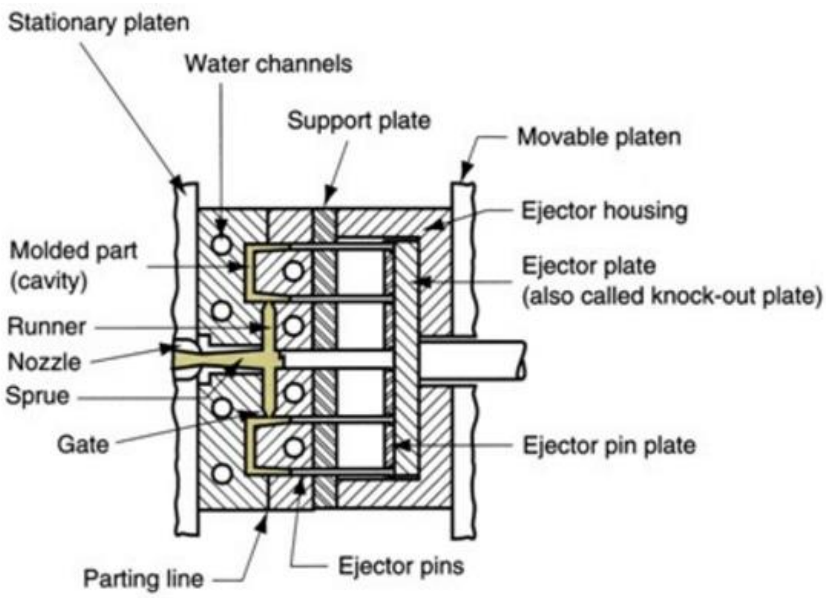


Fig. 1.5. Details of injection mould

Ejector pins:

These are provided to remove the moulded part from the mould easily. Generally, the ejector pins are operated by shoulder screw hitting a stop when the mould opens.

Gate:

It a small orifice which connects the runner to the cavity. It is also act as valve by allowing molten plastic to fill the mould. The following types if gates are used mostly.

1. Sprue gates - when sprue bush is directly feed to the mould cavity
2. Pin gates - reduce viscosity of plastic and mould fills more easily
3. Side gate – Simple one and feeding the plastic in side of the mould.

Runner:

The runner is the flow of molten plastic travels from the sprue to the gate. Cross sectional area of the runner must be large for little resistance to flow of plastic.

Sprue:

Sprue is the channel along which the molten plastic enters the mould. Is delivers molt from the nozzle to runner of the system. It has tapered cross section to pull out from mould.

Venting:

Before plastic is injected, the cavity is full of air. When the melt enters the mould, if the air cannot escape it become compressed. The sudden compression of air leads to occur heating and it is sufficient to burn plastic and create local hot spots. To avoid this, vents are accurately machined on mating surfaces of the mould to allow the air to escape. Normally, size of the vent is 0.025mm deep and several millimeters wide.

Structural foam injection moulding:

These plastics has cellular core with a high density. Foam effect is achieved by the dispersion of inert gas throughout molten resin directly before moulding introduction of the gas is usually carried out either by pre blending the resin with a chemical blowing agent which releases gas when heated or by direct injection of the gas. Usually nitrogen is used for this purpose. When the compressed gas or resin mixture is rapidly injected into the mould cavity. The gas expands explosively and forces the material into all parts of the mould.

Foamed plastics may be produced with good properties by using screw injection moulding machines. Specialized foam injection moulding machines are available to produce parts with 50kg.

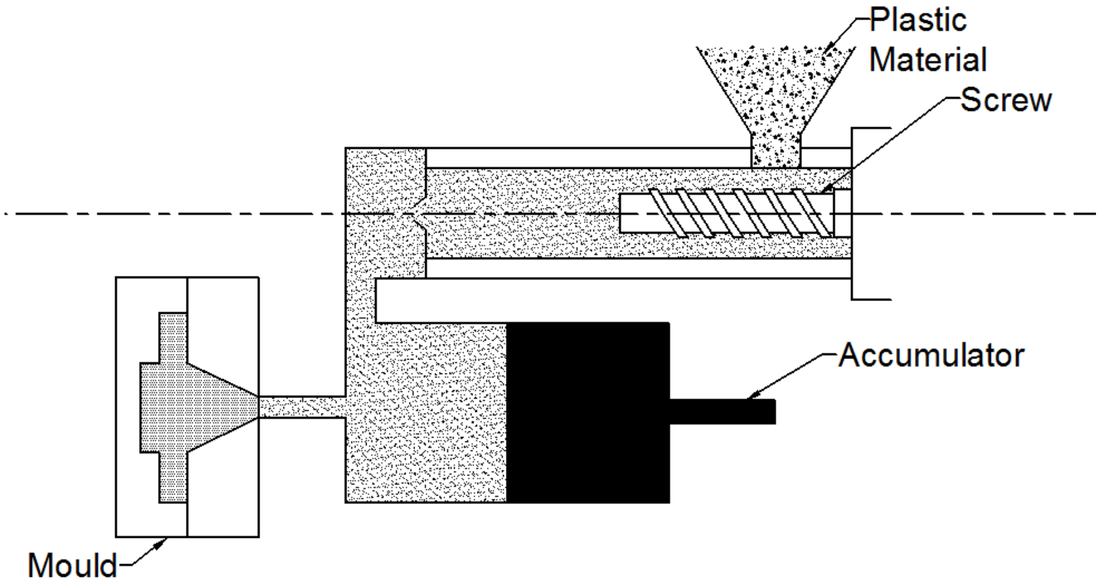


Fig. 1.6. Structural foam injection moulding

wall sections in foam moulding are thicker than in solid material. Therefore, longer cycle times can be expected due to both the wall thickness and the low thermal conductivity of the cellular material.

Advantages:

- These plastics are rigid one.
- Free form shrinkage.
- Cost of the mould is less.
- Very thick sections can be moulded.

Sandwich injection mould:

Sandwich moulding is defined as two or more polymers are injected one after the other through the dame gate in one or cavities. A thin boundary layer of the first injected material solidifies. The core remains plastic. Now, the second material is injected and fills the core.

The first material takes over the function of the skin, the process can be used for all thermoplastic materials. The sandwich can be used procedure, if functional, decorative or marbled moulded parts are specified. It is possible to combine this process with other high technical processes like water injection.

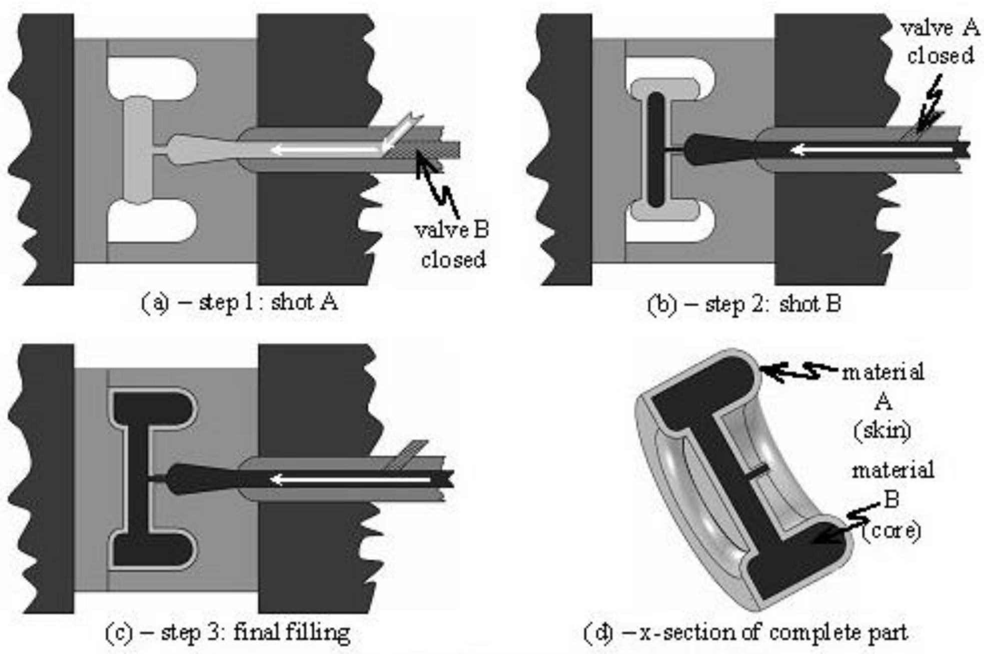


Fig. 1.7. Sandwich injection mould

Advantages:

- Material, weight and cost is saved.
- Increased stability and strength.
- Decorative effects.
- Combination of characteristics.

Gas injection moulding:

It is a modern technology, uses inert gas to act as the core in an injection moulded plastic product. Due to this, greater properties like stiffness, reduced stresses and distortion may have achieved.

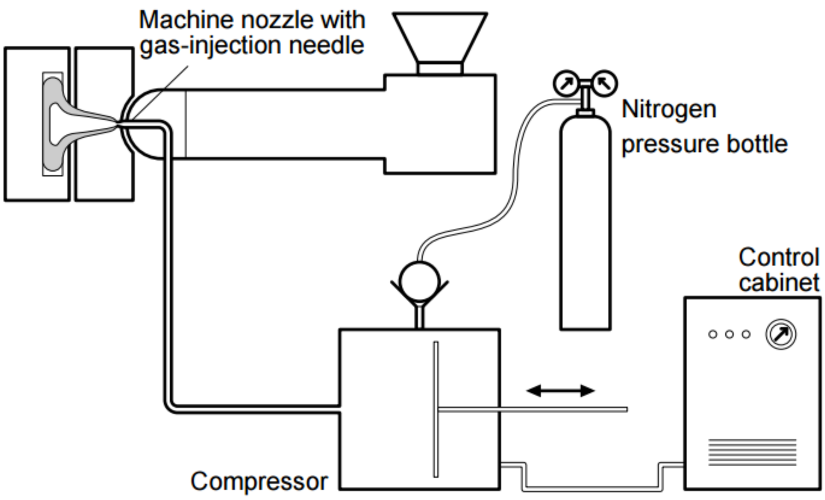


Fig. 1.8. Gas injection moulding

First the molten polymer is flowed into mould cavity through feed system. Just before full flow of molten plastic is complete, special nozzle is injecting the gas into mould. The speed of the gas injection. Timing and pressure is critical. The pressure is at the polymer gate is high. Therefore, the gas chooses a natural path through the hotter and less viscous parts of the polymer melt towards the lower pressure areas.

By controlling the amount of gas injected into the hollow core, the pressure on the cooling polymer is controlled and maintained until the moulding is packed, the final stage is the withdrawal of gas nozzle. It allows the gas geld in the hollow core vent. After this, the mould is opened.

Advantages:

- Lower cycle time.
- No surface imperfections
- Clamping forces are much lower

Injection moulding for Thermosetting materials:

Thermoset molding is the reverse process of thermoplastic. Thermoset molding in an irreversible process in which a chemical change takes place in the material, instead of a physical one. Thermoset material is injected into a hot mold and then cooled to maintain the final shape of the part.

Special barrel and screw are used in this process. The barrel is kept at warm (Generally 80 to 120° C) rather than very hot as with thermoplastics because the material must not cure in this section of the machine. Also, high viscosity of these material, screw must rotate at high torque and high injection pressure is required.

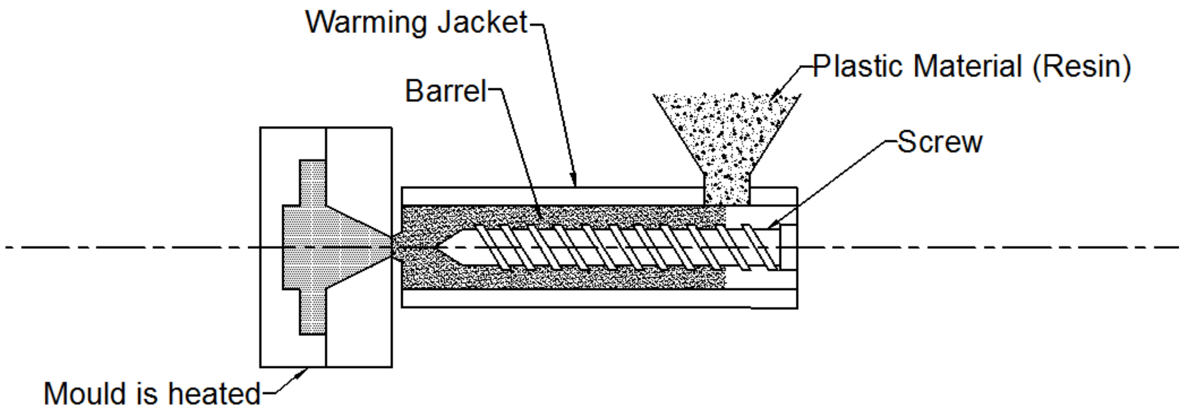


Fig. 1.9. Injection moulding for Thermosetting materials

The mould is maintained at very hot (150 to 200° C) for accelerate the curing of the material once it taken the shape of the cavity. Hydraulic mould clamping is generally preferred. During moulding of thermosets, wastage in sprues and runners is much more severe because it cannot be reused. Therefore, it is desirable to keep the sprue and runner sections of the mould cool so that these do not cure with the moulding. They can then be retained in the mould during the ejection stage and then injected into the cavity to form the next moulding.

Advantages:

- Fastest cycle.
- Efficient pre heating material
- Easiest finishing
- Mould cost is low.

Calendaring

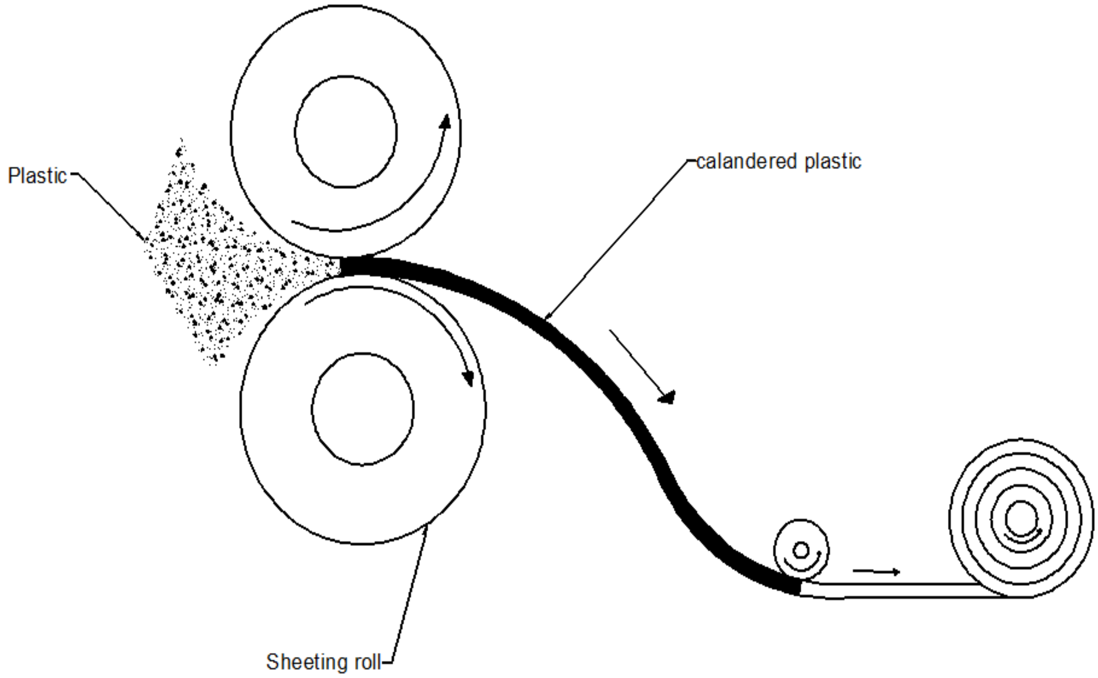


Fig. 1.10. Calendaring

- It is similar to rolling process.
- Calendaring is the process of producing the sheet of materials by rolling the plastics between multiple rollers. This process is carried out only for thermoplastics and not thermosetting plastics.

- In this, a heated plastic compound is passed through a serious of hot rollers where the material is squeezed into the form of thin sheet of uniform thickness.
- This process is suitable for making films and sheet.
- The first roll gap serves as a feeder, the second serves as a metering device, and third roll sets the gauge of the gradually cooling plastic which is then wound with about 25 % stretching onto drum.
- It is high production rate process.

Application

- This process is suitable for making the following products from flexible PVC and rigid PVC.
- Upholstery, rain wear, shower curtains, tapes and trays, credit cards, laminations.

Rotational Moulding

- In this, the plastic component is made inside a closed mould that is rotated about two axes as heat is applied.
- Liquid or powdered thermoplastic or thermosetting plastic is poured into the mould by manually or automatically. Then the mould halves and clamped.

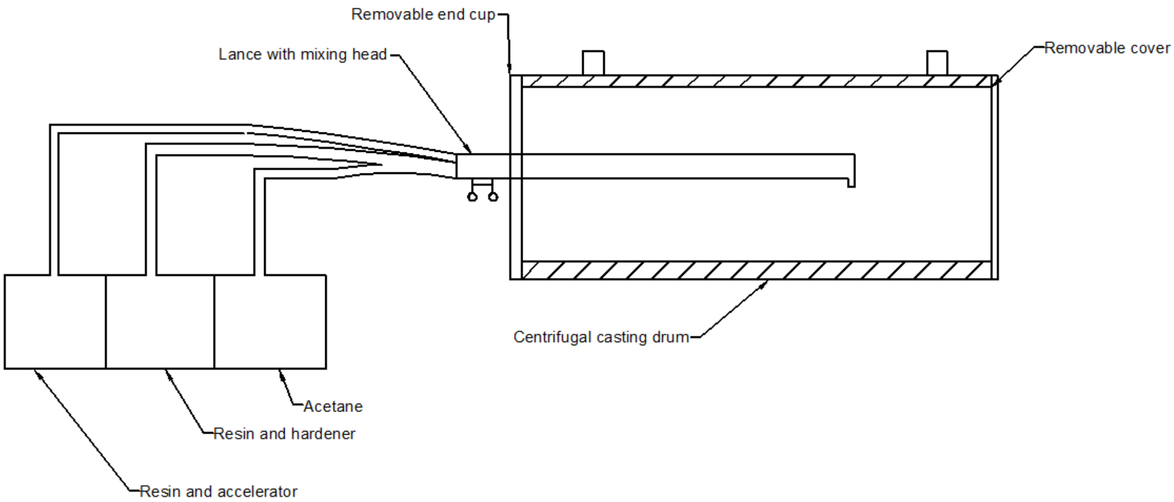


Fig. 1.11. Rotational Moulding

- The loaded mould is rolled, where the mould spurns on both axes. The heat converts the powdered materials to semi liquid or liquid materials to the form of gel.
- During the rotation of mould, the gel material distributed on mould cavity walls solely by gravitational force.

- After the formation of parts, the moulds are cooled by the arrangement of cold water spray, forced cooled air and cool liquid circulating inside the mould.

Advantages

- ✓ This process is suitable for making the products with complicated shapes and size.
- ✓ Less expanse than injection moulding.
- ✓ Less expanse for manufacturing few parts than the other process.

Disadvantages

- ✓ This process is suitable for manufacturing hollow parts only.
- ✓ Cycle time is slow.
- ✓ It is not easy to get varying wall thickness within a part.
- ✓ Only limited number of materials only can be mould.

Design considerations for Plastic Components

The following are the rules to be considered while designing plastic moulded components.

1. Location of the parting surface of the mould should be in one plane.
2. Avoid under cuts.
3. Provide shrinkage allowance.
4. Allow at least a minimum draft 0.5 to 10% for easy with drawl of the parts from the mould.
5. As far as possible, long cored holes should be avoided.
6. As far as possible, try to design projections to have circular cross sections.
7. Avoid sharp corners.
8. Ejector pins should be so located that they will not make their marks on the exposed surfaces.
9. Suitable inserts with correct size should be used. These should not slender. Brass inserts are best.
10. Provide ribs to increase strength and rigidly and to reduce distortions.
11. Thick sections should be preferable kept as nearly uniform in thickness as possible.

COMPOSITE MANUFACTURING

Composite:

A combination of two or more materials to form a new material with enhanced material properties.

Reinforcement + Matrix = Composite

Examples of composite materials are brick made of clay reinforced with straw, mud wall with bamboo shoots, concrete, concrete reinforced with steel rebar, granite consisting of quartz, mica and feldspar, wood (cellulose fibers in lignin matrix), etc.

Advanced composite materials are refereed to those composite materials developed and used in the aerospace industries. They usually consist of high performance fibers as reinforcing phases and polymers or metals as matrices.

Matrix phase: Polymers, Metals, Ceramics.

Reinforcement phase: Fibers, Particles of Flakes. Also may be Polymers, Metals, Ceramics.

Classifications:

Metal Matrix Composites (MMCs)

– Mixtures of ceramics and metals, such as cemented carbides and other cermets
– Aluminium or magnesium reinforced by strong, high stiffness fibers

Ceramic Matrix Composites (CMCs)

– Least common composite matrix
– Aluminium oxide and silicon carbide are materials that can be imbedded with fibers for improved properties, especially in high temperature applications

Polymer Matrix Composites (PMCs)

– Thermosetting resins are the most widely used polymers in PMCs.
– Epoxy and polyester are commonly mixed with fiber reinforcement

Characteristics of composite materials:

1. High strength to weight ratio
2. Lighter in weight
3. Fire resistance
4. Good electrical insulation properties
5. Chemical and weather resistance
6. Design flexibility
7. Low thermal conductivity

Hand laminating process

Hand lay-up is an open moulding method suitable for making a wide variety of composites products like boats, tanks, bath ware, housings, RV/truck/auto components, architectural products, and many other products ranging from very small to very large. Production volume per mould is low; however, it is feasible to produce substantial production quantities using multiple moulds.

First a gelcoat is applied to the mould using a spray gun for a high-quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mould. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement, and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials, such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate to produce sandwich construction.

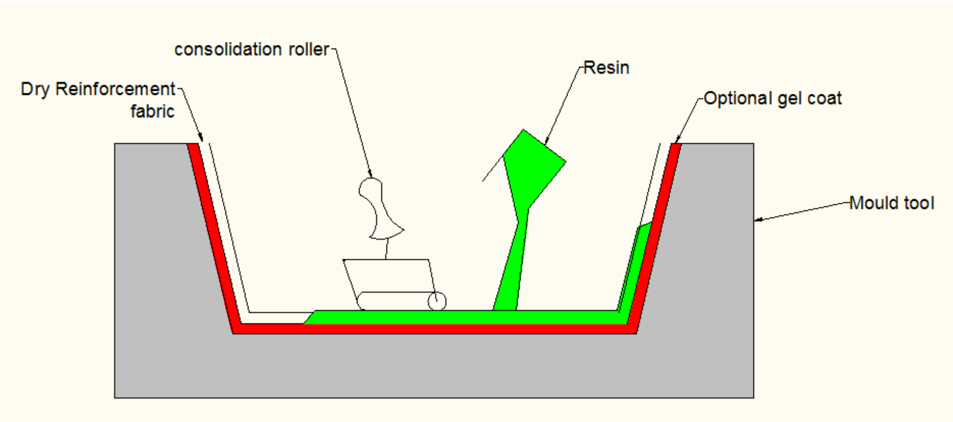


Fig. 1.12. Hand laminating process

Autoclave processing

Moulding of prepregs is usually done in an autoclave (effectively a pressurized oven). The autoclave process offers one of the highest manufacturing standards for composites. Fabrics and fibres are pre-impregnated by the prepreg manufacturer, under heat and pressure or with solvent, with a pre-catalyzed resin. The catalyst is largely latent at ambient temperatures giving the materials several weeks, or sometimes months, of useful life when defrosted. The prolong storage life of the materials are stored frozen. The resin is usually a near-solid at ambient temperatures, and so the pre-impregnated materials (prepregs) have a light sticky feel to them, such as that of adhesive tape. Unidirectional materials take fibre direct from a creel, and are held together by the resin alone.

The prepregs are laid up by hand or machine onto a mould surface, vacuum bagged and then heated to typically 120-180°C. This allows the resin to initially reflow and eventually to cure. The autoclave provides additional pressure for the moulding which can apply up to 5 atmospheres to the laminate.

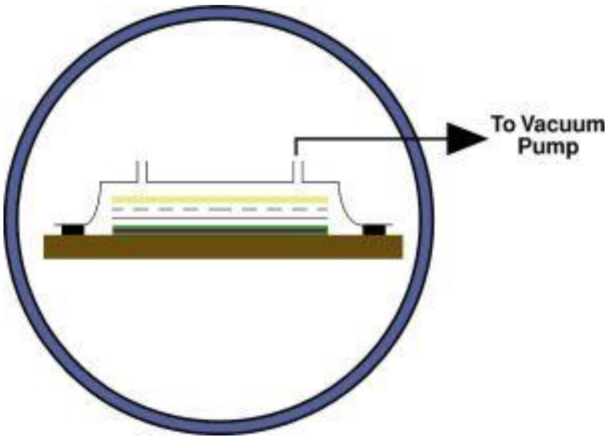


Fig. 1.13. Auto clave processing

Advantages:

- Widely used for many years.
- Simple principles to teach.
- Low cost tooling, if room-temperature cure resins are used.
- Wide choice of suppliers and material types.
- Higher fibre contents, and longer fibres than with spray lay-up.

Disadvantages:

- Resin mixing, laminate resin contents, and laminate quality are very dependent on the skills of laminators. Low resin content laminates cannot usually be achieved without the incorporation of excessive quantities of voids.

- Limiting airborne styrene concentrations to legislated levels from polyesters and vinylesters is becoming increasingly hard without expensive extraction systems.

- Resins need to be low in viscosity to be workable by hand. This generally compromises their mechanical/thermal properties due to the need for high diluent/styrene levels.

Applications:

Standard wind-turbine blades, production boats, architectural mouldings.

Filament Winding:

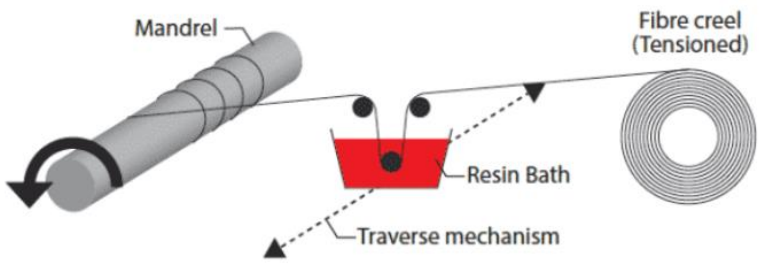


Fig. 1.14. Filament winding

Description

This process is primarily used for hollow, generally circular or oval sectioned components, such as pipes and tanks. Fibre tows are passed through a resin bath before being wound onto a mandrel in a variety of orientations, controlled by the fibre feeding mechanism, and rate of rotation of the mandrel.

Materials Options:

Resins: Any, e.g. epoxy, polyester, vinylester, phenolic.
Fibres: Any. The fibres are used straight from a creel and not woven or stitched into a fabric form.
Cores: Any, although components are usually single skin.

Advantages:

- This can be a very fast and therefore economic method of laying material down.
- Resin content can be controlled by metering the resin onto each fibre tow through nips or dies.
- Fibre cost is minimised since there is no secondary process to convert fibre into fabric prior to use.

- Structural properties of laminates can be very good since straight fibres can be laid in a complex pattern to match the applied loads.

Disadvantages:

- The process is limited to convex shaped components.
- Fibre cannot easily be laid exactly along the length of a component.
- Mandrel costs for large components can be high.
- The external surface of the component is unmoulded, and therefore cosmetically unattractive.
- Low viscosity resins usually need to be used with their attendant lower mechanical and health and safety properties.

Applications:

Chemical storage tanks and pipelines, gas cylinders, fire-fighters' breathing tanks.

Pultrusion:

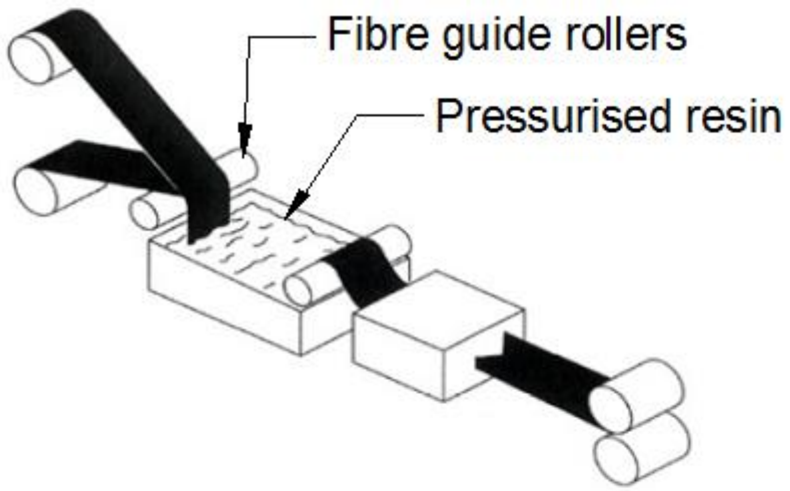


Fig. 1.15. Pultrusion

Description

Fibres are pulled from a creel through a resin bath and then on through a heated die. The die completes the impregnation of the fibre, controls the resin content and cures the material into its final shape as it passes through the die. This cured profile is then automatically cut to length. Fabrics may also be introduced into the die to provide fibre direction other than at 0°. Although pultrusion is a continuous process, producing a profile of constant cross-section, a variant known as 'pulforming' allows for some variation to be introduced into the cross-section. The process pulls the materials through the die for impregnation, and then clamps them in a mould for curing. This makes the process non-continuous, but accommodating of small changes in cross-section.

Materials Options:

Resins: Generally epoxy, polyester, vinylester and phenolic.
Fibres: Any.
Cores: Not generally used.

Advantages:

- This can be a very fast, and therefore economic, way of impregnating and curing materials.
- Resin content can be accurately controlled.
- Fibre cost is minimised since the majority is taken from a creel.
- Structural properties of laminates can be very good since the profiles have very straight fibres and high fibre volume fractions can be obtained.
- Resin impregnation area can be enclosed thus limiting volatile emissions.

Disadvantages:

- Limited to constant or near constant cross-section components
- Heated die costs can be high.

Applications:

Beams and girders used in roof structures, bridges, ladders, frameworks.

Liquid composite process:

Resin transfer moulding is the one of the liquid composite process.

Description:

Fabrics are laid up as a dry stack of materials. These fabrics are sometimes pre-pressed to the mould shape, and held together by a binder. These 'preforms' are then more easily laid into the mould tool. A second mould tool is then clamped over the first, and resin is injected into the cavity. Vacuum can also be applied to the mould cavity to assist resin in being drawn into the fabrics. This is known as Vacuum Assisted Resin Injection (VARI). Once all the fabric is wet out, the resin inlets are closed, and the laminate is allowed to cure. Both injection and cure can take place at either ambient or elevated temperature.

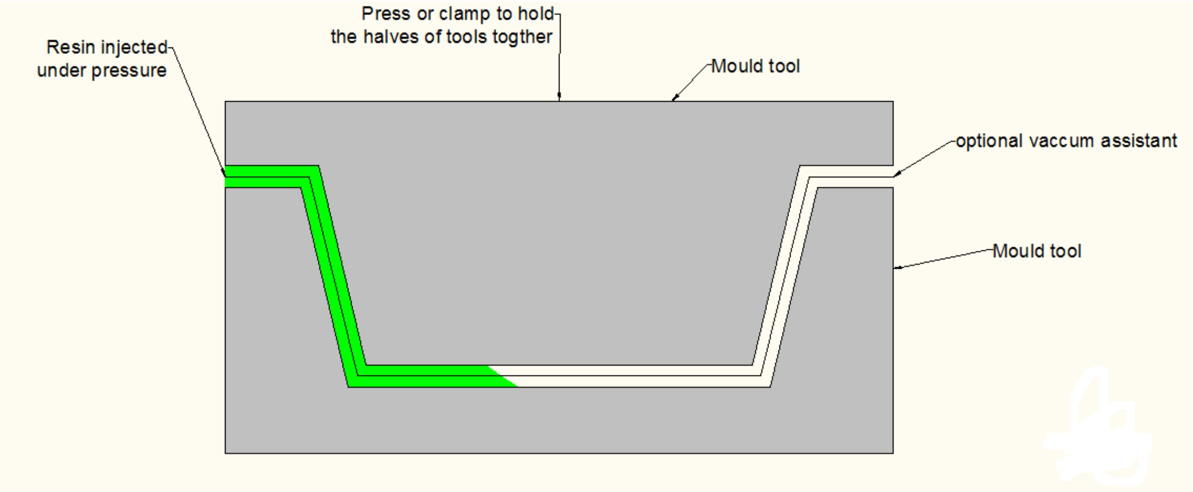


Fig. 1.16. Liquid composite process

Material options:

Resin: Generally epoxy, polyester, vinylester and phenolic, although high temperature resins such as bismaleimides can be used at elevated process temperatures.

Fibres: Any. Stitched materials work well in this process since the gaps allow rapid resin transport. Some specially developed fabrics can assist with resin flow.

Cores: Not honeycombs, since cells would fill with resin, and pressures involved can crush some foams.

Advantages:

- High fibre volume laminates can be obtained with very low void contents.
- Good health and safety, and environmental control due to enclosure of resin.
- Possible labour reductions.
- Both sides of the component have a moulded surfaces.

Disadvantages:

- Matched tooling is expensive, and heavy in order to withstand pressures.
- Generally limited to smaller components.
- Unimpregnated areas can occur resulting in very expensive scrap parts.

Applications:

Small complex aircraft and automotive components, train seats

UNIT II - RECIPROCATING MACHINE TOOLS

Planer, Shaper, slotter are reciprocating type machine tools, used to machine flat surface either horizontal, vertical and inclined surfaces by using single point cutting tool.

Movement	Planer	Shaper	Slotter
Table (Work	Reciprocates	Fixed	Fixed
Tool	Fixed	Reciprocates	Reciprocates
Feed	Given to cutting tool	Given to table	Given to work piece

PLANER MACHINE

Principles of Operation:

- ✓ Metal is cut during forward or cutting stroke.
- ✓ Feed is given at the end of the cutting stroke.
- ✓ During the return stroke no metal is removed and this is called idle stroke.
- ✓ Cutting stroke takes lower speed and return stroke has higher speed.
- ✓ The quick return of the table is obtained by quick return mechanism.

Types of Planer:

1. Double housing planer.
2. Open side planer.
3. Pit planer
4. Edge or plate planer.
5. Divided table planer.

DOUBLE HOUSING PLANER:

- ❖ This planer is high speed heavy duty machine.
- ❖ It is used to machine large table beds, table key ways, dove tails and sliding surfaces.
- ❖ It is used to machine work piece in both horizontal and vertical directions at the same time.

Parts:

- ➢ Bed
- ➢ Table
- ➢ Columns
- ➢ Cross Rail

➢ Tool Heads

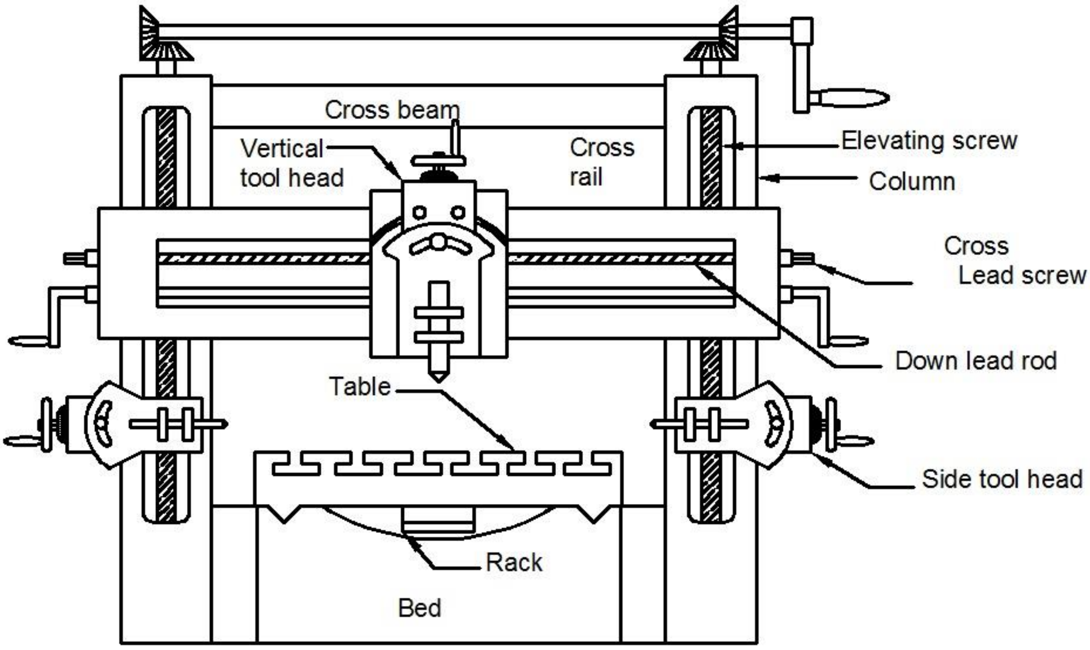


Fig. 2.1. Double Housing Planer

1. Bed

- Bed is strong box heavy type casting.
- It is strengthened by cross ribs on top "v" guide ways.
- Table reciprocates on these guide ways.
- It houses driving mechanisms.

2. Table

- Table is a box type rectangular casting and it has T-slots on its top.
- It reciprocates over the bed guide ways.
- Work pieces are clamped on the table by using T-bolts and clamps.
- The tip dogs are provided on the sides to adjust the stroke length of the table.

3. Housing or Column

- Two columns are mounted on the both sides of the bed.
- Two columns are connected by cross rail at top.
- Vertical guide ways are provided on the column and cross rail slides on it.
- Two side tool heads are slide on it.

- Feed mechanism and power transmission links are housed inside these columns.

4. **Cross rail**
   - Cross rail is a horizontal hollow structure.
   - It slides up and down vertically on the columns by elevating screw.
   - It carries tool feed arrangements.
   - Cross rail is clamped at any height.
5. **Tool head**
   - Totally four tool heads are in planer.
   - Two in cross rail and another two on vertical column.
   - They can have operated independently.
   - While machining inclined surface, the tool can be tilted to the required angle by tilting the swivel base.

Specifications of a planer:

1. Distance between the two columns
2. Dimensions of the table (l,b,t)
3. Maximum stroke length of table
4. Height from the top of the table of cross rail in its upper position.
5. Net weight of the machine
6. Type of drive
7. Floor area
8. Power of the motor

Planer Quick Return Mechanisms:

To move the planer table faster during the return strike, the following quick return mechanisms are used.

1. Belt drive
2. Electric drive
3. Hydraulic drive

Belt drive:

- This drive is used for smaller planers. An electric motor is used to drive a counter shaft, it is placed under the table.

- The shaft has two larger pulleys of same diameter and one smaller pulley. Open belt is connected to one pulley and cross belt is connected to another pulley.

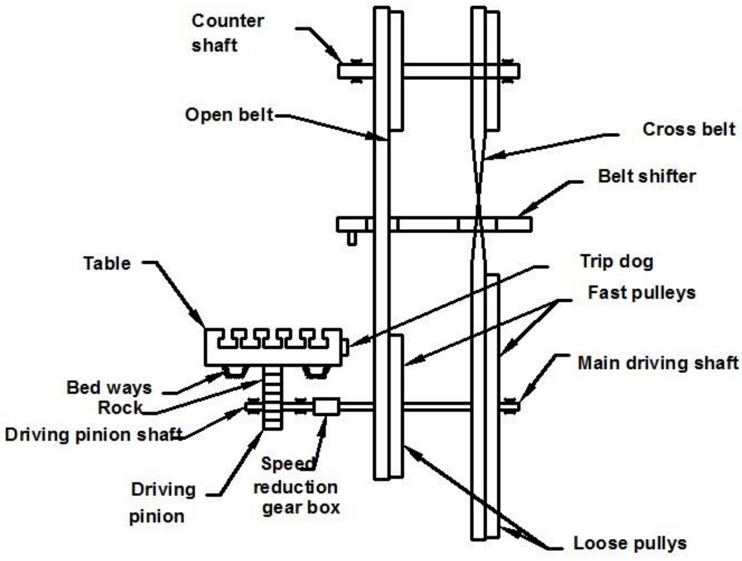


Fig. 2.2 Open & Cross belt drive mechanism

- Driving pinion is fitted to the one end of the shaft. One of the smaller pulley and one larger pulley is keyed to the shaft. They are called as fast pulleys.
- The other two pulleys rotate freely on the shaft. They are called loose pulleys.
- Driving shaft speed can be reduced by using a speed reduction gear box. The driving pinion meshes with the rack provided at the bottom of the table.
- The table reciprocates when the pinion rotates. The position of the open belt and cross belt is changed by a belt shifter.
- During the return stroke, cross belt is connected to the larger loose pulley and open belt is connected to the smaller fast pulleys.
- At the end of the return stroke, the trip dog pushes the belt shifter and both the belts are shifted to the right. Now cross belt connects the larger fast pulley and the open belt connects the smaller loose pulley.
- Next the drive is transmitted to the main shaft through the cross belt on the larger fast pulley. Due to this, the direction of rotation of main shaft is reversed.
- Due to the larger diameter of the pulley, the speed of main shaft is reduced. So, that the table moves slowly during the cutting stroke.

- At the end of the cutting stroke, both the belts are shifted to the previous position by another trip dog. Thus the return stroke and cutting stroke are obtained successively.

Electric drive:

- It is widely used modern method. AC motor is coupled with DC generator. DC generator supply current to variable DC motor.

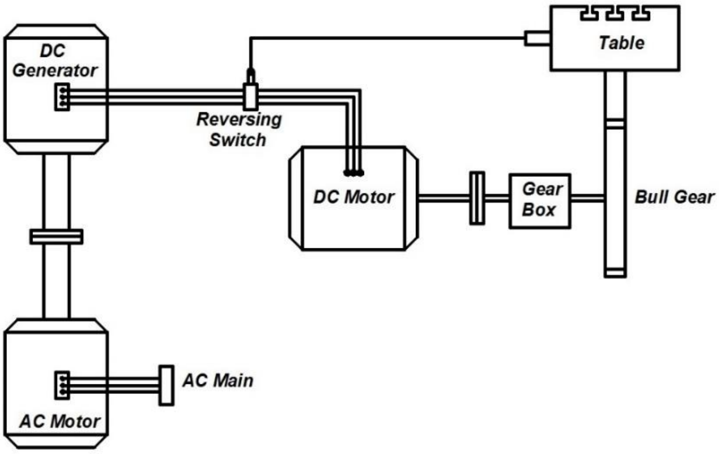


Fig. 2.3. Electric drive mechanism

- Reverse switch is used to change the current direction. DC motor transmit power to bull gear through gear box.
- Bull gear meshed with rack provided on table. Thus the table moves when the bull gear rotates slowly for forward cutting stroke.
- When power supply is given to AC motor, it rotates the DC generator and DC generator supplies current to DC motor. Then the table moves slowly for forward cutting stroke.
- After end of cutting stroke, the trip dog actuate reversing switch and faster return stroke.
- Due to this, DC generator supplies more current in opposite direction. Then DC motor rotates at high speed in opposite direction and table returns at faster speed.

Hydraulic drive:

- The planer table is fitted to piston and it reciprocates with hydraulic oil pressure. Hydraulic oil delivered to cylinder through 4-way valve from pump.

- Trip dogs change the direction of the oil flow in 4-way valve and table is reversed.

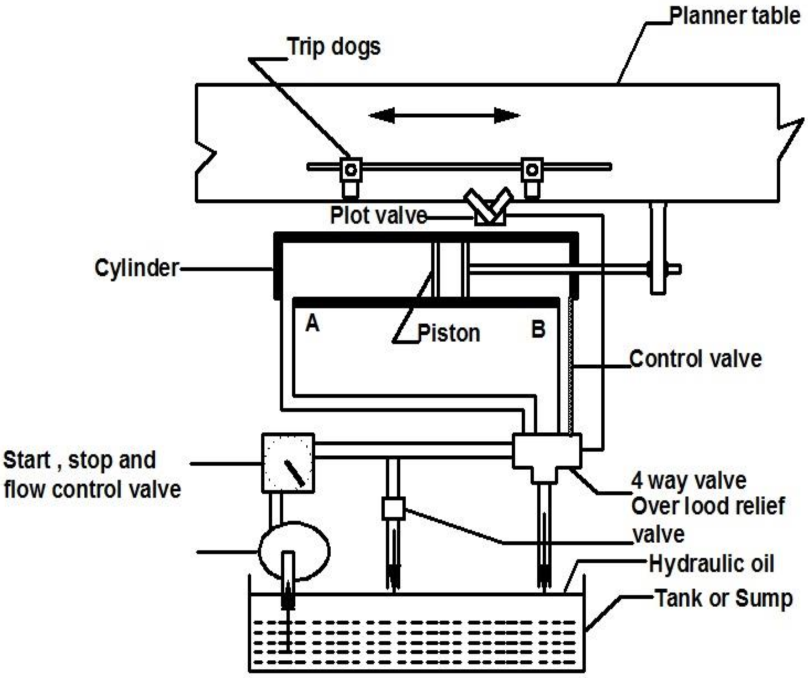


Fig. 2.4. Hydraulic drive mechanism

- During the cutting stroke, the oil enters in to the left side of the cylinder and pushes the piston to move to the right. Now the table moves slowly in forward direction. At the same time, oil in the right side flows to the oil sump through the valve.
- At the end of this stroke, the trip dog actuates the 4 way valve and intensity of pressure will be more compared with the intensity of pressure during forward stroke. Hence the return stroke is occurred at faster rate. Thus the quick return of the table is obtained. The stroke length can be adjusted by adjusting the distance between the trip dogs.

Feed mechanism:

Hand feed:

- The tool is moved in horizontal direction along the cross rail, then the feed is known as cross feed. The cross feed screw is rotated by a handle to move the tool head horizontally.
- The cross feed screw passes through a nut in the back side of the tool head.

- The tool is moved in downward direction is known as down feed. The down feed rod in the cross rail has sliding bevel gear. The bevel gear meshes with another bevel gear attached to the tool slides screw.
- When the down feed rod is rotated by a handle, the tool slide screw rotates and the tool head moves downward to give down feed.
  Refer the figure 2.3 for diagram

Automatic feed:

- A vertical splinted shaft is fixed on one side of the planer. A ratchet and pawl mechanism is keyed at the bottom of the shaft. At the end of each stroke, the trip dog hits the strike lever. This lever actuates the pawl plate in both directions.

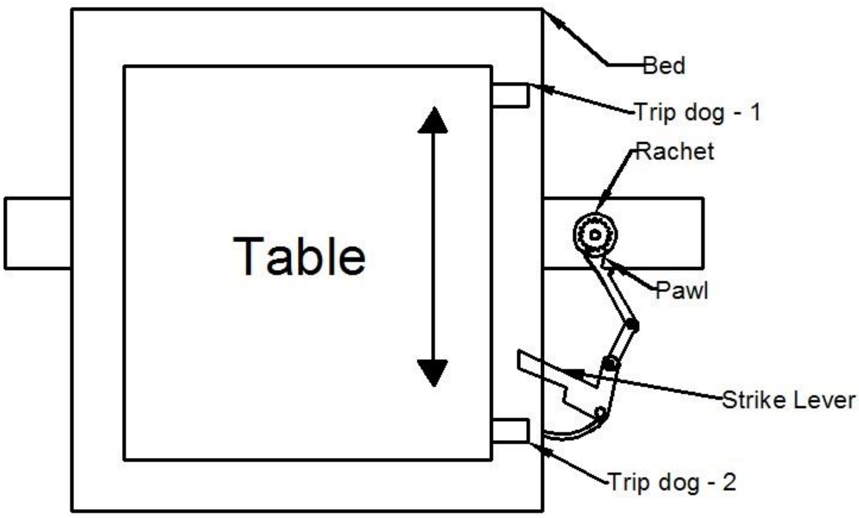


Fig. 2.5 Automatic feed mechanism

- The pawl plate rotates the ratchet when it is actuated in one direction and slips over the ratchet teeth when actuated in another direction. When the ratchet rotates, the splined shafts also rotates.
- There is a spur-bevel integral gear rotates freely on the down feed rod. This bevel gear is meshed with the bevel gear in the splined shaft. Another spur gear is keyed to the cross feed screw meshes with the spur-bevel integral gear.
- The rotation of the splined shaft is transmitted to the cross feed screw through these gears. The cross feed screw passes through a nut attached at the back side of the tool head. So the tool head moves horizontally along the cross rail when the cross feed screw rotates. Thus the automatic cross feed is obtained.

- For giving automatic down feed, the spur gear in the cross feed screw is disengaged by a lever. The spur-bevel integral gear is engaged with the down feed rod by inserting a key.
- Now the rotation of the splined shaft is transmitted to the down feed rod. Thus the automatic down feed is obtained.

Work holding devices:

1. Angle Plate.
2. Stop block.
3. Planer jacks & adjustable screw stop.
4. T bolt & strap clamps for long work pieces.
5. V blocks for cylindrical work pieces.
6. Fixtures.

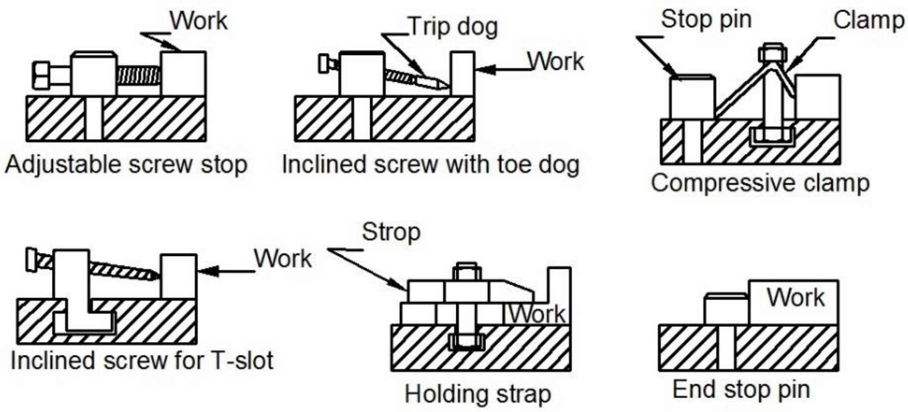


Fig. 2.6. Work holding devices

Setting of work pieces on the planer table requires high skill.

Planning fixtures:

- Planning fixtures are used to clamp the work piece identically.
- The Base of the fixture has two ‘V’ grooves to hold two round rods.
- ‘U’ clamps are inserted in the stand and work piece are clamped by using washer & nut.

Advantages:

- Setting time is reduced
- Production is increased.
- Accurate machining.
- Tolerance is less.

Types of tools:

- Single point cutting tool is used.
- For giving heavy cut, the tool must be heavier and larger.

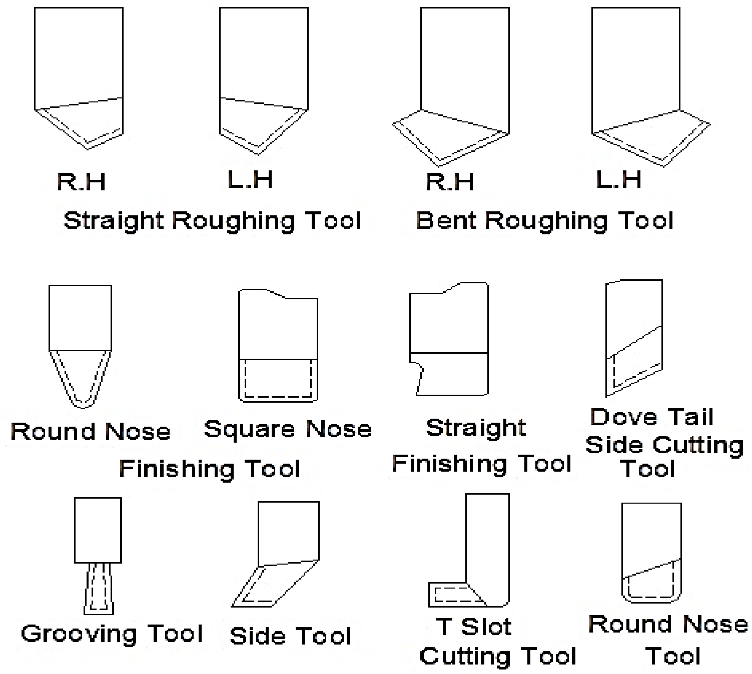


Fig. 2.7. Types of tool

Material:

- Solid
- Forged pit type
- HSS
- Tungsten carbide

Surface	Tool
Horizontal	RH or LH straight tool
Vertical	Bend tool (Down feed is given)
Finishing	Round nose
T slot	T slot cutting tool

Types of Planer operation:

- ✓ Machining Horizontal Surface
- ✓ Machining Vertical Surface
- ✓ Machining Angular Surface
- ✓ Machining ‘T’ Slots

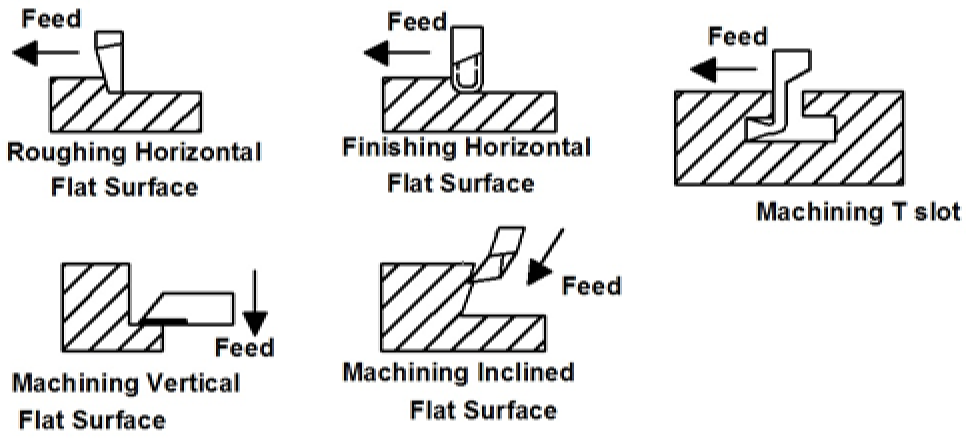


Fig. 2.8. Planer operations

SHAPER

Principle of Operation:

- ✓ It is a reciprocating machine tool used for flat machining.
- ✓ Also used for machining horizontal, vertical and inclined surfaces.
- ✓ Single point cutting tool is used and held in Ram.
- ✓ Ram reciprocates horizontally. Work piece is fixed on table.
- ✓ Metal is removed on forward stroke. Feed is given at end of cutting stroke.
- ✓ Metal is cut and removed by tool when ram reciprocates against work piece.

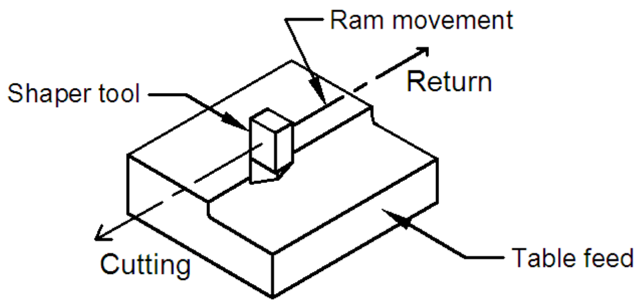


Fig. 2.9. Principle of operation

Types of shaper:

The shapers are classified as follows:

1. According to the type of driving mechanisms

    a) Crack and slotted link drive

    b) White worth mechanism

    c) Hydraulic drive

2. According to the travel of ram
    a) Horizontal shaper
    b) Vertical shaper
3. According to the type of table
    a) Standard or plain shaper
    b) Universal shaper
4. According to the type of cutting
    a) push cut shaper
    b) draw cut shaper

Standard Shaper:

Parts:

Base:

- It is made of CI and takes entire load.

Column:

- It is a hollow box and also made of CI.
- It is placed on base. It has quick return mechanism for ram and guide ways.
- Top of the column ram is fixed by dove tail guide ways.

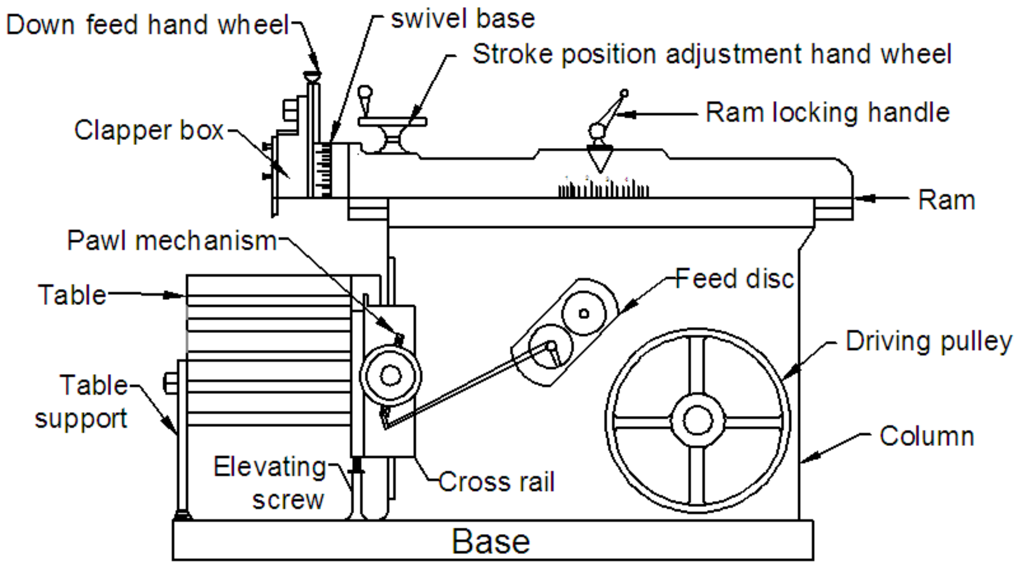


Fig. 2.10. Shaper

Cross rail:

- It is mounted on column.
- Horizontal guide ways are provided and called as saddle.

- The table slides over the saddle.
- The vertical movement of the cross rail elevating screw is provided.

Table:

- It is a rectangular and hollow CI block. It is slides on guide ways.
- It is supported by adjustable table support and it has T slots for clamping work piece.
- Table is moved in horizontally by rotating cross feed screw.
- Table is moved in vertically by rotating elevating screw.

Ram:

- It carries tool head at front end.
- Ram reciprocate along dove tail guide ways on the top of the column.
- It is connected to quick return mechanism.
- The length of the stroke of ram is adjusted by rotating hand wheel on ram.

Tool Head:

- It holds the tool. It has vertical slide and swivel base.
- Tool can be moved in vertical by rotating down feed screw and can be swiveled to the required angle.
- Vertical and angular feed can be given to tool head.
- Apron is fitted and it can be tilted to require position.

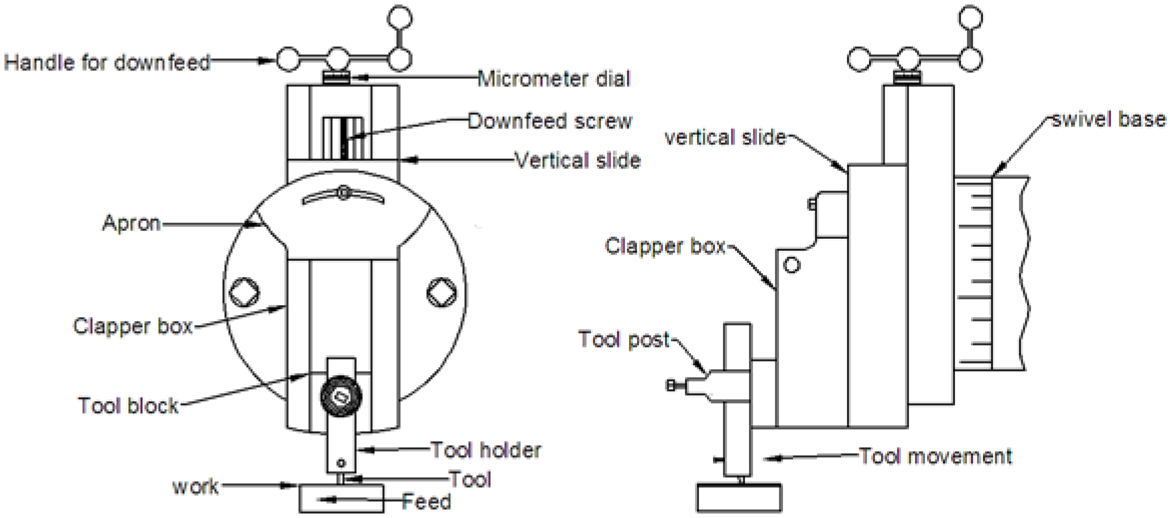


Fig. 2.11 Tool Head

- Apron has a clapper box and tool block is hinged inside in it.

- Tool block holds the tool. During the cutting stroke, the tool block fits rigidly inside the clapper box.
- During the return stroke, the tool block lifts out of the clapper box. This prevents the rubbing of the tool on the job.

Shaper specifications:

1. Maximum length of stroke
2. Maximum crosswise movement of the table
3. Maximum vertical movement of the table
4. Power of the motor
5. Type of driving mechanism
6. Ratio of cutting stroke time to return stroke time
7. Type of shaper – plain or universal
8. Net weight of the shaper
9. Floor space

Quick return mechanism:

- The metal is cut on the work piece in the forward cutting stroke.
- During the return stroke, no metal is cut and it is known as idle stroke.
- To reduce the total machining time, the time taken for the idle stroke must reduce.
- For this the return stroke is made faster than the cutting stroke and it is done by a mechanism called quick return mechanism.

Quick return of the ram can be obtained by the following quick return mechanisms.

1. Crank and slotted link mechanism
2. Whitworth mechanism
3. Hydraulic mechanism

1. Crank and slotted link mechanism:

- An electric motor is used to run the driving pinion at uniform speed and pinion rotates the bull gear at uniform speed.
- Bull gear is a large gear and it is fitted within the column. A slide is fitted along the diameter on the face of the bull gear.

- The bull gear sliding block can slide in the bull gear slide. Its position can be adjusted radially by rotating the stroke adjusting screw. This is done by rotating the bevel gears through a handle from outside.
- A crank pin is fitted to the bull gear sliding block. The rocker arm sliding block is fitted freely over the crank pin. The bottom end of the slotted link or rocker arm is pivoted.
- The upper end of the rocker arm is in the form of a fork. It is freely connected to the ram block by a pin. The slotted link has a slot in length wise. The rocker arm sliding block fits into this slot.
- When the bull gear rotates, the crank pin also rotates. The rocker arm sliding block also rotates on the crank pin circle. At this time, this sliding block slides up and down in the slot of the slotted link (rocker arm).
- It gives an oscillating movement to the rocker arm. It makes the ram to reciprocate.
- When the slotted links is in the position PA, the ram will be at the backward position (at the end of stroke). When the link is at PB, the ram will be at the forward position. PA and PB are tangential to crank pin circle.

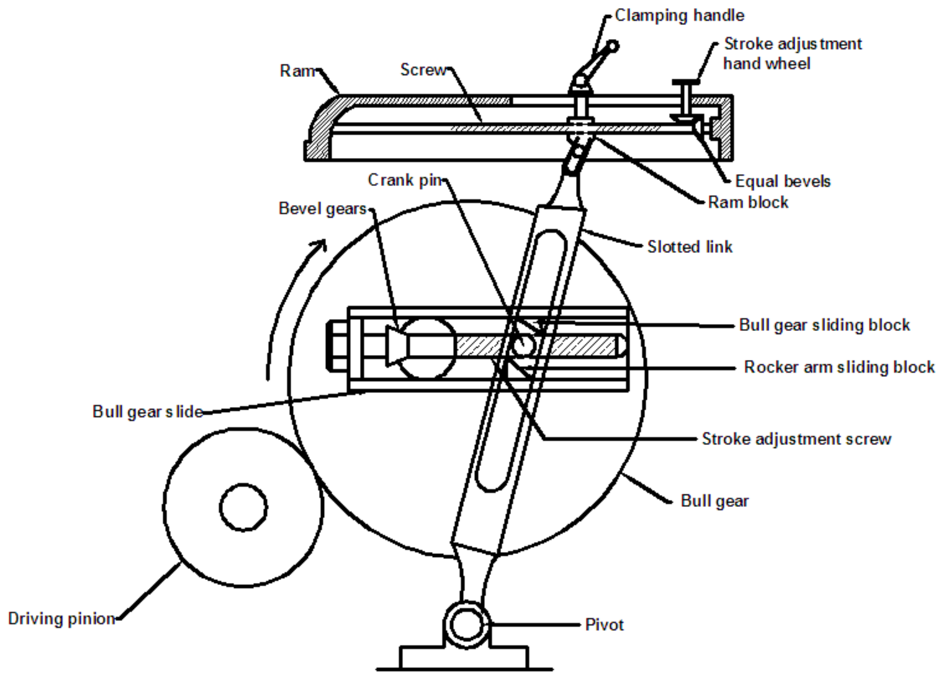


Fig. 2.12. Crank and slotted link mechanism-1

- The forward cutting stroke takes place when the crank pin rotates through the angle C1KC2. The return stroke takes place when the crank pin rotates through the angle C2LC1. Angle C1KC2 is larger than angle C2LC1. The speed of the bull gear is uniform. The length of stroke during forward stroke and return stroke are the same. So the return stroke will take a shorter time.

$$\frac{Cutting time}{Return time} = \frac{<C1\,KC2}{<C2\,LC1}$$

The ratio varies from 2:1 to 3:2

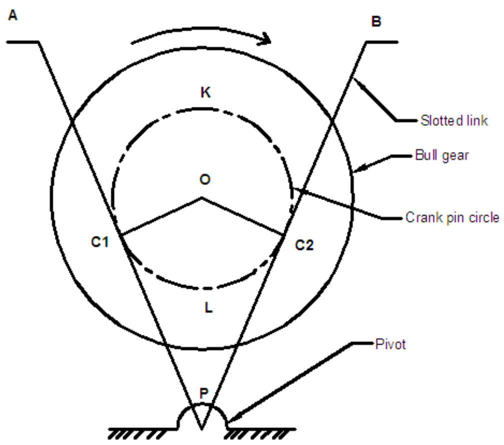


Fig. 2.13. Crank and slotted link mechanism-2

- Cutting speed is not uniform throughout the stroke length. It is minimum at the beginning and at the end of the stroke. It is maximum at the middle of the stroke.

For adjusting the Stroke position:

- The clamping handle on the ram is loosened first. The screw inside the ram will be rotated the stroking position adjustment handle.
- Now the ram moves forward or backward. After adjusting the position of ram, the clamping handle is tightened.

2. Whitworth Quick return mechanism

- An electric motor turns the driving gear at uniform speed and this gear rotates the bull gear at uniform speed.
- The driving pin (D) is fixed on the face of the bull gear. The driving pin fits into the slot in the driving crank. It rotates about the center of the bull gear 'O' and same time it slides along the slot of the driving crank.

- Due to this, the driving crank to rotate about its center P. When the pin D is at A, the ram is at its extreme backward position. When the bull gear rotates (anti clockwise) the pin travels through and angle α and reaches point B.

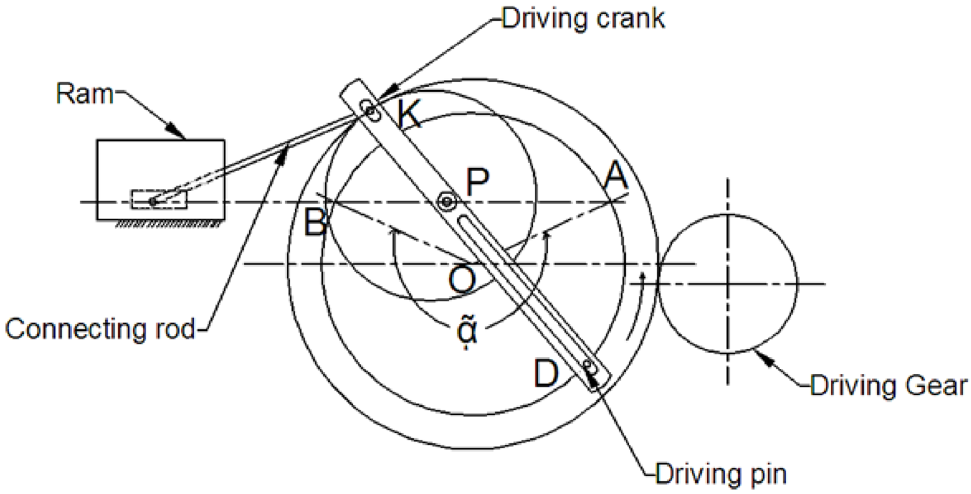


Fig. 2.14. Whitworth Quick return mechanism

- When D is at B, the ram is at its extreme forward position. So the cutting stroke takes place when the crank pin D moves through an angle α from B to A (anti clockwise) through an angle BKA, the return stroke takes place. The angle BKA is smaller than angle α. The speed of the bull gear is uniform.
- Hence the return stroke taking place through a smaller angle BKA will take shorter time.

3. Hydraulic drive

- A hydraulic cylinder is placed inside the hollow ram of the shaper. The cylinder is stationary. A piston moves inside the cylinder. It is connected to the ram by a piston rod.
- When piston moves inside the cylinder, the ram also moves. A gear pump pumps the oil from the reservoir at a constant rate. The oil passes through the 4-way control valve and enters the cylinder at side A.
- Because of the oil pressure, the piston moves forward. Cutting stroke takes place. The oil in the right side of the piston in the cylinder is pushed outside through B. It passes through the 4-way valve and reaches reservoir through the pipe C.

- The trip dog attached to the bottom of the ram shifts the valve lever from position P1. At the end of the forward stroke, the valve lever reaches position P2. Now the 4way valve allows the oil from the pump to enter the cylinder from the side B.

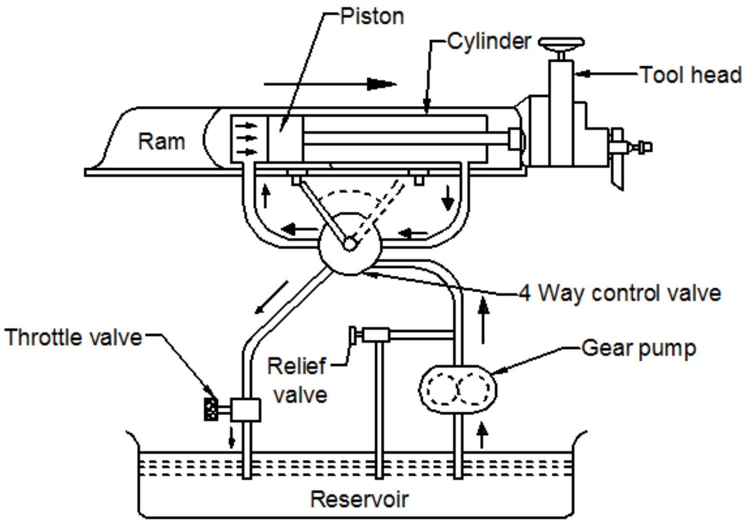


Fig. 2.15. Hydraulic drive

- The oil pressure pushes the piston backward. The ram completes its return stroke. The oil at the lift side of the piston is let out through A. It passes through the 4-way valve and reaches the reservoir through the pipe C. During the return stroke another trip dog shifts the valve lever from position P2 to P1. The cycle is repeated.

Feed mechanism:

In shaper, the feed is given at the end of return stroke. Cross feed is given by hand or automatically. For machining vertical and inclined surfaces, the down feed is given to the tool head by rotating the down feed screw by hand.

1. Hand feed

- When the table is moved horizontally in a direction perpendicular to the ram movement, it is called as cross feed. Cross feed can be given by rotating the cross feed screw with a handle. This screw passes through a nut fitted at the back side of the table.
- The table is adjusted vertically to hold work pieces of various heights. A horizontal rod with a bevel gear is meshed with the bevel gear in the elevating screw.

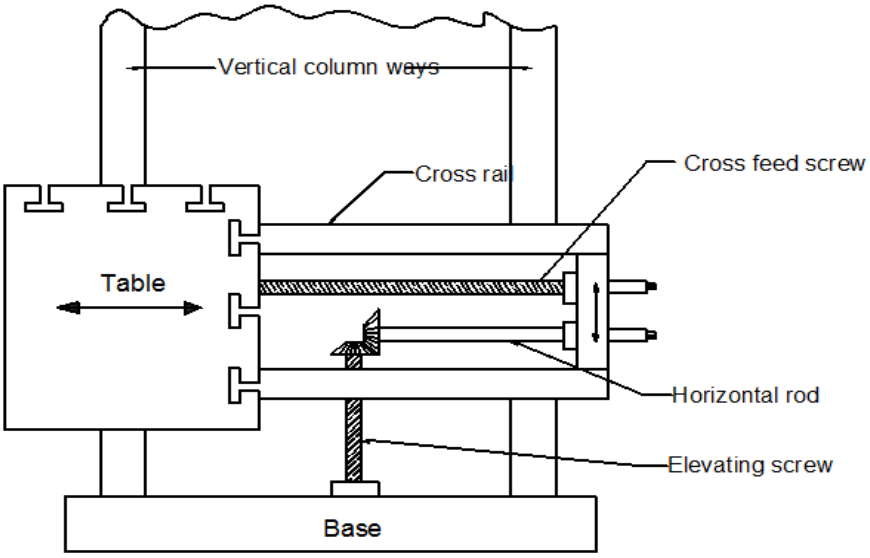


Fig. 2.16. Hand feed mechanism

- The table is moved by rotating the elevating screw through the horizontal rod. The downward movement of the tool is called down feed. Down feed is given to the tool side in the tool head by rotating the down feed screw by hand.

2. Automatic table feed

- The automatic feed mechanism used in the shaper is shown in the figure. A ratchet is keyed to the end of the cross feed screw. The rocker arm is provided at the centre of ratchet. The rocker arm has a spring loaded pawl on its top.
- One side of the pawl is straight and another side is slant. The bottom of the rocker arm is connected to a feed disc through a connecting rod. The feed disc gets drive from the bull gear.
- The feed disc has T-slots along its diameter. A crank pin fits in to this slot. The end of the connecting rod is fitted to the crank pin. When the bull gear rotates the feed disc also rotate. Now the rocker arm oscillates about the centre of the ratchet through the connecting rod.
- When the feed disc rotates half revolution in clock wise direction. The upper part of the rocker arm moves in clockwise direction. The straight side of the pawl fits in to the ratchet teeth and turns the ratchet in anti-clockwise direction.
- Now the ratchet rotates the feed screw. The table connected with feed screw horizontally. This feed is given to the table during return stroke only.

- To change the direction of table movement, the pawl pin is fitted up and turned through 180° and then seated back. As the straight side of the pawl is in opposite direction. This will rotate in opposite direction

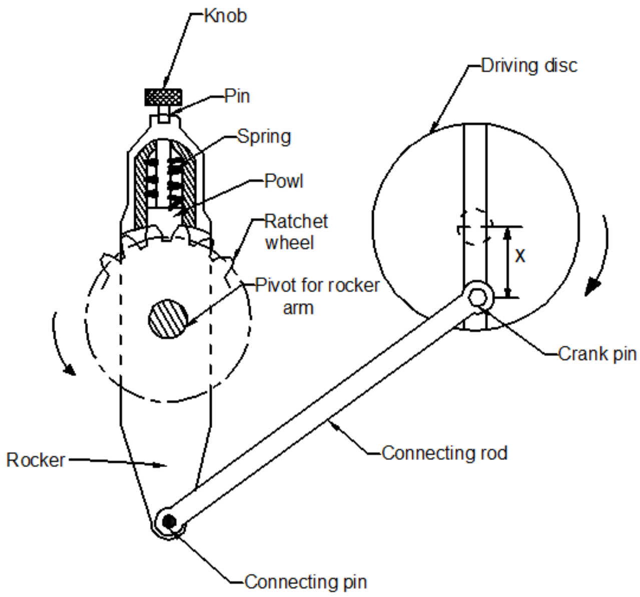


Fig. 2.17. Automatic feed mechanism

- This will rotate the feed screw in opposite direction. So the table movement is reversed. The amount of cross feed can be changed by changing the position of crank pin from the centre of feed disc in radial direction.

Work holding devices

The selection of work holding devices depends upon the type of operation, shape and size of the work piece. The following methods are used in a shaper clamp the work piece firmly.

1. Clamping in a vice
2. Clamping directly on the table
3. Clamping on an angle plate
4. Clamping over a V-block
5. Fixture

1. Clamping in vice:

- The vice is fitted on the table by means of T-bolts and nuts. The work piece is held in between the fixed and movable jaw.

- The work piece is clamped by tightening the screw. A graduated swivel base is provided in the bottom. The body of the vice can be swiveled to required angle. Vice is used to hold regular shaped work pieces quickly and easily.

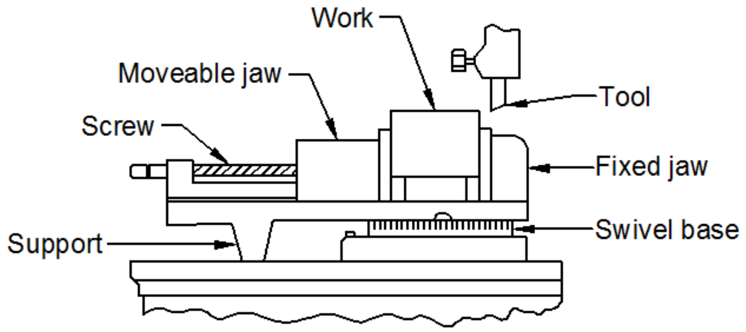


Fig. 2.18. Clamping in Vice

2. Clamping directly on the table - a) Using T-bolt and strap clamp

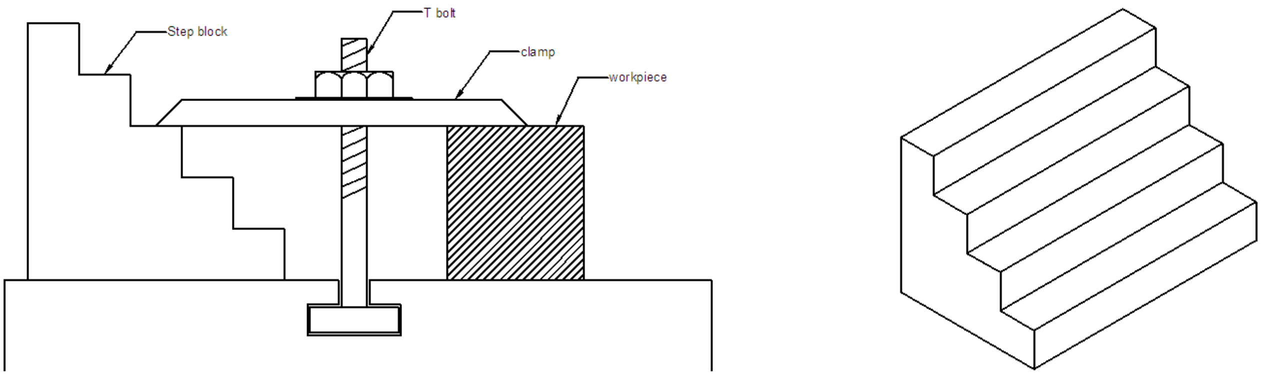


Fig. 2.19. Using T-bolt and strap clamp

- T-bolts are inserted in to the T-slot on the table. A strap clamp with a hole at its centre is inserted in to the bolt. One end of the clamp is made to rest on the Work piece and another end is on the step block. The work piece is clamped by tightening a nut on the bolt. Two or more T-bolt and clamps are used for clamping large work pieces.

b) Using wedge strip and stop pin

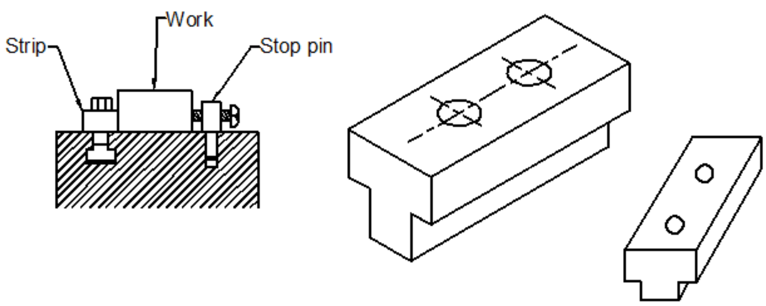


Fig. 2.20. Using wedge strip and stop pin

- This method is used for clamping large work pieces. A wedge strip has a long bar with tongue at its bottom and number of holes on its top. The tongue fits in to the T-slot of the table.
- The strip is tightened with the table by inserting T-bolts on the hole. The work piece is made to touch against the strip. A wedge block is placed on the other side of the work piece. Stop pin screws are tightened to clamp the work piece. A filler block is placed between the wedge block and stop pin to avoid the slipping of wedge block.

3. **Clamping on an angle plate**

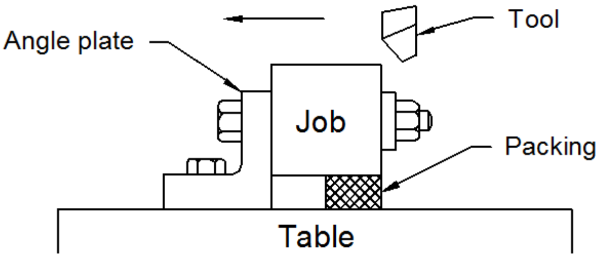


Fig. 2.21. Clamping on an angle plate

- This method is used for holding irregular shaped work pieces having holes. The angle plate is bolted to the vertical face of the angle plate by using bolts and nuts. Packing strips may be used for supporting the work piece at the bottom.

4. **Clamping over a 'V' block**

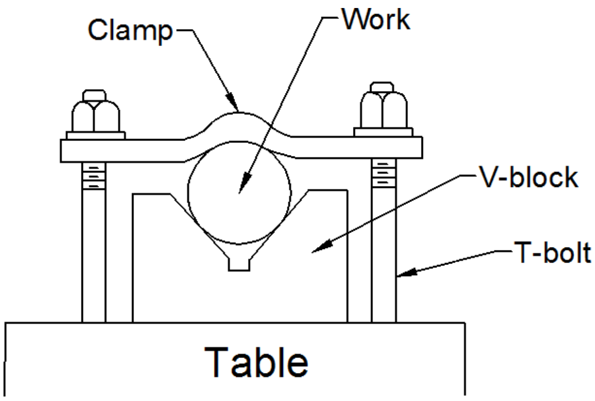


Fig. 2.22. Clamping over a 'V' block

- 'V' block is suitable for holding small cylindrical work pieces. The work pieces are held on the 'V' block and 'V' clamp is placed over it. The clamp is tightened by T-bolts and nuts for clamping the work piece firmly.

5. **Fixture**

- Fixture is a device used for clamping the work pieces easily and quickly. This reduces the setting time. As the work piece is exactly located, the machining can be done accurately. The productivity is considerably increased by using fixture in mass production.

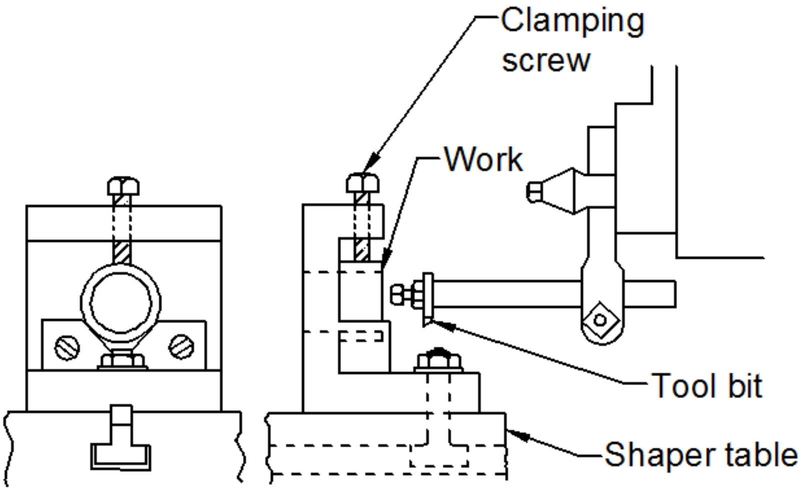


Fig. 2.23. Shaping Fixture

Types of shaping tools:

Single point cutting tools made of HSS or forged steel are used in shaper. The shaper tools are made heavier to withstand cutting forces and shock load. The shaper tools are classified as follows:

1. According to the shape
   Straight tool, cranked tool, goose necked tool
2. According to the movement of tool
   Left hand tool, right hand tool
3. According to the required surface finish
   Roughing tool, finishing tool
4. According to the type of operation
   Down cutting tool, parting off tool, side tool, squaring tool.
5. According to the shape of cutting edge
   Round nose tool, square nose tool

Shaping operation:

The various shaping operation done on a shaper are explained below.

1. **Machining horizontal surface**

- The work piece is held on the table by suitable work holding device. The table is moved vertically to a required height. The tool head is mounted vertically. The cutting tool is set in the tool post such that the tool is slightly inclined. This prevents the tool from rubbing over the machined surface of work piece during return stroke

- The stroke length is adjusted so that it will be 20mm longer than the work piece. The stroke position is adjusted so that the tool will have an approach of 12mm and an over travel of 8mm. the cutting aped and feed are selected suitably. Down feed is given by the rotating the down feed screw. The table is moved horizontally by the cross feed screw. Thus machining is done on the horizontal surface of the work piece.

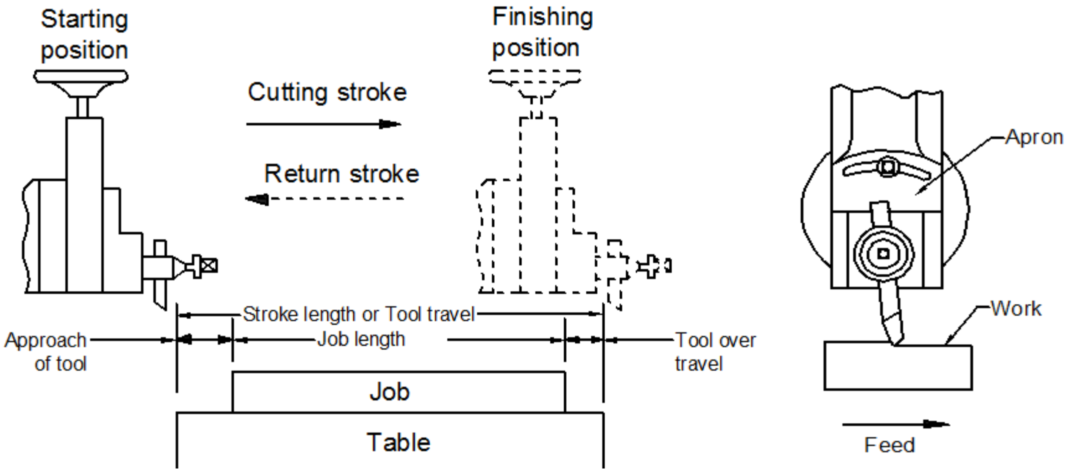


Fig. 2.24. Machining horizontal surface

2. Machining vertical surface

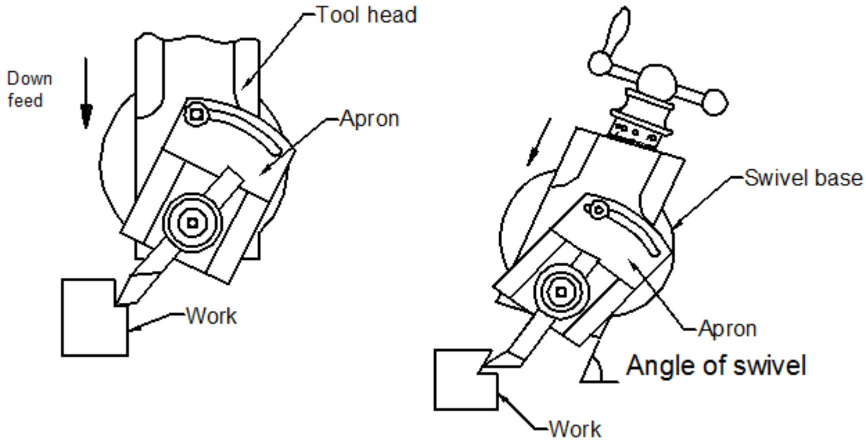


Fig. 2.25. Machining vertical surface and Machining angular surface

- The work piece is held on the table by suitable work holding device. The vertical surface to be machined is set parallel with the ram axis. A side cutting tool is fitted in the tool post with slight inclination. The apron is tilted so that it will be away from the surface to be machined.

- This prevents the tool from rubbing on the machined surface during return stroke. The cutting speed and feed are selected suitably. The depth of cut is given by moving the table horizontally. Feed is given to the tool by rotating down feed screw. Thus machining is done on the vertical surface of the work piece.

3. **Machining angular surface**
    - The work piece is held on the table by suitable work holding device. The vertical surface of the work piece is set parallel with the ram axis. The vertical slide in the tool head is swiveled to the required angle. The apron is tilted so that it will be away from the surface o be machined. The cutting speed and feed are selected suitably. The depth of cut given by moving the table horizontally. Angular down feed is given to the tool by rotating the down feed screw.
    - Dove tail and ‘V’ block can be made by angular machining. To make a dove tail, the vertical slide is tilted to the required angle and angular machining is done on the side. Then the vertical slide is tilted to the same angle on the other side and angular machining is done on that side.

Machining key ways, grooves and slots:

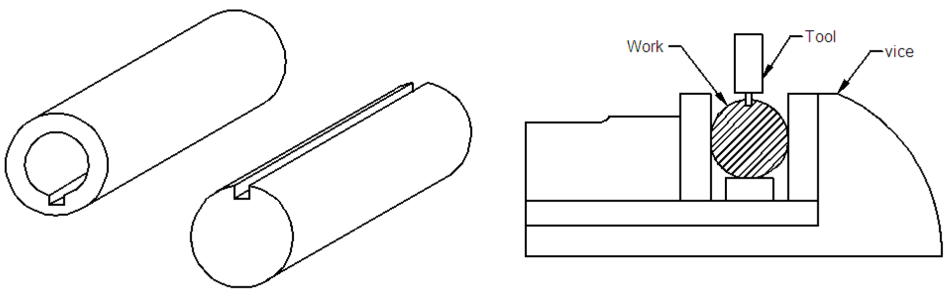


Fig. 2.26. Machining key ways, grooves and slots

- The square nose tool is used for cutting key way and slots. The arrangement for cutting key way piece is held on the table by suitable work holding device. Holes should be drilled at the ends of the key way required depth before machining.
- The stroke length and position are adjusted correctly. The machining is done at a slow speed. For cutting internal keyway, the tool is fitted in a special tool holder as shown in the figure.

Cutting speed:

Cutting speed is defined as the velocity at which the metal removed by the tool from the work piece. It is expressed in m/min.

Cutting speed = length of cutting stroke/ time taken for cutting = N x L (1+m)/1000 (m/min)

Where, N=Speed of bull gear (rpm)   L= Stroke length (mm)

M= Ratio between return time and cutting time (2/3 or ½)

Feed:

It is the relative movement of the tool or work piece in a direction perpendicular to the ram movement. It is expressed in mm/stroke. The feed is given at the end of the return stroke.

Depth of cut:

It is the thickness of metal removed in one stroke. It is expressed in mm. the depth of cut will be more for roughing operation and less for finishing operation.

Comparison of shaper and planer:

S#	Shaper	Planer
1.	Suitable for small and medium size work pieces.	Suitable for large and heavy work pieces.
2.	Tool reciprocates. Work piece is stationary.	Work piece reciprocates. Tool is stationary.
3.	Cross feed is given by moving the table.	Cross feed is given by moving the tool head.
4.	The machining accuracy is less due to the overhanging of ram.	The machining accuracy is more as the machine is grid.
5.	Heavy cut cannot be given.	Heavy cut can be given.
6.	Machining takes longer time as only one tool is used.	Machining can be done quickly as two or more tools are used.
7.	Only one work piece can be machined at a time.	Number of work piece can be machined at a time.
8.	Work piece can be clamped easily.	High skill is required for clamping the work piece.
9.	Heavy tool is not required.	Heavy tool is required.
10.	The cutting speed is not uniform throughout the stroke length.	The cutting speed is uniform throughout the stroke length.
11.	The cost of the machine is less.	The cost of the machine is more.
12.	Less floor space is sufficient.	More floor space is required.

SLOTTER:

Slotter:

1. **Base:**

It is a heavy casting made of cast iron. It supports all other parts of the slotter. Horizontal guide ways are provided on the base perpendicular to the column.

2. **Column:**

It is a hollow casting made integral with the base. The driving mechanism is placed inside the column. It has vertical guide ways on its front face. The ram slides on these guide ways.

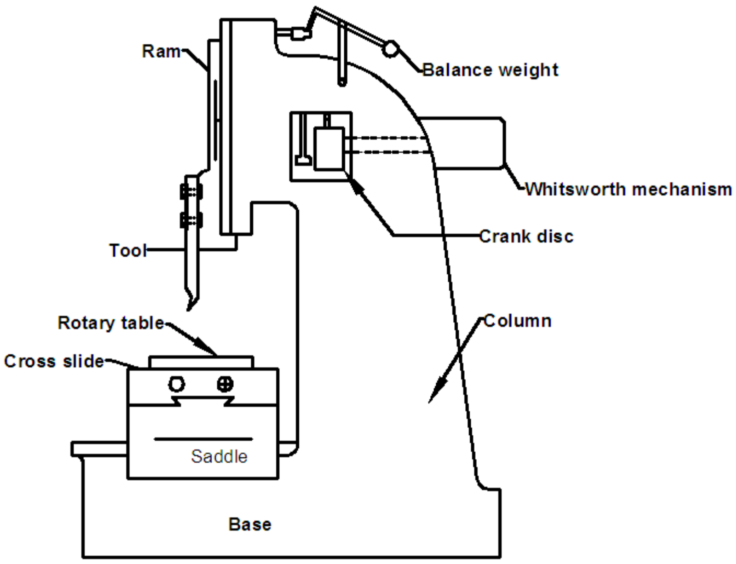


Fig. 2.27. Slotter

3. **Saddle:**

The saddle moves towards or away from the column along the guide ways provided on the base. The top face of saddle has guide ways perpendicular to the guide ways on the base. A cross slide moves crosswise along these guide ways.

4. **Rotary table:**

A circular rotary table is mounted on the top of the cross slide. It can be rotated about a vertical axis parallel with the column. The top of the table has T-slots for fitting the work holding device. The bottom of the table is graduated in degrees.

5. **Ram and tool head:**

The ram reciprocates along the guide ways provided on the face of the column. The ram has a tool head. The cutting tool is fitted in the tool head.

Specification of a slotter:

1. Maximum length of stroke
2. Diameter of circular table
3. The maximum crosswise and longitudinal movement of the table.
4. Type of drive.
5. Net weight of slotter
6. Power of the motor
7. Floor area

Method of operation:

Vertical and curved surfaces are machined by using slotter. Grooves and key ways can also be cut. A single point cutting tool is fitted in the tool head. The work piece is held on the table by suitable work holding device. The required stroke length I adjusted correctly. Metal is removed when the cutting tool reciprocates up and down against the work piece. The feed is given crosswise or in a circular path.

The metal is cut only in the cutting stroke (down ward movement of ram). Cross feed is given at the beginning of cutting stroke. During the return stroke (upward movement of ram), no metal is removed. Hence it is called idle stroke. Therefore, cutting stroke takes place at a slower speed and the return stroke takes place at faster speed. The quick return of the ram is obtained by a quick return mechanism. Various types of quick return mechanisms are used in slotter.

Quick return mechanism

In slotter, the rotary motion of the electric motor will be converted in to reciprocating motion of the ram. Moreover, the return stroke will be faster than the cutting stroke. This is done by any one of the following quick return mechanisms.

1. White worth quick return mechanism
2. Variable speed reversible electric motor drive
3. Hydraulic drive

Whit worth quick return mechanism:

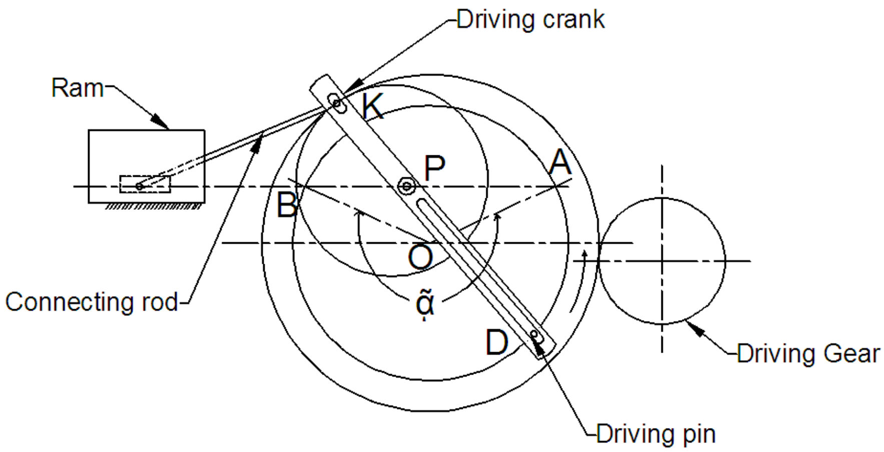


Fig. 2.28. Whit worth quick return mechanism - Slotter

The whit worth quick return mechanism generally used in slotter is shown in figure. An electric motor drives a pinion at constant speed. The pinion drives a bull gear at uniform speed. The bull gear has a crank pin fitted with a sliding block.

A crank plate is pivoted eccentrically on the bull gear at the point O by a pin. The crank plate has a slot along its length. The crank pin with sliding block slides along the slot of the crank plate. The other end of the crank plate is corrected to a connecting rod through a pin P. the ram is fitted to this connecting rod.

When the bull gear rotates, the crank pin rotates about its centre. At the same time, the sliding block slides along the slot of the crank plate. This makes the crank plate to rotate about the point O. thus the rotary motion of the crank plate is converted into the reciprocating motion of the ram to the connecting rod.

Quick return motion

In the figure, C1 and C2 represent those two extreme positions of crank pin with sliding block. During the cutting stroke, the crank pin rotates fromC1 to C2 in anti-clockwise direction through an angleØ1. During the return stroke, the crank pin rotates from C2 to C1 in anti-clockwise direction through an angle Ø2. The speed of the bull gear and the length of stroke during both the strokes are the same. Referring the figure, angle Ø2 is less than angle Ø1. So the time taken for the return stroke is less. Hence the ram moves faster during return stroke.

Feed mechanism

In slotter, the feed is given at the end of cutting stroke. The following feed movements can be given in a slotter.

1. Longitudinal feed: it is given by moving the saddle towards or away from the column.
2. Cross feed: it is given by moving the cross slide parallel to the face of the column.
3. Circular feed: it is obtained by rotating the table about a vertical axis parallel to the column. The feed may be given by hand or automatic.

Automatic feed mechanism

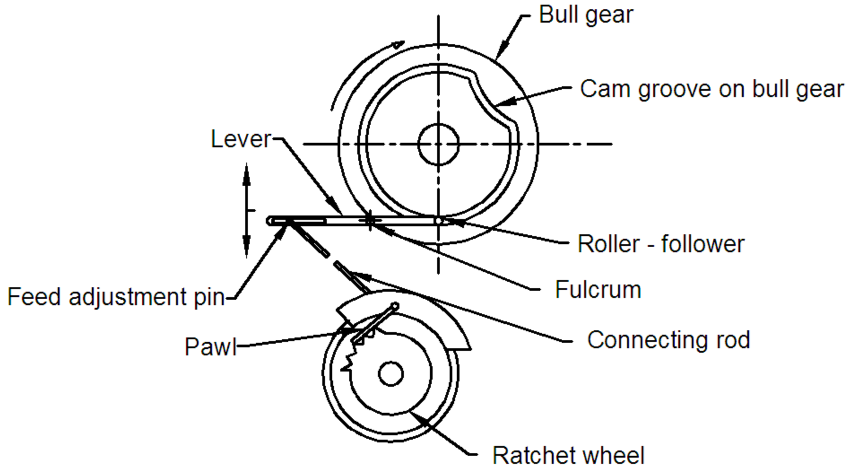


Fig. 2.29. Automatic feed mechanism

The auto feed mechanism used in the slotter is shown in the figure. A cam groove with lobe is cut on the face of the bull gear. A roller follower slides in this groove. The roller is fixed to a lever. The lever is pivoted at the middle. The other end of the lever has a slot. A feed adjustment pin is fitted in the slot. This pin is connected to the feed disc through a connecting rod.

The feed disc has a pawl on its face. The disc has a pawl on its face. The disc rotates freely on the feed shaft. A ratchet driven by the pawl is keyed to the feed disc. When the bull gear rotates, the roller follows the cam grooves. When the lope portion of the groove passes the roller, the lever moves up and down. This makes the connecting rod to rotate the feed disc in both directions.

When the feed disc rotates in anticlockwise direction, the pawl rotates the ratchet wheel. Hence the feed shaft rotates. When the feed disc rotates in clockwise direction, the pawl slips over the teeth of ratchet. Now the feed shaft will not rotate. The feed shaft can be engaged with required feed screw to obtain longitudinal, cross or circular feed. The amount of feed can be changed by adjusting the position the feed adjustment pin in the lever slot.

Work holding devices

The work holding devices used in shaper can be used in slotter. The work piece can be held on the slotter table by using vice, T-bolt and clamp and fixtures.

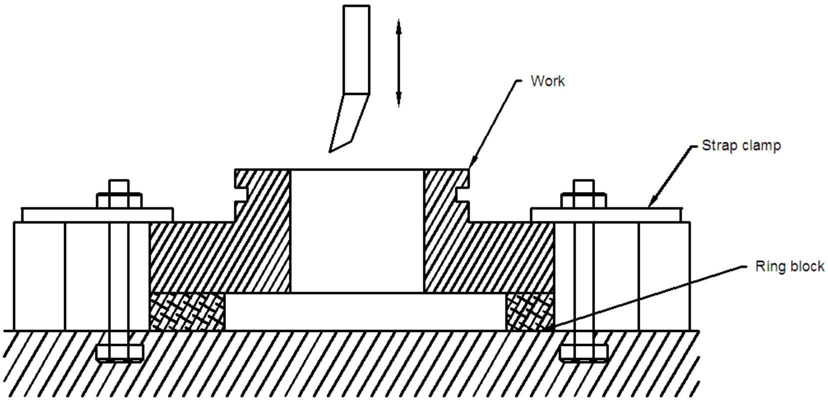


Fig. 2.30. Work holding by using T-bolt and clamp

The arrangement for holding a cylindrical work piece by using T-bolt and clamp is shown in the figure. Ring blocks of sufficient height is provided under the work piece for the over travel of the tool. The upper end of the work piece is clamped by using T-bolt and strap clamp. The centre of the work piece should be aligned with the axis of the rotary table.

Slotting fixtures:

A fixture used for cutting internal key way in a gear blank is shown in the figure. The gear blank is located by cylindrical locater. The cylindrical locater is correctly located by a pin provided at the centre of the travel. Thus the centre of the work piece is aligned with axis of the table. T- bolts and clamping plate are used for clamping the work piece.

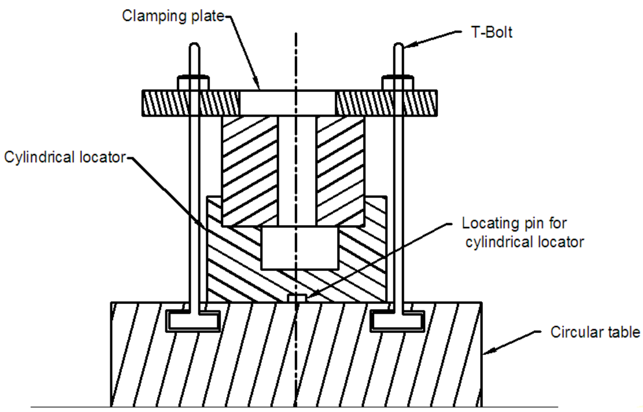


Fig. 2.31. Slotting fixtures

Slotter tools

The slotter tool is fitted vertically. The cutting forces act along the length of the tool. So the tool should have thick cross section.

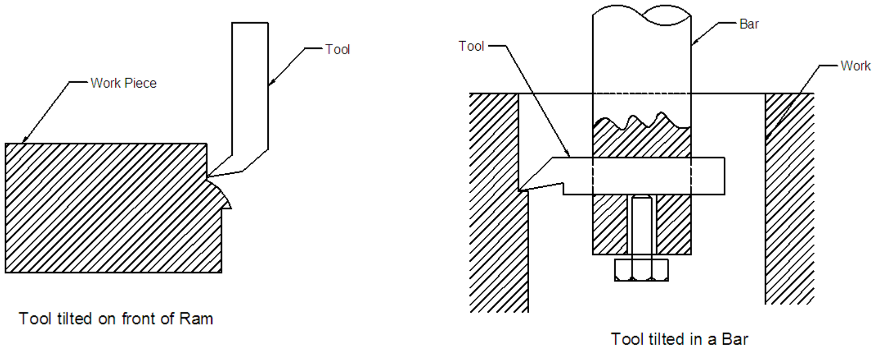


Fig. 2.32. Slotter tools

The tool is provided with front clearance angle, top rake angle and side clearance angle. No side rake angle is given. The nose of the tool is slightly bent away from the shank to give clearance during cutting. Forged type tools are generally used in slotter. The tool with slant cutting edge can be fitted directly in the ram. A straight tool holding bar is also used in slotter.

Slotter operations

The various operations performed in a slotter are explained below.

1. **Machining flat surface**

Ring block of sufficient height is provided for the over travel of the tool.

The work piece is held on the ring block and clamped by using suitable work holding device. The tool is fitted in the ram. The stroke length is adjusted according to the height of the work piece. Suitable cutting speed and feed are selected. Rotating movement of the table is locked. The depth of cut is given by moving the saddle. Feed is given by moving the cross slide parallel to the column. Thus machining is done on the vertical flat surface of the work piece.

2. **Machining grooves and keyways**

The key way to be machined is marked on the work piece. Ring block of sufficient height is provided on the table. The work piece is held on the ring block and clamped by using suitable work holding devices. The centre of the work piece is aligned in line with the centre of the travel. The tool having the width equal to the width of key way is fitted in the ram. The cutting speed, feed and length of stroke are suitably adjusted.

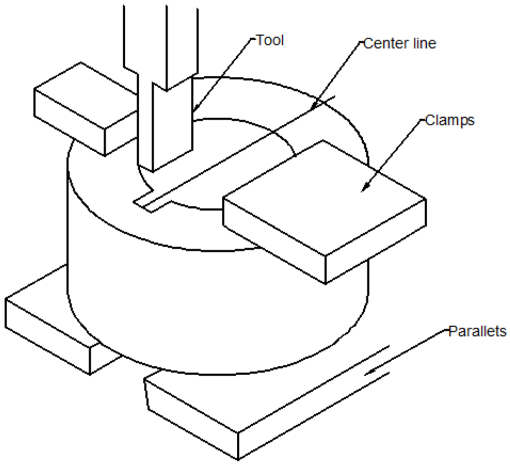


Fig. 2.33. Machining grooves and keyways

The key way and grooves of required length is cut by moving the cross slide. Number of key ways with regular intervals can be cut by indexing the circular table to required angle. Spindle shaft and spindle hole can be produced by this method.

3. **Machining curved surface**

The work piece is held on the circular table. The centre of the curved surface to be machined is aligned with the centre of the table. The depth of cut is given by moving the saddle. Then the movement of the saddle and cross slide is locked. The curved surface is machined by giving feed to the table.

BROACHING

It is a process of removing metal from a work piece using broach tool has multiple cutting edges arranged along its length. The broach tool has successively higher cutting edges in a fixed path and each tooth removes a particular amount of metal. The work piece is completed in one stroke of the machine. The metal removal rate is less in this operation. Broaching operation is suitable for machining external and internal surfaces.

SPECIFICATION OF A BROACHING MACHINE:

1. Maximum stroke length
2. Maximum force developed by the slide in Tons.
3. Type of drive for the straight line motion
4. Power of the motor
5. Weight of the machine
6. Floor space required

ADVANTAGES OF BROACHING:

- Roughing, Semi finishing and finishing cuts are completed in one pass of the broach.
- External and internal surface can be machined
- Suitable for mass production
- Semi-skilled operator can operate this machine
- Loading and unloading can be done very fatly.

LIMITATION OF BRIACHING:

- Initial cost if the tool is high.
- Broach tool is not suitable for removing large amount of metal.
- Not suitable for producing blind holes.
- Fixture is required for holding the work pieces.
- Not suitable for batch production.

TYPE OF BROACHING MACHINE:

1. According to the cutting motion
   a) Horizontal broaching b) Vertical and continuous broaching
2. According to the purpose
   a) Internal surface broaching b)External surface broaching
3. According to the method of operation
   a) Pull broaching b) Push broaching
4. According to the method of operation
   a) Solid broach b) Inserted c) Progressive cut
5. According to the function
   a) Key way broaching b) Spline broaching c) Surface broaching
6. According to the number of main spindle
   a) Single b) Double or multiple slides.

HORIZONTAL BROACHING MACHINE:

BED:

The type of machine has box type bed. The length of the bed is twice the length of stroke. Driving mechanisms are housed inside the bed.

Adopter:

Adopter is used for holding the work piece in the machine. Adopter is fitted at the front face of the machine.

Pulling head:

Pulling head is fitted in the front end of the ram.

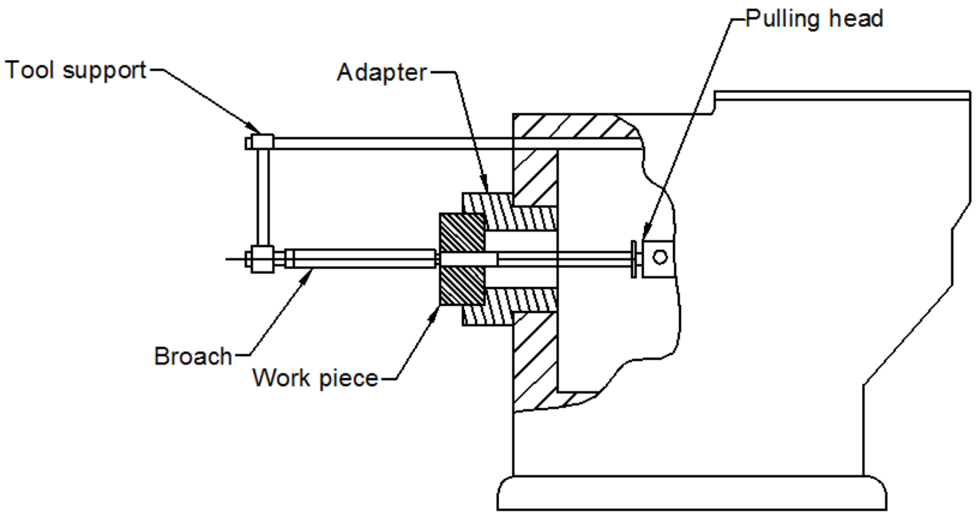


Fig. 2.34. Horizontal Broaching Machine

Ram:

- This part is connected with any one type of driving mechanism and reciprocates for machining.
- The rear end of the broach is supported by a guide. The broach is moved along the guide ways. Automatic stops are provided in this machine for controlling the length of the stroke of ram.
- Horizontal type internal broaching machine is used for small and medium sized works. This machine can be used for machining key ways, Splines, serrations and internal gears.

Horizontal type surface broaching machine:

In this type of machine, the broach is pulled over the top surface of the work piece held in the fixture on the worktable. The broaches are always connected in the draw head while doing surface broaching operation. The cutting speed of this machine is from 3 to 12 rpm and the return speed is upto 30 rpm.

VERTICAL BROACHING MACHINE:

The different types of vertical broaching machines are given below.

1. Pull type
2. Pull down type
3. Pull down type

1. Push down type vertical broaching machine:

This type of machine is used for surface broaching operation. It has a box shaped column, slide and drive mechanism. Broaching tool is mounted on slide which is on the column guide ways. A Hydraulic driving mechanism is used for controlling the slide movement. The broach tool with slides moves at various speeds and obtained by the driving mechanism.

The table is mounted on the base in front of the column. The fixture is clamped to the table. The work piece is fixed in the fixture. Table is moved for the broaching operation and clamped. Then the slide with the broach is moved downwards for broaching the work piece.

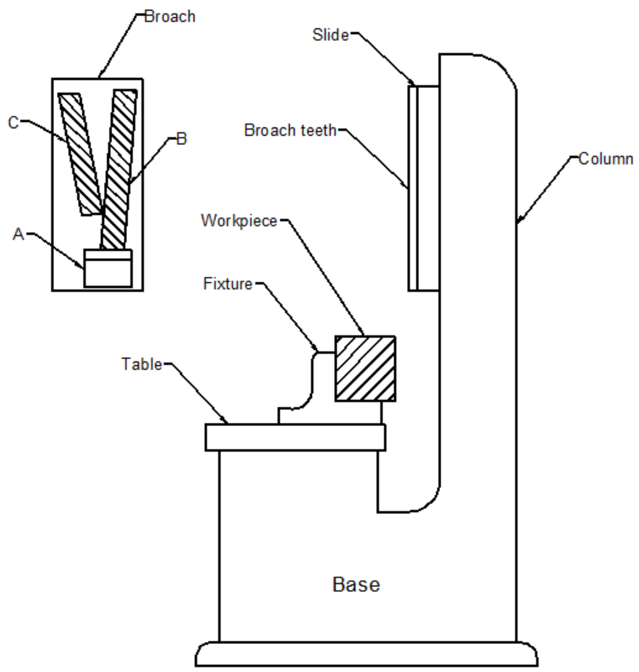


Fig. 2.35. Push down type vertical broaching machine

2. Pull down type vertical broaching machine:

Mostly, this machine is used for internal broaching. The broach is pulled through the job by the machine. The work piece is held in the fixture. The fixture is clamped on the table. The broach tool is automatically engaged by pulley mechanism and it is pulled down through the job. Then the broach returns to its beginning position after the completion of the operation.

3. Pull up type vertical broaching machine:

In this method, the ram slides on the vertical column of the machine. A pulling head is fitted at the bottom of the ram. The broach is in the base of the machine. The pulling mechanism is above the work table. The broach enters the job held against the underside of the table and it is pulled upward. The work piece falls down after the end of the operation.

CONTINUOUS BROACHING

The machines are used for producing small size work pieces with large quantity and available in three types. They are the following

1. Horizontal 2. Vertical 3. Rotary type

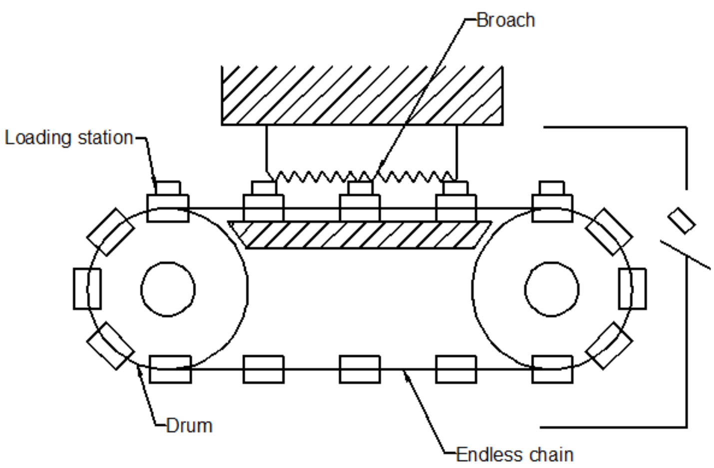


Fig. 2.36. Continuous Broaching

1. Horizontal continuous broaching machine

This machine is a surface broaching machine. It has a driving unit with two sprockets. They are connected by an endless chain. Fixtures are mounted at the interval on the chain. The work pieces are held in that fixture. The broach tool is fixed horizontally in the frame of the machine. A guiding member is arranged under the chain in the place where the work piece passes under the broach.

The endless chain moves continuously when operating the motor. When the fixture passes the loading station, the operator will put the work piece in the fixture and the part is automatically clamped before it reaches the tunnel. The broaching operation is carried out when the work piece moved under the broach. After completion of the operation, the work pieces are automatically released by a cam and they fall out from the fixture at the unloading point.

2. Vertical continuous broaching machine

In this machine, the exes of the two sprockets are vertical. So it is called vertical broaching machine. It works like a horizontal continuous broaching machine. The broach tool is placed vertically on the frame of the machine.

3. Rotary type continuous broaching machine

Rotary table and vertical column are provided in this machine. Fixtures are continuously arranged on the rotary table for holding the work piece. They move past the stationary broach. This machine is suitable for the broaching of small parts.

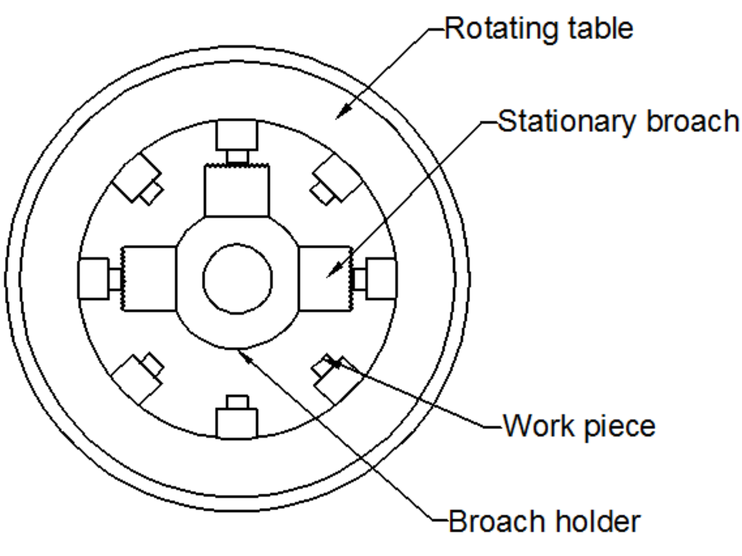


Fig. 2.37. Rotary type continuous broaching machine

TOOL NOMENCLATURE:

A series of teeth is provided in the broach. Every tooth height is slightly higher than the previous one. This rise per tooth is the feed per tooth. Normally a broach tool has three sets of teeth. They are given below.

1. **Roughing teeth:**

   These teeth remove maximum metal from the work piece and have highest rise per tooth.

2. **Semi-finished teeth:**

   These teeth remove smaller amount of metal when comparing to the roughing teeth. Because the teeth have slightly smaller in rise per tooth than the previous one.

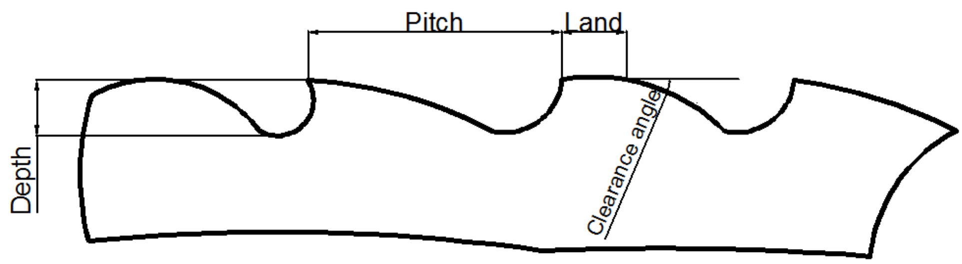


Fig. 2.38. Broach Nomenclature

3. **Finishing teeth:**

   These are the last set of teeth used for finishing the surface. These teeth remove very little amount of material. These teeth are all in the same size.

4. **Pull end**

   This is an end and it is connected to the pulling head of the broaching machine.

5. **Front pilot**

   Front pilot is for locating the broach centrally with the hole to be broached.

6. **Rear pilot and follower grip**

   This part gives the support to the broach after the last tooth leaves the surface.

7. **Land**

   The top portion of the teeth is called Land.

8. **Pitch**

   The distance between one teeth to another tooth is called pitch.

9. **Clearance angle**

   It is the relief angle on the land.

TYPES OF BROACHING TOOLS

Broaching tools are classified in the following

1. According to the method of operation
   a. Push broaching
   b. Pull broaching

2. According to the type of operation
    a. Internal broaching
    b. External broaching
3. According to their construction
    a. Solid broach
    b. Built up broach
    c. Inserted tooth broach
    d. Overlapping broach
    e. Progressive cut broach

1. Push broaching tool:

This is used in push type broaching machine. The broach is pushed through work piece during broaching. The broach is made shorter to avoid the bending when the compressive load acts on it while broaching.

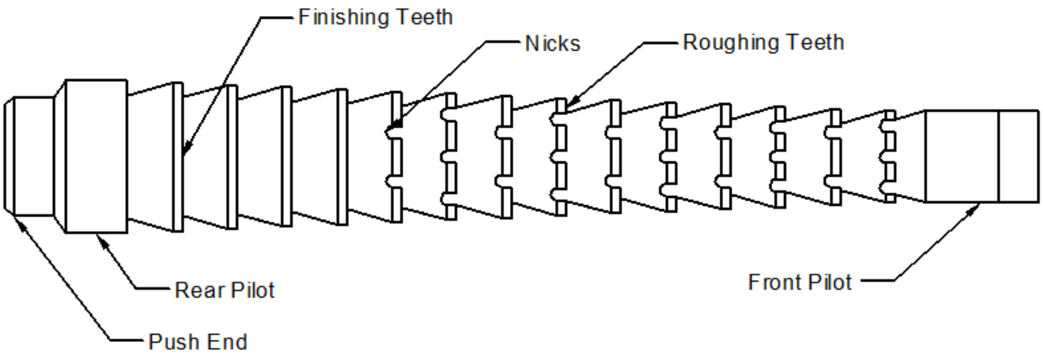


Fig. 2.39. Push Broach

2. Pull broach:

This broach is pulled through the work piece during broaching. So there are no chances for bending of tool. This broach is made lengthier.

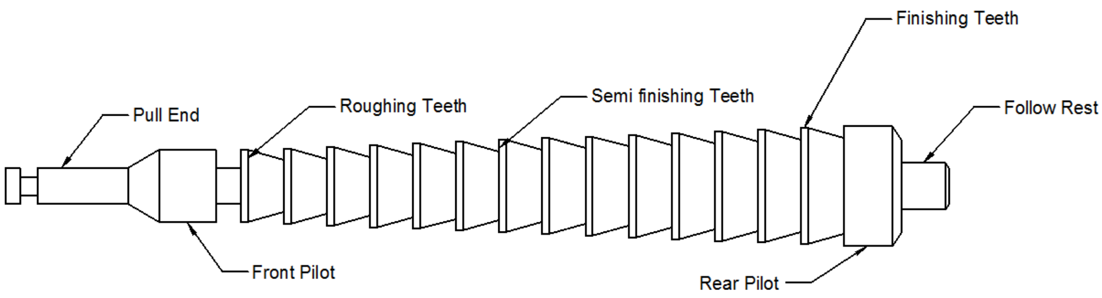


Fig. 2.40. Pull Broach

3. **Solid broach**

Solid broach is manufactured in one part. Internal broaches belong to solid type.

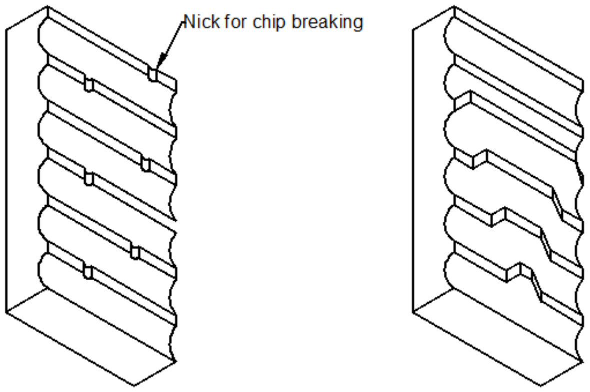


Fig. 2.41. Solid Broach and Progressive Broach

4. **Progressive:**

The teeth of the progressive broach are made with same height and different width. The last set of teeth of progressive broach removes very little amount of metal. The width of the finishing teeth finishes the surface.

BROACHING OPERATIONS:

The various types of broaching operations are given below

1. **Broaching the splines:**

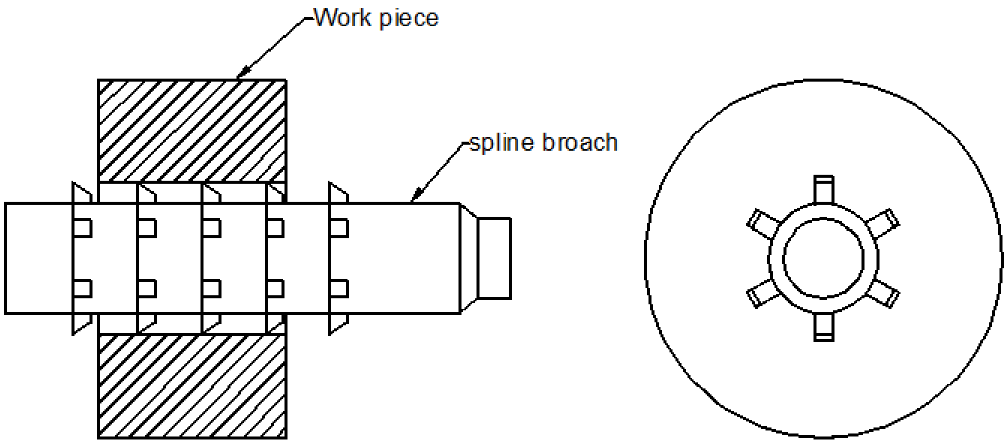


Fig. 2.42. Broaching the splines

A hole with a number of slots is called splines. Spline broaching is very similar to the key way broaching. The broach has four or more rows of teeth on its periphery according to the splines to be produced. The work piece is clamped on the fixture. The broach is inserted in the hole of the work and pulled throughout the work piece. Internal broaching machine is used for this operation.

2. Broaching a keyway:

This operation is also done on internal broaching machines. The guide of the broach is supported by a standard guide bushing with a rectangular slot. Bushing is placed in the bore of the work piece and the front pilot of the broach is pushed in the slot until the first tooth touches the work piece. Then the broach is pushed throughout the work piece for broaching the key way. The same procedure is repeated up to getting the required depth of key way.

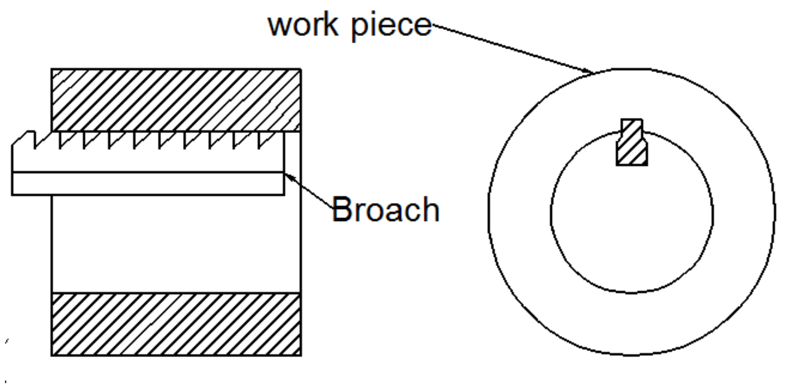


Fig. 2.43. Broaching a keyway

3. Surface broaching:

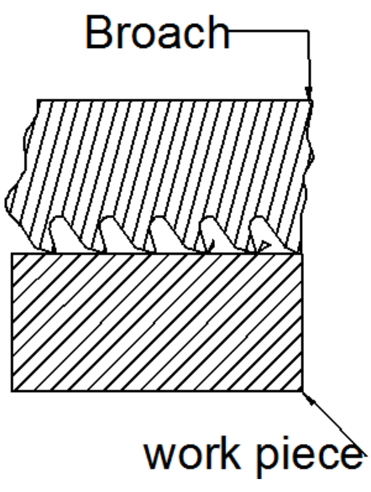


Fig. 2.44. Surface broaching

A push type solid broach is used in a vertical broaching machine. Progressive broach is also used for surfaced broaching the work piece held in a fixture on the machine table then the broach is passed on the work piece and the work piece is broached in the one pass of the broach because the width of the broach is more than the width of the work piece.

4. Hole broaching

This operation is done on a cylindrical work piece. A push type round broach is used in vertical broaching machine. The work piece is held on the fixture or table. Then the broach is pushed on the work piece hole. Roughing and semi-finished teeth remove more amount of metal form the work piece and finally the finishing teeth of the broach finishes the hole of the required shape.

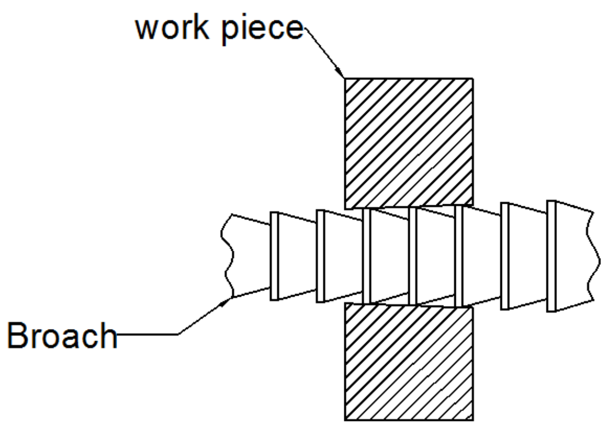


Fig. 2.45. Hole broaching

UNIT III - MILLING MACHINES

Milling is the process of removing metal by a rotating multipoint cutter. The work is fed past the cutter. The metal is removed in the form of small chips. As multipoint cutter is used, metal removal is very fast. One or more number of cutters can be used at a time. Milling produces a good surface finish. The accuracy is high. Hence milling machines are used for production works.

Principles of Operation:

The milling machine has a rotating cutter. The cutter is mounted on a rotating spindle or arbor. The cutter has multiple cutting edges. The work piece is clamped on the table. The cutter rotates at the required cutting speed. The work piece is feed slowly past the cutter. The feed may be longitudinal, cross wise or vertical. Angular feed can also be given in certain milling machines.

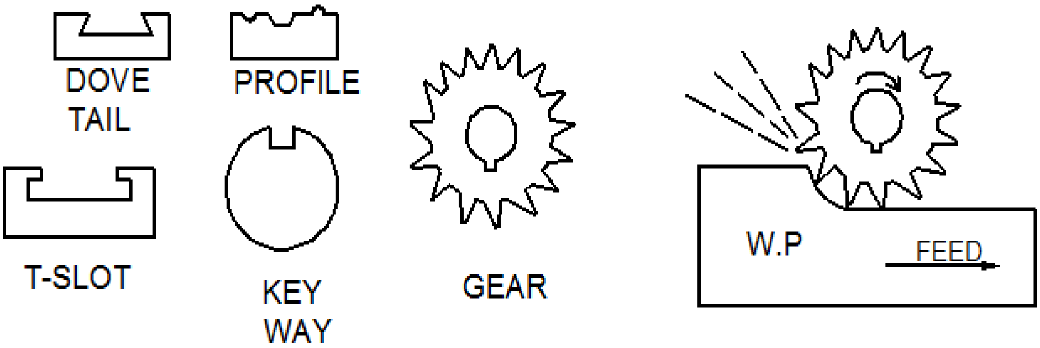


Fig. 3.1. Principles of Operation

As the work is feed, the cutting edges remove metal from the work piece in the form of chips. During the cutting, each cutting edge cuts metal only during a part of the cutter revolution. So in the remaining part of the cutter revolution the cutting edge rotates idle and can cool off. Therefore, the stress on the cutting edge is not continuous. So the cutting will be effective.

Types of Milling Machine:

The milling machines are classified as follows:

I) Column and knee type.

  i. Plain milling machine.
  ii. Universal milling machine.
  iii. Om universal milling machine.
  iv. Vertical milling machine.

II) Plano miller

III) Manufacturing or fixed bed type milling machine.

IV) Special type

i. Rotary table milling machine.
ii. Drum type milling machine.
iii. Planetary milling machine.
iv. Pantograph milling machine.

Column and knee type milling machine:

Column and knee type milling machines are most commonly used. This type of milling machine has vertical column on its base. The column has machined guide ways on its front face. The knee is mounted on this column. The knee can slide up and down on the guide ways of the column. The knee carries the saddle and work table. The column and knee type machines are general purpose machines. Different varieties of jobs can be done on these machines.

Plain milling machine:

Plain milling machine is also known as horizontal milling machine, since the spindle of the machine is horizontal.

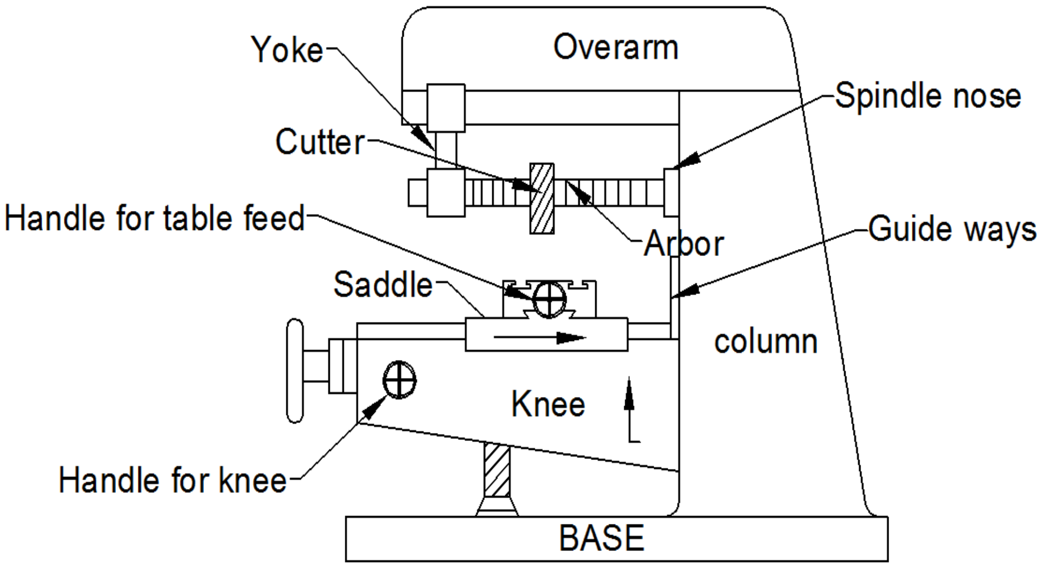


Fig. 3.2 Plain Milling Machine

There is a vertical column on the base. The column houses the main drive and the spindle. The column has vertical dovetail guide ways on its front face. The knee can move vertically on these guide ways. This is done by rotating the elevating screw. The knee at its top has horizontal dove-tail guide ways perpendicular to the front face of the column. The saddle can slide on these guide ways away from the column or towards the column. The top of the saddle has horizontal guide ways parallel to the face of the column.

The table travels longitudinally along these guide ways. The longitudinal travel of the table is perpendicular to the axis of the spindle. The top surface of the table is accurately machined. There are T-slots along the length of the table for holding the work.

The vertical movement of knee, crosswise movement of the saddle and the longitudinal movement of table can be obtained by hand or power. The knee houses the feeding mechanism. The spindle of the machine is located in the upper part of the column. It is rotated by an electric motor through belts and gear.

The front end of the spindle is called nose. The nose just projects from the column face. It has tapered hole. Arbors or various cutting tools can be inserted into this hole. There is an over arm mounted on the top of the column. It acts as support for the arbor. The over arm supports the arbor by means of yoke.

Universal milling machine:

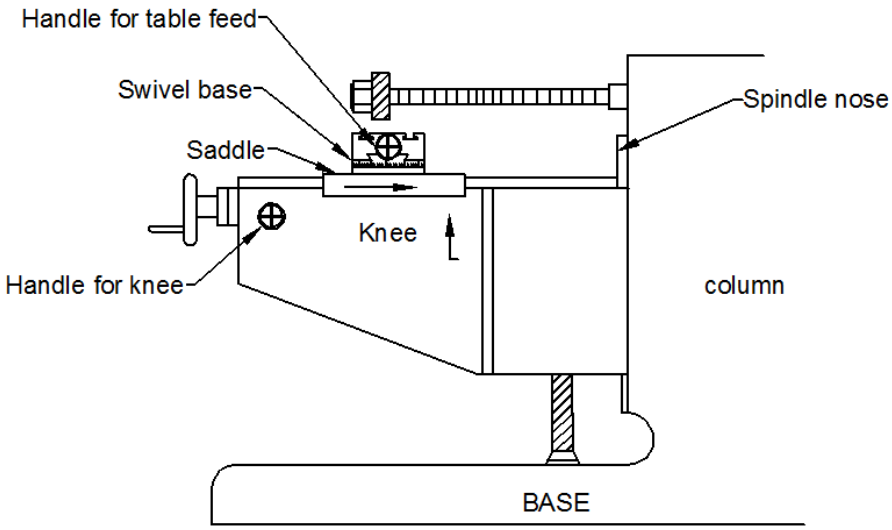


Fig. 3.3. Universal milling machine

The Universal milling machine is similar in all respects to the horizontal plain milling machine except for additional swiveling movement for table. The table is mounted on a swivel base. The swivel base has got degree graduations. The table can be swiveled about a vertical axis. It can be swiveled up to a maximum of 45˚ on either side of the normal position.

Thus the universal milling machine table has the following movements:

- ✓ Vertical movement – through the knee
- ✓ Cross wise movement – through the saddle

- ✓ Longitudinal movement of the table.

Angular movement of the table – by swiveling the table on the swivel base. By swiveling the table, the work can be fed at an angle to spindle axis. This is used in helical milling operations.

Special attachments like dividing head, Vertical milling attachment, and rotary table attachment are used in the universal milling machines. Using these attachments, the machine can procedure spur gear, helical gear, bevel gear, twist drill and reamers.

Omniversal milling machine:

The table of this machine has all the four movements of the universal milling machine. In addition, it has one more adjustment for the table. The table can also be swiveled about a horizontal axis "XX" parallel to the spindle.

In this machine, the knee has a swiveling arrangement. Using additional swiveling movement, we can machine tapered spiral grooves in reamers, bevel gears etc. Universal milling machine is a tool room machine.

Vertical milling machine:

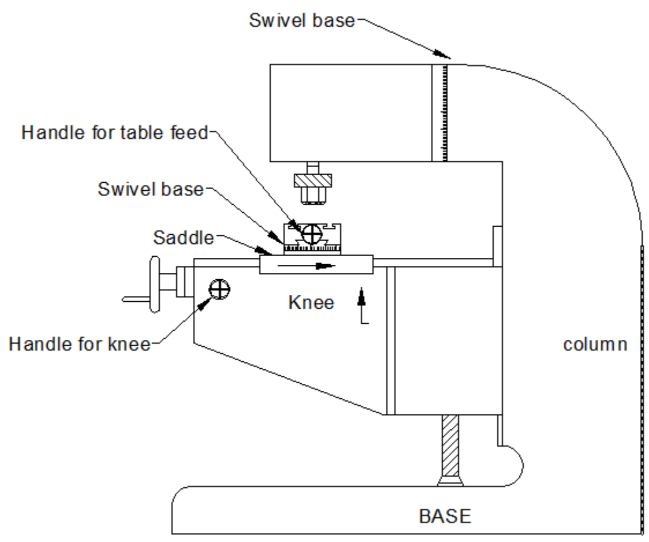


Fig. 3.4. Vertical milling machine

In a vertical milling machine, the spindle is vertical. The table may be plain type or universal type. The vertical column is mounted on the base. The front face of the column has vertical guide ways. The knee moves on these vertical guide ways. The knee has horizontal guide ways on its top surface. The saddle can move cross wise on these guide ways perpendicular to the spindle axis away from the column or towards the column. The saddle has guide ways on its top. The table can move longitudinally along these guide ways. This movement is perpendicular to the spindle axis.

The spindle head is mounted on top of the column and it has swivel base. So the head can be tilted at an angle. This permits machining of angular surfaces. In some machines, the spindle can be adjusted up or down. The vertical movement of the knee, cross wise movement of the saddle and the longitudinal movement of the table can be obtained by hand or power. The knee houses the feeding mechanism. This machine is used for machining grooves, slots and flat surfaces. End milling cutters and face milling cutters are generally used in vertical milling machine.

Plano Miller:

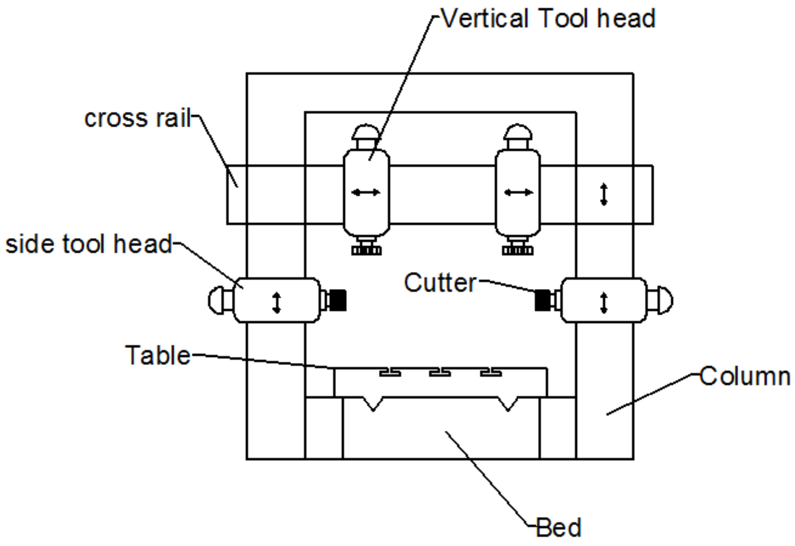


Fig. 3.5. Plano Miller

Construction of a Plano miller is similar to a double housing planer. The working of the Plano miller is similar to the planning machine. The machine has a fixed bed and the bed has longitudinal guide ways. The table reciprocates longitudinally over these guide ways.

There are two vertical columns one each on the sides of the bed. A cross rail slides vertically along the column guide ways. The cross rail carries vertical cutter heads. These cutter heads can slide along the cross rail. There are two cutter heads mounted on the vertical columns. These can slide over vertical guide ways on the column. These vertical and horizontal tool heads have separate motors for driving the cutter. All the four cutter heads can be used to machine the work surfaces at a time. The cutter heads can also be swiveled for machining angular surfaces.

This machine is used for heavy duty production work. Lathe bed ways, other machine bed ways etc. are machine using the Plano miller.

Specification of a Milling Machine

• The table length and width	1120 x 280 mm
• Maximum longitudinal, cross and vertical travel of the Table - 558 x 229 x 406 mm	
• Number of spindle speeds and feeds	6
• Floor space and net weight	2000 kg
• Spindle nose taper size	ISO 40
• Type	Universal

Work Holding Devices:

The following work holding devices are used in milling machine.

- Plain vice.
- Swivel vice.
- Universal vice.
- Indexing head.
- Milling fixture.

Plain vice:

The plain vice is bolted directly to the table. Base of the vice has slots for clamping the vice to the table.

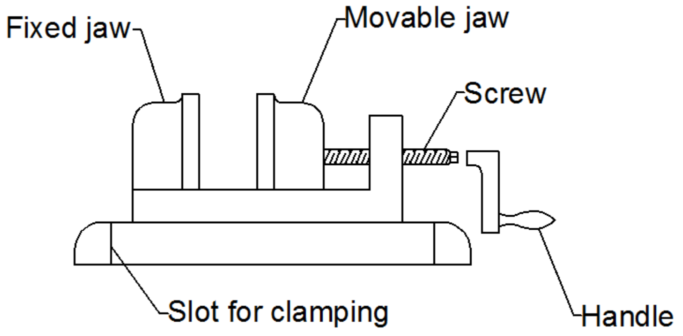


Fig. 3.6. Plain vice

The vices may be positioned on the table with their jaws either parallel or at right angles to the T-slots. The work piece is held between the jaws. Plain vice is used for simple milling operation on the work piece.

Swivel vice:

This vice has a swivel base, graduated in degrees. The base of the vice is clamped on the table by T-bolts. For clamping the vice, lugs with slots are available in the base. The vice is swiveled over the swivel base after loosening the clamping bolt. After setting the vice to the required angle the clamping bolts are tightened. The swivel vice is used for milling angular surface on the work piece.

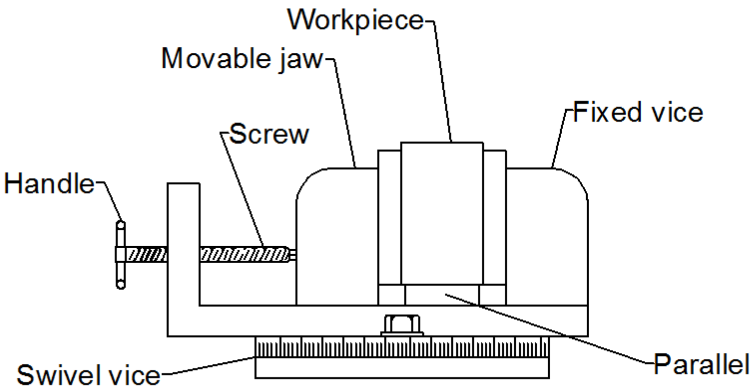


Fig. 3.7. Swivel vice

Universal vice:

The universal vice can be tilted in a horizontal plane, similar to swivel vice. It can also be tilted in a vertical plane. The cutting edge of the tool may be straight or spiral. The base of the vice is clamped on the table by T-bolt. There is a horizontal swivel base, on the base of the vice. This swivel base is used for tilting the vice in horizontal plane. A vertical swivel arrangement is provided over the horizontal swivel base. The vice body is fitted to the vertical swivel arrangement. The vice body can be tilted in a vertical plane using the vertical swiveling arrangement. After setting the vice to the required angle, the vice is clamped in position by clamping nuts.

Using this universal vice, surfaces with compound angles can be machined. This vice is not rigid in construction. It is mainly used in tool rooms.

Indexing Head:

Indexing head is a device which is used for dividing the periphery of the work pieces into any number of equal divisions. Indexing is necessary for cutting gears, splines on shafts and for cutting helical grooves on drill and reamers. Indexing head is also known as dividing head. The indexing head is clamped to lathe table by using T-bolts.

Indexing head has a head stock and a tail stock. The work piece is held between the centres of head stock and tail stock. Short work pieces can be held in a chuck fitted to the head stock spindle. The work piece can be indexed by rotating the crank in the head stock.

The crank movement is transmitted to the work piece through a worm and worm wheel. An indexing plate is provided in the head stock. With the help of this indexing plate, the required movement of the crank is obtained.

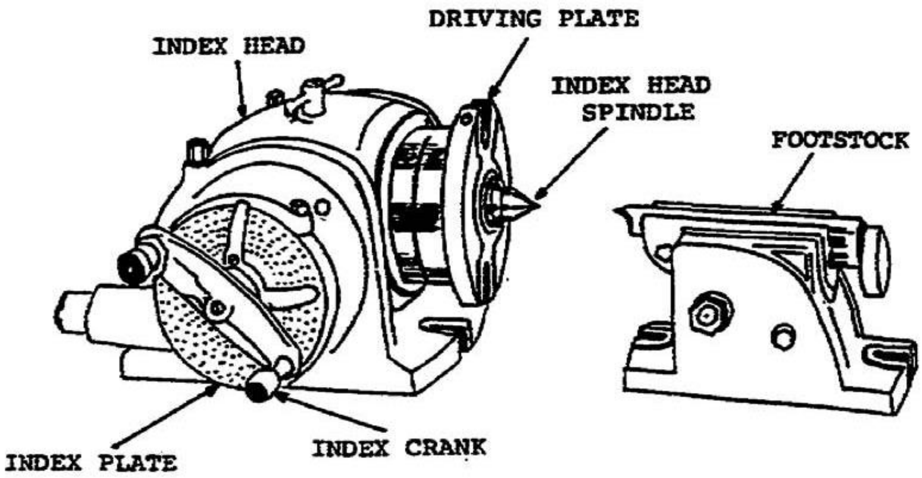


Fig. 3.8. Indexing Head

Milling fixture:

Milling fixtures are used for locating and clamping the work in correct position with respect to milling cutter. Milling fixtures are used when large number of identical work pieces is to be machined. By using fixtures, loading, locating, clamping and unloading time are very much reduced.

Vice jaw milling fixture:

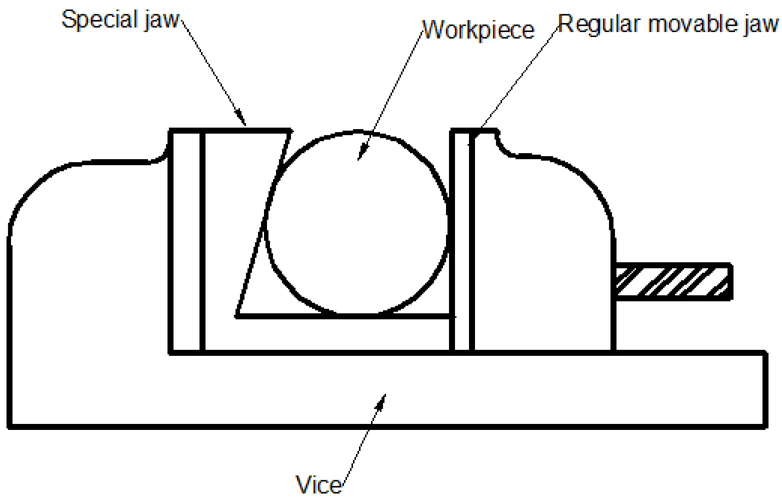


Fig. 3.9. Vice jaw milling fixture

The jaws of the machine vice are modified to suit the type of the work piece.

The vice has extended jaws. The work piece is clamped between the extended jaws. For proper alignment of jaws, the movable jaw has a guide pin. A bush is provided in the fixed jaw to receive the guide pin.

Figure shows an arrangement for holding cylindrical work pieces. The vice has a vice shaped fixed jaw. The movable jaw is a regular one. The work piece is firmly held between the two jaws.

Plain Milling Fixture or slot milling fixture or string milling fixture:

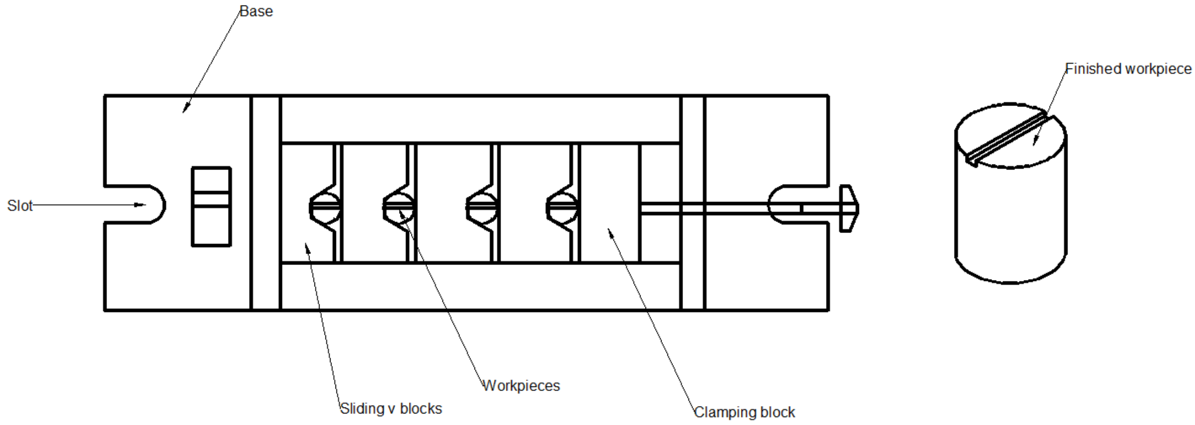


Fig. 3.10. String milling fixture

Plain milling fixture is designed to hold a single component. Plain milling fixture is used when a small number of components are to be milled. In the fixture has a slot has to be milled in the component. Big hole ‘A’ in the component is located by a cylindrical locator. One of the small holes ‘B’ is located by a diamond pin locator. The bottom surface of the component rests on the fixture base. Two strap clamps are used for clamping the component. There are two tension strips at the bottom of the fixture base. (One tension at each end of base). These tension strips are interested through slots of machine table for locating the fixture in the required position.

A setting block is fitted stop of fixture base by two screws and two dowels. The fixture is clamped firmly to machine table by using T bolts through the four U – grooves in fixture base.

Tool Holding Devices

The different tool holding devices used in milling machine are

1. Arbors

   (a) Standard arbor (b) Stub arbor

2. Adapters
3. Spring collets

Arbor:

Standard arbor:

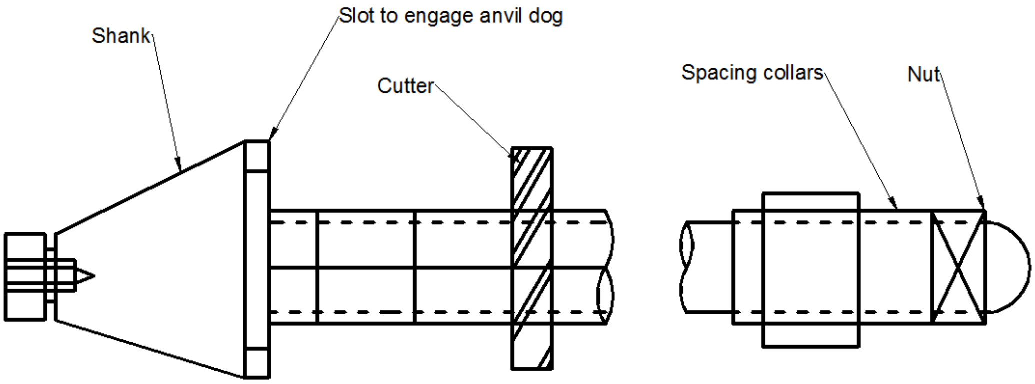


Fig. 3.11. Standard arbor

Cutters having a central bore are mounted on a standard arbor. Arbor is a short shaft, one end of which is fitted to the taper bore in the spindle nose. A draw bolt holds the arbor in position. The draw bolt is introduced into the spindle bore from the back of the milling machine column. The draw bolt is used to pull in or push out the arbor from the spindle. The slots on the flange of the arbor engage the driving lugs of the spindle. A key runs for the whole length of the arbor. The cutter is mounted on the arbor. The key way of the cutter bore fits on the arbor. Spacing collars are used on both sides of the cutter for adjusting the position of the cutter along the length of the arbor.

The arbor is supported at the other end by the yoke. A clamping nut is used at the end of the arbor to hold the cutter in position. Arbors of different diameters are used to suit the central bore of the cutter.

Stub arbor:

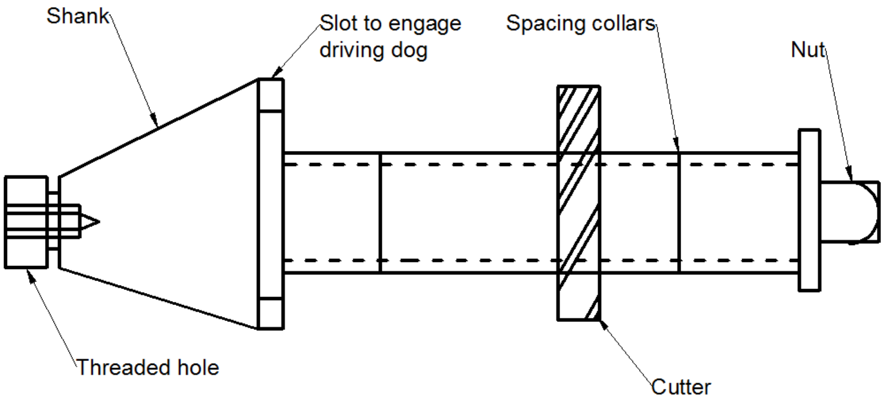


Fig. 3.12. Stub arbor

It is a short arbor. This is used for holding shell end mills, T-slot cutters and key way cutters. The Stub arbor has a tapered shank which fits into the main spindle of the milling machine.

The slots in the flange portion of the stub arbor fit into the main spindle of the milling machine. The slot in the flange portion of the stub arbor fits into the diving lugs of the spindle nose. A clamping screw is used to clamp the cutter to the arbor.

Adapter:

If the size of the cutter is small, it cannot be fitted in the nose of the spindle. An adapter is used in this case. The adapter has taper bore to receive the shank of the cutter to be held. The flange or collar of the adapter has two slots. These slots fit over the driving lugs of the spindle. The rear end of the adapter has a threaded hole. The end of the draw bolt is screwed to this thread.

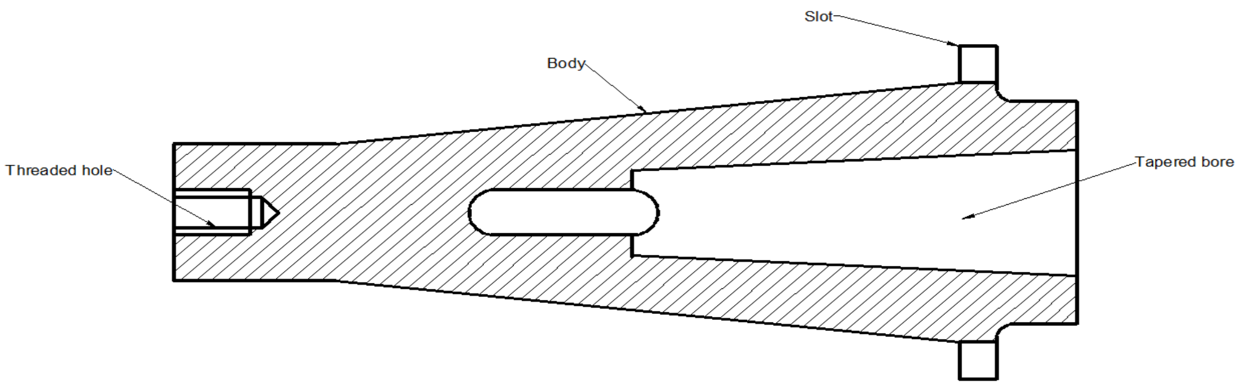


Fig. 3.13. Adapter

Spring Collets:

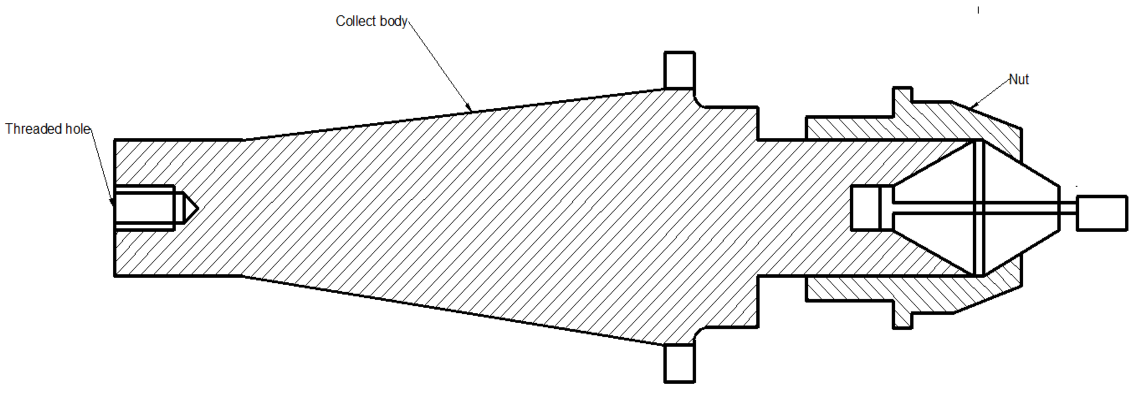


Fig. 3.14. Spring Collets

Spring collet is used for holding straight shank milling cutters. End mill cutters, woodruff key cutters etc. are held using spring collet. The front portion of the collet is tapered. The tapered portion is spilt by three equally spaced slots. After the tapered portion there are external threads. A special nut fits over the taper and the threaded portion. The front end of the collet has straight cylindrical hole. The front end of the collet has straight cylindrical hole. The straight shank of the cutter is introduced into this hole. When the nut is tightened, the split jaws of the collet close over the straight shank of the cutter.

Thus the tool is held firmly on the Collet. The rear of the collet has a taper shank to fit into the spindle nose. The two slots in the collar fit over the driving lugs of the spindle. The back of the collet has a threaded hole to receive the draw bit.

Milling cutters:

The following milling cutters are commonly used in milling.

- Cylindrical milling cutter
- Slab milling cutter.
- Slitting saw.
- Side milling cutter
- Angle milling cutter
- End milling cutter
- T-slot milling cutter.
- Woodruff key slot milling cutter
- Fly cutter

Form cutter

Most of the cutters are made of high speed steel. Carbide tipped teeth cutters are also available. The cutters may be held on arbors. These cutters will have central holes. Cutters can also be held directly on the spindle using adapters and collets. These cutters will have straight or taper shank ends.

Cylindrical milling cutter

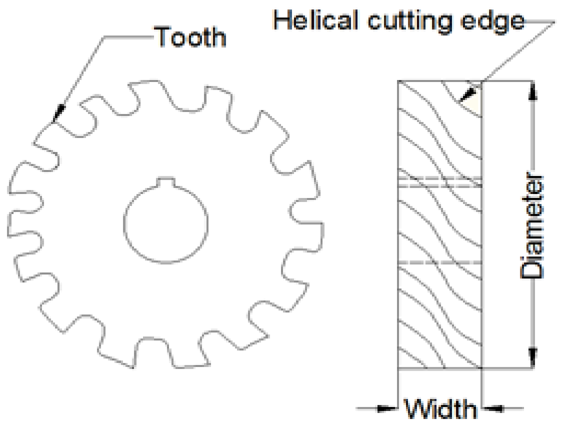


Fig. 3.15. Cylindrical milling cutter

This milling cutter is cylindrical in shape. It has cutting teeth only on its periphery. It is used for machining flat surfaces parallel to its axis. The cutter may have straight or helical teeth. The figure shows a cutter with helical teeth. Helical teeth produce a smooth surface.

The cutter has a central bore with key way. This is for mounting the cutter in a standard arbor. Cutters of various diameters and widths are available. Roughing cutters will have less number of teeth. Finishing cutters will have more number of teeth, for the same diameter.

Slab milling cutter:

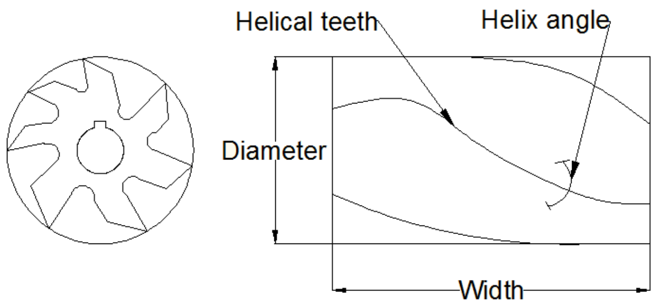


Fig. 3.16. Slab milling cutter

This is a cylindrical milling cutter having a width more than its diameter. This is used for rough machining with coarse feed. The cutter has less number of teeth. The teeth will have larger helix angle. Long slab milling cutter will have nicked teeth. The cutting edges will not be continuous. The nicking is done to break the chips.

Slitting saw:

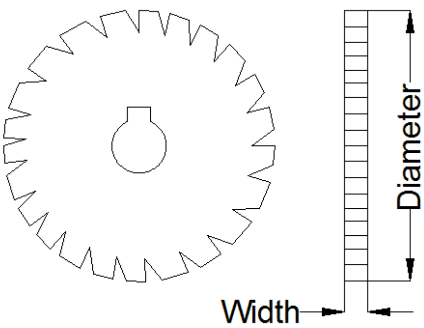


Fig. 3.17. Slitting saw

Slitting saw is used for slotting for cutting off operations. The cutter is very thin. Its width varies from 0.8 to 5mm. The sides of the cutter are ground concave. This is to prevent the sides from rubbing the work piece.

Side milling cutters:

Side milling cutter has cutting edges on its periphery and also on the sides. This cutter is used for removing metal from the side of the work pieces. It is also used for cutting slots.

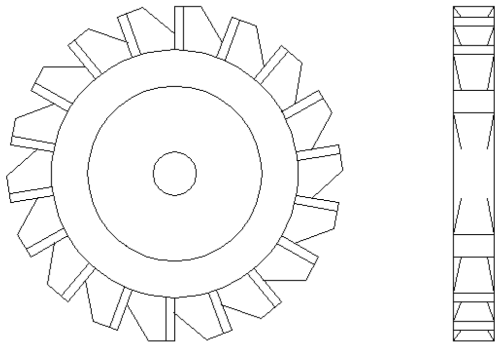


Fig. 3.18. Side milling cutter

Cutters of various diameters and widths are available. Figure shows plain side milling cutter having straight teeth. The cutters can also have staggered teeth.

The cutters are used for milling deep and narrow slots

Angle milling cutters

Angle milling cutters are used for producing angular surfaces Fig. shows a single angle milling cutter. The cutter has inclined teeth on its conical periphery. It also has teeth on its large flat side. The angle of the cutter θ is specified by the included angle between the conical periphery and the large flat side of the cutter. The angle cutter will produce only a particular angle. Cutters with different included angles are available.

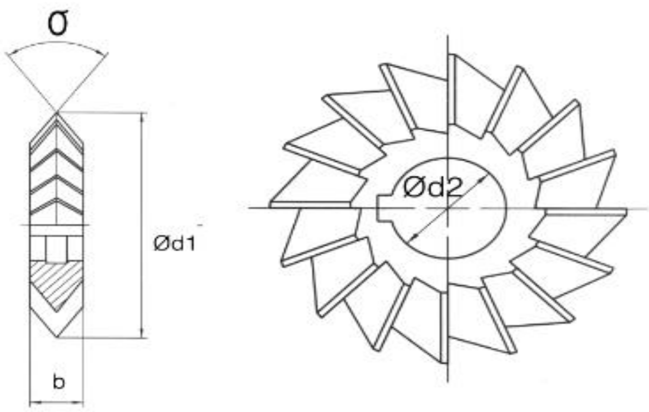


Fig. 3.19. Angle milling cutters

It has two conical surfaces. The conical surfaces are at angles to the end faces. The conical surfaces have cutting teeth. These cutters have equal angles on both sides. But they may also have unequal angles. These cutters are used for producing spiral grooves. The angle milling cutters have central bores with key-slots. These cutters are held in arbors.

End milling cutter:

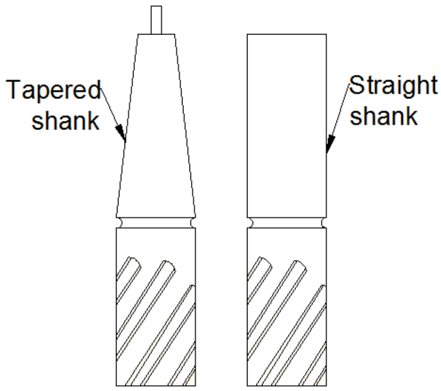


Fig. 3.20. End milling cutter

An end mill is a cylindrical cutter. It has cutting teeth on the end and also at the cylindrical periphery. The teeth on the periphery may be straight or helical. The end mill cutter is similar in construction to a twist drill or reamer. The main difference is that the end mill has cutting edges on the ends also. The cutter may have a tapered or straight shank. Tapered shank cutters are fitted to the spindle using adapters. Straight shank cutters are fitted to the spindle using collets.

End mills are commonly used for vertical milling operations. They are used for machining slots, accurate holes and producing narrow flat surfaces. End mills are also used for die sinking and profile milling.

T-slot Milling Cutter

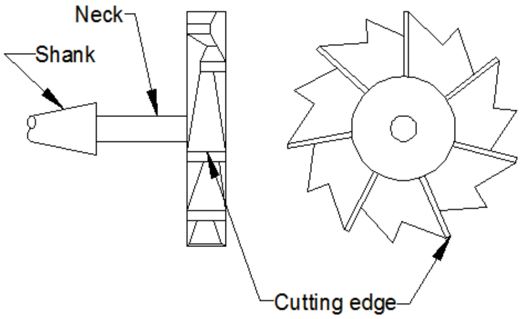


Fig. 3.21. T slot milling cutter

It is used of producing T-slots. The arrangement of cutting teeth is similar to that of a side milling cutter. But this cutter has a tapered shank. A neck is formed between the cutting face and the shank. The cutter has cutting teeth on its periphery (A) and on its sides (B & C). The cutter is fitted to machine spindle, using an adapter.

Woodruff key slot milling cutter:

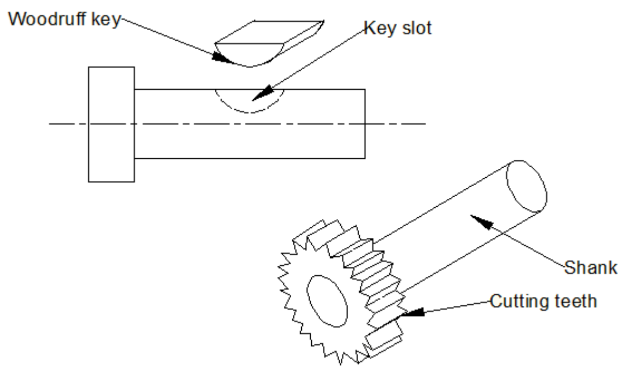


Fig. 3.2. Woodruff key slot milling cutter

The cutter is similar to a small, thin plain milling cutter. It has a tapered shank and a neck. The cutter may have straight or staggered teeth. The sides of the cutter are ground concave. This gives clearance for the cutter movement. This cutter is used for cutting woodruff key slots on shafts.

Fly cutter:

This is a special cutter. It is used in milling machine when standard cutters are not available. A single point cutting tool is fitted to the end of a bar using clamping screws. The bar is fitted to the spindle. The cutting edge of the tool is ground to the required shape. The cutter removes metal when it rotates. The rate of metal removal will be very slow.

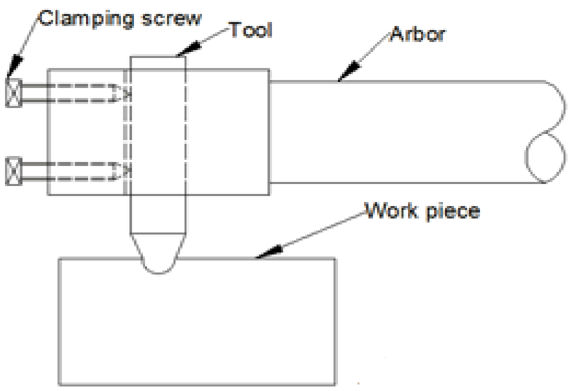


Fig. 3.23. Fly cutter

Form cutters

Form cutters are used to produce the required shape on the work pieces. The cutting edges are ground to the required profile. So the cutter will produce only the form on its teeth. Some of the form cutters are explained below:

Convex Form Milling cutter

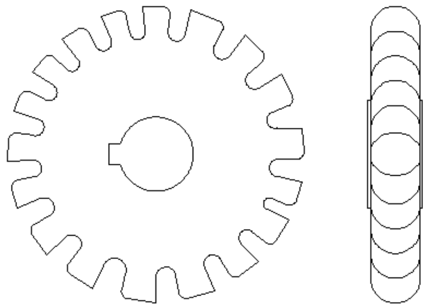


Fig. 3.24. Convex Form Milling cutter

This cutter has teeth curved outward on its periphery. The cutter will produce a concave semi-circular surface on the work piece. Cutters of various diameters and widths are available.

Concave Form Milling Cutter

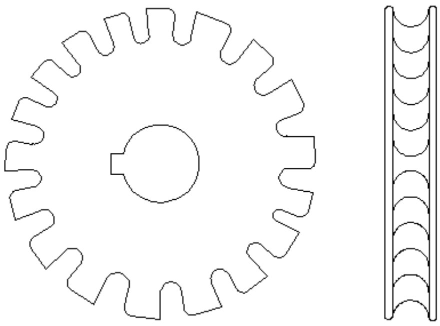


Fig. 3.25. Concave Form Milling Cutter

This cutter has teeth curved inwards on its periphery. The cutter will produce a convex semi-circular surface on the work piece. Cutters of various diameters and widths are available.

Involute Gear Tooth Cutter

The cutter has formed cutting edges. The shape of the cutter teeth is involute. The cutter will produce groove of the involute shape.

An involute gear tooth is formed between two grooves milled by the cutter. The profile of the gear tooth depends upon the module and the number of teeth on the gears. So, for cutting different number of gear teeth of same module, different cutters are required. In practice, a set of eight cutters are available for each module. The range of teeth is from 12 to infinity (rake).

Nomenclature of Cylindrical Milling Cutter

Face of tooth

Face is the front portion of the tooth. The chip cut by the cutting edge slides over the face.

Land

It is the portion of the tooth which is adjacent to the cutting edge.

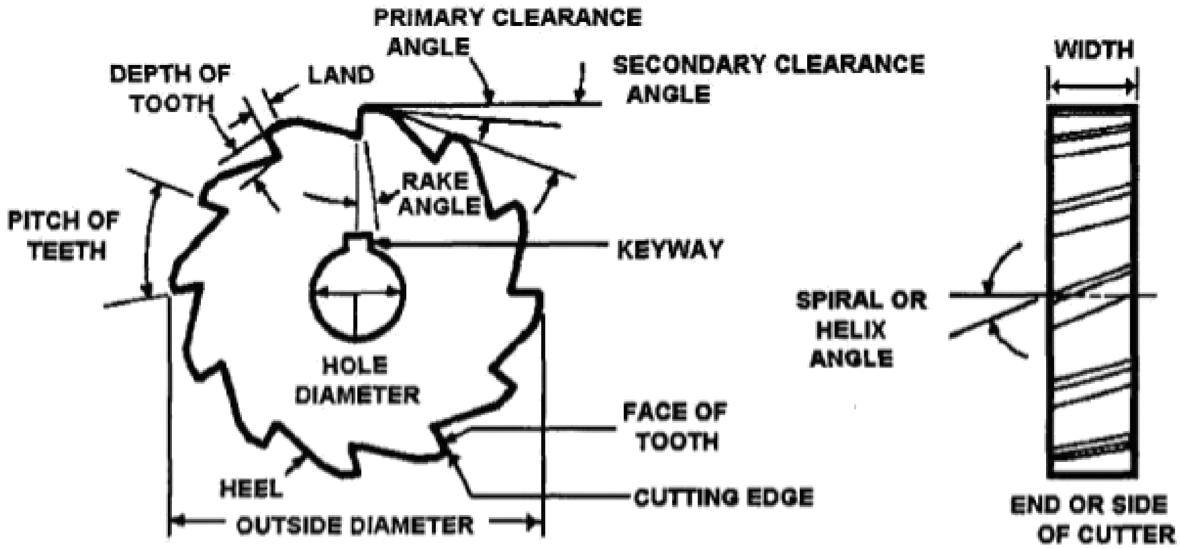


Fig. 3.26. Nomenclature of Cylindrical Milling Cutter

Cutting edge:

This is the chisel like edge which cuts the metal. It is the edge formed by the face of the tooth and the land.

Back of tooth:

It is the portion of the tooth behind the land. It slopes downwards from the land. It gives clearance to the tooth.

Gash:

It is the gap between the teeth. It provides space for chip flow.

Fillet:

It is the curved surface at the bottom of gash.

Outside diameter:

This is the diameter of the circle passing through the cutting edges of the teeth.

Root diameter:

This is the diameter of the circle passing through the bottom of the fillet.

Cutter Angles: Relief angle:

It is the angle between the land and the cutting edge.

Primary clearance angle:

This is the angle between the back of tooth and the tangent to the outside circle.

Secondary clearance angle:

This is the angle between the sloping surface of the tooth and the tangent to the outside circle.

Radial rake angle:

It is the angle between the face of the tooth and the radial line passing through the cutting edge.

Lip angle:

It is the included angle between the land and the face of the tooth.

Milling Processes

Up milling:

It is also called conventional milling. Metal is removed when the cutter teeth move upwards. Here the cutter rotates opposite to the direction of feed of work piece. In up milling, the chip thickness is minimum at the end of the cut. So the stress on the teeth is minimum at the beginning of the cut.

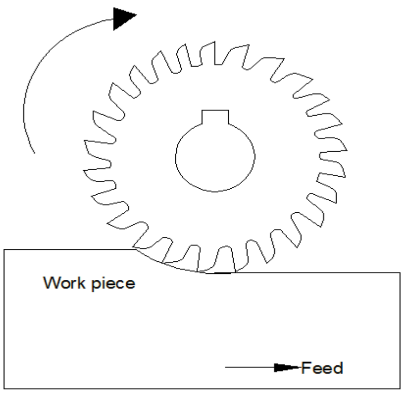


Fig. 3.27. Up milling

The stress increases gradually and is maximum at the end of the cut. The cutting action of the teeth is upwards. So it will try to lift the work piece from the vice. The machined surface is not very smooth. Applying the coolant at the cutting zone. So chip removal is difficult. Chips interfere with the cutting action.

Down Milling:

It is also called Climb milling. Metal is removed when the cutter teeth move downwards. Here the cutter rotates in the same direction as the feed for work piece. In down milling, the thickness decreases to the minimum at the end of the cut. Here the maximum stress acts on the teeth at the beginning of the cut.

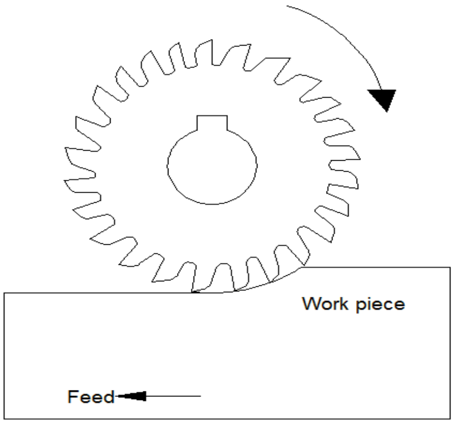


Fig. 3.28. Down Milling

This gives shock load to the teeth. The cutting action of the teeth presses the work piece downwards. This helps clamping of the work pieces. Down milling will give better surface finish. Coolant can be effectively applied on the cutting edge. The chips accumulate at the back of the cutter away from the cutting zone. So chip removal is easy. Chips do not interfere with the cutting action.

Milling Operations

- Plain milling
- Form milling
- Face milling
- Side milling
- End milling
- T-slot milling
- Straddle milling
- Gang milling

Plain milling

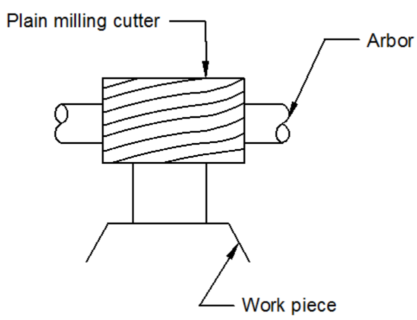


Fig. 3.29. Plain milling

Figure shows plain milling operation. Plain milling is the operation of producing flat, horizontal surface. A cylindrical milling cutter is used here. The cutter is held in the arbor. The work piece is held in a vice or a fixture. The depth of cut is adjusted by raising the table. The axis of the cutter is parallel to the flat surface machined.

Form milling

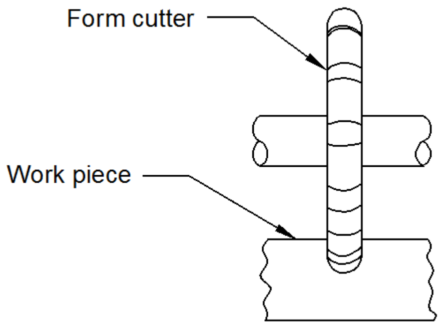


Fig. 3.30. Form milling

Figure shows the form milling operations. Form milling is the operation of producing the required profiles on the work piece. A form milling cutter is used. The cutter is held in the arbor. The cutting speed is slightly lesser than plain milling operations.

Face Milling

Figure shows face milling operations. Face milling is the operation of milling flat surface on the face of the work piece. The axis of the cutter is perpendicular to the surface machined. A face milling cutter is used. Normally inserted teeth cutters are used. The cutter can be mounted directly on to the spindle or using a stub arbor. Depth of cut is given by giving cross feed to the table.

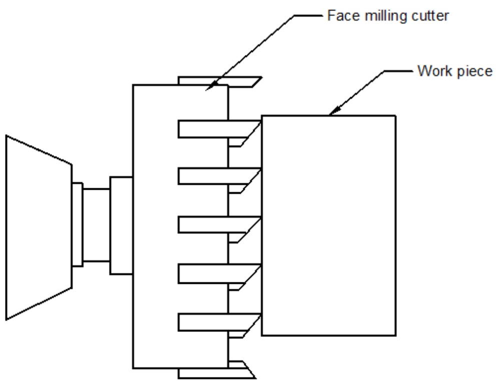


Fig. 3.31. Face Milling

Side Milling

Figure shows side milling operation. A side milling cutter is used for milling the vertical side of the work piece. The cutter has teeth on the periphery and also at its sides.

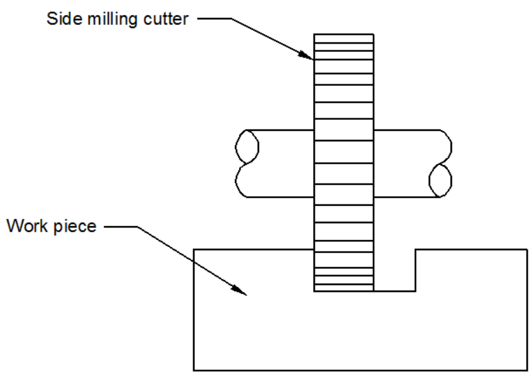


Fig. 3.32. Side Milling

End milling

End milling is the operation of producing narrow slots, grooves and key ways using end mills. The slots produced may be vertical or horizontal.

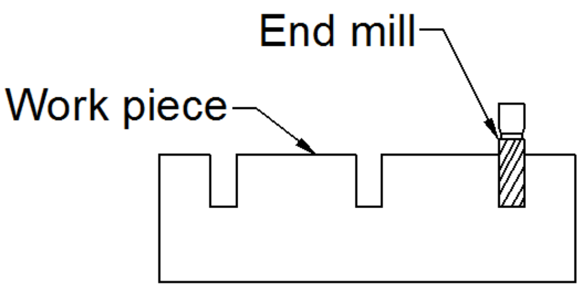


Fig. 3.33. End milling

End milling is normally done is a vertical milling machine. Fig. shows an end milling operation. An end mill is held in the spindle of the vertical milling machine. It is held using adapters or collets. The work piece is clamped to the machine table. By giving longitudinal feed to the work piece, the slot is cut. Depth of cut is given by raising the table. To complete a slot, several cuts may be needed.

T-slot milling

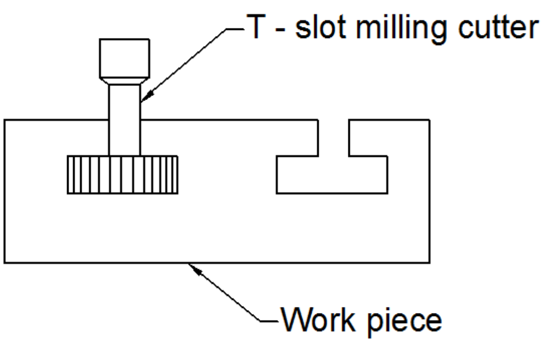


Fig. 3.34. T-slot milling

A T-slot is produced by using a T-slot cutter. Figure shows a T-slot milling operation. First a plain slot is cut on the work piece using an end mill. Then the T-slot cutter is fed from the end of the work piece. The neck portion of lathe cutter passes through the already milled plain slot.

Straddle milling

Figure shows the straddle milling operation. It is the operation of machining two vertical surfaces of the work piece at a time. The vertical surfaces are at a fixed distance between them. Two side milling cutters are used. The cutters are mounted on the arbor with the fixed distance 'X' between them. The given distance 'X' between the cutters is obtained by using spacing collars.

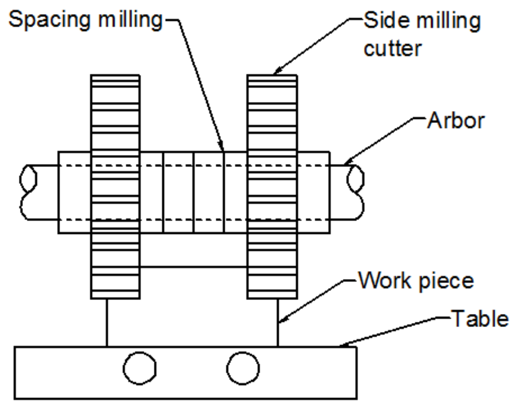


Fig. 3.35. Straddle milling

Longitudinal feed is given through the table. The depth of cut is given by raising the table. Straddle milling is very commonly used for milling square and hexagonal surfaces. A component produced by straddle milling is shown in figure.

Gang milling

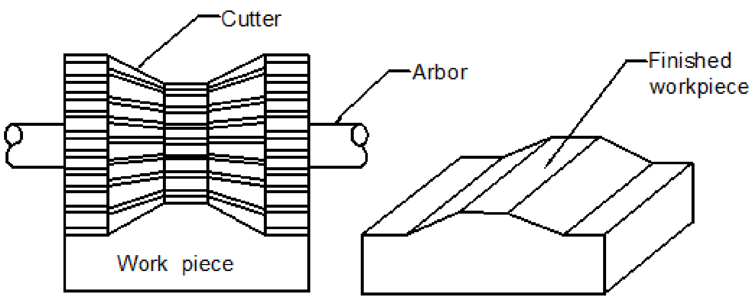


Fig. 3.36. Gang milling

Figure shows a gang milling operation. Gang milling is the operation of milling several surfaces of the work pieces at a time. Number of cutters are mounted on the arbor. There is no gap between the cutters. The figure shows a gang of three side milling cutters and two cylindrical milling cutters fitted to the arbor. The two cylindrical milling cutters have helical teeth of opposite hands. (Right hand and left and helix)

By this arrangement, the axial thrust is balanced. Longitudinal feed is given through the table. The depth of cut is given by raising the table. A component produced by gang milling is shown in figure. Gang milling operation is used in mass production.

Vertical Milling Attachment

Vertical milling attachment is used for doing vertical milling operations on a horizontal milling machine. It is shown in figure. The over arm of the milling machine is pushed back. Then the vertical milling attachment is connected to the spindle. It is bolted to the column face. The attachment can be swiveled about the machine spindle axis using a swivel block.

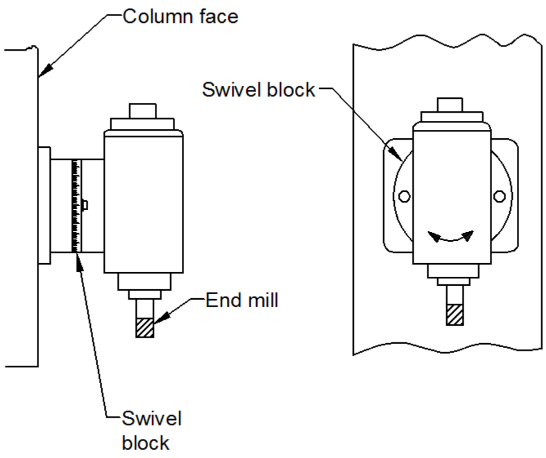


Fig. 3.37. Vertical Milling Attachment

End milling cutter is held to the vertical spindle of the attachment. This vertical spindle gets the drive from the machine spindle through a set of gears. By using this attachment grooving, T-slot milling and face milling operations can be done. Angular surfaces can be milled by tilting the attachment to the required angle. The depth of cut is given by raising the table.

Cutting speed, feed and depth of cut

Cutting Speed is the linear velocity with which the cutting edge passes the work.

$$\text{Cutting Speed} = \frac{\pi DN}{1000} \text{ m/mt}$$

Where D= Diameter of cutter in mm, N= Speed of cutter in rpm

Feed in a milling machine is the rate at which the work piece moves under the cutter. Feed can be expressed as feed in mm per tooth or mm per revolution or mm per minute.

Depth of cut is the thickness of the material removed in one pass of the work under the cutter. This expressed in mm.

Index plate

It helps to accomplish indexing (dividing) of the work into equal divisions. It is a circular plate approximately 6 mm thick, with holes (equally spaced) arranged in concentric circles. The space between two subsequent holes is same for each circle; however, it is different for different circles. A plate can have through holes or blind holes on its faces.

For a plain dividing head, the index plate is fixed to the body of the dividing head while in the case of universal dividing head it is mounted on the sleeve of the worm shaft. Various manufactures in U.S.A. and other countries have produced index plates with different number of hole circles.

For example, The index plates available with the Brown and Sharpe milling machines are:

Plate No. 1	-	15, 16, 17, 18, 19, 20
Plate No. 2	-	21, 23, 27, 29, 31, 33
Plate No. 3	-	37, 39, 41, 43, 47, 49

The index plate used on the Cincinnati and Parkinson milling machine is:

Obverse (A)	-	24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43
Reverse (B)	-	46, 47, 49, 51, 53, 54, 57, 58, 59, 62, and 66

Index plates made in Germany are:

Plate No. 1	-	23, 25, 28, 31, 39, 43, 51, 59
Plate No. 2	-	16, 27, 30, 33, 41, 47, 53, 61
Plate No. 3	-	22, 24, 29, 36, 37, 49, 57, 63

The high number index plates are used to increase the indexing capacity. These index plates are similar to those discussed earlier except that these contain very large number of holes. Cincinnati Milling Machine Co. U.S.A. produces a set of three plates with holes on both sides of the plate as given below:

Plate No. 1	Obverse (A)	-	30, 48, 69, 91, 99, 117, 129, 147, 171, 177, 189
	Reverse (B)	-	36, 67, 81, 97, 111, 127, 141, 157, 169, 183, and 194
Plate No 2	Obverse (A)	-	34, 46, 79, 93, 109, 123, 139, 153, 167, 181, 197

	Reverse (B)	-	32, 44, 77, 89, 107, 121, 137, 151, 163, 179, and 193
Plate No. 3	Obverse (A)	-	26, 42, 73, 87, 103, 119, 133, 149, 161, 175, 191
	Reverse (B)	-	28, 38, 71, 83, 101, 113, 131, 143, 159, 173, and 187

It is importance to note that there is no standard followed internationally in this regard. The number of plates supplied varies with different manufacturers. However, this does not change the principle of indexing. It should be put up with in mind that larger the number of plates, and more the hole circles and holes wider is the range of indexing and accuracy.

Types of dividing heads

The various dividing heads used with milling machines are:

Plain indexing head

A plain dividing head has a fixed spindle axis and the spindle rotates only about a horizontal axis.

Universal indexing head

In this, the spindle can be rotated at different angles in the vertical plane from horizontal to vertical. This head performs the following functions: indexes the work piece, imparts a continuous rotary motion to the work piece for milling helical grooves (flutes of drills, reamers, milling cutters etc.) and setting the work piece in a given inclined position with reference to the table.

Optical indexing head

These models are used for high precision angular setting of the work piece with respect to the cutter. For reading the angles, an optical system is built into the dividing head.

Methods of indexing

The various methods of indexing are discussed below:

Direct indexing

In this, the index plate is directly mounted on the dividing head spindle. The intermediate use of worm and worm wheel is avoided. For indexing, the index pin is pulled out on a hole, the work and the index plate are rotated the desired number of holes and the pin is engaged. Both plain and universal heads can be used in this manner. Direct indexing is the most rapid method of indexing, but fractions of a complete turn of the spindle are limited to those available with the index plate. With a standard indexing plate having 24 holes, all factors of 24 can be indexed, that is, the work can be divided into 2,3,4,6,8,12 and 24 parts.

Simple or plain indexing

In this, the index plate selected for the particular application, is fitted on the worm shaft and locked through a locking pin. To index the work through any required angle, the index crank pin is withdrawn from a hole in the index plate. The work piece is indexed through the required angle by turning the index crank through a calculated number of whole revolutions and holes on one of the hole circles, after which the index pin is relocated in the required hole. If the number of divisions on the job circumference (that is number of indexing) needed is z, then the number of turns (n) that the crank must be rotated for each indexing can be found from the formula:

n = $\frac{40}{Z}$ turns.

Example 3.1: Indexing 28 divisions.

The rotation of the index crank = $\frac{40}{Z} = \frac{40}{28} = \frac{10}{7} = 1\ \frac{3}{7}$ turns

This can be done as follows using any one of the Brown and Sharpe plates.

One full rotation + 9 holes in 21 hole circle in plate No. 2.

One full rotation + 21 holes in 49 hole circle in plate No. 3.

Example 3.2: Indexing 62 divisions.

The rotation of the crank turns = $\frac{40}{Z} = \frac{40}{62} = \frac{20}{31}$ turns

This can be done as follows using the Brown and Sharpe plates.

20 holes in 31 hole circle in plate No. 2.

Compound Indexing

The word compound indexing is an indicative of compound movements of indexing crank and then plate along with crank. In this case indexing plate is normally held stationary by a lock pin, first we rotate the indexing crank through a required number of holes in a selected hole circle, then crank is fixed through pin. It is followed by another movement by disengaging the rear lock pin, the indexing plate along with indexing crank is rotated in forward or backward direction through predetermined holes in a selected hole circle, then lock pin is reengaged.

Following steps are to be followed for compound indexing operation. The procedure is explained with the help of numerical example.

Example

Let us make 69 divisions of work piece circumference by indexing method. (Using compound indexing)

Solution

Follow the steps given below:

- Factor the divisions to be make (69 = 3 X 23) N = 69.
- Select two hole circles at random (These are 27 and 33 in this case, both of the hole circles should be from same plate).
- Subtract smaller number of holes from larger number and factor it as (33 – 27 = 6 = 2 X 3).

Differential indexing

This is an automatic way to carry out the compound indexing method. In this the required division is obtained by a combination of two movements:

The movement of the index crank similar to the simple indexing. The simultaneous movement of the index plate, when the crank is turned. Figure schematically shows the arrangement for differential indexing.

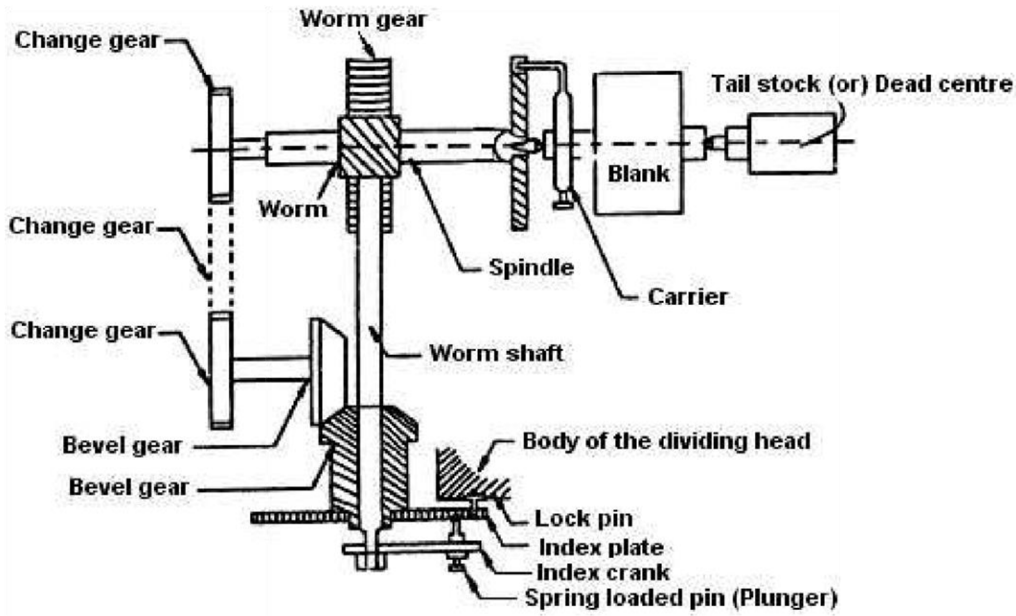


Fig. 3.38. Differential indexing

In differential indexing, the index plate is made free to rotate. A gear is connected to the back end of the dividing head spindle while another gear is mounted on a shaft and is connected to the shaft of the index plate through bevel gears as shown in figure. When the index crank is rotated, the motion is communicated to the work piece spindle. Since the work piece spindle is connected to the index plate through the intermediate gearing as explained above, the index plate will also start rotating. If the chosen indexing is less than the required one, then the index plate will have to be moved in the same direction as the movement of the crank to add the additional motion. If the chosen indexing is more, then the plate should move in the opposite direction to subtract the additional motion.

The direction of the movement of the index plate depends upon the gear train employed. If an idle gear is added between the spindle gear and the shaft gear in case of a simple gear train, then the index plate will move in the same direction to that of the indexing crank movement. In the case of a compound gear train an idler is used when the index plate is move in the opposite direction. The procedure of calculation is explained with the following example. The change gear set available is 24 (2), 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100.

Example: Obtain the indexing for 97 divisions.

The required indexing is 40/97 which cannot be obtained with any of the index plates available. Choose the nearest possible division. For example, the indexing decided is 40/100 = 2/5 = 8/20.

The actual indexing decided is 8 holes in a 20 hole circle. This indexing will be less than required. Ideally the workpiece should complete one revolution when the crank is moved through 97 turns at the above identified indexing. The actual motion generated when the crank is moved 97 times is $40 - \frac{97 \text{ X } 40}{100} = \frac{3 \text{ X } 40}{100} = \frac{6}{5}$

Hence the index plate has to move forward by this amount during the 97 turns to compensate for the smaller indexing being done by the index crank. Hence the gear ratio between the spindle and the index crank is $\frac{6}{5}$

The change gear set used is $\frac{\text{Gear on spindle}}{\text{Gear on index}} = \frac{6}{5} = \frac{48}{40}$

An idler gear is to be used since the index plate has to move in the same direction.

Gear Generating Process

It is based on the fact that any two involute gears of the same module will mesh together. Here one of the meshing gears is made as the cutter. The other gear rotates and also reciprocates along the width of the gear blank. Because of the relative rolling motion of cutter and the blank, gear teeth are generated on the gear blank. The gears may be generated by a rack cutter, pinion cutter or a hob. Using the generating method, profile of the gear teeth can be very accurately produced.

The following generating methods are used for gear production

1. Gear shaping.
2. Gear planning.
3. Gear hobbing.

Gear shaping

It is done on a special type of machine called gear shaper. In gear shaping, a pinion type cutter is used. The cutter teeth are ground with a top rake and clearance. It is mounted on a vertical spindle. The axes of the cutter and blank are aligned as a parallel. The cutter and the blank are made to rotate together as two gears which are in mesh. Both cutter and the blank are rotate at same speed.

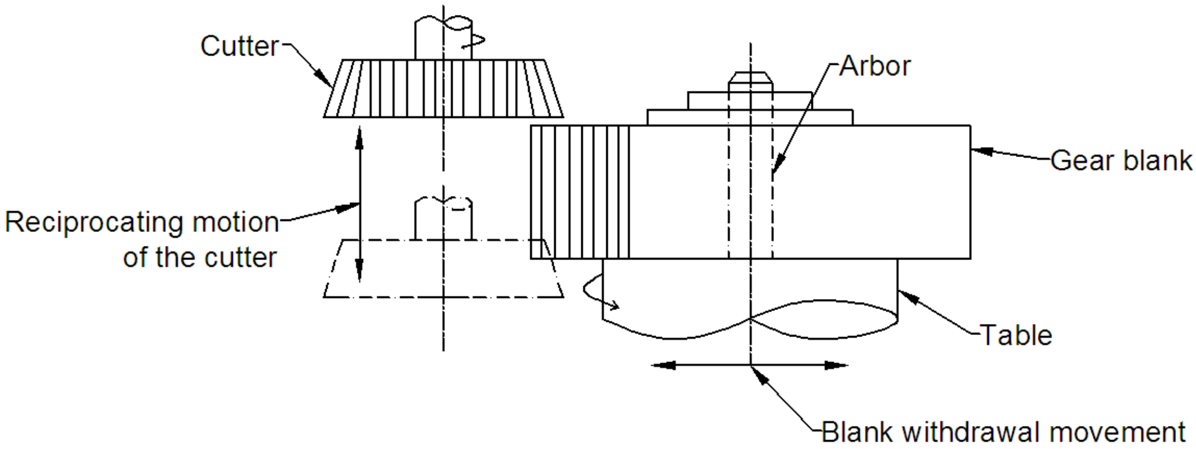


Fig. 3.39. Gear Shaping

The cutter reciprocates in a vertical direction along the width of the blank. The pinion cutter is feed radially into the gear blank to give the depth of cut. The cutter and the blank slowly rotate together till all the teeth are generated on the blank.

During each return stroke of the cutter, the blank is withdrawn. This is done to prevent rubbing of the cutting edges and damage to gear teeth being cut.

The different movements are given below:

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

Application:

Gear shaping is used for cutting external and internal spur gears. Helical gears can also be shaped using special attachments.

Advantages:

1. Single cutter can be used for cutting spur gears of any number of teeth having the same module as that of cutter.
2. Internal gears can be easily cut.
3. As the cutting action is continuous, the rate of production is high.
4. Cluster gears can be cut.

Limitations:

Worm gears cannot be produced in this method.

Gear hobbing:

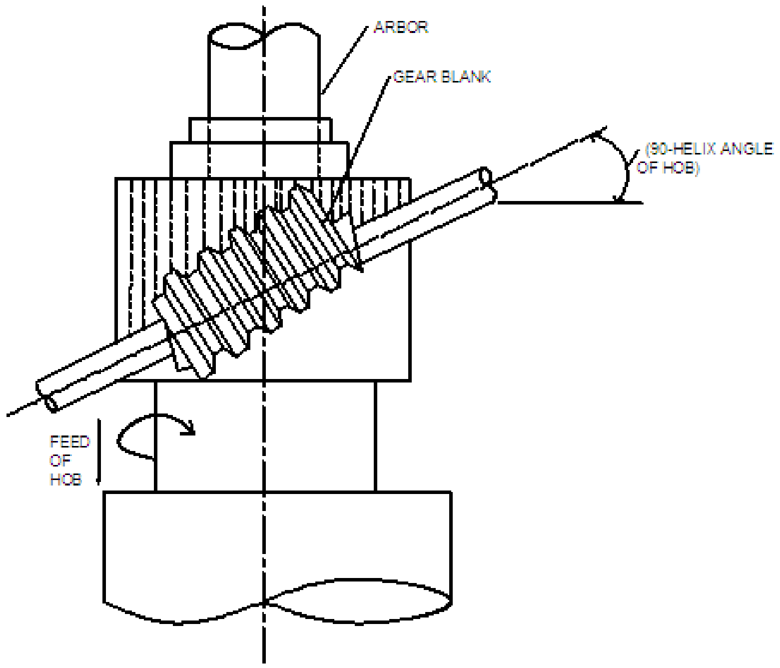


Fig. 3.40. Gear Hobbing

It is a process of generating a gear by using a rotating cutter called hob and hob has helical threads. Grooves are cut in the threads parallel to the axis and this will provide the cutting edges. Proper rake and clearance angles are ground on these cutting edges. The rotating hob acts like a continuously moving rack as it cuts. The gear blank is mounted on a vertical arbor. The hob is mounted on a rotating arbor.

The hob axis is tilted through the hob lead angle **α** so that its teeth are parallel to the axis of the gear blank.

Then $\alpha = (90°-\alpha)$

Where $\alpha 1$ = helix angle of the hob thread.

The hob axis is inclined at $\alpha°$ with the horizontal as shown in the figure 3.40.

(Note: hob lead angle = 90°- hob helix angle)

The hob is rotated at suitable cutting speed. It is fed across the blank face. The hob and blank are made to rotate in correct relationship to each other i.e., they rotate like a worm and worm gear in mesh. (In case of single start hob).

For cutting helical gears, the axis of the hob is inclined to horizontal by $\alpha°$ where

$\alpha 1 = \theta + (90°-\alpha 1)$ (If the helix of the hob and the helix of the gear to be cut are different i.e., one is right handed and another left handed)

$\alpha = \theta - (90° - \alpha 1)$ (If the helix of the hob and the helix of the gear to be cut are both right handed or both left handed)

Where θ- Helix angle of the helical gear to be cut and $\alpha 1$- Helix angle of the hob.

Applications:

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

Advantages:

1. A single hob with the given module can be used for generating gear with any number of teeth of the same module.
2. The same hob can be used for spur and helical gears.
3. Operations are continuous. So very fast rate of production.
4. Perfect tooth shape is obtained.
5. Process is automatic and so less skilled operator is sufficient.
6. Worm gears are generated only by hobbing.
7. Multiple blanks can be cut at a time. Hence high rate of production.

Limitations:

1. Internal gears cannot be generated.
2. Hobbing cannot be used for producing gear teeth very near to shoulders.

S#	Gear Planning	Gear hobbing
1.	Can cut spur helical and bevel gears.	In addition to these, worm gear can also be cut.
2.	Rack type cutter is used.	Cylindrical hob is used.
3.	Cutting is intermittent.	Cutting is continuous.
4.	Production rate is moderate.	Production rate is very fast.
5.	Internal gears cannot be cut.	Internal gears cannot be cut.
6.	Cluster gears can be cut.	Cluster gears cannot be cut.
7.	Tooth profile is very accurate.	Tooth profile is accurate.
8.	Cutter reciprocates and moves originally.	Cutter rotates and moves parallel to the axis of the blank.
9.	Cutter fed against the blank.	The gear blank is moved in towards the hob axis.

GEAR FINISHING PROCESSES

Gears manufacturing by different machining processes will have rough surfaces. The machined gears may have errors in tooth profiles, concentricity and helix angles. For quiet and smooth running of gears, these errors and rough surfaces should be removed. Gear finishing operations are done for this purpose.

Gear burnishing:

This is a method of finishing of gear teeth which are not hardened. This is a cold working process. This method is used to improve the surface finish of the gear teeth. This also increases the hardened at the teeth surface. The principle of working of a burnishing process is shown in figure. In burnishing, the gear to be finished is rolled between three burnishing gear. The teeth of burnishing gears are very hard, smooth and accurate. They are arranged at 120° position around the work gear. Power drive is given to one of the burnishing gears. The other two gears are idlers. Burnishing pressure is applied to the idlers. The gears are rotated in one direction for some period. Then they are rotated in the reverse direction for the same period.

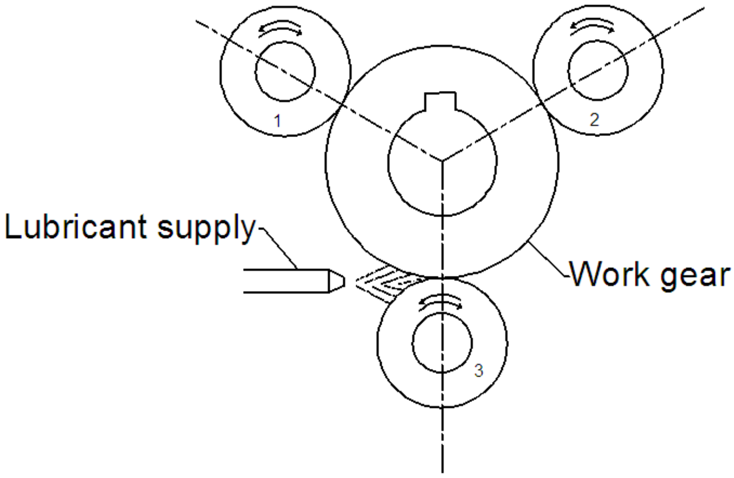


Fig. 3.41. Gear Burnishing

The pressure is applied by the harder burnishing teeth on the work gear. The surface hardness of teeth in the work gear is also increased. The teeth are finished on both the faces uniformly. This is obtained by the rotation of the gears in both the directions. A lubricant is applied between the teeth to get smooth surface finish. They also reduce friction and heat.

Gear shaving:

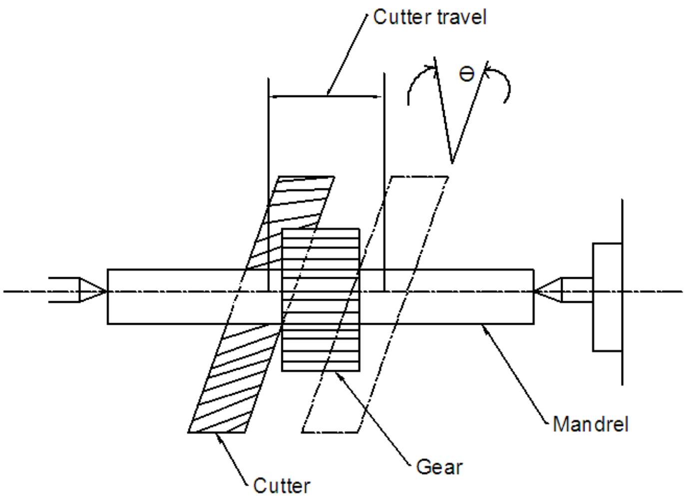


Fig. 3.42. Gear Shaving

This is the most common method of gear finishing. In this method, a very hard gear shaving cutter is used to remove fine chips from the gear teeth. The shaving cutter may be in the form of a rack or a pinion. The rotary method using pinion cutter is used on all types of gears. The rotating cutter will have helical teeth of about 15° helix angle. The tooth form of a cutter is shown in figure. The cutter has a number of serrations on its periphery. These act as cutting edges.

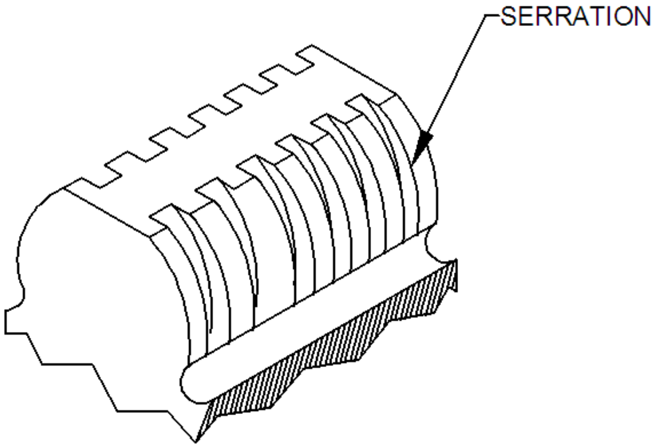


Fig. 3.43. Gear Shaving tooth cutter

The work gear is held between centres and is free to rotate. The shaving cutter meshes with the work gear. The axis of the cutter is inclined to the gear axis at an angle equal to the helix angle of the cutter (θ). When the gear and the cutter rotate, the cutter reciprocates in a direction parallel to the gear axis. The cutting edges of the shaving cutter remove burns, nicks and high points on the surface of the work gear. If can remove from the teeth flank, chips up to 0.01 mm thick.

Gear grinding:

Gear grinding is used for finishing gears after hardening. Gear grinding is done for

a) Increasing the accuracy of gears.
b) Improving the surface finish.
c) Removing the distortion due to heat treatment. There are two method of gear grinding. They are 1. Formed wheel grinding 2. Generation gear grinding

a) Formed wheel grinding:

In formed wheel grinding, the grinding wheel is dressed to the form of tooth space of the gear (involute profile). The grinding wheel is moved parallel to the work gear axis. After grinding one tooth space, the work gear is indexed to the next tooth space. About three passes are required to finish the tooth space. Proper coolant should be used while finishing by grinding.

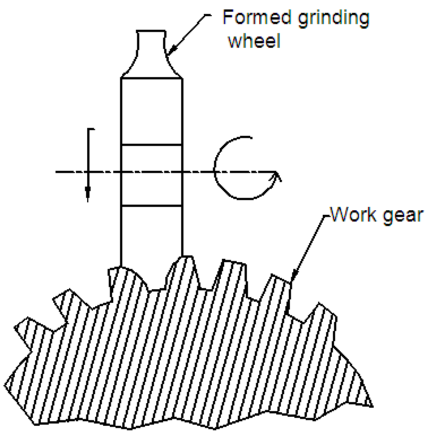


Fig. 3.44. Formed wheel Gear grinding

b) Generation Gear Grinding:

The work gear is rolled along an imaginary rack. Rolling is done in both the direction to grind both sides of the tooth. The grinding wheel reciprocates along the length of the tooth. The grinding wheel is dressed in the form of rack teeth. This work gear rotates about its axis. The gear is also given a linear motion along its axis. The linear motion and rotary motion are opposite to each other. These two motions together give a generating motion. Bevel gears are also ground by type grinding wheel as shown in the figure.

Gear lapping:

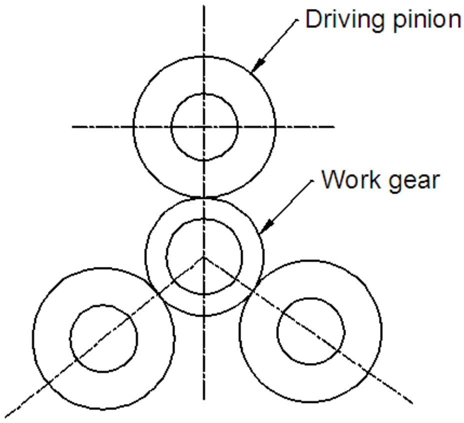


Fig. 3.45. Gear lapping

The hardened gears are finishing accurately by lapping process. Lapping removes very small amount of metal (not more than 0.05 mm). The work gear is rolled between three lapping gears. The lapping gears are made of cast iron. The lapping gears are arranged at 120° position around the work gear.

The axis of the two lapping gears (2&3) are inclined at about 4° to the work gear axis. The axis of the other lapping gear (1) is parallel to the work gear axis. The drive is given through this gear. When gear rotate, a lapping compound is applied between them. The compound is a mixture of a very fine abrasive powder and kerosene. The lapping process improves the tooth contact.

Gear materials:

The selection of materials depends upon the load transmitted and smoothness of operation required. It also depends upon the surface finish and accuracy required on the teeth profile. The material selection also depends on the cost of material and the size of the gear required.

The following materials are generally used for the manufacture of gears.

1. Cast iron 2. Steel 3. Alloy steel 4. Brass

5. Bronze 6. Aluminum 7. Nylon 8. Fibre

Cast Iron:

Cast iron is widely used for the manufacture of gears. Cast iron is used where strength is not very important but good wear resistance is required. It is cheaper one and it absorbs vibrations. Large size gears are easily made by cast iron. But cast iron is relatively weak and brittle. Cast iron can be easily machined. To improve the strength and shock resistance, nickel and chromium are alloyed with cast iron. Cast iron gears are used as bull gears and in construction equipment.

Steel:

Steel is also widely used for manufacturing gears. Gears can be manufacturing from steel by various method. They are

- Machining
- Forging
- Rolling

- Casting
- Blanking

It is stronger. Hence it can transmit heavy loads. Steel also take shock loads also. By using steel as a gear material we can achieve our required property on the surface by heat treatment. Carburizing and nitrating can be done to increase the surface hardness. Hardened steel gears are used for heavy duty service i.e. automobiles, machine tools etc.

Steel alloys:

Properties of steel can be improved by adding the following alloying elements; nickel, manganese, chromium and molybdenum. Nickel increase toughness and corrosion resistance. Manganese increase strength and wear resistance. Chromium improves the wear resistance. Molybdenum increase toughness. Alloy steel can take heavy loads. By adding proper alloying elements, wear resistance, corrosion resistance, impact strength etc. can be increased. Alloy steels are always costly.

Brass:

Brass gears are made using die casting and cold drawing processes. It is very high resistant to corrosion. Very surface finish and smooth operation are achieved in brass. Small motors, instruments, cameras, electrical appliances, toys etc. Use brass gears. It is not suitable for heavy load transmission. Generally brass gears are driven with steel pinions. Hence it reduces friction and gives long life.

Bronze:

Bronze is used for producing highly wear resistant gears. Worms and worm gears are generally made bronze. According to the alloying element added, bronze is classified as phosphor bronze, manganese bronze, aluminium bronze and silicon bronze. Bronze gears are used in gear pumps worm and worm gear drives, motor armature etc. Bronze gears are produced in die-casting and cold drawing processes. Bronze gears run without noise.

Aluminium:

Aluminium gears have light weight. They are used in small gear boxes for weight reduction. Because of light weight, the inertia effect is very less. Alloyed aluminium is used for making gears. Gears in aluminium are generally produced by centrifugal casting. Aluminium gears are used for light duty work only. By anodizing, the aluminium gear surface can be made hard. Anodized aluminium gears will have wear and corrosion resistance. Aluminium gears are used in instruments, toys, cameras, electrical appliances etc.

Nylon:

Nylon is used for production of gears in large quantity. Nylon gears are cheaper. These gears are generally produced in injection moulding process. It is a self-lubricating one. So no lubrication is necessary. Nylon develops low friction and runs very smoothly without noise. They have good impact and tensile strength. When run by steel pinion, nylon gears give good performance. Very low inertia is caused while running. Nylon gears are used in instruments, counters, time gears, cameras, projectors, television sets etc. nylon gears are used for light duty operation. These gears are used for transmitting motion only. It is not suitable for transmitting power. Nylon is anti-corrosive. Nylon is affected by moisture. Nylon gears cannot withstand high heat.

UNIT IV - ABRASIVE PROCESS AND NON- CONVENTIONAL MACHINING PROCESSES

ABRASIVE PROCESSES

INTRODUCTION

Grinding is a metal removal operation in which the metal is removed with the help of a rotating grinding wheel or abrasive wheel. The grinding wheels are made of abrasive materials held together by a bonding material. Grinding process removes very little amount of metal and also it gives very good surface finish with accuracy. This operation is suitable for machining very hard metals.

TYPES OF GRINDING

1. Rough Grinding or non-precision
2. Finish or precision grinding

1. Rough Grinding

Chips, Sharp edges, burr, unwanted projections on the workplaces are removed by Rough grinding process.

2. Precision Grinding

Precision grinding operation used for grinding the cutting tool materials. In this method the grinding wheel with very thin abrasive is used for grinding. So the metal is removed as very small particles. Due to this, the work piece can be machined accurately. Grinding process is classified based on the grinding method. They are given below.

1. External cylindrical grinding
2. Internal surface grinding
3. Surface grinding
4. Form grinding

1. External cylindrical grinding

The grinding operation which is done on a straight or tapered cylindrical workplace is called external cylindrical grinding. The work piece is rotated in its axis and moved across the face of the grinding wheel for grinding the surface of the work piece.

2. Internal cylindrical grinding

The grinding operation which is done on the internal hole of the cylindrical work piece and the inside taper surface of the cylindrical work piece is called internal cylindrical grinding. In this method, the work piece is held in the chuck and rotated in its axis then the rotating grinding wheel is passed inside the work piece for grinding.

3. Surface grinding

In this operation, the flat surface is produced by grinding the surface. For this, the work piece is moved forward and backward under the rotating grinding wheel.

4. Form grinding

The required form of grinding wheel is used for grinding the work piece. So this grinding operation produce the shape of grinding wheel used on the work piece for grinding.

CLASSIFICATION OF GRINDING MACHINES

1. Cylindrical Grinding
    1. Plain cylindrical grinder
    2. Universal cylindrical grinder
    3. Centreless grinder
2. Internal Grinders
    1. Chucking type internal grinders
        A. Plain internal grinders
        B. Universal internal grinders
    2. Planetory internal grinders
    3. centreless internal grinders
3. Surface grinders
    1. Reciprocating table type
        A. Horizontal spindle type
        B. Vertical spindle type
    2. Rotating table type
        A. Horizontal spindle type
        B. Vertical spindle type
4. Tool and cutter grinders
    1. Universal grinders
    2. Special grinders
5. Special and single purpose grinding machines

1. **Floor stand grinder**

In this grinder, an electric motor fitted in the base. The motor has a horizontal spindle with grinding wheel mounted at each end of the motor shaft extensions.

Floor grinder is used for sharpening the tools, boring tools and drills. The machine has a grinding wheel with coarse grains on one end and a grinding wheel with fine grains on the other end.

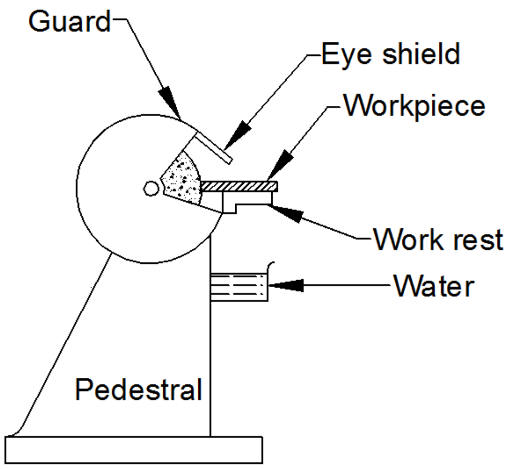


Fig. 4.1. Foot stand Grinder

2. Bench grinder

The appearance of this grinder is similar to the floor grinder. But this machine is placed on the bench. This type of grinder is used for grinding of tools and other small parts.

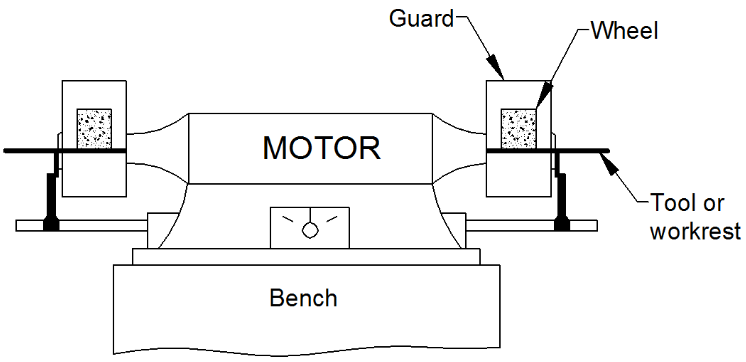


Fig. 4.2. Bench Grinder

3. Portable grinder

The machine can be carried from place to place. A small electric motor is provided in this grinder. A small grinding wheel is attached to the end of the motor. This grinder is suitable for grinding castings, and weld mesh.

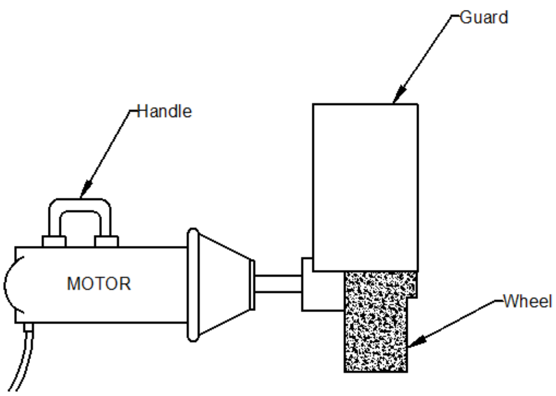


Fig. 4.3. Portable Grinder

4. **Swing frame grinder**

This type of grinder has horizontal frame to the length from 2 to 4 meter. A grinding wheel is fitted at the one end of the frame and this grinding wheel is attached to the motor. The other end of the frame carries balancing weight. A handle is provided at the wheel end.

It is used for moving the grinding wheel and pressing on the work piece for rough grinding. The grinder is suspended at its centre so as to move freely within the area of operation.

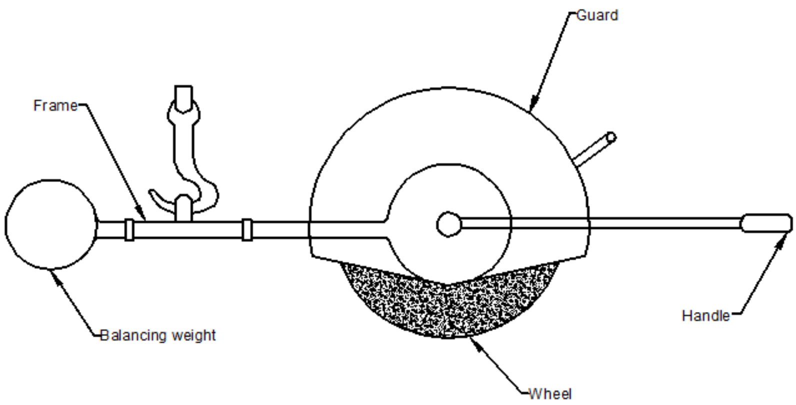


Fig. 4.4. Swing frame grinder

5. **Abrasive belt grinder**

In this grinder, abrasive belt is used instead of the grinding wheel. An endless belt is placed on the pulley. When this pulley is rotated by an electric motor the abrasive belt also rotates. Then the work piece is fed against this rotating abrasive belt for grinding the surface.

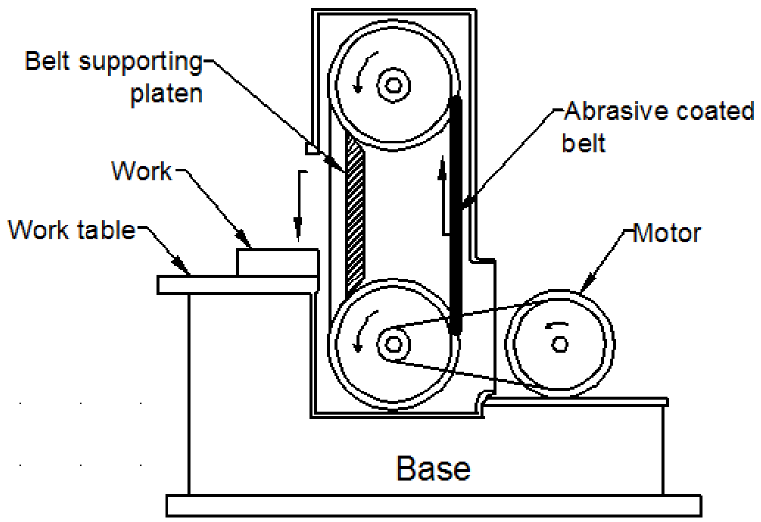


Fig. 4.5. Abrasive belt grinder

PRECISION GRINDERS:

Surface grinding machine, cylindrical grinding machine and internal grinding machine are belonging to the precision grinding machines. In this type of machines, one end of the work piece is held in the dead centre and the other end is held in the dead centre and the other end is held in the dog or driver of the plate. There are four movements in this type machines given below.

1. Rotation of work piece
2. Rotation of grinding wheel
3. Movement of the work piece to the grinding wheel
4. Movement of the grinding wheel.

1. Cylindrical grinding

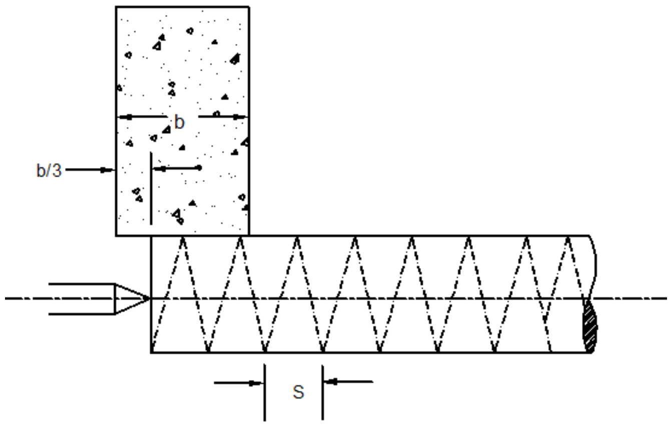


Fig. 4.6. Cylindrical Grinding

1. Traverse grinding

This method is used when the job length is more than the width of the grinding wheel. The work piece is held between two centres. The grinding wheel is made to rotate in a fixed position. The rotating work piece is made to traverse and the grinding is done on the work piece.

2. Plunge grinding

Plunge grinding operation is suitable when the length of the workplace is smaller than the width of the grinding wheel. Here, the work piece need not to be fed longitudinally.

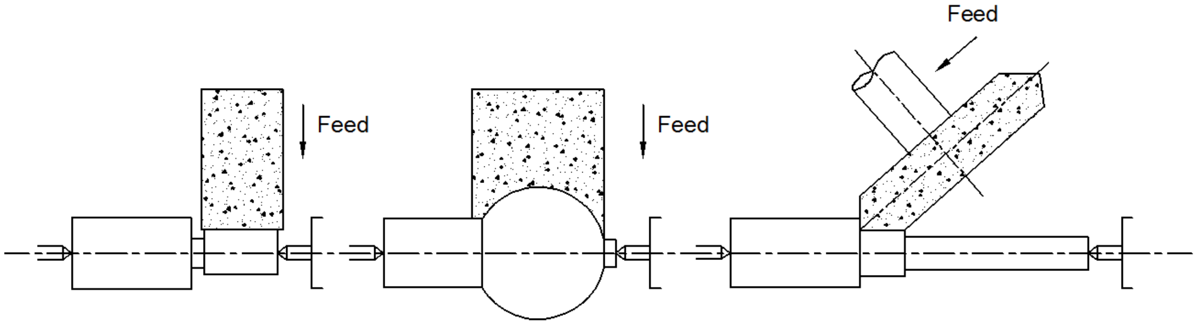


Fig. 4.7. Plunge cut Grinding

Then the grinding is done by grinding is done by giving only the cross feed to the grinding wheel. Plunge grinding is used for grinding shoulders, stepping and various contours.

CYLINDRICAL GRINDING MACHINE (CENTRE TYPE GRINDER)

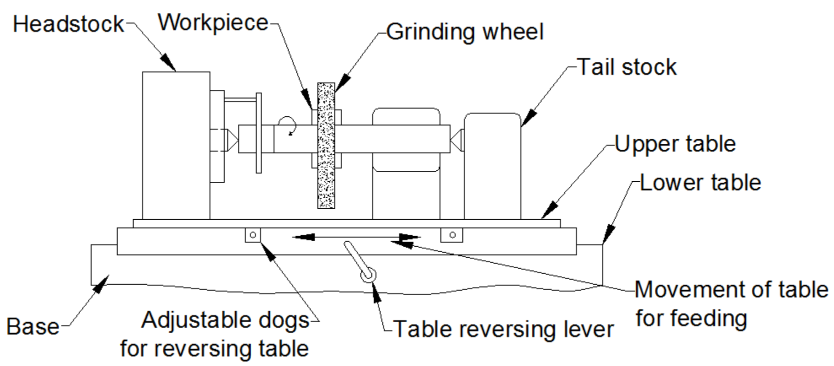


Fig. 4.8. Cylindrical Grinder

1. Base

This is made of CI and rests on the floor and it supports the other parts which are mounted on it. Horizontal guide ways are set on the top of the base. Table slides on these guide ways are set on the top of the base. The table slides on these guide ways for giving traverse motion to the work piece. The driving mechanism for the table is housed inside the base.

2. Table

This machine has two tables such as upper table and lower table. The lower table slides on the bad guide ways to give the longitudinal feed of the work past the grinding wheel. The table can be moved by hand or by power. The dogs are provided at the side table to reverse the table at the end of the stroke. The upper table is mounted on the lower table. Head stock and tail stock are mounted on the upper table. The table can be swivelled for the maximum angle up to 100 on either side

3. Head stock

The head stock has dead centre on which the work piece is supported. The work piece is driven by head stock through a dog and driving pin. A separate motor is used in the head stock for rotating the workspace

4. Tail Stock

Different length of work piece is clamped between head stock and tail stock by adjusting the distance through tail stock. The work piece is held between head stock and tail stock.

5. Wheel head

The grinding wheel is held in the wheel head and it is driven by a motor housed in the head stock. The wheel head is placed over the bed at the back side. It can be moved perpendicular to the table guide ways by hand or power.

6. Working

The required work piece is held between centres. It is rotated by a dog or a face plate. Then the grinding wheel is made to rotate in its own axis in the opposite direction of work. Then the grinding wheel is fed by hand or automatically towards the work piece.

UNIVERSAL CENTRE TYPE GRINDERS

This type is mostly used in tool room for grinding the tools. This machine is similar to the cylindrical grinding machine. But the wheel head and head stock can be swiveled to the required angle. This machine is provided with the following features.

1. The centre of the head stock spindle can be used alive or dead.
2. The wheel head can be swiveled in a horizontal plane in any angle.
3. The head stock can be swiveled in a horizontal plane in any angle.

4. The wheel head may be arranged for internal grinding.

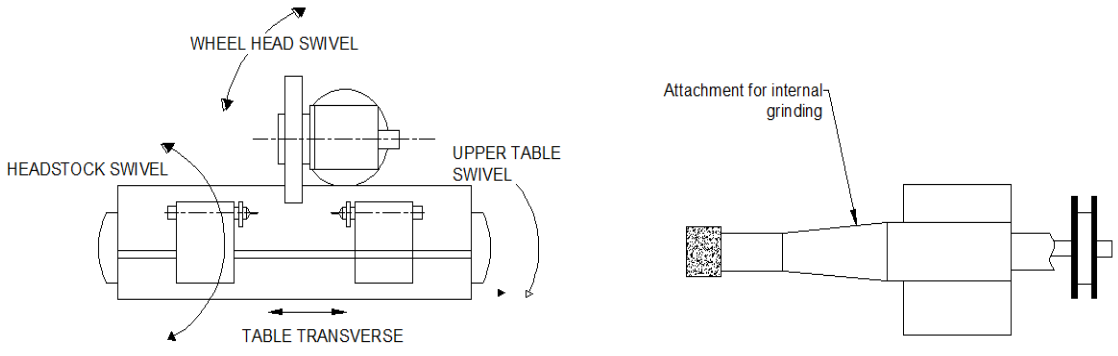


Fig. 4.9. Universal Grinder

The following equipment's are used in universal grinding machine.

1. Support slender work
2. Wheel truing device
3. Arbor
4. Internal grinding spindle
5. Three jaw self-centering chuck

CENTRELESS GRINDER

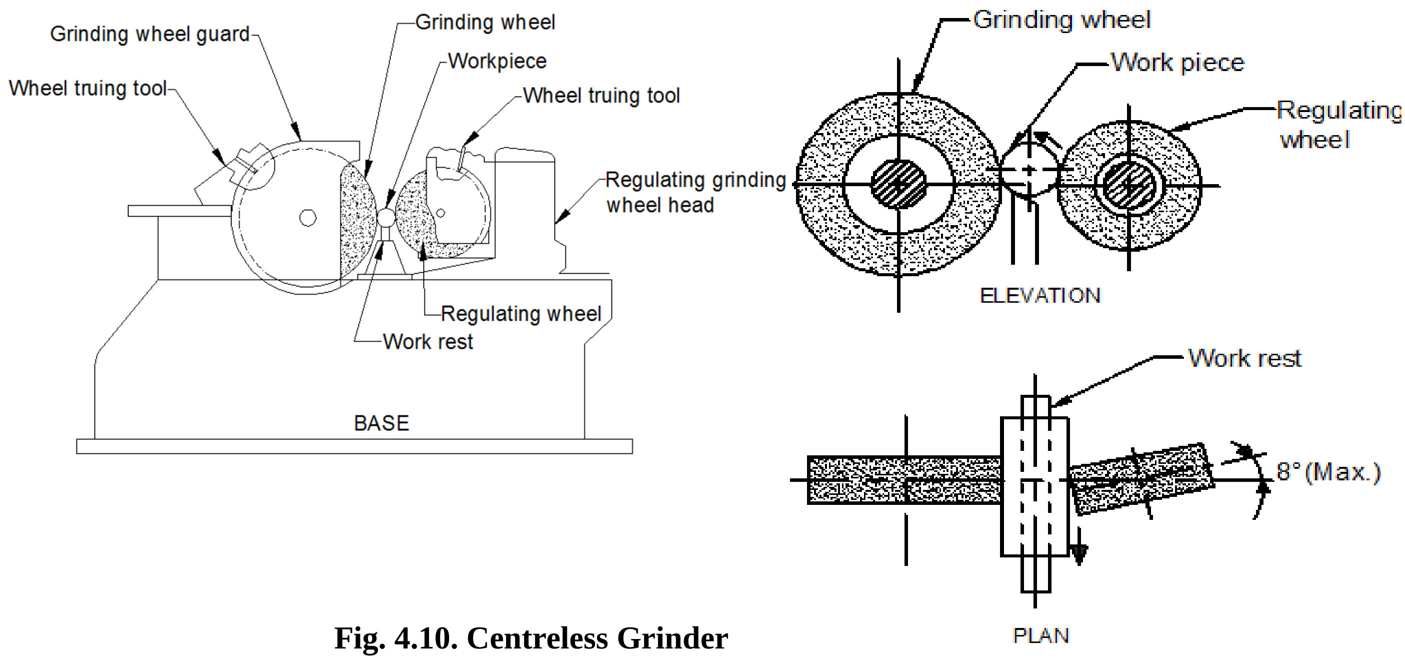


Fig. 4.10. Centreless Grinder

Horizontal Spindle Surface Grinder:

The work piece cannot be held between the centres of the machine can be machined by this type of grinding machine. The external centreless grinding machine has grinding wheel, regulating wheel or backup wheel and work rest. The two wheels are rotated in same direction. The larger grinding wheel revolves at a high speed and small regulating wheel revolves at slow speed. The work rest is placed between the two wheels. The work piece is placed on the rest. The regulating wheel is moved forward for forcing the work against the grinding wheel. This causes friction between the grinding wheels makes the work piece to rotate.

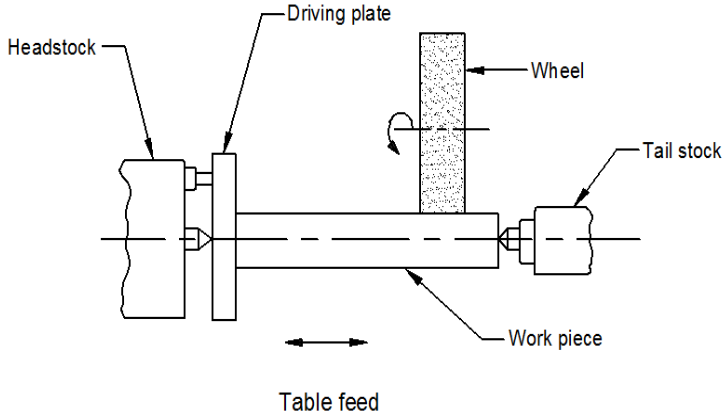


Fig. 4.11. Horizontal Spindle Surface Grinder

Then the rotating work piece is pressed between the two grinding wheels and they grind the surface. The regulating wheel does not remove the metal. The work piece is placed in a floating condition between the grinding wheel and regulating wheel while doing the grinding operation. So, this grinding operation is called centreless grinding.

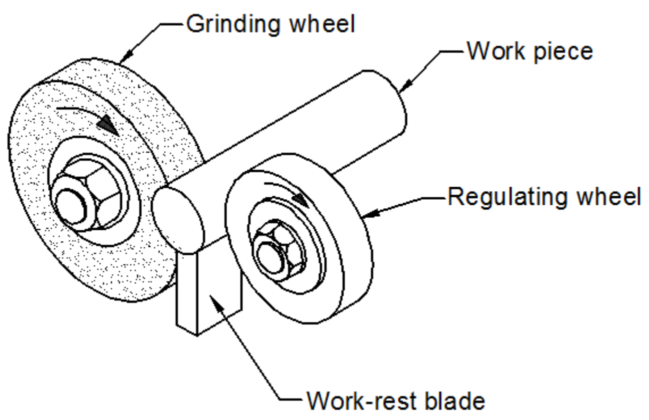


Fig. 4.12. Centreless Grinding

METHODS OF CENTRELESS GRINDING

1. Through feed
2. In feed
3. End feed

1. Through feed

This method is suitable for grinding the long shaft or bars and rollers pins. In this method, the regulating wheel is tilted at a small angle for moving the work piece axially through the space between the grinding wheels and regulating wheel. Guides are provided at both ends of the wheel for guiding the movement of the work piece.

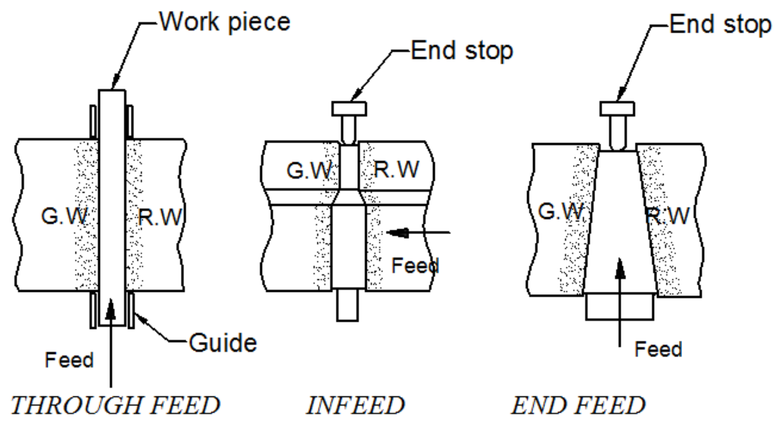


Fig. 4.13. Methods of Centreless Grinding

2. In feed grinding

In this method, the work piece is placed on the work rest against an end stop. Due to this, the axial movement of the work piece is avoided. Then the regulating wheel and the work rest with the work piece are moved towards the grinding wheel by giving hand feed. This method of grinding is similar to the plunge grinding. Shoulders and formed surfaces are ground by this method.

3. End feed grinding

This method is suitable for producing tapered surface. So, the grinding wheel or regulating wheel with required form of taper is used for grinding. The work piece is fed axially between the wheels and ground. An end stop is provided at the rear end of the wheel for stopping the work piece at the required length.

Advantages of centreless grinding

1. Fixtures and other clamping devices are not required for holding the work piece.
2. This is the faster process than the centre type grinding.
3. The size of the job can be controlled easily by the regulating wheel.
4. Skilled operators are not required
5. Suitable for mass production.

Limitations

1. Work piece with steps and multiple diameters as cannot be ground easily
2. The cylindrical surface with a keyway or holes cannot be ground.

INTERNAL GRINDERS

Internal grinder is used for grinding inside surface of the work piece. The inside surfaces may be straight, tapered or formed holes. Generally, the following three type of internal grinder are used.

1. Chucking
2. Planetary
3. Centreless

1. Chucking type internal grinders

In this machine the work piece is held in the chuck and rotated about its axis. The work head is mounted at the left side of the machine and the wheel head is mounted at the right end of the machine. The grinding operation is done on the work piece by reciprocating the rotating grinding wheel through the length of hole in the work piece. This type of machine is suitable of grinding the work piece which can be held in the chuck.

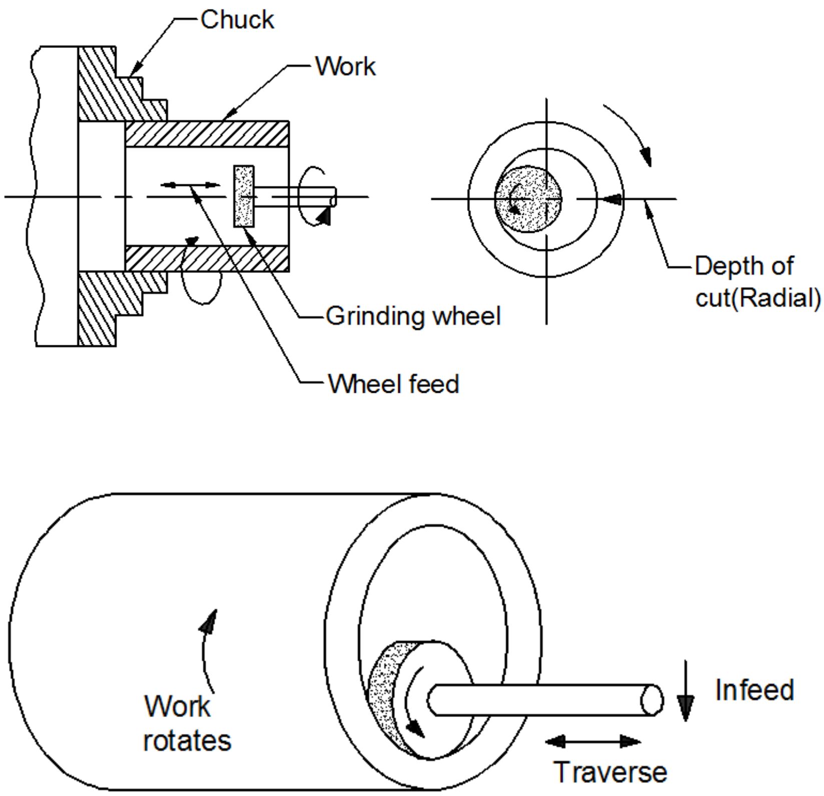


Fig. 4.14. Chucking type Internal Grinder

2. **Planetary type grinders**

   The work piece is held in the reciprocating table and the work piece is clamped rigidly. The work piece will not be moved. But for grinding the work piece, the rotating grinding wheel is moved inside the work piece and reciprocates for grinding the surface. Planetary grinder is useful for grinding the large size holes.

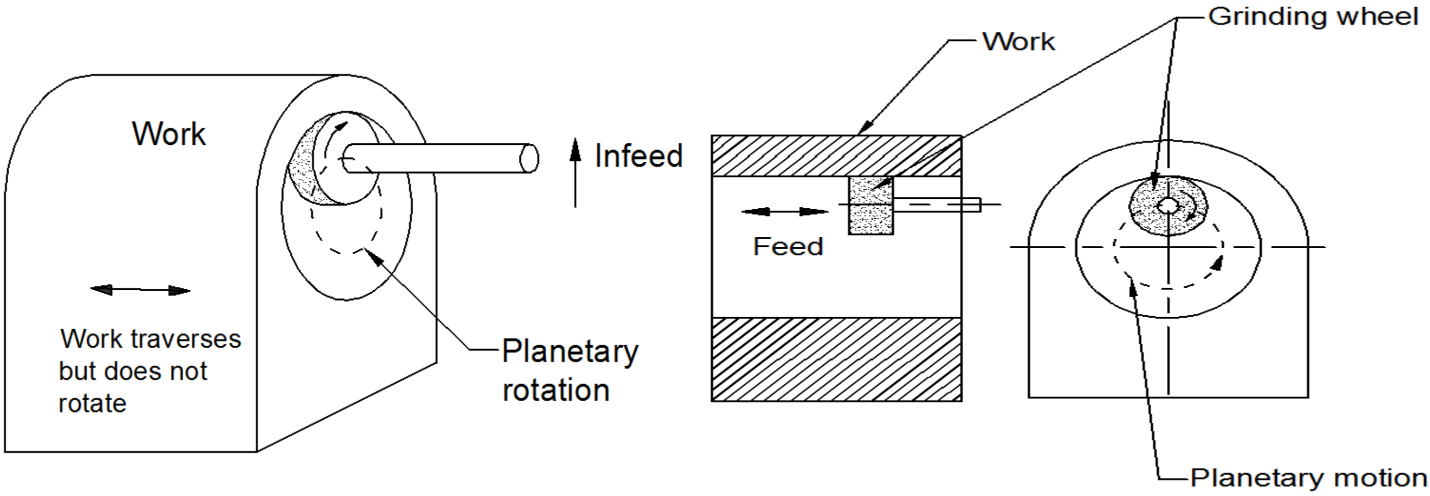


Fig. 4.15. Planetary type Internal Grinder

3. **Centreless grinding**

In this grinding, the work piece is supported by the three rolls. One is regulating wheel, second is a supporting wheel and other is a pressure roll to hold the work piece against the support and regulating rolls. The regulating wheel makes the work piece to rotate. The rotating grinding wheel is moved inside the diameter of the work piece and reciprocates for grinding the surface. Then the grinding wheel is moved in a cross wise direction for giving depth of cut.

SURFACE GRINDERS:

This machine is suitable for grinding flat and plane surface. Irregular, curved and tapered surfaces also can be ground using this machine. Die, Valve, Piston rings, surface plates are finished by this grinding machine.

HORIZONTAL SPINDLE – RECIPROCATING TABLE SURFACE GRINDER

1. **Base**

Base is made by casting with rectangular shape. Driving mechanism is housed inside the base. A vertical column is mounted on the back side of base. Horizontal guide ways are in the top of the base and these are perpendicular to the column.

2. **Table and saddle**

Saddle rests on the base. The saddle moves on the guide ways which are perpendicular to the column and gives cross feed. The table moves on the horizontal guide ways of the saddle. Longitudinal feed is given by moving the table. ‘T’ slots are provided on the table for holding the work.

3. **Wheel head**

A separate motor is mounted at the top of the column for operating the wheel head. The wheel head moves up and down on the vertical guide ways of the column.

Operation

Magnetic chuck or fixtures are used for holding the work piece on the table. The trip dogs are adjusted suitably to get the correct stroke length of the table. Then the table with work piece reciprocates and the periphery of the rotating grinding wheel grinds the work piece. Depth of cut is given by lowering the wheel head or raising the table. Cross feed is given to the work piece at the end of every stroke.

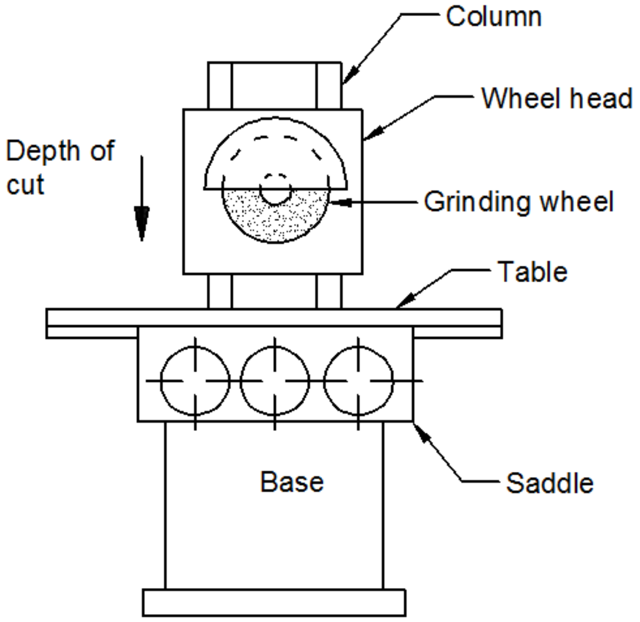


Fig. 4.16. Surface Grinder

HORIZONTAL SPINDLE – ROTARY TABLE SURFACE GRINDER

Rotary Table Surface Grinder

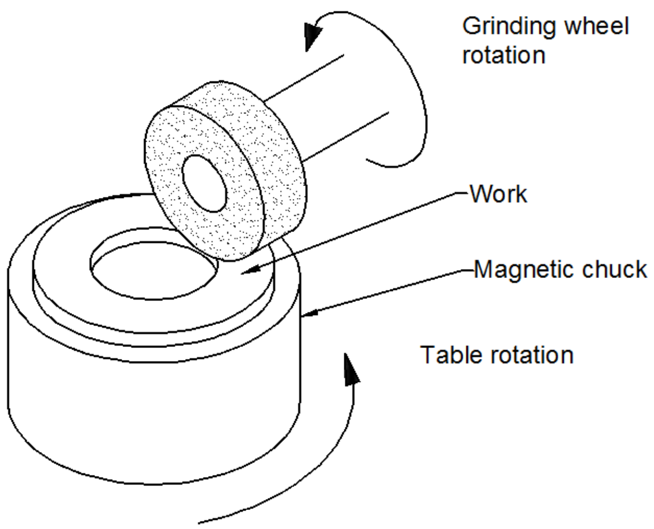


Fig. 4.17. Horizontal spindle Rotary table Surface Grinder

In this grinder, a rotary table is used. Small size work piece is held in the table and rotated. Wheel head of the machine reciprocates in its axis. This movement gives the cross feed. The wheel head is moved down for giving depth of cut. The peripheral surface of the grinding wheel grinding the surface. This machine is suitable for grinding small and medium size works.

VERTICAL SPINDLE RECIPROCATING TABLE SURFACE GRINDER

The work piece is clamped on the reciprocating work table using a magnetic chuck or a fixture. A grinding wheel rotates in its vertical axis. The face or side of the grinding wheel cuts the metal. The wheel head is moved down for giving the depth of cut. The longitudinal and cross feed are given through the table. This machine is useful for grinding the flat surfaces of medium size work piece.

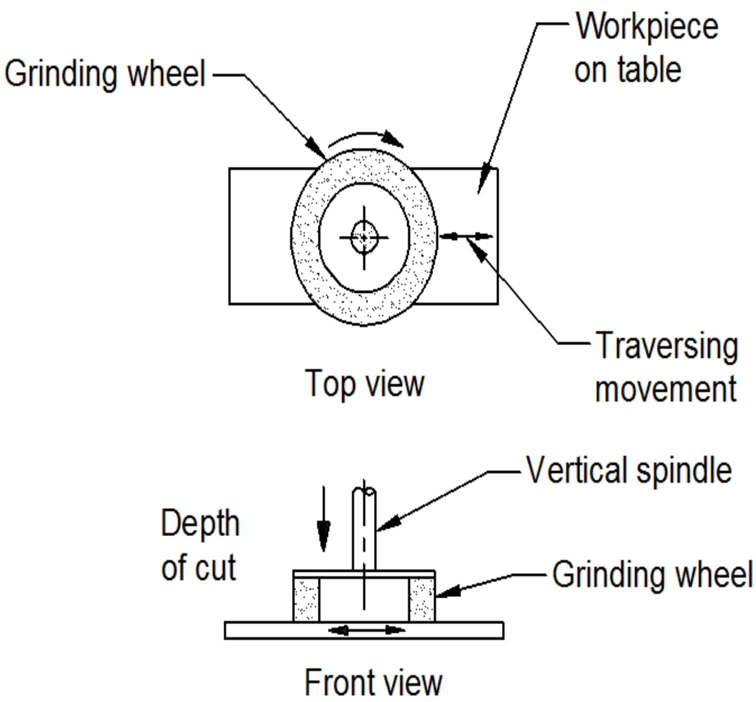


Fig. 4.18. Vertical spindle Reciprocating table Grinder

VERTICAL SPINDLE-ROTARY TABLE SURFACE GRINDER

The grinding spindle is mounted vertically on the face of a column and rotates in fixed position. The grinding wheels are moved down for giving depth of cut and grinding the work piece which are rotating with the rotary table. This grinding machine is used for grinding large quantity of small work piece

GRINDING WHEEL:

Grinding Wheel

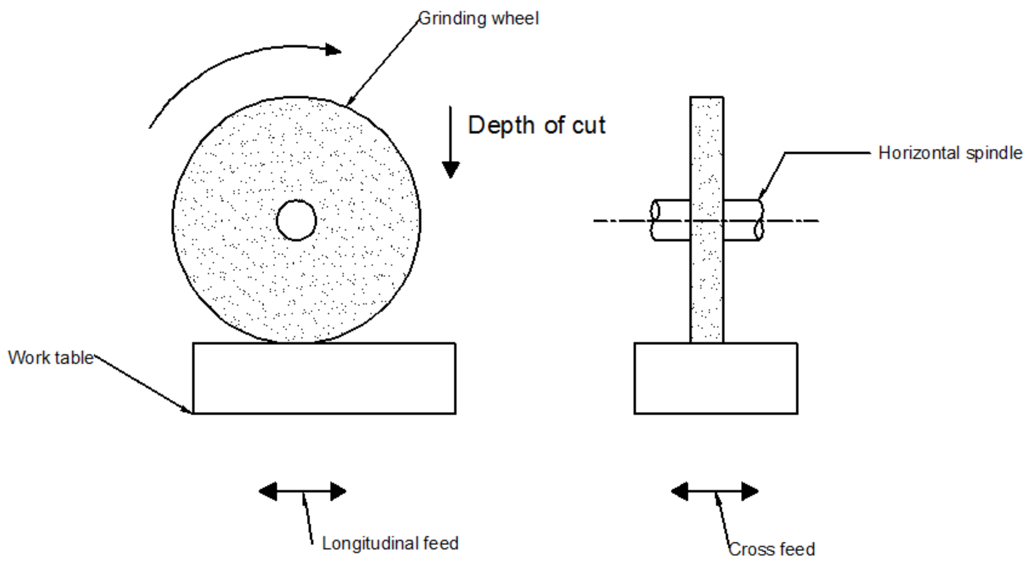


Fig. 4.19. Grinding wheel

Wheel Head

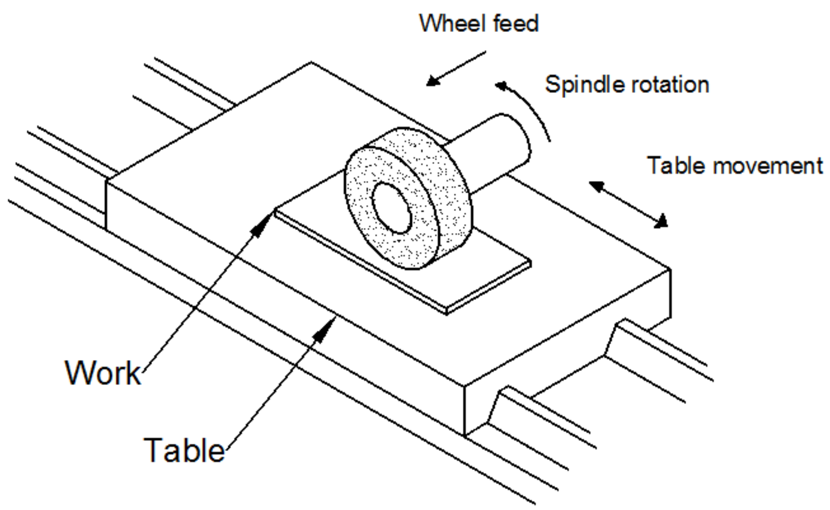


Fig. 4.20. Grinding wheel head

It is made up of small abrasive particles held together by a bonding material.

ABRASIVES

It is a hard material. Small abrasive particles are used in grinding wheel. Abrasives are classified into two types. They are

1. Natural abrasive 2. Artificial abrasive.

1. **Natural abrasive**

   This type of abrasive is available in nature. The following are the natural abrasives.

   1. Sand stone
   2. Emery
   3. Diamond
   4. Corundum

2. **Artificial abrasives**

   Abrasives particles are manufactured with required quality by artificial method. Mostly artificial abrasives are used for manufacturing the grinding wheels. Quality and the hardness of the artificial abrasives are more than the natural abrasive. The various manufactured abrasives are given below.

   1. Aluminium oxide
   2. Silicon carbide
   3. Artificial Diamond
   4. Ceramic aluminium oxide
   5. Boron carbide

a. Aluminium oxide

This type of abrasives is manufactured from the bauxite mineral. It is manufactured by fusing the bauxite in an electric furnace mixed with coke and iron scrap. After fusing, it is crushed and finally ground. Mostly the grinding wheel with aluminium oxide abrasive is used for grinding the carbon steel, alloy steel, HSS, wrought iron alorite, abrasite, Electrite and Alundum are the other names of the Aluminium

b. Silicon carbide

It is manufactured from the silica sand. Silica sand, coke and wood dust are mixed and kept in the electric furnace for beating them for producing silicon carbide. This made with this abrasive is used for grinding the metals like iron, aluminium and copper.

BONDS

Bond is an adhesive substance which holds the abrasive grains together to form the grinding wheel. Vitrified bond is used for precision grinding. Resinoid bond is used for rough grinding. The following are the different bonding materials.

1. Rubber bond (R)

The regulating wheel which is used in centreless grinder is manufactured by rubber bond. Sulphur with rubber is used for manufacturing rubber bonded grinding wheel.

2. Shellac bond or Elastic bond (E)

Shellac bonded wheels are made by mixing the abrasive grains with shellac in a mixture. Then the mixture is rolled or pressed to the desired shape and hardened about 200˚c for a particular time.

3. Vitrified bond

In this, clay and water is mixed and placed in mould to get the shape of the wheel and air dried at room temperature. Then the moulded wheels are kept about 1260˚C for a few days. Then they are trimmed to the required size. Thus the vitrified bonded grinding wheels are manufactured.

4. Silicate bond (S)

Here, sodium silicate is used as bonding material. Abrasive particles with sodium silicate are mixed and placed in the mould to get the required wheel shape and kept it about 270˚C for 20 to 80 hrs.

5. Oxy chloride bond

Oxide and magnesium chlorides are used as bonding material for manufacturing grinding wheel.

6. Resinoid bond

Synthetic Resins are used as bonding material. Synthetic resin mixed with abrasive grain and placed in the mould to get the required wheel shape and heated about 2000˚C for several hours. During the heating time, the resin melts and joined with the abrasive grains. This type of bonded wheel can be rotated with higher speed. And used for rough grinding on steel parts and castings.

GRAIN OR GRIT

Abrasive particles size is mentioned as grain or grit. Same or different sizes of grains are used for manufacturing the grinding wheel. The selection of grit or grain size mainly depends on the following:

1. The amount of material to be removed
2. Required finishing
3. Property of the metal

Soft and Elastic materials can be ground by course grit wheels and brittle materials are ground by fine grit wheels. Grain size is mentioned as number. This number indicates the number of meshes per linear inch through which they are passed. The grain sizes are divided as shown in the table.

Grinding Operation	Grit or Grain size						
Coarse	10	12	14	16	20	24	
Medium	30	36	46	54	60		
Fine	80	100	120	150	180		
Very fine	220	240	280	320	400	500	600

GRADE:

Grade indicates the strength, with which bonding material holds the abrasive grains in the grinding wheel. Bonding strength or hardness is indicated by English alphabets. 'A' is the softest wheel and 'Z' is the hardest wheel. The grinding wheel with different grades is shown in the following index.

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

STRUCTURE OF GRINDING WHEEL

Structure indicates the space between the abrasive grains. Structure is denoted by a number when the spacing between the grains is small, the structure is called dense structure when the spacing between the grains is more, and the structure is called open structure.

The following table shows the structure of grinding wheels.

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

WHEEL SHAPES AND SIZES

1. **Peripheral grinding wheel**

   In this the periphery of the wheel is used for grinding and these are mounted on horizontal spindles.

a) **Straight wheels**

   These are used for cylindrical, Internal, Centreless and surface grinding operations.

b) **Tapered face wheels**

   Two sides of the wheel are tapered and these are used for grinding threads on and gear teeth.

c) Recessed wheels

This type of wheel has recess on both sides. The sides and periphery of the wheels are used for grinding.

2. Face grinding wheels

a) Ring or cylindrical wheels

These are suitable for grinding small flat surfaces.

b) Flaring cup wheels

These wheels are used for tool and cutter grinding.

c) Dish wheels

These are also used for tool and cutter grinding

d) Cup wheels

Large flat surfaces are ground by these wheels.

STANDARD MARKING SYSTEM OF GRINDING WHEELS

The grinding wheel is specified by a standard system of marking the grinding wheels. The following are indicated in the marking system Type of abrasives

1. Grit size or grit number
2. Grade of the wheel
3. Structure
4. Type of Bond
5. Manufacturer’s code

The standard marking system is shown below.

W A 36 K 5 R 17

Manufacturer's

Manufacturer's

symbol

symbol

Abrasive

A - Aluminium

Rubber

Silicon carbide

Shellac

Silicate

Oxychloride

Coarse Medium

Vitrified

10	30
12	36
16	46
20	60
24	

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

B- Resinoid

R-

E-

S-

O-

V-

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

SELECTION OF GRINDING WHEEL

Selection of suitable grinding wheel is very important one. The selection of grinding wheel depends on the following factors.

1. Constant factors 2. Variable factors

1. Constant factors

a. Physical properties of material to be ground

Tensile strength and toughness is more in the steel and bronze. So these metals are best ground with aluminium soft bronze, chilled cast iron and aluminium metals can be ground by silicon carbide wheels. Hard wheels are used for grinding soft metals and soft wheels are sued for grinding hard materials.

b. Amount and rate of stock to be removed

Coarse grain and wide spacing abrasive wheels are used for grinding with faster speed. Fine grain and close spacing abrasive wheel are used for grinding the surface with good surface finish.

c. Area of contact

The area of contact between the wheel and work affects the pressure over the number of cutting points. If the contact area of the grinding wheel is small, fine grain and close spacing will be useful if the contact area of the grinding wheel is larger, coarse grain and wide spacing is suitable.

d. Type of grinding machines

Soft wheels are better for using in heavy rigidly constructed machines. Suitable grinding wheel are selected according to the feeds and speed available in the machine.

2. Variable factors

a) Work speed

The speed at which the work piece traversed across the wheel face is called work speed. If the work speed is more, the wear of grinding wheel will be more, in this case hard wheel is better. If the work speed is slow, the wear will be low on the grinding wheel in this case soft wheel is better.

b) Wheel speed

The speed of the grinding wheel is influenced by the grade and bond. If the wheel speed is high, soft wheel is better if the speed is low, hard wheel is better. Vitrified bonded wheels are suitable for grinding with the speed up 2000m/min. Rubber, Shellac and retinoid bonded wheels are better when the wheel speed is above 2000m/min.

c) Condition of the grinding machine

Soft wheels are better when grinding in dry condition. Hard wheels are better when grinding in wet condition. Well maintained machine can use soft grade wheels. Light machine ash use hard wheels.

d) Personal factor

The skill of the worker is very important one. A UN skilled worker cannot handle soft wheels so he must be allowed to work on hard wheels.

MOUNTING OF GRINDING WHEEL

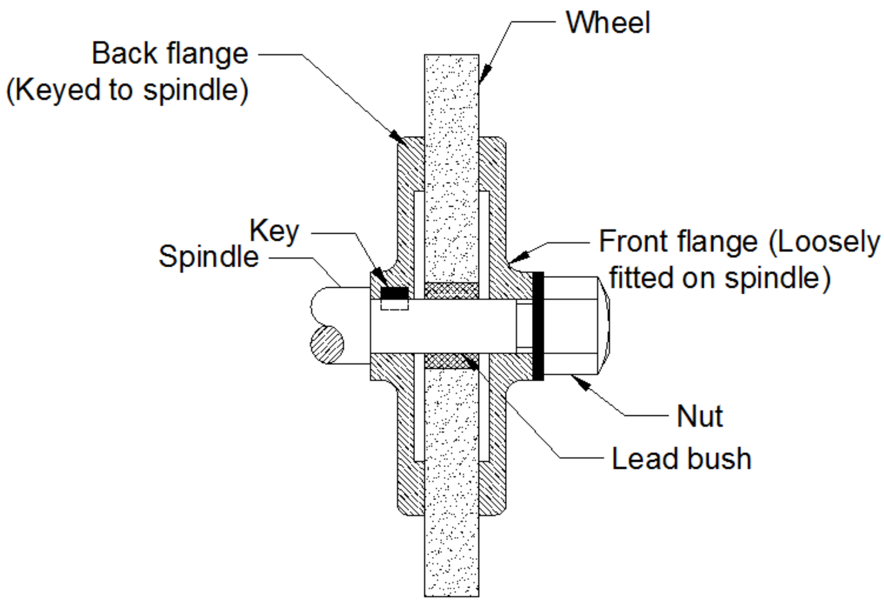


Fig. 4.21. Mounting of Grinding wheel

The grinding wheel rotates at high speed. If it is not fitted properly, it will be dangerous to the operator, before mounting, all grinding wheels should be inspected by ringing test. A good wheel gives a ringing sound on light taping with a metal bar. A cracked wheel will give a dull sound. The following points should be considered while mounting the grinding wheel.

1. Grinding wheel should not be forced on the spindle. The wheel must have sliding fit.
2. A bush is used in the bore of a grinding wheel and it should not project beyond the wheel face.
3. Flanges are used while fitting the wheel. That flanges diameter must be at least equal to half of the wheel diameter.

4. Wheel side and flange side should be perfectly flat.
5. Flanges should have the clearance only on their faces.
6. The inner fixed flange should be keyed to the spindle. The outer flange has a sliding fit with the spindle.
7. Thick compressive washers should be placed on both sides of the wheel faces and flanges for gripping of flanges on the wheel.
8. The nut should be tightened property.
9. Wheel guard should be placed in position.

LOADING IN WHEELS

When grinding a surface, the metal is removed in the form of fine particles. The removed fine particles enter into the spaces between the abrasive particles in a grinding wheel. This is called loading. After the loading, the cutting ability of the wheel will be reduced. Loading of fine particles is removed by dressing.

Glazing

When a grinding wheel is used for a long time, the cutting surface of the grinding wheel becomes smooth and gets a glass like appearance. It is known as glazing. If the grinding wheel gets a glazed surface, then it will not grind the surface effectively.

RECONDITIONING OF GRINDING WHEEL

Due to the long-time usage of grinding wheel, it is affected by glazing and loading. To make the wheel surface in good condition, it must be reconditioned. The grinding wheels are reconditioned by dressing and truing operations.

DRESSING

It is an operation of removing glazing and loading from a grinding wheel. This is done by using a tool to called dresser.

1. **Dressing by star wheel dresser**

   A star dresser made of steel is used for dressing course grained wheel the dresser tool has hardened teeth on its periphery and it is kept in a tool rest.

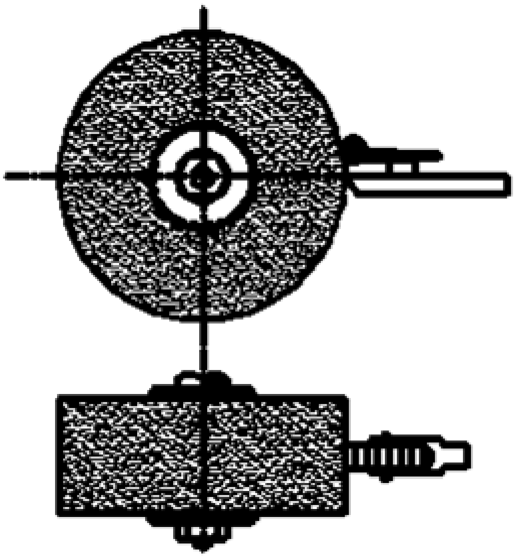
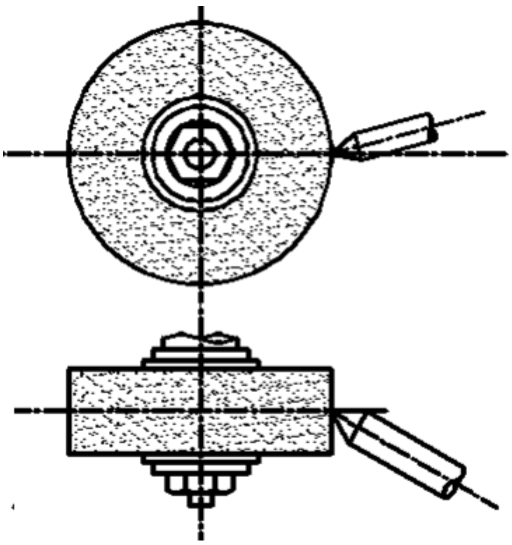


Fig. 4.22. Dressing by star wheel dresser

The dresser is pressed against the periphery of the slowly rotating grinding wheel. The dresser is moved cross wise along the width of the wheel.

2. Round abrasive stick

Bonded abrasives are filled in a tube and it is called round abrasive stick. Dressing is done on the grinding wheel by moving the tube on the rotating grinding wheel face.



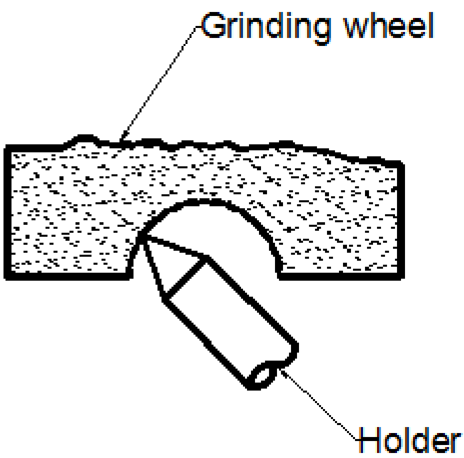


Fig. 4.24. Dressing formed wheel

Fig. 4.23. Diamond tip dresser

3. **Diamond dressing tool**

A diamond tipped dresser is used for dressing the grinding wheel which are used for precision grinding. The diamond tip is held in a holder and kept at an angle to the wheel. The dresser is pressed against the slowly rotating wheel, and moved cross wise along the width of the bale.

BALANCING OF GRINDING WHEELS

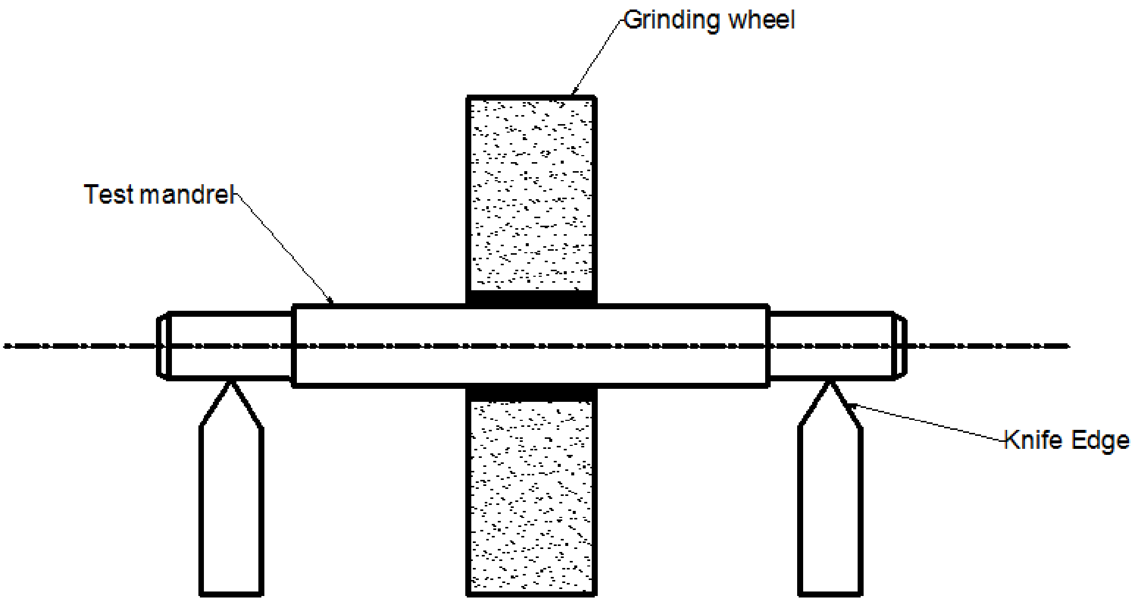


Fig. 4.25. Balancing of grinding wheel

During grinding, the grinding wheel rotates at very high speed. So the weight of the grinding wheel should be evenly distributed throughout the body of the wheel. If it is not distributed uniformly, unbalanced centrifugal force will be developed. It causes to the cracking and breaking of wheel when it rotates with high speed. So, the grinding wheel is balanced by the following ways.

The wheel is fitted to the test mandrel at the middle. The mandrel is placed over the two knife edges. These edges are parallel and placed on truly horizontal plane. The mandrel is slowly rotated to roll over the knife edges. When the wheel comes to rest, a marking is done with paint at the bottom of the wheel. Similarly, the same procedures are done for several times. If the markings arte in various place, then the wheel is in balance. If the markings are at a particular place, then it is considering as unbalanced wheel. For balancing the grinding wheel, the weight at the particular place should be reduced. This is done by removing some lead from the lead bush at this marked place. Again the same procedures are carried out for balancing the wheel correctly.

<u>Modern machining process / Unconventional machining process:</u>

Modern machining process 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. **Modern machining process are also known as Non-traditional machining process / Unconventional machining process.**

<u>Difference between Conventional and Unconventional machining process:</u>

S#	Conventional machining process	Unconventional machining process
1	The cutting tool and work piece are always in ***physical contact***, with a relative motion against each other, which results in friction and a significant tool wear.	In Unconventional processes, there is ***no physical contact*** between the tool and work piece. Although in some non-traditional processes tool wear exists, it rarely is a
2	***Material removal rate*** of the traditional processes is ***limited*** by the mechanical properties of the work material	Non-conventional processes ***easily*** deal with such ***difficult-to-cut materials*** like ceramics and ceramic based tool materials and super
3	In conventional processes, the ***relative motion*** between the tool and work piece is typically ***rotary or reciprocating***. Thus, the ***shape*** of the work surfaces is ***limited*** to circular or flat	It is not as such in the non-conventional process as a lot of ***variety of shape*** can be given to the work piece
4	Machining of small ***cavities, slits, blind or through holes is difficult*** with conventional	It is ***not a problem*** as such in these processes.
5	Traditional processes are well established; use relatively simple and ***inexpensive*** machinery and readily available cutting tools.	Non-traditional processes require ***expensive*** equipment and tooling which increases significantly the capital cost.

<u>Needs / Importance of Modern machining process</u>

- Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling.
- Need to machine newly developed metals and non-metals with special properties that make them difficult or impossible with special properties that make them difficult or impossible to machine by conventional methods.

- Need to avoid surface damage that often accompanies Need to avoid surface damage that often accompanies conventional machining.
- Very hard fragile materials difficult to clamp for traditional machining.
- Temperature rise or residual stress in the work piece are undesirable.

The Unconventional machining process slightly overcome the above mentioned problems

Classifications of Modern machining process.

The non-conventional manufacturing processes may be classified on the basis of type of energy namely, mechanical, electrical, chemical, thermal or magnetic, apply to the work piece directly and have the desired shape transformation or material removal from the work surface by using different scientific mechanism.

S#	Energy	Process
1.	Mechanical Energy	1. Ultrasonic machining process (USM) 2. Abrasive jet machining process (AJM) 3. Water jet machining process (WJM)
2.	Electrical Energy	1. Electrical discharge machining process (EDM) 2. Wire cut electro discharge machining process (WCEDM)
3.	Chemical and Electro-chemical Energy	1. Chemical machining (CHM) 2. Electro chemical machining (ECM) 3. Electro chemical grinding (ECG)
4.	Thermal Energy	1. Electron beam machining (EBM) 2. Laser beam machining (LBM) 3. Ion beam machining (IBM)

ULTRASONIC MACHINING PROCESS (USM)

Principle

In this method with the help of piezoelectric transducer tool is vibrate at high frequency in a direction normal to the surface being machined abrasive slurry are used for the remove the metal from work piece.

Working

In ultrasonic machining, the tool vibrates at very high frequency i.e. 20 KHz. Per second. An abrasive slurry is applied between the tool and work piece. By this, very minute particles of work piece are removed by erosion and abrasion. The tool is slowly fed on the work piece. The tool shape is reproduced in work piece. The ultrasonic equipment has a transducer, tool holder and the tool. The transducer has nickel laminations wound with a coil.

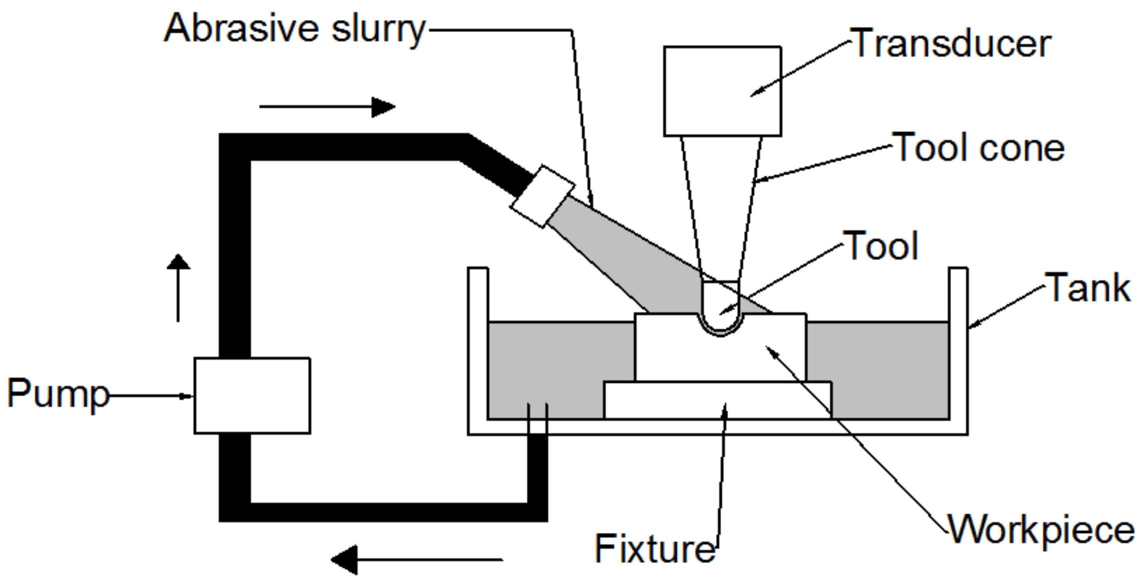


Fig. 4.26. Ultrasonic machining process

A high frequency current is supplied to the coil of the transducer. The transducer converts this high frequency current into mechanical vibration. These mechanical vibrations are transmitted to the tool through the tool holder. The tool vibrates axially with an ***amplitude of 0.05 mm*** and a ***frequency of about 20 KHz.*** An abrasive slurry is applied between the work surface and the tool. The slurry is made of a mixture of water and fine grains (***800 to 1000 grit size***) of aluminium oxide, silicon carbide or boron carbide.

Because of the tool vibration, the abrasive grains in the slurry are hammered into the work surface. Hence by abrasion and erosion, the metal is removed from the work as minute particles. By this action, the shape of the tool is reproduced in the work. The tool is fed downwards very slowly. Maximum ***feed rate is 0.1 mm/sec.***

The tool is made 0.01 mm smaller than the required hole. The tool is made of soft ductile material such as soft steel, copper or brass. The tool holder is made of stainless steel. Dimensional accuracy up to 0.05mm is possible.

The abrasive particles, as they indent, the work material, would remove the same, particularly if the work material is brittle, due to crack initiation, propagation and brittle fracture of the material. Hence, ***USM is mainly used for machining brittle materials*** {which are poor conductors of electricity and thus cannot be processed by Electrochemical and Electro-discharge machining (ECM and EDM)

Applications of USM:

- For drilling holes in hard and brittle materials like ceramics, glass, boride, ferrite, carbides, precision stones like diamond and hardened steel.
- For making wire drawing dies in tungsten carbide or diamond.
- For engraving, die sinking, slicing and broaching of hard materials,
- For machinery both conducting and non-conducting materials.
- For machining precision stones and ceramics.

Advantages of USM:

- Very hard and brittle materials like carbide and tungsten are easily machined by this process. These materials cannot be machined by the ordinary process.
- Set up of the machine is simple. Less skilled operator is sufficient.
- It is possible to make holes of any shape (circular and non-circular) for which a tool can be made.
- Set up time is less and Production cost is less and Accuracy is more.
- It can be used for machining both machining both conducting and non-conducting material.

Limitations of USM:

- Very slow metal removal; hence machining time is more.
- High power consumption.
- Not suitable for heavy stock removal.

CHEMICAL MACHINING (CHM):

In chemical machining, some chemicals are used to remove material from the required portions of the work piece.

This process is also called **chemical milling.** The figure shoes the process of chemical milling. Chemical milling is done in the following steps.

1. **Cleaning**

The wok piece surface is thoroughly cleaned.

2. **Masking**

The portions of the work piece which do not require machining is covered with masking sheets. The sheet is cut and removed from the area where ***machining is required.*** Templates are used for this purpose. If the entire area of the work piece is to be machined, masking is not necessary usually ***vinyl, neoprene and rubber based materials*** are used as mask sheets.

3. **Etching**

After masking, the work piece is submerged in a hot chemical solution. This solution is called the etchant. <u>*Caustic soda is used as etchant for Aluminium. Acids are used for steel, magnesium and titanium alloys.*</u>

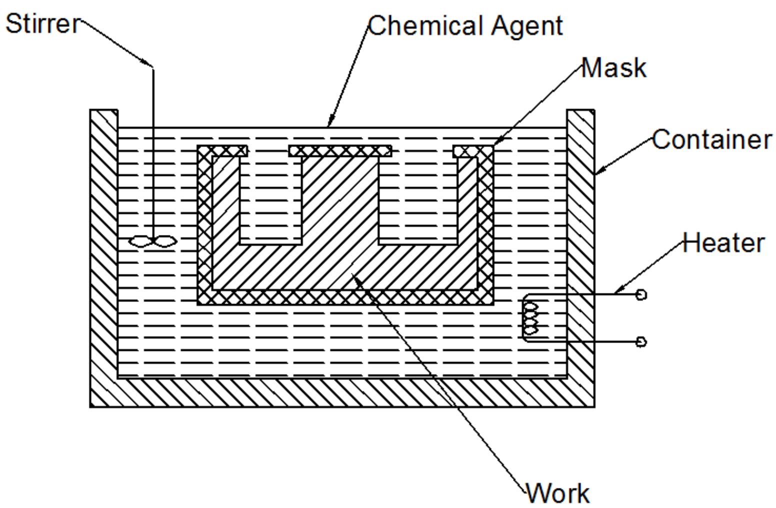


Fig. 4.27. Chemical machining process

The etchant removes the metal from work piece by chemical action. The rate of metal removal is about <u>***0.025 mm per minute.***</u> The rate of metal removal depends upon the concentration and the temperature of the etchant.

Higher the concentration and temperature, more is the rate of metal removal. The amount of metal removal also depends upon the time duration for which the work piece is immersed in the etchant.

4. **Demasking**

After etching, the work piece is ***taken out from the etchant***. The work piece is cleaned in water. Then the marking is removed.

Applications:

- Chemical machining is effectively used for removing metal from a curved or irregular surface.
- It is used for machining on very thin surface.
- It is used to produce special profiles in aeroplane parts, automobile parts, electronic equipment's and instruments.
- Sheets having taper on its surface can be produced in this process.
- Chemical machined parts are used in tape-recorders, Computers, cameras, T.V. sets, electric motors, timers, telephones, medical instruments, etc.

Advantages:

- Very low operating costs.
- Low skill of the operator.
- Parts of any profile can be machined.
- The process does not produce any stress in the work piece. The process can be used for any metal.
- Parts of large size as well as thin sections are machined in the process.
- Uniform metal removal in all surface. Metal removal is easily controlled.
- All the slides of the work piece at machined at the same time.

Limitations:

- Very slow process.
- Heavy stock material removal is not possible.
- Chemical vapours are injurious to health.
- Larger floor space is required.

ELECTRO CHEMICAL GRINDING (ECG)

Electro chemical grinding is also called electrolytic grinding. Metal is removed from the surface of the work piece by electro chemical action and also by abrasive action of a grinding wheel. 90% of metal is removed by electro chemical action and 10% of metal is removed by the abrasive action of the grinding wheel.

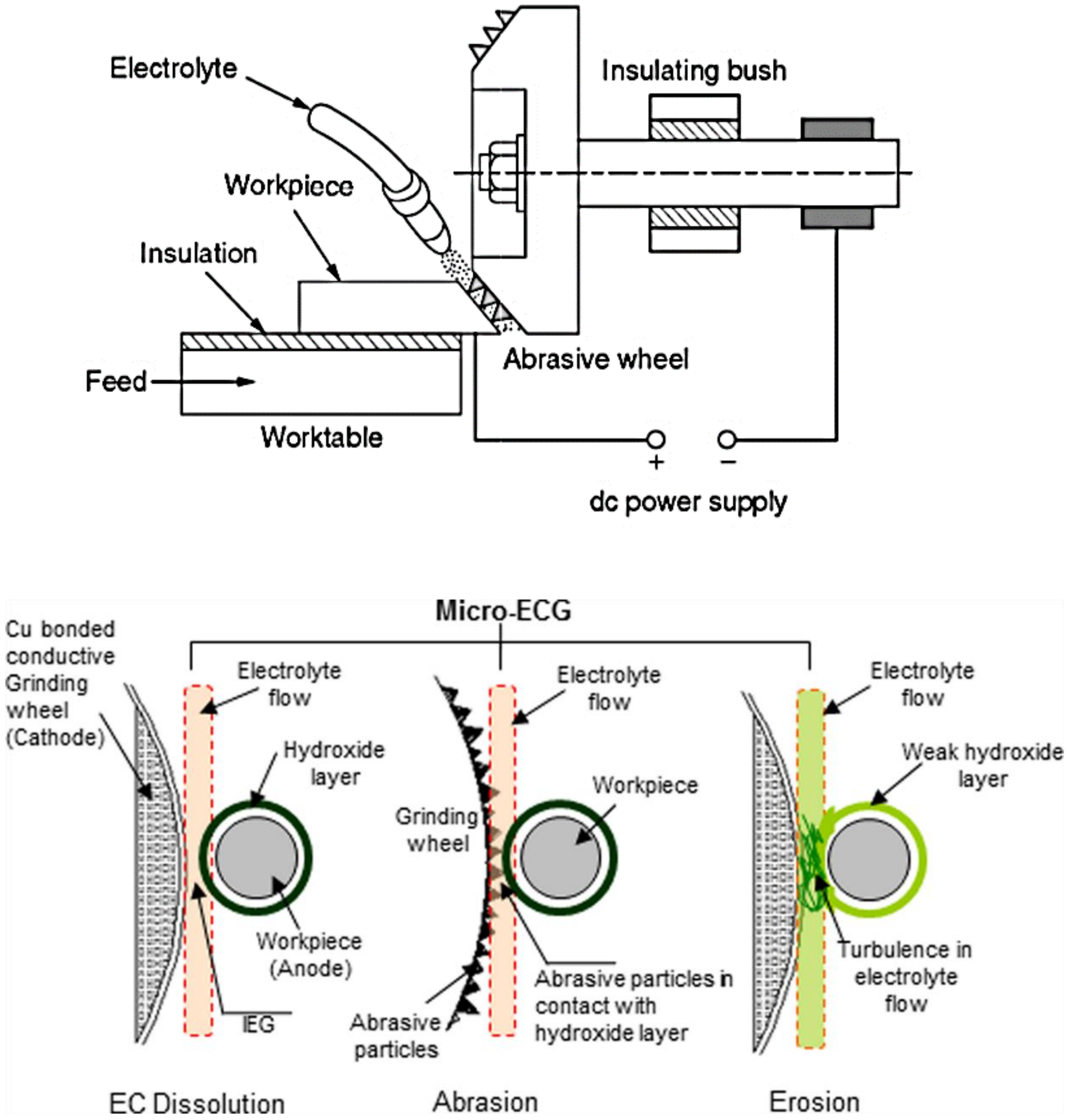


Fig. 4.28. Electro chemical grinding process

The equipment has a metal bonded grinding wheel. Brass, bronze and copper are bonded with abrasive grains in the grinding wheel. Diamond abrasive is used for grinding tungsten. Aluminium oxide abrasives is used for other metals.

The wheel is held in a horizontal spindle. The spindle is supported on insulated bearings. The work piece is held in a fixture against the grinding wheel. A gap of about 0.01 mm is maintained between the wheel and the surface of the work piece. The work piece is connected to the –ve terminal of a D.C. supply. The grinding wheel is connected to the –ve terminal. 4 to 16V, 300 to 1000 Amps D.C supply is applied.

A mixture of sodium chlorite, sodium chlorate or sodium nitrate and water is used as the electrolyte. The electrolyte solution is made to flow between the work piece and the grinding wheel. Electro chemical action takes place. Metal from surface of the work piece is removed in small particles. In addition to this, the rotating grinding wheel also removes metal from the work surface by abrasion. The small particles of metal removed from the work piece are carried away by the electrolyte. The electrolyte is collected in a reservoir.

It is filtered and recirculated by a pump. Electrolyte also acts as a coolant. The work piece is slowly fed towards the grinding wheel maintaining a constant gap between the work piece and the grinding wheel.

Applications:

- Used for machining hard material which are conductive to electricity.
- Used for grinding of tungsten carbide tool tips and hard steels.
- Used tom grinding, form grinding, plunge grinding and surface grinding operations are done using this process.
- Used for machining refractory materials, high strength steels, nickel and cobalt base alloys etc.,

Advantages:

- Very fine finish is obtained (0.2 to 0.4 microns cab be obtained)
- Suitable for machining very hard materials like carbides. Carbides are difficult to machine by other processes.
- No heat is generated during the process. No distortion to the work piece
- No burrs are produced. Fast operation.
- Thin materials can be ground without deflection as the grinding wheel does not press the work piece.
- No heat is generated so there is no danger of burning or heat distortion.
- Tolerances of about ±0.02mm can be obtained.

Limitations:

- This process can be used to machine only metals which are conductive.
- Sharp corners of the work piece cannot be machined.
- Electrolytic solution is corrosive.
- Initial cost of the equipment is high when equipped with larger power supplies.
- Intricate shapes may not be formed.

Electrical Discharge Machining (EDM)

Principle of metal removal:

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate ***electrical spark and material removal mainly occurs due to thermal energy of the spark.***

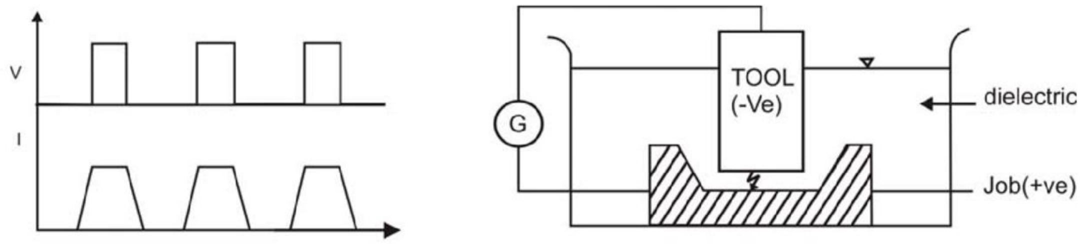


Fig. 4.29. Electrical discharge machining process

Working:

Whenever ***sparking takes place between two electrical contacts***, a small amount of material is removed from both the contacts. This eroding effect of an electric spark is used in EDM. This process is also known as Spark Erosion Machining. If both electrodes are made of same material, greater erosion *takes place at positive (+) electrode*; therefore the work is made positive and *tool is made negative (-).*

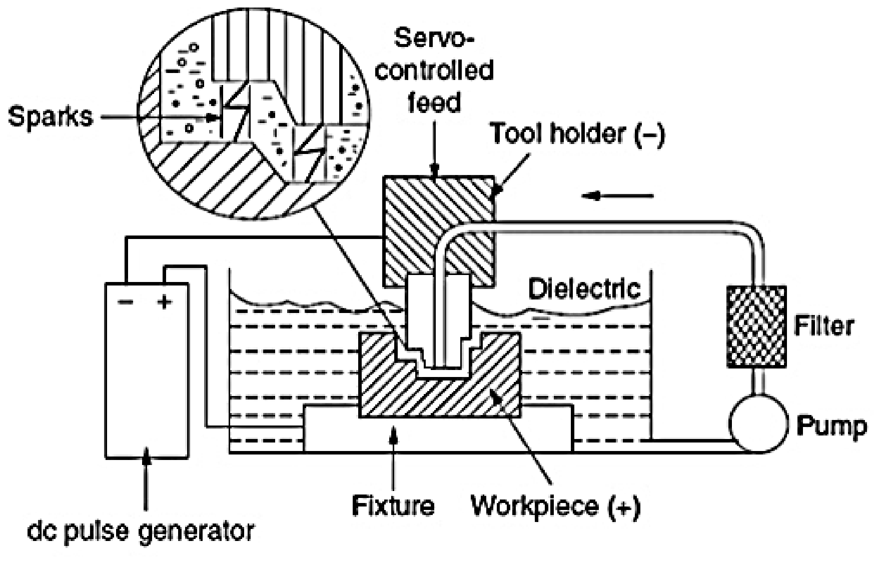


Fig. 4.30. Electrical discharge machining process

EDM arrangement is illustrated in the figure. Electric power is supplied from an A.C. source to a rectifier. D.C. output from rectifier (***80-100 Volt***) is then fed to the spark generating circuit. The tool and work are connected to the circuit.

The tool and work are submerged in a ***dielectric fluid (kerosene, paraffin, transformer oil).*** Dielectric fluid does not conduct electric current. The servo mechanism maintains a very small gap (***0.025 to 0.075***) between work and tool. The tool is fed down into work piece surface. Now sparking takes place. When the tool fully enters the work, sparking takes place across whole area of tool front face.

This reproduces tool shape upon the work surface. Again and again spark takes place in an interval of ***10 to 30 micro second***. Temperature of approximately ***1200°C*** is generated. Thus, thousands of spark discharge takes place per second. Work piece material is eroded. The dielectric fluid acts as coolant. It carries away the eroded metal particles.

Application of EDM

- Fine cutting with thread shaped electrode (wire cutting EDM)
- Die sinking, making: stamping tools, complicate mould cavities, wire drawing dies, extrusion dies, forging dies.
- Machining very hard material like tungsten carbide to make complicate cavities & shapes.
- Drilling very small (0.15 mm dia) holes in orifices, fuel injection nozzles.
- Making blanks from sheet metals. Curved hole drilling.
- Sharpening of tools, cutters and broaches.

Advantages of EDM:

- All metals and non-metals that conduct electricity can be machined.
- Complicated shapes can be produced.
- There is no cutting force. Therefore, thin work pieces can be machined.
- Very good surface finish is produced (0.2 micron). Machining accuracy is good (±0.05 mm)
- Very hard and even hardened materials can be machined.

Limitations of EDM:

- Power consumption is high.
- Only electrically conducting materials can be machined.
- Square corners can be produced.
- Work piece surface is heated. This changes metallurgical properties.
- Tool wear is high.

PLASMA ARC MACHINING (PAM)

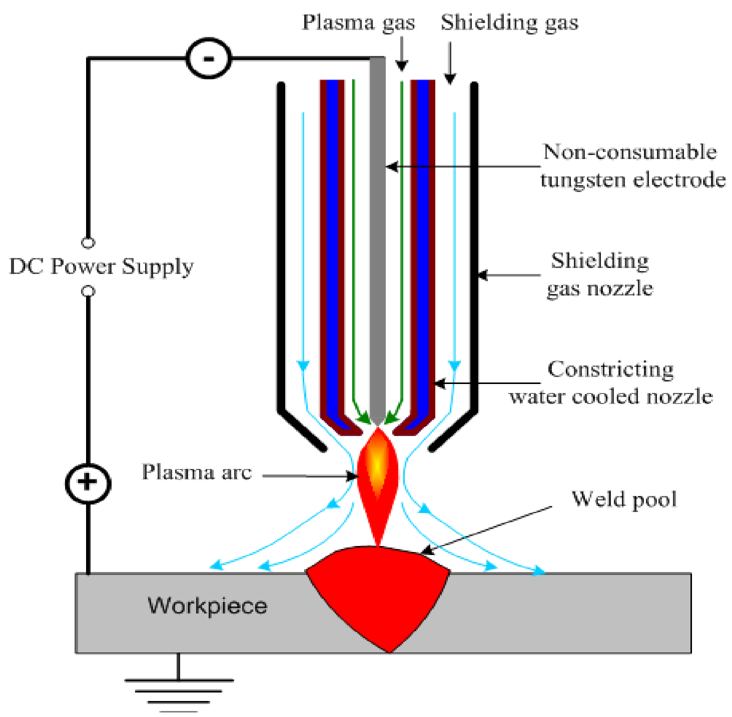


Fig. 4.31. Plasma arc machining process

When a flowing gas is heated to a very high temperature (about 1600°C) it becomes partially ionised. This ionised gas is known as plasma. In Plasma Arc Machining, metal is removed from the work piece surface by means of high temperature plasma. Metal is also removed due to electron bombardment.

The equipment has a chamber with a copper nozzle at the bottom. A tungsten electrode is held vertically in the gas chamber. The tungsten electrode is connected to the –ve terminal of a 400 V, 200 kW D.C. supply. The nozzle is connected to the +ve terminal.

When the supply is given, an arc is produced between the tungsten electrode (cathode) and the copper nozzle (anode). A di-atomic gas, usually H2, N2 or O2 is passed through the gas chamber. The gas passes through the arc. It is heated and gets ionised by the arc because of the high temperature. The ionised gas flows out of the nozzle as plasma flame. The plasma flame is forced on the work surface.

Because of the high temperature of the gas, the surface of the work piece gets melted. Due to the bombardment of ions on the surface of the work piece, the metal is eroded. The rate of metal removal can be increased by increasing the gal flow. Nozzle is water cooled. In due course, the tungsten electrode tip gets eroded due to high temperature. So the position of the electrode has to be adjusted.

Applications:

- Used for cutting stainless steel and aluminium alloys.
- Used for profile cutting and slitting in hard materials such as super alloy steels.

Advantages:

- This process can be used to cut any metal.
- The cutting action is very fast.
- It is possible to cut thick material up to 150mm

Limitations:

- Because of the high heat, metallurgical change takes place on the work piece.
- The process is unsafe. Safety precautions are necessary.

LASER BEAM MACHINING

The word LASER means ***Light Amplification by Stimulated Emission of Radiation***. Laser is an electromagnetic radiation. It is an electromagnetic radiation.

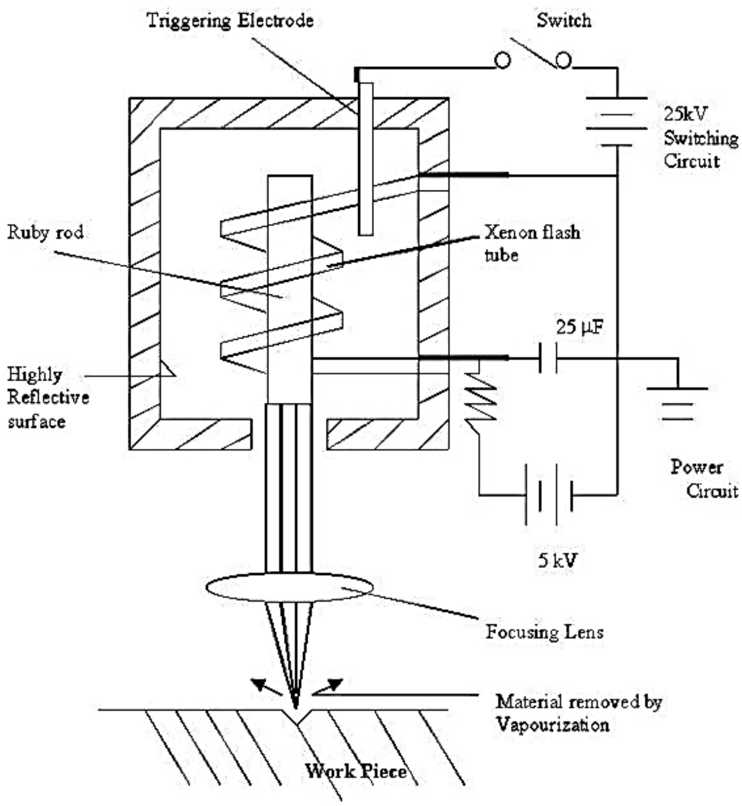


Fig. 4.32. Laser beam machining process

Principle:

- It is a beam of light having the same wave length (monochromatic light).
- This beam can be focussed by a lens on a very small spot on a work piece, the laser beam emits high heat which can melt and vaporises any material in the world.

- The equipment has a ruby crystal. The crystal is placed inside a flash lamp coil (1000 w) as shown in figure. The flash lamp is filled with Xenon gas. When the flash lamp is switched on, it gives high intensity light. The ruby crystal is stimulated and it emits the laser beam.
- By using a lens, the beam is focussed on the work piece. The work piece is fed past the beam. The portion of the metal is melted and vaporised.

Applications:

- Laser beam machining is a micro machining method. It is used for producing very fine and minute holes (0.005 mm) dia.
- It is used for drilling in small nozzle, orifices in very hard materials.
- Laser beams can be used in surgery.
- Used for drilling holes in surgical needles, oil or gas orifices and relief holes in pressure plugs.
- Used for cutting complex profiles in thin and hard materials like ceramics.

Advantages:

- It can melt and vaporise any known material. There is no tool wear.
- The machining operation is localised. Precision location can be achieved.
- Welding dissimilar metals can be done using laser beam.
- Can be used for machining materials that are less sensitive to heat-like ceramics.
- No mechanical force on the work piece and it machine both metals and non-metals.
- Holes can easily be drilled on curved or angular surfaces and holes are burr free.
- No direct tool content with work piece, so heat is extremely localised.

Disadvantages:

- High cost
- Large amount of metal removal is not possible.
- It cannot be used for cutting metal of high heat conductivity of high reflectivity (e.g. AL, Cu, and their alloys)
- Machined holes will not be perfectly round.
- Life of flash lamp is short and Efficiency of the process is low.
- The laser beam can be dangerous if it not used carefully.

S#	Aspects	LBM	PAM	CHM
1.	Principle of material removal	High electro-magnetic energy is (by laser beam) focussed on small work piece surface. Metal melts and vaporises.	Material is removed by striking on work-piece surface with a jet of high velocity and high temperature (16500°C) ionised gas. (Plasma). Metal melts and vaporises.	Materials is removed by chemical action by an etchant. (0.025 mm / min)
2.	Tool	Laser Beam	Plasma Beam	Etchant removes material
3.	Electrolyte or Chemicals used	--------------------	-----------------------	Etchants are used. Depending upon work piece material etchant is selected. Caustic soda for Aluminium. Acids for steel Hydrogen fluoride for Titanium & Silicon. Ferric Chloride for stainless steel, lead, Nickel & copper.
4.	MRR (Metal Removable Rate)	70 mm3/min.	Cutting rate 250 to 1700 mm/min.	Very slow metal removal 0.015 to 0.03 cm3 per minute. Depends upon the etchant, time duration of etching & area of work surface machined.

S#	Aspects	ECG	USM	EDM
1.	Principle of material removal	Material is removed by the combined effect of electro-chemical action & abrasive grinding action. 90% metal removal by electro-chemical action. 10% by grinding.	Abrasive grains mixed in water erode material as minute particles – by striking work at very high ultrasonic vibrations (20 KHz)	Material is eroded by electric sparks, produced across the gap (0.025-0.075 mm) between tool & work piece surface. 12000°C is generated. Spark erosion takes place by vaporisation & also by ionisation.
2.	Tool	Rotating metal bonded of aluminium oxide grinding wheel. (-ve terminal)	Fine grains (80-1000 grit size) of aluminium oxide, silicon carbide or boron carbide are mixed with water. Kerosene, benzene, glycerol or thin oil are also used.	Petroleum based hydro-carbon fluids, paraffin, white spirit, kerosene transformer oil, mineral oil and mixture of these.
3.	Electrolyte or Chemicals used	Borax, Sodium Nitrate, Sodium Silicate, Sodium Nitrite	Tool is made of mild steel, monel, stainless, steel, copper or brass. Its shape is reproduced in work piece. It is 0.1 mm lesser than the size of shape to be produced. Tool axially vibrates at 20 KHz. Amplitude 0.05 mm.	Copper, brass, Zinc & tin alloys, hardened plain carbon steel, copper tungsten carbide, copper-graphite and graphite (-ve terminal)
4.	MRR (Metal Removable Rate)	Depends upon the electrolyte, pressure between grinding wheel & work surface (up to 15 mm3/sec)	Depends upon hardness of abrasive grains, grain size, amplitude of tool vibration, the gap between tool and work piece.	Depends upon electric current, duration of sparking and pulse generators. Heavy currents for roughing. Low current for finishing.

UNIT V - CNC MACHINE AND ITS COMPONENTS

CNC MACHINES

NUMERICAL CONTROL (NC)

Numerical control can be defined as a form of programmable automation in which the process is controlled by letters, numbers and symbols.

Numerical control (NC) of machines tools is a method of automatic control that uses symbolically. Coded instructions are to cause the machine to perform a specific series of operations. Basically, it is control of machine tools by numbers.

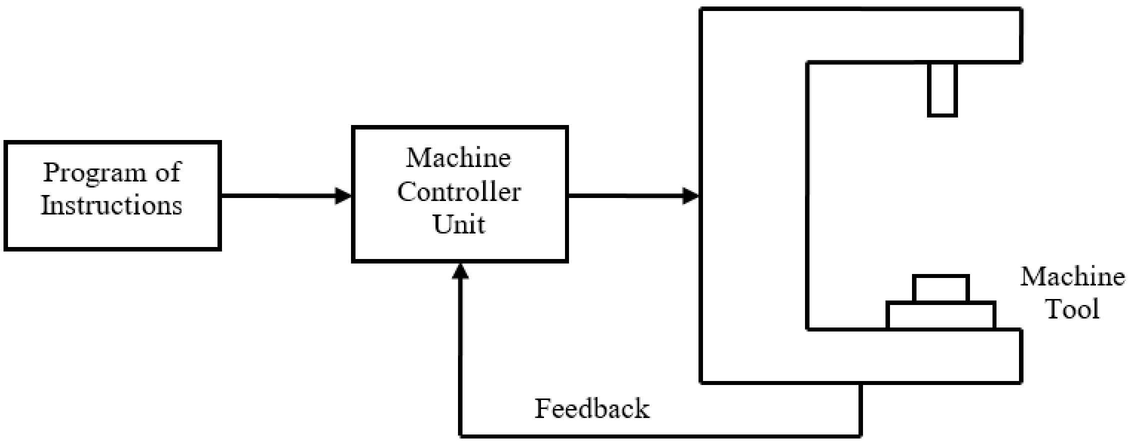


Fig. 5.1. NC system

In NC machine tools one or more of the following functions may be automatic.

1. Starting and stopping of machine tool spindle.
2. Controlling the spindle speed.
3. Positioning the tool tip and desired locations and guiding it along desired paths by automatic control of the motion of slides.
4. Controlling the rate of movement of tool tip i.e., feed rate.
5. Changing of tool in the spindle

CNC (COMPUTER NUMERICAL CONTROL)

CNC may be defined as NC systems where in a dedicated, stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programs stored in the read write memory of the computers.

In CNC, the program is entered once and they stored in the computer memory. Direct entry of programs in the CNC became possible only when keyboards came in use as input devices. A block diagram of CNC is shown in the figure.

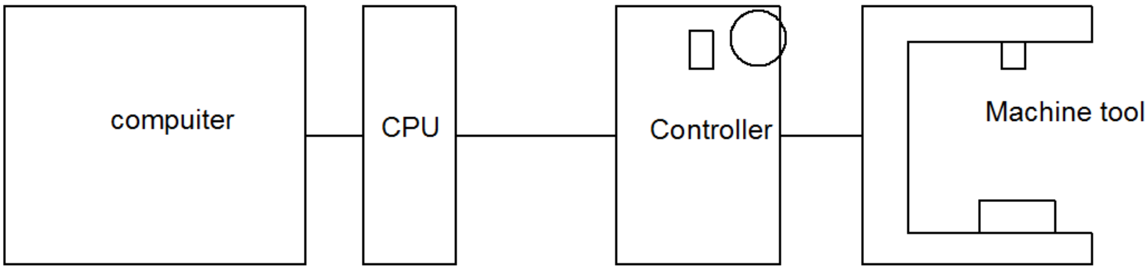


Fig. 5.2. CNC system

In CNC systems the part program is fed into the computer. Then the instructions are read and interrupted by the controller to convert it into signals that activate the machine tool. The signals are sent to the machine tool for performing different operations.

Advantages of CNC

1. High accuracy and repeatability
2. Longer tool life
3. Reduction in production lead time
4. Reduced inspection
5. Reduced the rejected number of the component
6. Greater flexibility
7. Graphic tool path display is available
8. Require no special tool setting
9. Automatic adjustments of the speed and depending on the machining conditions etc.
10. CNC provides a total manufacturing system.

Difference between NC and CNC

S#	NC	CNC
1	NC Systems use punched tapes as	In CNC input in given directly through the computer
2	Tape reader is least reliable	Computer memory is more reliable,
3.	Tape reading at the remote place	Reading and editing at the machine site itself.
4.	Metric conversion is not possible	Automatic conversion is possible
5.	Modification and editing of programs	Modification and editing of programs are possible

6.	Modern manufacturing technique of	CIM and FMS can be implemented.
7.	The program cannot be changed	Any part program can be changed during the progress of work
8.	NC programmers are skilled persons	Programmer not necessarily a skilled person
9.	Control is hard wired	Computer controls the NC systems.

Adaptive Control (AC)

The term adaptive control denotes a control system that measures certain output process variables and uses these to control speed and feed. Some of the process variables that have been used in adaptive control machining systems include spindle deflection or force, torque, cutting temperature, vibration amplitude, and horsepower. The typical measure of performance in machining have been metal removal rate and cost per volume of metal removed. The figure shows the schematic diagram for adaptive NC system.

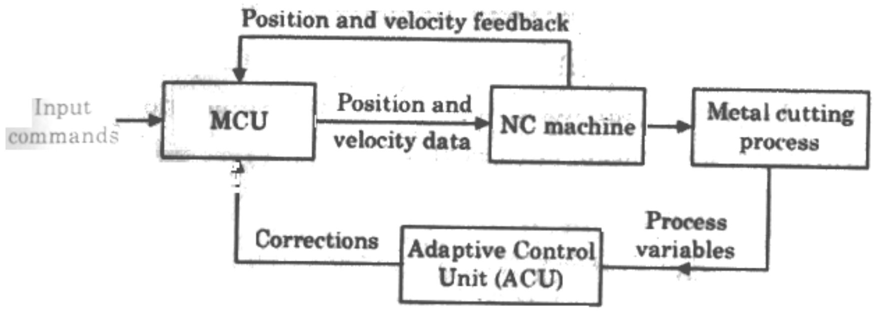


Fig. 5.3. Schematic Diagram for adaptive NC system

The following characteristics can be used to identify situations are adaptive control can be beneficially applied.

1. The cutter is engaged in the work piece more than 40% of the time it is on the machine.
2. The cost of operating the machine tool is high.
3. The typical jobs are ones involving steel, titanium and high strength alloys.
4. Degree of variability in machining.
5. Variable geometry of cut in the form of changing depth or width of cut.
6. Variable work piece hardness and variables machinability.
7. Variable work piece rigidity.

8. Tool wear
9. Air gaps during cutting

The benefits of adaptive control machining are,

1. Increased production rates
2. Increased tool life
3. Greater part production
4. Less operator intervention
5. Easier part programming

TURNING CENTRES / CNC LATHE

Main parts of the CNC chucking and turning centre are bed head stock, tailstock turrets, servo system and MCU. The various work holding devices are,

- Self-centering chuck
- Collect chuck
- Counter centrifugal chuck

Classification of Turning Centers

1. Horizontal machines
   a. CNC chucking centre
   b. CNC turning centre
   c. Universal lathes
2. Vertical Machines

1. Horizontal machines

a) CNC chucking centre

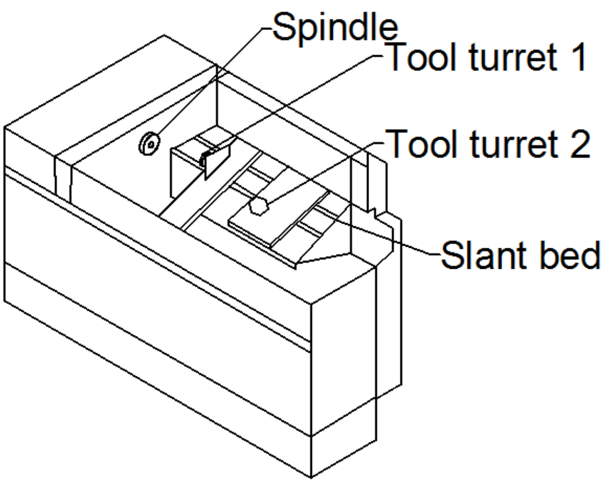


Fig. 5.4. CNC chucking centre

CNC chucking centre is designed to machine most work that is held in a chuck. Chucking machines usually have shorter beds and a single saddle with single drum type turret which accommodates both ID and OD tools or two independent saddles with turret is shown in the figure. The four axes chucking centre incorporates two turrets operating independently on separate slides, machining the work piece simultaneously.

b) CNC turning centre (Shaft Lathes)

CNC turning centers are designed mainly for machining shaft-type work pieces which are supported by a chuck and a heavy duty tailstock centre.

c) Universal lathes

Universal lathes are suitable for both chucking and for bar work. Four axes machines have two turrets each mounted on an independent slide and facilitate simultaneous machining with two tools. Some lathes have rotation tools in the turrets to facilitate off axis machining such as drilling milling reaming, tapping, boring etc. These machines have in addition to the conventional X and Z axes. CNC control of the spindle rotation, C axes. Such machines are known as turning centers.

Tooling and Turret slide

The present trend is to have single heavy drum type turret capable of accommodating both external and internal working tools. Some machines have two independent slides with one turret on each slide, one for external working tools and the other for internal tools. This arrangement will need four axes CNC. External and internal machining can be carried out simultaneously.

Some machines have an automatic tool changer with multi station tool magazine and a tool clamping arrangement on a single slide. This is common in flexible turning centers. Linear tooling system is used in some of the less expensive CNC lathes.

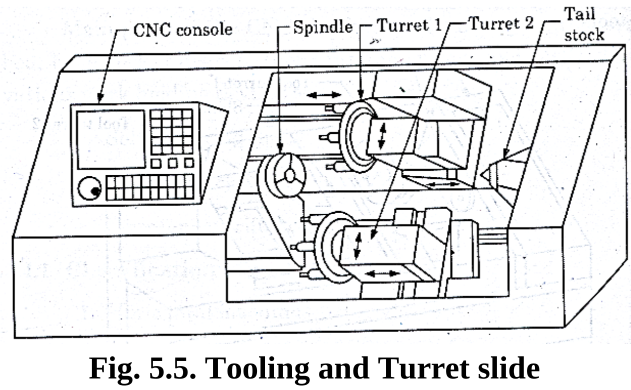


Fig. 5.5. Tooling and Turret slide

2. Vertical CNC lathes

Vertical CNC lathes widely used for machine heavy components. The figure shows a typical vertical CNC lathe. Some of these machines can also be used for milling operations. Such machines are sometimes known as turn - mill centers.

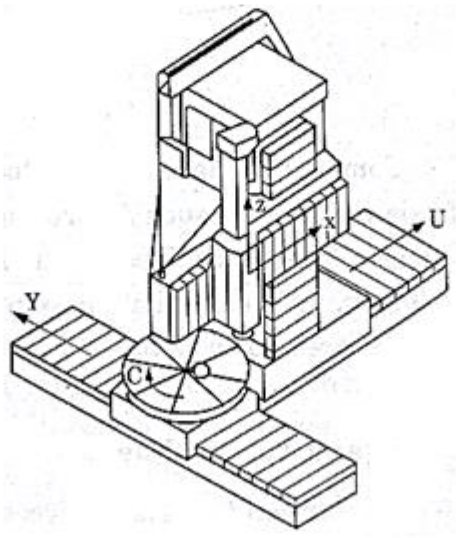


Fig. 5.6. Vertical CNC lathe

MACHING CENTRES (MILLING CENTRE)

A machining centre consists of machine tools, usually numerically controlled, capable of automatically drilling, reaming, and tapping, milling and boring multiple faces of a part. They are often equipped with a system for automatically changing cutting tools.

Main parts of a machining centre are Bed, saddle, column, table servo-system, spindle, tool-changers and MCU.

Machine axes for a five axes machining centre are

1. X, Y and Z axes for linear movements.
2. A axes for tilt/contour spindle.
3. B axes for rotary table.

Type of work holding devices are Swivel-base vice, angle plates, V-blocks, step blocks, parallels, support jocks and clamps.

Classification of Milling Centers

1. Horizontal spindle machining centre
2. Vertical spindle machining centre
3. Universal spindle machining centre

1. **Horizontal spindle machining centre**

Horizontal spindle machining centers are generally single spindle machine with automatic tool changers. Some exceptions consist of multi-spindle turrets, combination of horizontal/vertical spindles etc. Horizontal spindle machining centers are generally bad type machines with the structural configuration as shown in the figure.

In this type of machines x axis traverse is provided by table or column and Y axis provided by spindle head. The Z axis traverse is provided by the saddle or column or headstock or spindle head. These machines are invariably used with a rotary indexing table to facilitate multi-face machining at different angles in a single set UP. The axis of rotary table is parallel to Y axis and is called 'B' axis. The rotary of the table can be used for machining contour surfaces of work pieces located on the rotary table, if CNC is available for B axis.

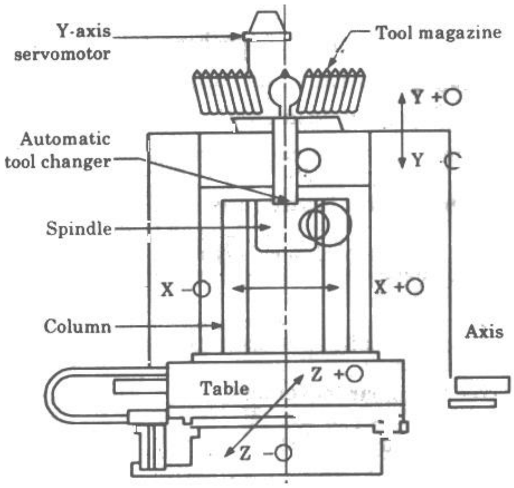


Fig. 5.7. Horizontal spindle machining centre

The present day trend is to build the machined with traveling column construction with all the movements behind the tool so that the work module is independent of the basic machine. This enables choice of work holders to suit the user's requirements and also enables the use of machining centre in NC transfer lines.

2. Vertical spindle machining centre

Vertical spindle machining centers are also bed type machines with (a) Single spindle and auto tool changers (b) Multi spindle with turret head (turret machining centers). The structural configuration is as follows,

X-axis traverse provided by table or the column.

Y-axis traverse provided by the saddle or the columns or ram.

Z-axis traverse provided by the headstock.

Vertical spindle machines are not suitable for large widths as this increase the throat distance. For very large widths horizontal spindle configuration or bridge type configuration (double column planer type) is used.

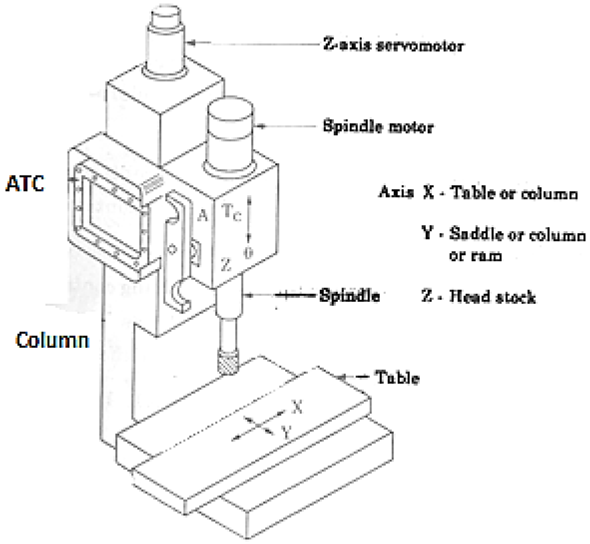


Fig. 5.8. Vertical spindle machining centre

A rotary / index table could be used also with a vertical machining centre with the axis of the table usually parallel to 'X' axis i.e. 'A' axis. The figure shows the typical vertical machining centre. There are many variations of vertical machining center. Profilers are a class of vertical machining centers which are used for large material removal involving several pocketing operations. Such machines find wide applications in aircraft industry.

3. Universal machining centre

These are similar to horizontal machining centers but with the spindle axis capable of tilting from horizontal to the vertical position continuously under the computer control. This constitutes the fifth axis of the machine. In some cases, this movement is provided by tilting of the table indeed of the spindle. Such machines facilitate approach to the top surface pf work piece mounted on the table in addition to the multiple side faces in a single set up. The fifth axis facility is essential for machining of some components which require the cutter axis to be perpendicular to the surface being machined.

Recently new designs of machining centers have been introduced which can be used as either horizontal or vertical machines.

In order to save setting up time machining centers are now available with two or more pallets. It is also possible to load and machine different components depending upon the need.

COORDINATE MEASURING MACHINES

Co-ordinate measuring machine is used to measure the dimensions of a work piece. It consists of,

1. A probe suitably mounted on a structure that allows positioning on the probe in all the three axes X, Y and Z.
2. A precision work table to place the work piece.

During operation the probe into contact with part surface to be measured and the three co-ordinate position (x, y and z values) are indicated to a high level of accuracy. The probe can be position to a resolution of 1 micron.

The measuring accuracy of a typical CMM is quoted 2.6 (+ or -) L/300 micrometers, where L is measured length in mm.

A typical CNC CMM shown in the figure is equipped with a PC AT. The major features of a CMM are,

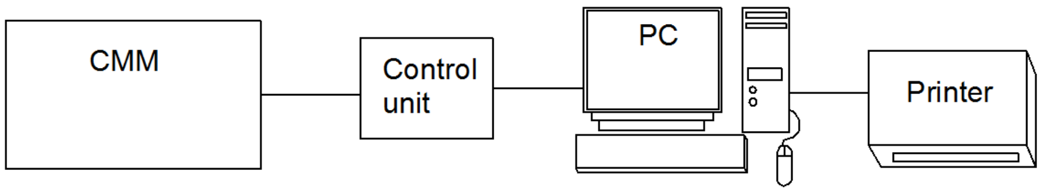


Fig. 5.9. CMM

1. Stationary granite measuring table
2. Length measuring system
3. Air bearings
4. Control unit
5. Software

1. Stationery granite measuring table

Granite table provides a stable reference plane for locating parts to be measured. As the table has a high load carrying capacity and is accessible from three sides, it can be easily integrated into the material flow system of CIM.

2. Length measuring system

A 3 axis CMM is provided with digital incremental length measuring system for each axis.

3. Air bearings

The bridge, cross beam and spindle of the CMM are supported on air bearings with high rigidity. They are designed insensitive to vibrations.

4. Control unit

Control unit allows manual measurement and self-teach programming in addition to CNC operation. The control unit is microprocessor controlled. CNC measuring centers are provided with dynamic probe heads and a probe changing system which can be operated manually or automatically

5. Software

The features of CMM software will include,

a. Measurement of diameter, centre distances, lengths.
b. On line statistics for statistical information in a batch.
c. Measurement of plane and spatial curves.
d. Data communications
e. Programs for the measurements of spur, helical, bevel and hypoid gears.
f. Interface to CAD software.

Construction of CMM

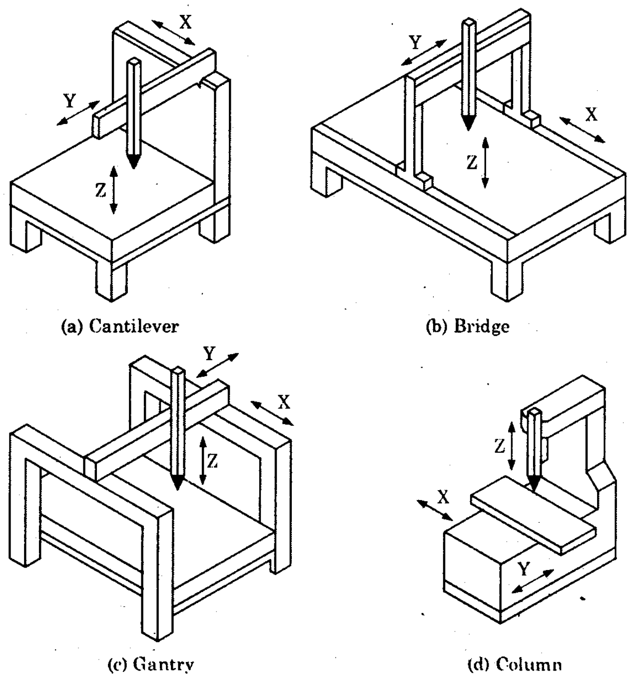


Fig. 5.10. Construction of CMM

Depending on the construction of the CMM it can be classified as,

1. Cantilever construction
2. Bridge construction
3. Column construction
4. Gantry construction

1. Cantilever construction

In the cantilever configuration the probe is attached to a vertical quill that moves in Z axis direction relative to a horizontal arm that overhangs the worktable. The quill can also be moved along the length of arm to achieve Y axis motion and the arm can be moved relative to the work table to achieve X axis motion and enable quick dispatch or right spare parts or spare boards to the user of the machine.

2. Bridge construction

The bridge configuration is most common type used in industry. Instead of a cantilevered arm to achieve the Y axis movement of the probe the arm is supported on both ends like a bridge. This construction provides greater inherent rigidity. It gives more accuracy than cantilevered CMM.

3. Column construction

This construction is similar to the construction of a machine tool. Instead of achieving the relative motion by moving the probe, the column type CMM obtains X axis and Y axis relative motion by moving the work table. The probe quill is moved vertically along a rigid column to obtain the Z axis motion.

4. Gantry Construction

This configuration is generally intended for inspecting large objects. X axis and Y axis motions are achieved by a construction similar to a gantry crane. The probe quill moves relative to the horizontal arm extending between the two rails of the gantry.

CMM can be operated by means of the following methods.

1. Manual control
2. Manual computer assisted control
3. Motorized computer assisted control
4. Direct computer control CMM or CNC-CMM

Direct computer control CMM or CNC-CMM

The probe is programmed to move to the desired location. Programming can be done by,

a. Manual lead through method as in robots
b. Conventional CNC part programming

Movement of the probe is done by the CMM controller, and recording and processing of the data are done by the computers.

Measuring Capabilities of a CMM

1. Dimension measurements
2. Determination of hole location and diameter
3. Determination of cylinder axes and diameter.
4. Checking parallelism between two planes
5. Definition of a plane
6. Determination of angles between two planes
7. Flatness
8. Determination of angle and point of intersection of lines

Benefits of CMM

1. Flexibility
2. Increased productivity
3. Unmanned operation in CNC-CMM
4. Greater accuracy
5. Reduced operator error
6. Easy integration with FMS or CIM

CNC COMPONENTS

SLIDE MOVEMENT ELEMENTS

Precise positioning and repeatability of machine tool slides are the major functional requirements of CNC machines. The inaccuracies that caused are mainly due to the stick slip motion when plain slide ways (metal to metal contact) are used.

To fulfill the requirements of elimination of stick-slip, there are different sideways systems such of rolling friction slide ways and sideways with low friction. These have low wear, negligible stick-slip, good vibration, damping, easy machinability, low price and low co-efficient of friction properties.

Requirements of a good slide way system

1. Low co-efficient of friction at varying slide velocities.
2. Low rate of wear
3. Sufficient damping
4. High stiffness at the sliding joints.

PLASTIC COATED SLIDEWAYS

The cross section of a slide way system in which plastic or non-metallic inserts used is shown in the figure.

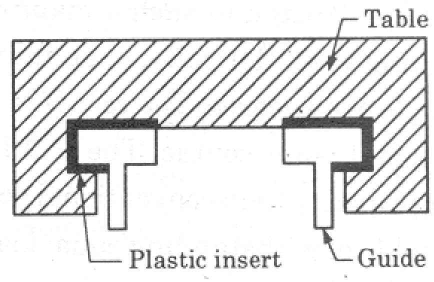


Fig. 5.11. PLASTIC COATED SLIDEWAYS

The inserts are thermoplastics (Turcite - B) or thermosetting types. In these coated slide ways, the static coefficient of friction is less than the dynamic coefficient of friction. With increase in speed, dynamic coefficient of friction increases to a value and remains constant.

These inserts are made of two or more materials. These reduce coefficient of friction, increase strength, and wear resistance and load bearing capacity. They also have self-lubricating property. Advantage is the ease with which a worn-out strip can be replaced without the need for any machining of bed ways.

LINEAR MOTION BEARING SYSTEMS

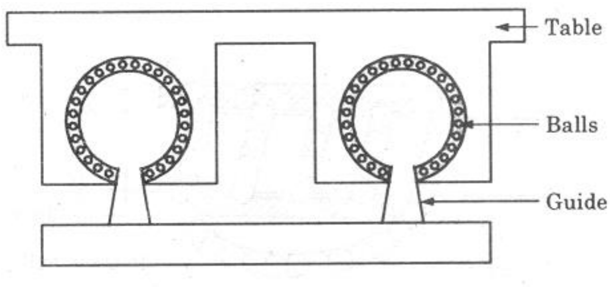


Fig. 5.12. Linear Motion Bearing Systems

Linear motion guide system is shown in the figure. The unit consists of a bearing block and rail. Two race ways are provided on one side of the bearing block where two rows of rolls are retained and caused to recirculate by means of retainer and two end plates.

The unit is constructed in such a manner that each of the rows of balls, rolling over the rail comes into contact with the race-way at an angle of 45 degree. The race is in line contact rather than the conventional point contact. The ball has 13 more times allowable carrying capacity than conventional point contact system. The system is capable of withstanding equal load in any direction.

RECIRCULATION BALL SCREW

Ball screws are primarily employed in feed mechanism of CNC machine tools. The balls provide only physical contact between the nut and the lead screw. The balls are recirculated from one end to the other by return tubes.

When the lead screw rotates, the balls in the groove between the nut and lead screw push the nut affecting its liner motion. The ball screws provide many advantages.

1. Low coefficient of friction due to point contact by the rolling members
2. Higher transmission efficiency
3. Backlashes can be eliminated by preloading the assembly.
4. Stick slip phenomenon is absent.
5. Friction forces independent of the travel velocity and the friction at is very small.

A lead screw running on the bearing balls is shown in the figure.

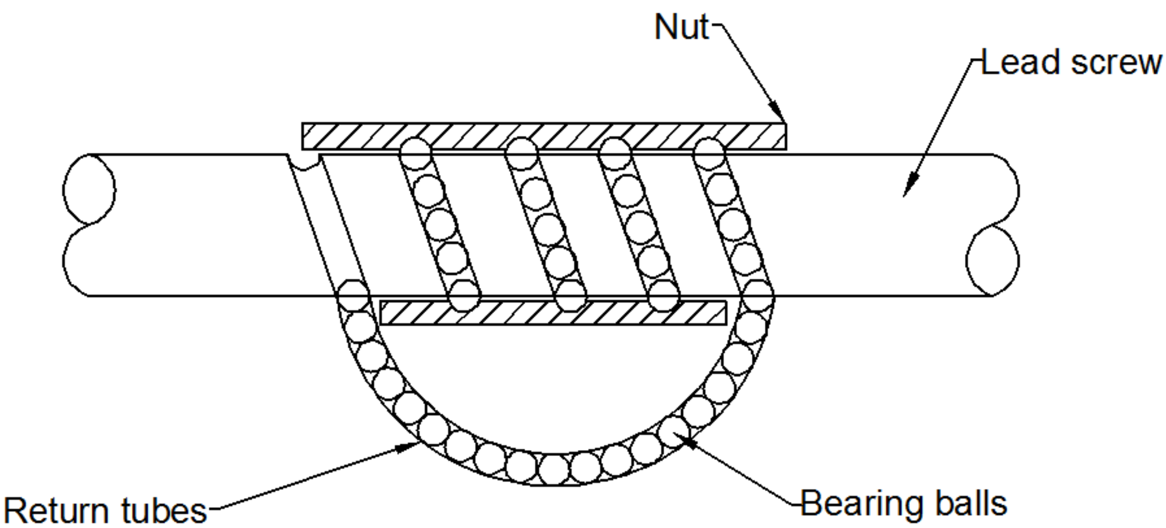


Fig. 5.13. Recirculation Ball Screw

ATC (AUTOMATIC TOOL CHANGER):

ATC is an important part of a machining centre. ATC picks up a tool from the magazine and keeps it ready for swapping with the tool in the spindle which is presently cutting. Time for tool change varies between 3 to 7 seconds.

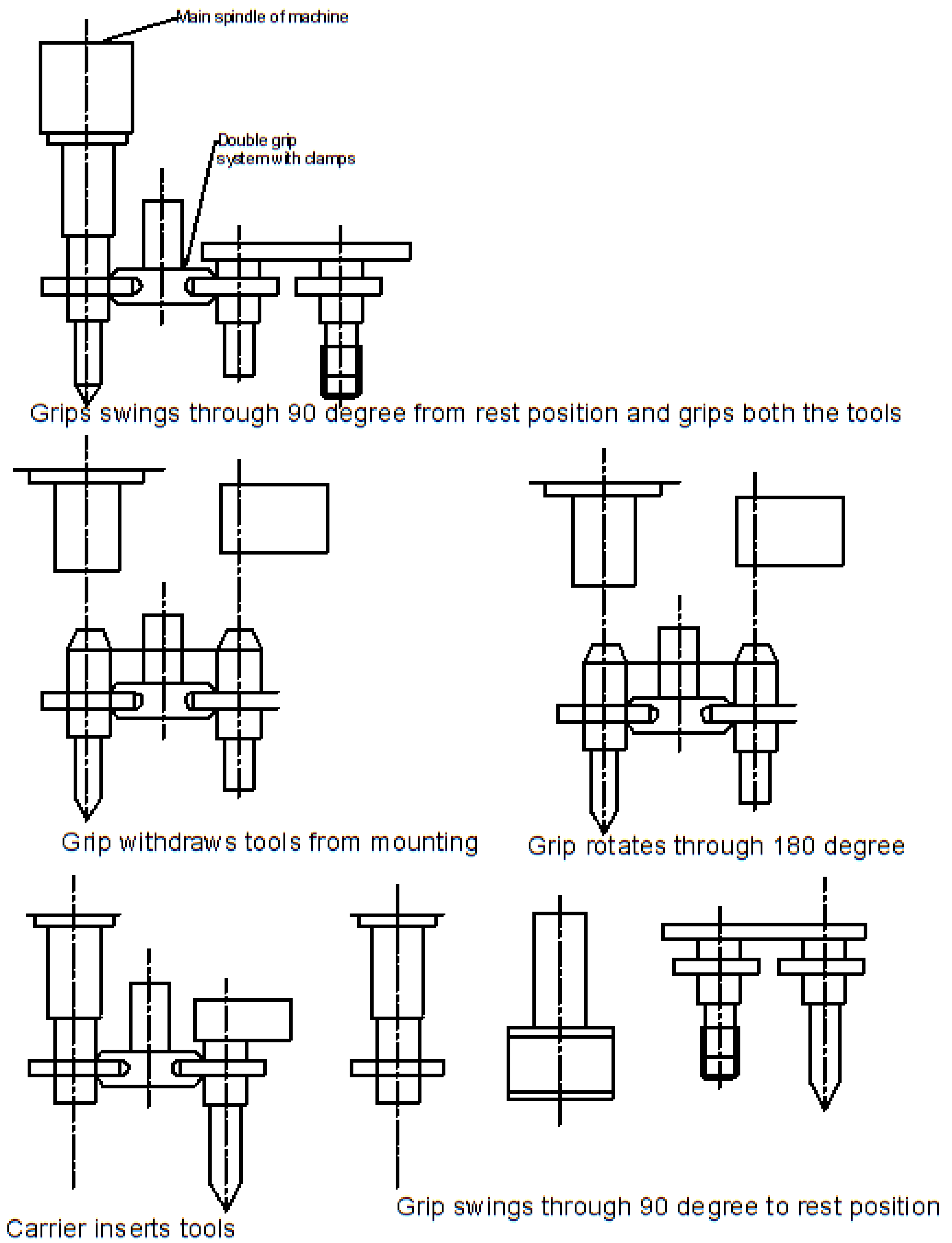


Fig. 5.14. ATC

Operation of a double-ended arm type ATC is shown in the figure. The desired tool is collected from the magazine in one end of the special arm. At the moment of tool change, the empty end of the arm grips the tool in the spindle, removes it, indexes 180 and inserts the new tool into the spindle

Quill-type spindles generally move out towards the stationary (after rotation) arm to accept a new tool or replace a sued one.

Non quill-spindles machines, the double-end arm incorporates an in-out motion to insert or extract the tool from the spindle taper.

The magazine not only transport the tool during storage and keep it clean and free from damage but it also keeps track of which tools are where. This can be done by coding the tools physically either on the tool itself or in the magazine adjacent to the tool when the pocket is loaded.

Types of ATC and Magazine

The concept of the ATC is that the range of tools for a specific job shall be made available for automatic selection and positioning. ATC can be,

Turret head type : Used on drilling machines; strictly speaking, it is not on ATC.

Drum type : For holding small number of tools usually not more than 30, on periphery of drum. Tool search speed is faster.

Chain type : For more number of tools (30-40or more tools can be used). Tool search speed is lees.

Characteristic of Tool Magazines

Tool magazines should satisfy the following requirements.

1. Tools magazine has to be compact and as simple as possible.
2. Interchange of tools should not interfere with the work piece space and tool space
3. Easier and safer manual exchange of tools in the tool magazine during loading and unloading
4. All preparatory works for tool exchange should be made during machining.
5. Tool magazine must be capable of holding enough tools needed for performing complete operations for some typical work piece on the machining centers.

Classification of ATC

1. According to the kind of cutting tools,
    a. Single tool
    b. Multi tool heads
    c. Special tools such as micro bores

2. According to the system tool exchange,
    a. With tool parking change arm
    b. With tool parking position
    c. With tool chance arm
3. According to the position of axes of tool and spindle,
    a. With parallel axes
    b. With intersecting axes
4. According to tool position,
    a. With horizontal tool position
    b. With vertical tool position

ROTARY ENCODER DISC

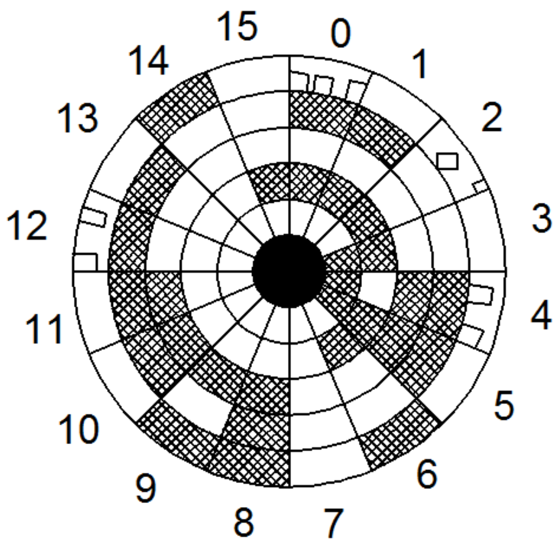


Fig. 5.15. Rotary Encoder Disc

A NC system in which all positional dimensions are measured with respect to a common datum point is called a digital absolute system. The transducers give a direct reading of position with reference to the common datum.

All position commands are given as absolute distances from the datum point (zero point). Main advantage of the absolute system as compared with the incremental one is in case of interruption that forces the operator to stop the machine. The figure shows an absolute rotary encoder. These devices the angle positions directly from the code pattern of the graduated disc and convert it into a coded signal which corresponds to one definite angle position. Multi-turn absolute rotary encoders provide electronically coded measured values for several revolutions.

The code pattern on the disc has several tracks. The number of tracks depends upon the desired resolution and the type of code. Each track is assigned its own solar cell so that all tracks can be read simultaneously. Most frequently used code is gray code. Gray code measured value can be electronically converted to corresponding positions.

TRANSDUCER

Transducer is an instrument which receives the messages in one form and transfers the same into a form which the receiver can accept. There are two types of transducer in CNC machine.

1. Rotary (angular) transducers
2. Linear transducers

Rotary transducer is fixed in drive shaft or lead screw. The gives the displacement of the rotating disc. From this the linear position is found.

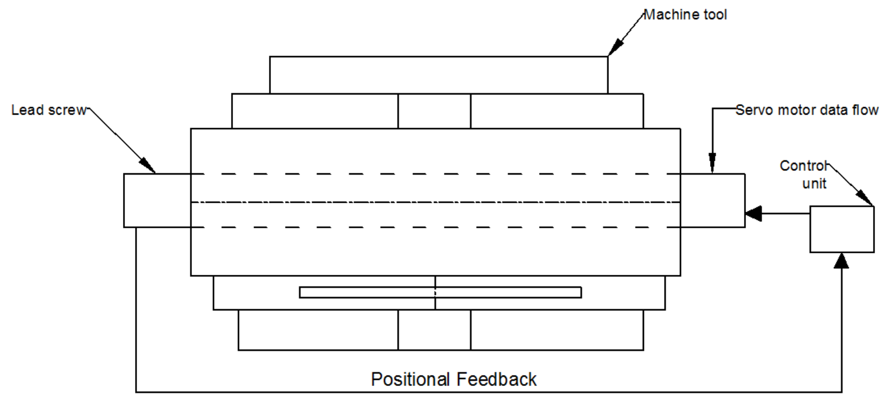


Fig. 5.16. Rotary transducer

Linear transducer is fixed near to the axis sideway. It is used to measure the linear position directly.

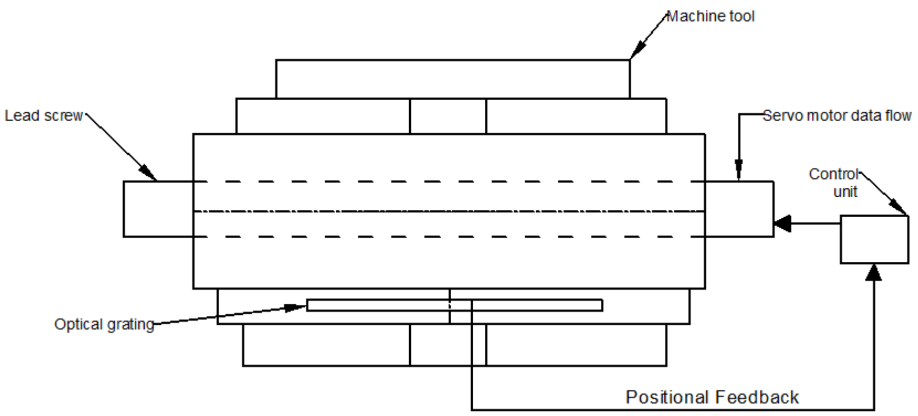


Fig. 5.17. Linear transducer

The following techniques are used to measure the rotary and linear transducer.

1. Binary encoders
2. Engraved gratings
3. Moire fringe grating
4. Synchro - resolvers

IN PROCESS PROBING

In-process part-gaging and probe-assisted tool setting right on the machine tool is proving to be valuable in the quest for consistent quality machined parts. The technology is now refined and growing in popularity. Today, many new CNC machining centres and turning centres along with some transfer lines and indexing machines come equipped with probes, software, and electronic controllers for in-process probing. An increasing number of grinding machines and systems are being equipped for in-process probing. The hardware and software details differ from those on spindle-type machines, but the principles and applications are the same.

For one thing, in-process, on-machine part-gaging allows a CNC controller to catch its own errors. The system automatically compensates for effects of tool wear and temperature fluctuations, so you can meet specs on every part. Further, application of this technology eliminates the need for extremely precise fixturing and orientation of part to spindle. The CNC finds each part on its own, referencing the machining program to part features rather than to a single point on the fixture.

In setup, on-machine probing and tool setting nullifies many types of operator errors, and speeds the setup process. On spindle-type machines, tool length and diameter can be checked before and during machining, while the tool is held in its spindle or turret. The system enters and updates offsets automatically.

One of the most important advantages of 100% parts inspection is the feedback to the manufacturing process that is obtained to permit the process to be altered before the targeted process deteriorates or before scrap is produced.

Part handling is one of the manufacturing variables which must be considered with 100% inspection of parts.

Tool Materials

Cutting tools are available in three basic material types:

High-speed steel

Tungsten carbide

Ceramic

High-speed steel is generally used on aluminum and other nonferrous alloys, while tungsten carbide is used on high-silicon aluminums, steels, stainless steels, and exotic metals.

Ceramic inserts are used on hard steels and exotic metals. Inserted carbide tooling is becoming the preferred tooling for many CNC applications.

For the full utilization of CNC machines it is essential to pay due attention to the selection and usage of tooling, namely tool holders, cutting tools and work holding devices. The tools for CNC machines must be quickly changeable to reduce non-cutting time, preset and reset outside the machine, high degree of interchangeability, increased reliability and high rigidity.

The cutting tools can be classified on the basis of setting up of tool, tool construction and cutting tool material:

On the Basis of Setting up of Cutting Tool

(a) Preset tools

(b) Qualified tools

(c) Semi qualified tools

On the Basis of Cutting Tool Construction

(a) Solid tools

(b) Brazed tools

(c) Inserted bit tools

On the Basis of Cutting Tool Material

(a) High speed steel (HSS)

(b) High carbon tool steel (HCS)

(c) Cast alloy

(d) Cemented carbide

(e) Ceramics

(f) Boron Nitride

(g) Diamond

(h) Sialon