KeralaNotes

KTU STUDY MATERIALS

BASICS OF MECHANICAL ENGINEERING

EST120

Module 6

MODULE 6

Basic description of the manufacturing processes – Sand Casting, Forging, Rolling, Extrusion and their applications. **Metal Joining Processes:** List types of welding, Description with sketches of Arc Welding, Soldering and Brazing and their applications **Basic Machining operations:** Turning, Drilling, Milling and Grinding. **Description about working with block diagram of:** Lathe, Drilling machine, Milling machine, CNC Machine. Principle of CAD/CAM, Rapid and Additive manufacturing.

Manufacturing Process

There are ***four basic manufacturing processes*** for producing desired shape of a product. These are ***casting, machining, joining (welding, mechanical fasteners etc.), and deformation processes.***

 Casting process

solidifies in a mould. It's the primary manufacturing process.

 Machining processes provide desired shape with good accuracy and precision but tend to waste material in the generation of removed portions.

 Joining processes permit complex shapes to be constructed from simpler components and have a wide domain of applications.

 Deformation processes exploit a remarkable property of metals, which is their ability to flow plastically in the solid state without deterioration of their properties. With the application of suitable pressures, the material is moved to obtain the desired shape with almost no wastage

CASTING

"It is a manufacturing process in which molten metal is poured in a mould or cavity and allowed to solidify". Mould has the shape of the product to be made. Molten metal on solidification gets the shape of the mould.

Mould: negative print of the product to be cast (cavity whose geometry determines the shape of the cast part).

Moulding: process of making mould of desired shape using sand, pattern and core

Casting is classified into two;

1) Sand Casting
2) Metal Mould Casting

SAND CASTING

In sand casting, sand moulds are prepared in a specially made box called ***moulding box*** or ***moulding flask***, which is open at the top and bottom. It is made in two parts and held in alignment by pins. The ***top part is called cope and lower part is called drag***. These flasks are made of wood or metal.

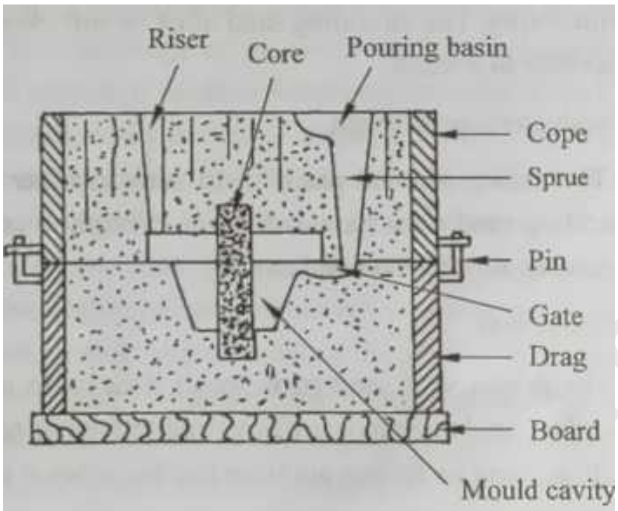


Fig. 7.1. Sectional view of a sand mould

Gating system in Sand casting

The passage for bringing the molten metal to the mould cavity is known as gating system. It consists of a pouring basin, sprue and gate.

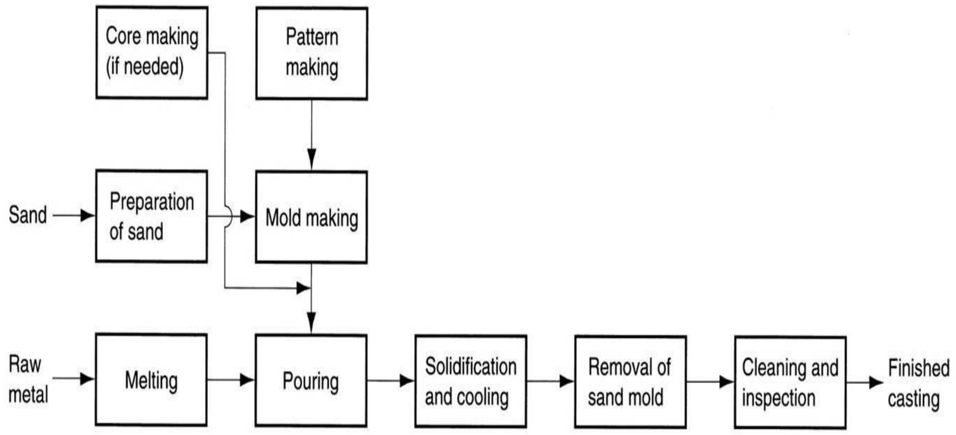
- **Pouring basin**: is made at the top of the mould for pouring the molten metal at the required rate into the mould cavity. It also prevents slag from entering the mould cavity.
- **Sprue:** vertical passage made through the cope for connecting pouring basin with the gate
- **Runner**: for connecting the sprue and gate
- **Gates**: Gate is the passage through which molten metal flows from the sprue base to the mould cavity. It is the passage for connecting the base of the runner with the mould cavity.
- **Riser**: passage made in the cope to permit molten metal to rise up after filling the mould cavity.
- **Pattern:** model or replica of the component to be made by casting. Types of patterns are; One piece pattern, Split pattern, Loose piece pattern, Match plate pattern ,Cope and Drag pattern.

"Core is a prepared solid mass of dry sand, in order to introduce into the mould cavity, to form a hole." Cores are kept in the mould after the pattern is removed. It is used to obtain the desired hole or recess in the casting which otherwise could not be obtained by normal moulding process.

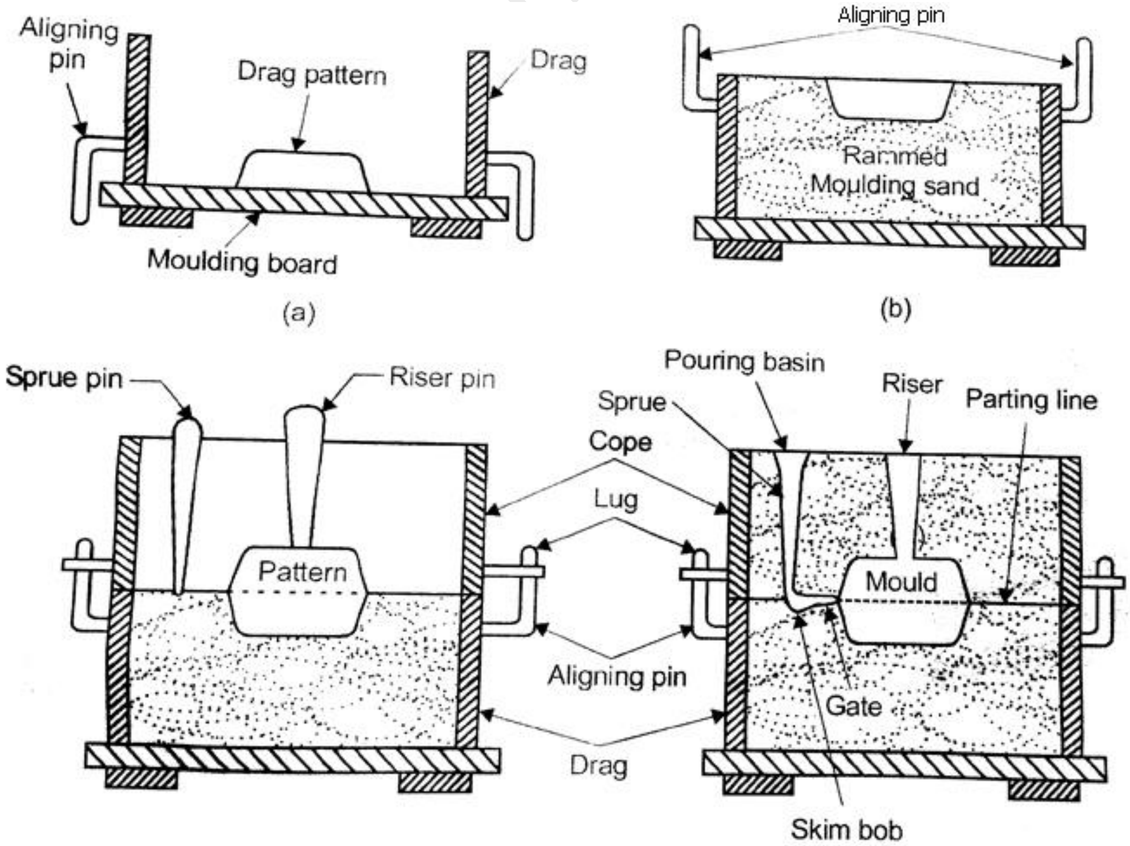
Types of core

- Horizontal core, Vertical core and Hanging core

Steps involved in Sand casting (Sand casting process



The following sand casting process step by step carried out in foundries:



1. Drag is placed on the moulding board with upside down and drag half (lower part) of pattern is placed inside the drag.
2. Drag is filled with moulding sand and properly rammed. Excess sand above top level of drag is removed.
3. Drag is turned over and placed on another board.
4. Cope half (upper part) of pattern is kept over drag half of pattern and cope is placed over the drag.
5. Runner, riser pins and sprue pins are placed at appropriate places and cope is filled with moulding sand and rammed properly. Excess sand at top is removed.
6. Runner, riser pins and sprue pins are removed and vent holes are made and pouring basin is cut at the top of the sprue.
7. Cope is carefully turned over to a board and pattern halves are removed.
8. Gate is prepared on the top surface of the drag and repairs if any and cleaning of mould cavity is carried out.
9. Core is kept carefully in position and Cope is kept back over drag and clamped.
10. Molten metal is poured into the pouring basin.
11. After sufficient time is allowed for metal solidification, casting is taken out by breaking the mould.
12. Unwanted projections in the casting are removed by metal removal processes and casting is cleaned.

Advantages of casting process:

- Molten material can flow into very small sections so that intricate shapes can be made by this process.
- Possible to cast both ferrous and nonferrous materials
- Tools are very simple and expensive
- Useful for small lot production
- Weight reduction in design
- No directional property

Limitations:-

- Accuracy and surface finish are not very good for final application
- Difficult to remove defects due to presence of moisture
- Metal casting is a labour intensive process

Application: Cylindrical bocks, wheels, housings, pipes, bells, pistons, piston rings, machine tool beds etc

Moulding sand properties

- **FLOWABILITY**: behave like a fluid, sand to get compacted to uniform density

- **GREEN STRENGTH**: strength of the sand in moist condition
- **DRY STRENGTH**: strength of the sand in dry condition
- **POROSITY/ PERMEABILITY**: ability to allow the passage of mould gases
- **REFRACTORINESS**: ability of the sand to withstand high temperature
- **ADHESIVENESS**: ability of the sand to stick on to the mould walls
- **CHEMICAL STABILITY**: resist chemical reaction
- **COLLAPSIBILITY**: ability of the sand to collapse after the casting solidifies
- **FINENESS**: ability of the sand to produce smooth surfaced castings
- **COEFFICIENT OF EXPANSION**: less coefficient of expansion
- **DURABILITY**: ability of the sand to be used again and again

Forging

Forging is the process in which, ***metal and alloys are deformed to the specified shapes by application of repeated compressive force from a hammer.*** It is usually done hot (hot forging); although sometimes forging is done at room temperature (cold forging). Forged product has better mechanical properties than a cast one.

It is generally employed for those components which require high strength and other better mechanical properties. The components that are produced by forging are:

- nails, bolts, spanners, crane hooks, axles, crankshafts, connecting rods etc.

Classification of Forging

According to the Forging equipment:

- hand forging (smith forging)
- drop forging
- press forging
- machine forging.

A. HAND FORGING

•Traditional forging operation carried out by blacksmith in a section of workshop called smithy

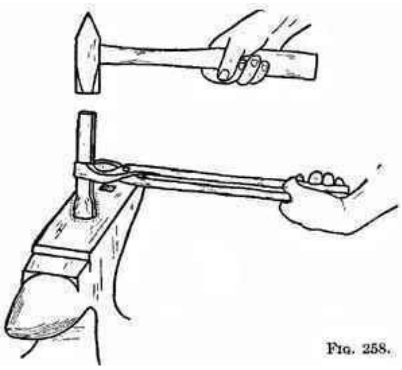


Fig. 258.

•Hand tools are used for forging (eg. Hammer, chisel…etc)

•Not suitable for mass production

Smith forging is traditional method of metal forming. It is open die forging method in which the work piece is placed on a stationary anvil and a hammer strikes and deform the work piece. The force is applied either by manually or power hammers.

Hand forging operations

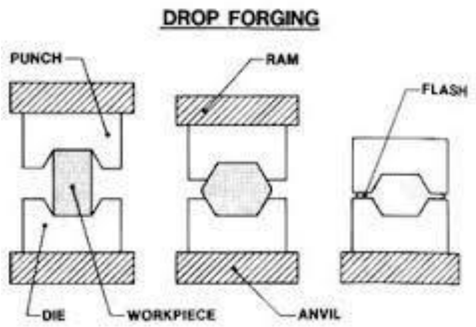
a)Upsetting b)Drawing down(necking down) c)Setting down d)Bending e)Welding f)Cutting g)Swaging h)Drifting i)Fullering j)Edging

B. DROP FORGING

•Force for shaping the component is applied in a series of blow by using drop hammers

•Open die or closed dies are used for this purpose

Drop forging is done in closed impression dies. An automatic hammer applied the force in series of blow by dropping action. In this type, a sudden applied force is used.



C. PRESS FORGING

•Process is similar to drop forging but for the method of application of force

•In this case the force is applied by a continuous squeezing operation by means of a hydraulic press

•Mass production technique

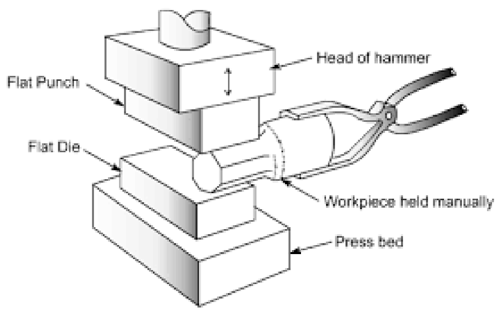
D. MACHINE FORGING

This process makes use of forging machines, also known as up setters, for the application of force. In this process also the shaping of the product is done by using two halves of a die which contains the impression of the required product. Some of the examples are bolt heads, rivets, small shafts etc.

According to arrangement of Die:

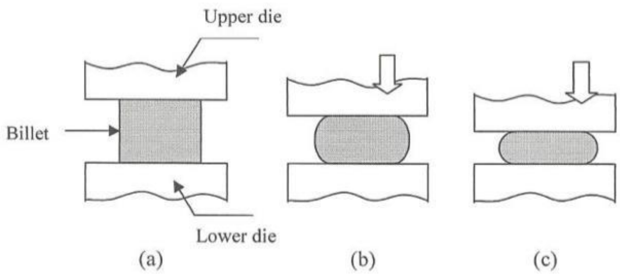
Forging can be broadly classified into;

1) Open-Die Forging



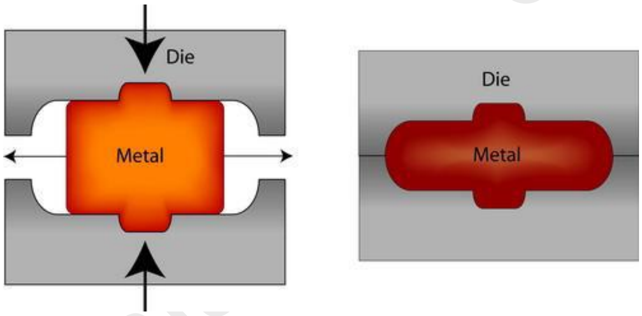
Open-die forging is also known as smith forging. In open-die forging, a hammer strikes and deforms the work piece, which is placed on a stationary anvil. Open-die forging gets its name from the fact that the dies do not enclose the work piece, allowing it to flow except where contacted by the dies. Therefore the operator needs to orient and position the work piece to get the desired shape.

The dies are usually flat in shape, but some have a specially shaped surface for specialized operations. For example, a die may have a round, concave, or convex surface or be a tool to form holes or be a cut-off tool.



2) Closed/Impression Die Forging

In closed-die forging metal is placed in a die resembling a mold, which is attached to the anvil. Usually the hammer die is shaped as well. The hammer is then dropped on the work piece, causing the metal to flow and fill the die cavities. Depending on the size and complexity of the part the hammer may be dropped multiple times in quick succession. Excess metal is squeezed out of the die cavities.



It is used for forging complicated shapes. Process is usually carried out at elevated temperatures.

<u>Forging – Advantages and Disadvantages</u>

Advantages:

- Forging gives comparatively tougher product compare to casting.
- The fatigue strength and creep resistance of forge product is higher.
- Forge product has higher mechanical properties.
- Low cost operation.
- This process does not required special skill operator.
- Variety of shapes can be formed by this process.

Disadvantages:

- Higher initial cost for big forging presses.
- Secondary finishing process required in hot forging.

- It cannot produce complex shapes.
- Size is limited due to size of press.
- Brittle metal cannot be forged.

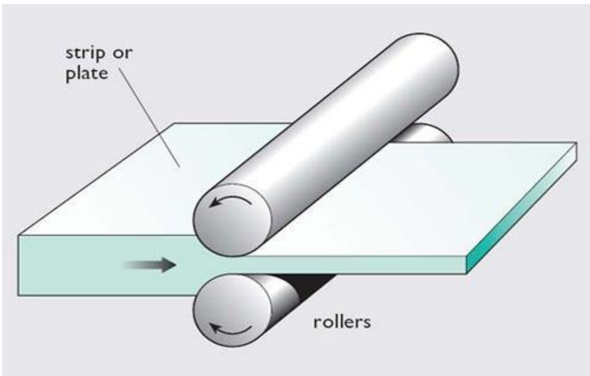
METAL FORMING PROCESS

ROLLING

Rolling is a fabricating process in which the metal, plastic, paper, glass, etc. is passed through a pair (or pairs) of rolls.

Work is subjected to high compressive stresses

Rolling helps to improve various physical properties such as strength , toughness, ductility, shock resistance



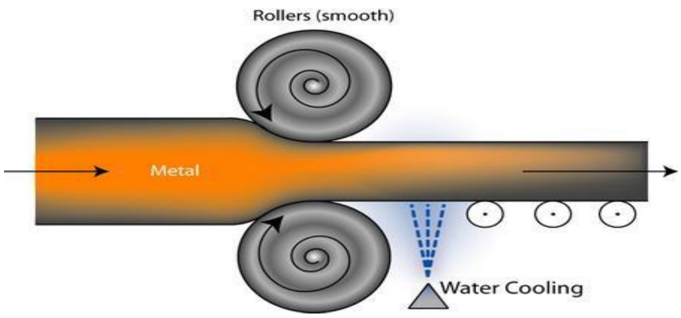
Two types

•Hot rolling

•Cold rolling

Types of rolling Process

HOT ROLLING



•Rolling a metal above its recrystallization temperature

•Grains are elongated in the direction of rolling

•Friction is high

•Heavy reduction in area

•Surface finish is not good and Roll radius is generally larger

COLD ROLLING

•Rolling a metal below its recrystallization temperature

•Worked at room temperature

•Less friction

•Heavy reduction area cannot be obtained

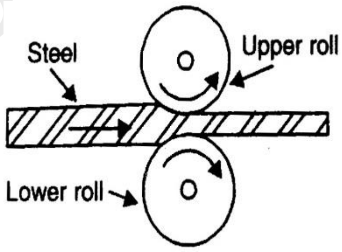
•Roll radius is smaller

Types of rolling mills

a) Two high mill b)Three high mill c) Four high mill

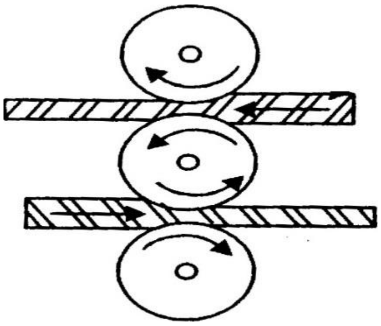
d) Cluster mill

a. Two High Mill



- Two rolls
- Lower roll will be fixed
- Upper roll can be moved to adjust the space between the rolls
- Both the rolls rotate at the same speed but in opposite directions
-

b. Three High Mill



- Three rolls positioned one over another
- Upper and lower rolls rotate in the same direction
- Middle roll rotates in the opposite direction
- Middle roll is fixed
- Upper and lower rolls are moved to adjust the roll gap
-

c. Four High Mill

- Four rolls
- Two rolls are working rolls and the other two are back up rolls
- Back up rolls preventing the deflection of the working rolls

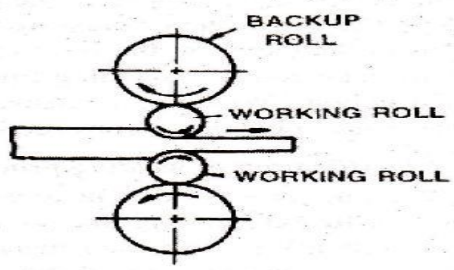
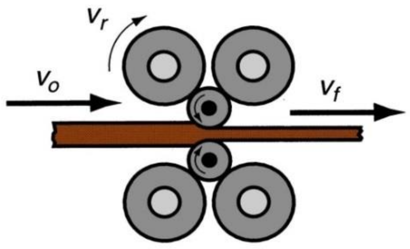


Fig 5.53 Four High Rolling Mill

d. Cluster Mill

- Used for rolling very thin sheet or foils
- It consists of a Pair of working rolls of very small diameter, supported by a number of back up rolls on either side



(d)

EXTRUSION PROCESS

Extrusion is a process ***used to create objects of a fixed cross-sectional profile***. ***A material is pushed through a die of the desired cross-section.*** The two main advantages of this process over other manufacturing processes are its ability to create very complex cross-sections, and to work materials that are brittle. It also forms parts with an excellent surface finish

- Process of forcing a metal enclosed in a container to flow through the opening of a die.
- Metal is subjected to plastic deformation
- Metal undergoes reduction and elongation during extrusion
- Used for manufacture rods, tubes, circular, rectangular, hexagonal and other shapes both in hollow and solid form.

Types of Extrusion

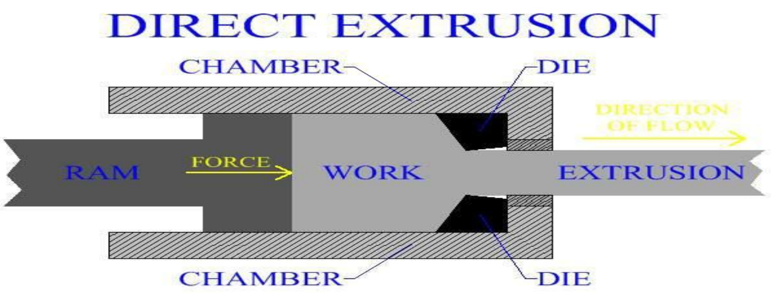
a) Direct Extrusion

b) Indirect Extrusion

c) Cold Extrusion/ Impact Extrusion

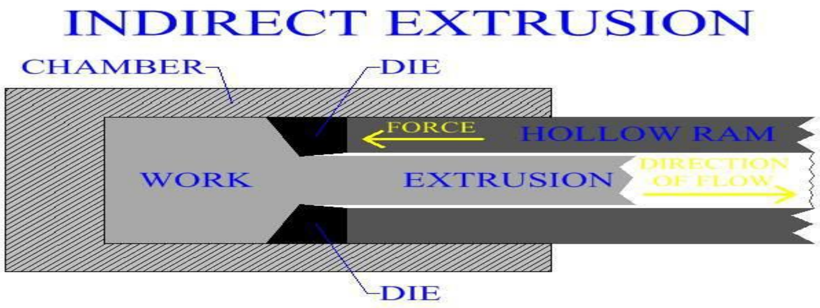
a) Direct Extrusion

Direct extrusion, also known as forward extrusion, is the most common extrusion process. It works by placing the billet in a heavy walled container. ***The billet (material) is pushed through the die by a ram or screw. Flow of metal through the die is in the same direction as the movement of ram.*** The major disadvantage of this process is that the force required to extrude the billet is greater than that needed in the indirect extrusion process.



b) Indirect Extrusion

- Also called backward extrusion
- Flow of metal through the die is in the opposite direction as the movement of ram
- Hot billet (work piece) is used
- Ram used is hollow
- Billet remains stationary while die is pushed into the billet by the hollow ram
- Less force is required as compared to direct extrusion

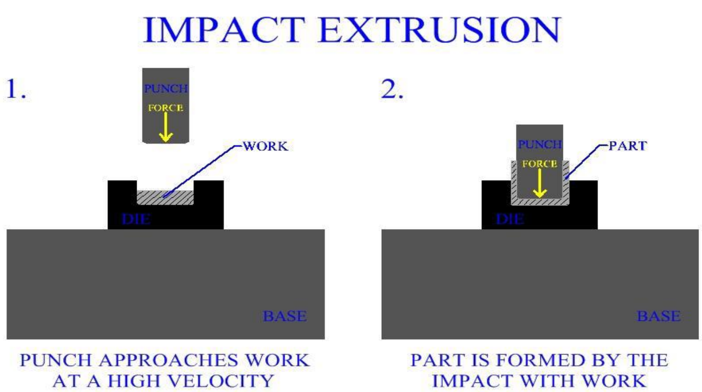


Hot extrusion: Hot extrusion is a hot working process, which means it is ***done above the material's recrystallization temperature*** to keep the material from work hardening and to make it easier to push the material through the die. Most hot extrusions are done on horizontal hydraulic presses.

Cold Extrusion: Cold extrusion is ***done at room temperature or near room temperature***. The advantages of this over hot extrusion are the lack of oxidation, higher strength due to cold working, closer tolerances, better surface finish, and fast extrusion speeds if the material is subject to hot shortness.

Impact Extrusion

- Carried out at higher velocity
- Unheated metal is placed in the die cavity
- Punch is forced into the die cavity causing the metal to flow upwards through the gap between punch and die
- Tooth pastes tubes are made by this process



Metal Joining Processes

Welding

Welding is the process of joining two metal parts together to give a strong joint. It is the process of joining similar or dissimilar metals ***by the application of heat***, with or without the application of pressure and with or without the addition of filler material. Heat for welding process can be obtained from many sources such as smith's hearth for forge welding, electric current for resistance welding, gas flames for gas-welding, chemical reaction for thermit welding and electric arc for arc welding etc.

The welding process is subdivided into two main classes.

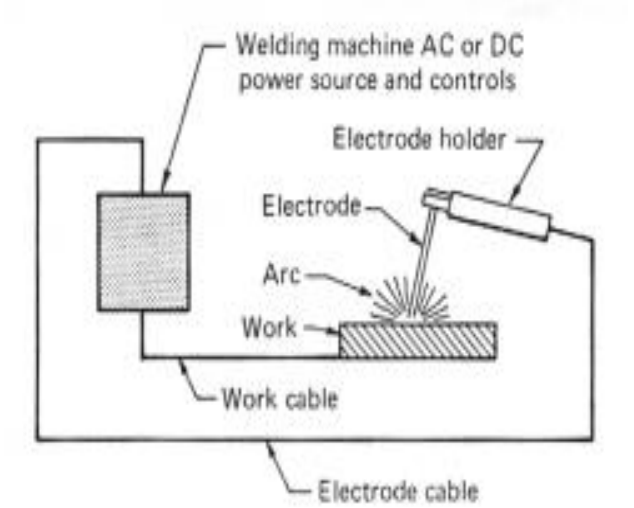
1. **Fusion welding:** which involves heating the ends of metal pieces to be joined to a temperature high enough to cause them to melt or fuse and then allowing the joint to cool
2. **Pressure welding:** which involves heating the ends of metal pieces to be joined to a high temperature, but lower than their melting point and then keeping the metal pieces joined together under pressure for some time

Welding is done with the help of a welding machine. The welding machine raises the temperature of the required portions of the work pieces so that it can fuse them. Depending upon the type of heat production welding processes are classified as,

a. Electrical resistance welding
b. Electric Arc welding
c. Gas welding and
d. Thermit welding

Electric Arc welding

In this the surfaces to be joined are fused by the heat produced from an electric arc. It is the method of fusion welding in which the metals at the joint are heated to molten state by an electric arc. ***Arc column is generated between an anode (electrode) and the cathode (metal to be joined).*** Temperature of the arc is about 6000ºC to 7000ºC. A metal electrode is used for obtaining the electric arc between the work piece and the electrode; together an electric current is established. Separating electrode from the work piece by a short distance, an electric arc is formed in which the electrical energy is converted into heat.

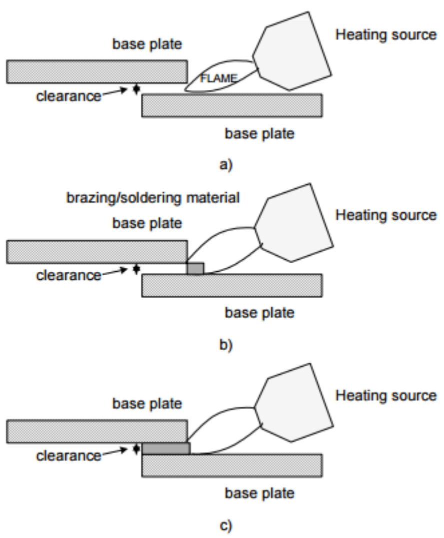


The intense heat produced by the arc, melts the work piece under the arc forming a pool of molten metal which if forced out of the pool by the blast from the arc as shown in fig. The electrode end is also melted by the heat and it is transferred across the arc to the molten metal pool. The arc is maintained by uniformly moving the electrode towards the work piece and hence keeping constant gap between the electrode and the work piece. At the same time the electrode is moved along the desired line of welding.

Generally the electrodes are coated with slagging or fluxing materials. It is to provide a gas shield around the arc to prevent direct contact of oxygen and nitrogen in the air with the deposited metal. It also covers the weld metal with a protective slag coating which prevents oxidation of the weld metal during cooling. The slag is brushed off after the joint has cooled.

Soldering

It is a form of joining metals, by using another metal or alloy heated to its melting point. Method of joining two or more metal pieces ***by means of a fusible alloy or metal called solder (filler alloy), applied in molten state.*** The melting temperature of filler metal is lower than 450°C and also lower than the melting point of the components to be joined. The heated metal, called solder, flows between the metals to be joined and solidifies. The mechanical and physical properties of the solder should be near to those of the metal to be joined.



Schematic of Step used for soldering process a) heating of plates, b) placing brazing/soldering metal and heating and c) filling of molten metal by capillary action followed by solidification

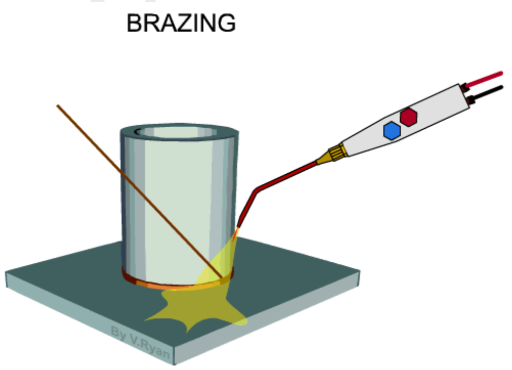
Soldering process:

- The method of heating the solder is by using a soldering iron which is heated by electric current.
- The parts to be joined are first cleaned and are coated with flux.
- The soldering iron is then heated to red hot. The joints are placed in a clamp.
- A few pieces of solder are then put on the tip of the soldering iron and a few drops of the molten solder are applied over the joint.
- The spots of solder in the joint are spread evenly over the entire length of the joint.

Soldered joints can be easily separated and hence ***are useful only for semi-permanent work***. It cannot withstand high temperature and pressure. ***Soldering process is applied in the fabrication works on drain water pipes, radiator tubes of motorcars, copper pipes of automobiles, wiring joints etc.***

Brazing

Brazing is the process of making joints which can with stand temperatures up to 800°C and moderately high pressure. A filler material called brazing solder or spelter is heated to its melting point and allowed to flow between the metals to be joined. On solidification, a moderately strong joint is formed. The filler material is generally a mixture of copper, zinc and tin.



Brazing operation

- In operation, the ends of the metal pieces to be joined are initially cleaned.
- Spelter is then spread over the surface together with the flux.
- The parts are then clamped together and are heated.
- After cooling it solidifies and the joint is formed.

Normally a brazing mixture is prepared in the form of a paste. This will be applied to the surfaces to be joined instead of spreading the spelter. This paste is made by mixing the spelter and flux in equal parts and then adding water to it. ***The applications of brazing are found in parts of bicycle, pipe joints subjected to vibrations, suction pipes in automobiles, stove burners, steel tips of lathe tools, saw blades etc.***

Basic Machining operations: Turning, Drilling, Milling and Grinding.

Turning

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal.

Turning operations performed on a lathe include:

- **Facing**

Facing is an operation of machining the ends of a work piece to produce a flat surface. The operation involves feeding the tool perpendicular to the axis of rotation of the workpiece.

- **Plain turning**

It is an operation of removing excess material from the surface of the cylindrical workpiece. In this operation, the work is held either in the chuck or between centres and the longitudinal feed is given to the tool either by hand or power.

- **Step turning**

In this type of lathe operation various steps of different diameters in the workpiece are produced. It is carried out in the similar way as plain turning.

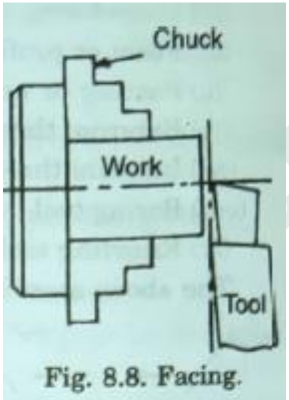


Fig. 8.8. Facing.

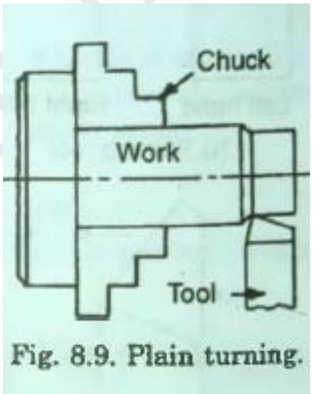


Fig. 8.9. Plain turning.

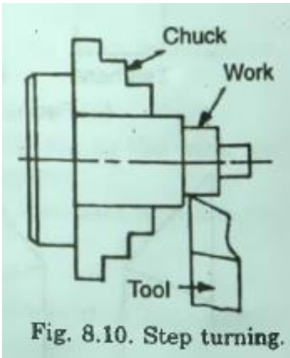
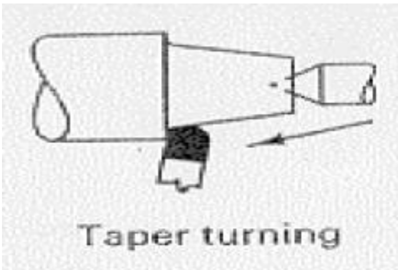


Fig. 8.10. Step turning.

- **Taper turning**

A taper may be defined as a uniform increase or decrease in diameter of a piece of work measured along its length.



Taper turning means to produce a conical surface by gradual reduction in diameter from a cylindrical work piece.

Taper turning can be carried out on lathes by the following methods

1. By setting over the tailstock centre.
2. By swiveling the compound rest
3. By using a taper turning attachment
4. By manipulating the transverse and longitudinal feeds of the slide tool
5. By using a broad nose form tool.

➢ **Drilling**

It is an operation of producing a cylindrical hole in a work piece by the rotating cutting edge of a cutter known as the drill.

For this operation, the work is held in a suitable device, such as chuck or face plate, as usual, and the drill is held in the sleeve or barrel of the tail stock. The drill is fed by hand by rotating the hand-wheel of the tailstock.

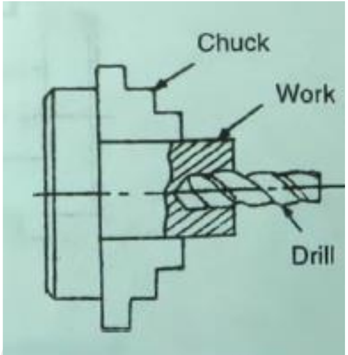


Fig. 8.16. Drilling.

➢ **Reaming**

Reaming is the operation which usually follows the earlier operation of drilling and boring in case of those holes in which a very high grade of surface finish and dimensional accuracy is needed.

The tool used in called the reamer, which has multiple cutting edges. The reamer is held on the tailstock spindle, either direct or through a drill chuck and is held stationary while the work is revolved at very slow speed.

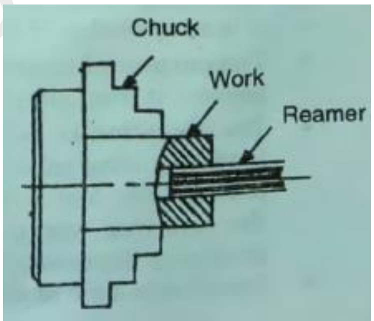


Fig. 8.17. Reaming.

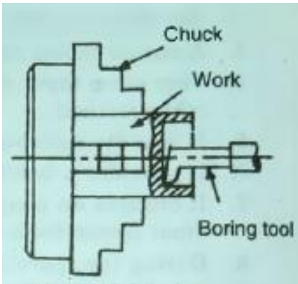


Fig. 8.18. Boring.

It is the operation of enlarging and turning a hole produced by drilling, punching, casting or forging. In this operation, as shown in Fig. 8.18, a boring tool or a bit mounted on a rigid bar is held in the tool post and fed into the work by hand or power in the similar way as for turning.

➢ **Under cutting or grooving.**

It is the process of reducing, the diameter of a workpiece over a very narrow surface. It is often done at the end of a thread or adjacent to a shoulder to leave a small margin.

The work is revolved at half the speed of turning and a grooving tool of required shape is fed straight into the work by rotating the cross-slide screw.

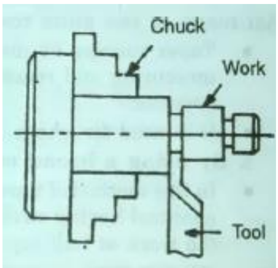


Fig. 8.19. Undercutting.

Threading

Threading is an operation of cutting helical grooves on the external cylindrical surface of the workpiece.

In this operation, as shown in Fig. 8.21, the work is held in a chuck or between centres and the threading tool is fed longitudinally to the revolving work. The longitudinal feed is equal to the pitch of the thread to be cut.

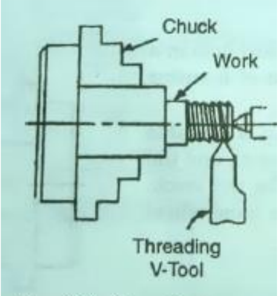


Fig. 8.20. Threading.

- **Knurling**

It is an operation of embossing a diamond shaped pattern on the surface of a workpiece. The purpose of knurling is to provide an effective gripping surface on a workpiece to prevent it from slipping when operated by hand.

The operation is performed by a special knurling tool which consists of 1 set of hardened steel rollers in a holder with the teeth cut on their surface in a definite pattern. The tool is held rigidly on the tool post and the rollers are pressed against the revolving workpiece to squeeze the metal against the multiple cutting edges, producing depressions in a regular pattern on the surface of the workpiece.

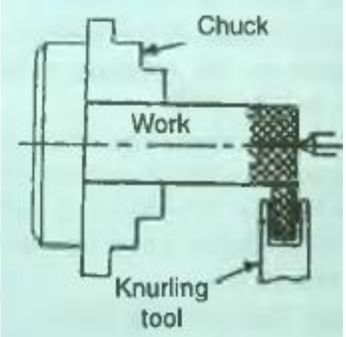
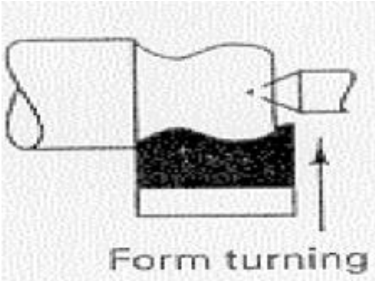


Fig. 8.21. Knurling.

- **Forming**

It is an operation of turning a convex, concave or any irregular shape.

Form turning may be accomplished by the following methods: (i) Using a form tool, (ii) Combining cross and longitudinal feed (iii) Tracing or copying a template.



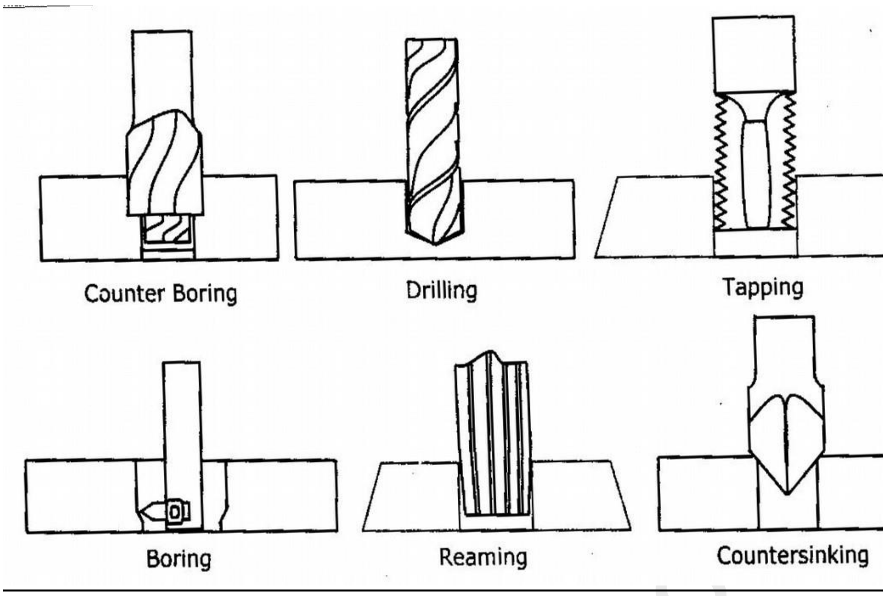
Drilling

Drilling is the operation of producing circular hole in the work-piece by using a rotating cutter called DRILL.

Different drilling operations are

- **Drilling:** Drilling is the operation of producing circular hole in the work-piece by using a rotating cutter called DRILL.
- **Reaming:** It is an operation of finishing an existing drilling hole. The tool used is reamer.
- **Boring**: It is an operation of enlarging an existing hole.
- **Counter boring**: It is an operation of enlarging a drilled hole partially, that is for a specific length.

➢ **Countersinking**: is an operation of forming a conical shape at the end of a drilled hole.
➢ **Tapping:** It is an operation in which external threads are cut in the existing hole.



Milling

Milling is the operation of cutting metal with a multiple-tooth cutting tool called a milling cutter. Based on the direction of the cutter motion and work piece feed, milling can be classified into two

1. Conventional milling or Up milling
2. Climb milling or Down milling

- **Conventional Milling or Up Milling**

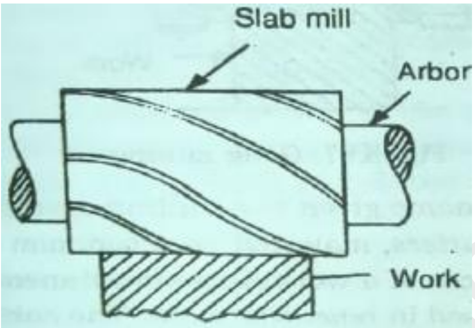
In upmilling the work piece is fed in the opposite direction of that of the rotating cutter. Chip thickness varies from minimum at the start of cut to a maximum at the end of cut. Load on each cutting edge is gradually increased. Cutter tends to lift the work piece from the table and surface finish is poor.

- **Climb Milling or Down Milling**

In down milling the work piece is fed in the same direction of that of the rotating cutter. Chip thickness varies from a maximum at the start of cut to a minimum at the end of cut. Cutter forcing the work piece towards the table. Down milling produce higher surface finish, because the cutting pressure keeps the work piece firmly pressed against the table.

The different milling operations are

- **Plain or slab milling:** Plain milling is used to machine flat and horizontal surfaces (Fig. 8.52). Here plain milling cutter is used, which is held in the arbor and rotated. The table is moved upwards to give the required depth of cut.
- **Face milling:** This milling process (Fig. 8.53) is used for machining a flat surface which is at right angles to the axis of the rotating cutter. The cutter used in this operation is the face milling cutter.
- **Angular milling:** In angular milling, an angle milling cutter is used (Fig. 8.54). The cutter used may be a single or double angle cutter, depending upon whether a single surface is to be machined or two mutually inclined surfaces simultaneously.
- **Form milling:** This milling process (Fig. 8.55) is used for machining those surfaces which are of irregular shapes. The form milling cutter used has the shape of its cutting teeth conforming to the profile of the surfaces to be produced.



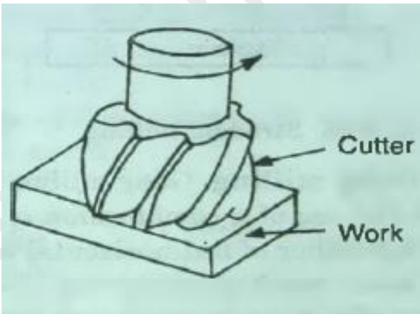


Fig. 8.53. Face milling.

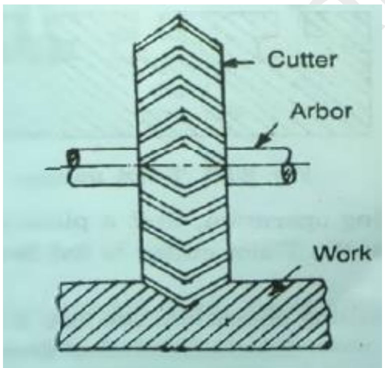


Fig. 8.54. Angular milling.

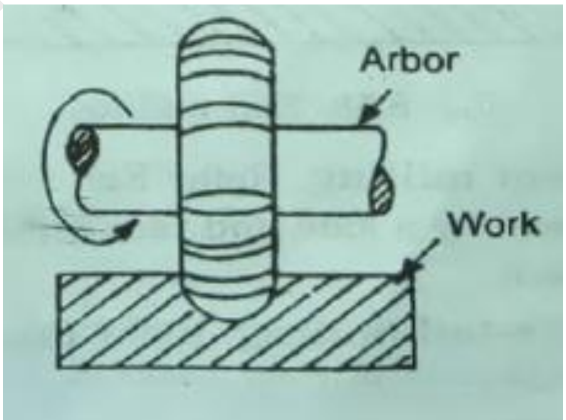


Fig. 8.55. Form milling.

- **End milling:** It is an operation of producing narrow slots, grooves and keyways using an end mill cutter. The mill tool may be attached to the vertical spindle for milling the slot. Depth of cut is given by raising the machine table.

- **T-slot milling:** In this milling operation, first a plain slot is cut oh the workpiece by a side and face milling cutter. Then the T-slot cutter is fed from the end of the workpiece.

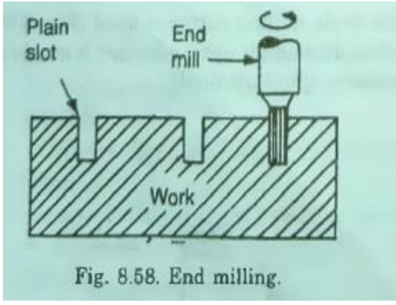


Fig. 8.58. End milling.

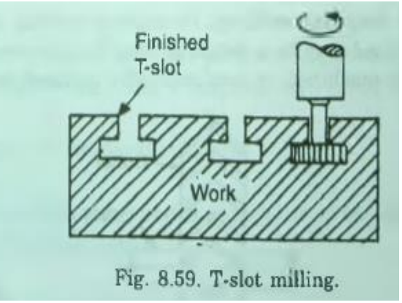


Fig. 8.59. T-slot milling.

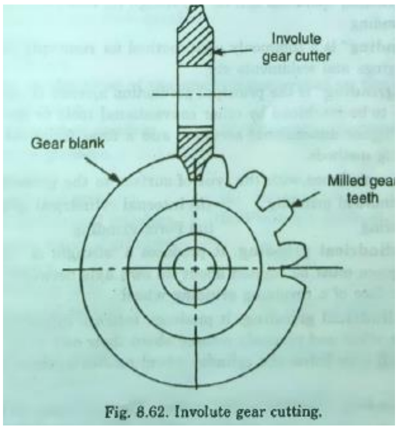


Fig. 8.62. Involute gear cutting.

Involute gear cutting: Gear milling operation, often referred as gear cutting, involves cutting of different types of gears on a milling machine. For this, either an end mill cutter or a form relieved cutter is used, which carries the profile on its cutting teeth corresponding to the required profile of the gap between gear teeth.

Grinding

Grinding is a metal cutting operation performed by means of a rotating abrasive tool, called "grinding wheel". Such wheels are made of fine grains of abrasive materials held together by a bonding material called bond. Each individual and irregularly shaped grain acts as a cutting element.

The wheel is rotated at high speeds and the circumferential surface of the rotating wheel is brought into contact with the material being machined. Grinding is done on surfaces of almost all conceivable shapes and materials of all kinds.

Reasons for grinding:

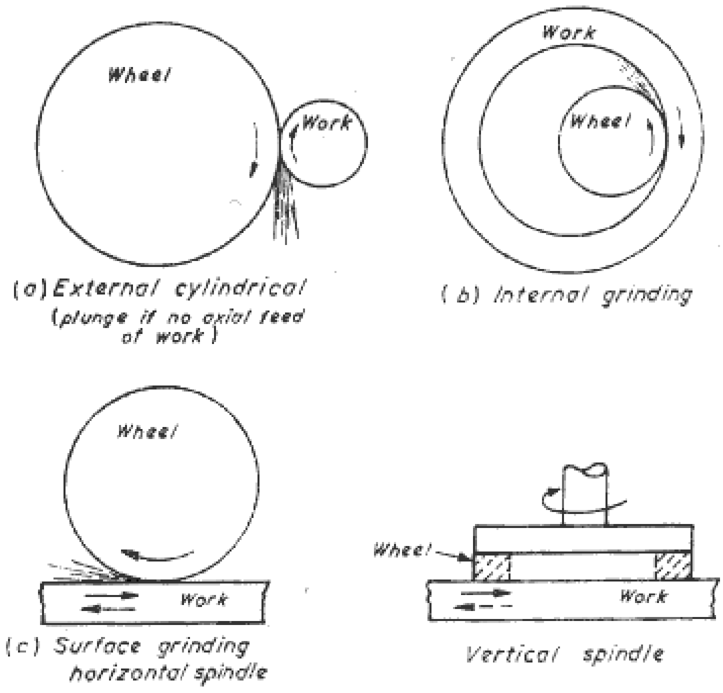
- Removal of surplus material
- Production of high quality surface finishes
- Machining very hard materials

Grinding operation can be

1. **Rough (non-precision grinding):** Rough grinding is a commonly used method for removing excess material from castings, forgings and weldments etc
2. **Precision grinding:** Precision grinding is the principal production method of cutting materials that are too hard to be machined by other conventional tools or for producing surfaces on parts to higher dimensional accuracy and a finer finish as compared to other manufacturing methods.

Grinding in accordance with the type of surface to the ground, classified as;

- External cylindrical grinding
- Internal cylindrical grinding
- Surface grinding
- Form grinding



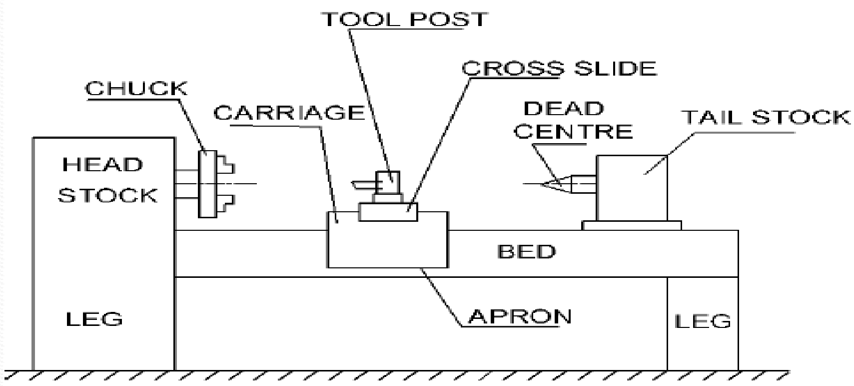
GRINDING OPERATIONS

1) **External cylindrical grinding**: It produces a straight or tapered surface on a workpiece. The workpiece must be rotated about its own axis between centres as it passes lengthwise across the face of a revolving grinding wheel.
2) **Internal cylindrical grinding:** It produces *internal cylindrical holes and tapers*. The workpieces are chucked and precisely rotated about their own axes. The grinding wheel or, in the case of small bore holes, the cylinder wheel rotates against the sense of rotation of the workpiece.
3) **Surface grinding:** It produces flat surface. The work may be ground by either the periphery or by the end face of the grinding wheel. The workpiece is reciprocated at a constant speed below or on the end face of the grinding wheel.
4) **Form grinding:** This operation is done with specially shaped grinding wheels that grind the formed surfaces as in grinding gear teeth, threads, splined shafts, holes etc.

Description about working with block diagram of: Lathe, Drilling machine, Milling machine, CNC Machine.

Lathe

Lathe is the most general purpose machine tool in which the workpiece is held & rotated against suitable cutting tool for the purpose of producing surface of revolution. That is why, the lathes are also called “Turning machines”. Lathe has become so popular because of its versatility and it is usually found in almost all workshops.



LATHE MACHINE

Main parts of a lathe

Bed: Usually made of cast iron. Provides a heavy rigid frame on which all the main components are mounted.

Headstock: mounted in a fixed position on the inner ways, usually at the left end. Using a chuck, it rotates the work.

Chuck: 3-jaw (self centering) or 4-jaw (independent) to clamp part being machined. It allows the mounting of difficult work pieces that are not round, square or triangular.

Tailstock: Fits on the inner ways of the bed and can slide towards any position the headstock to fit the length of the work piece. An optional taper turning attachment would be mounted to it.

Carriage: Moves on the outer ways. Used for mounting and moving most of the cutting tools.

Cross Slide: Mounted on the traverse slide of the carriage, and uses a hand wheel to feed tools into the work piece.

Tool Post: To mount tool holders in which the cutting bits are clamped.

Apron: Attached to the front of the carriage, it has the mechanism and controls for moving the carriage and cross slide.

Principle of working

The purpose of a lathe is to rotate a part against a tool whose position it controls. It is useful for fabricating parts and/or features that have a circular cross section. The spindle is the part of the lathe that rotates. Various work holding attachments such as three jaw chucks, collets, and centers can be held in the spindle. The tailstock can be used to support the end of the work piece with a center, or to hold tools for drilling, reaming, threading, or cutting tapers.

In a lathe, the workpiece is held in a chuck or between centres and rotated about its axis at a uniform speed. The cutting tool held in tool post is fed into the workpiece for desired depth and in desired direction (i.e., in linear, transverse or lateral direction). Since there exists a relative motion between the workpiece and the cutting tool, therefore the material is removed in the form of chips and desired shape is obtained.

DRILLING MACHINES

Drilling is the operation of producing circular hole in the work-piece by using a rotating cutter called DRILL. The machine used for drilling is called drilling machine. The drilling operation can also be accomplished in lathe, in which the drill is held in tailstock and the work is held by the chuck

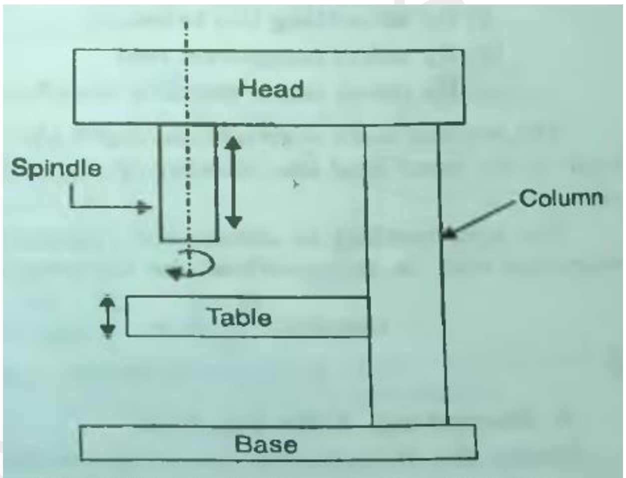


Fig. 8.37. Block diagram of a drill press.

Drilling machine is one of the simplest, moderate and accurate machine tool used in production shop and tool room. It consists of a spindle which imparts rotary motion to the drilling tool, or mechanism for feeding the tool into the work, a table on which the work rests and a frame. It is considered as a single purpose machine tool since its chief function is to make holes. However, it can and does perform operations other than drilling also.

Working principle: The rotating edge of the drill exerts a large force on the workpiece and the hole is generated. The removal of metal in a drilling operation is by shearing and extrusion.

Working

When the power supply is given, the spindle which is in conjunction with the motor starts to operate. The Radial arm is adjusted according to the type of operation and height of the work piece. The chuck is connected to the spindle and it holds the drill bit in its jaws. The Drill head is adjusted on to the point of application at work piece and a suitable feed is given. The drill bit then drives into the work piece very easily. When the hand wheel is rotated, the pinion which is attached to the rack also rotates which converts the rotary motion to the linear motion. This driving mechanism is called as Rack and Pinion mechanism.

Milling Machines

A milling machine is a machine tool that cuts metal with a multiple-tooth cutting tool called a milling cutter. The workpiece is fastened to the milling machine table and is fed against the revolving milling cutter. The milling cutters can have cutting teeth on the periphery or sides or both. The cutting teeth can be straight or spiral.

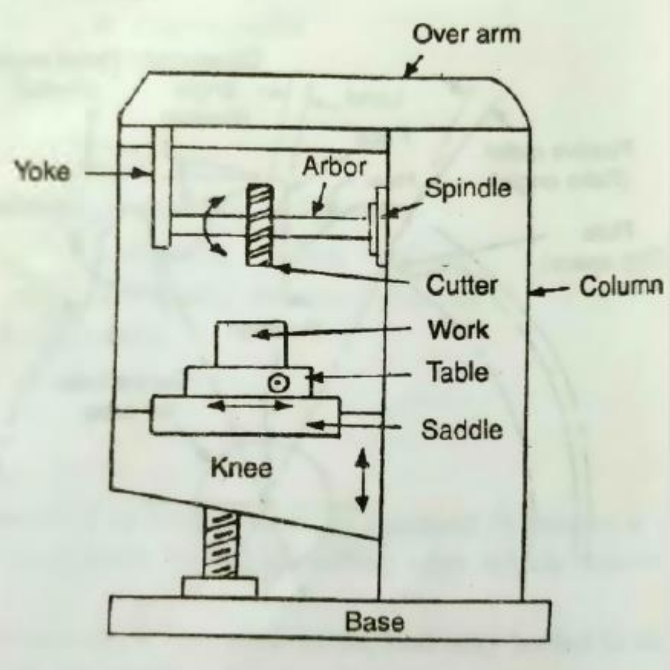


Fig. 8.51. Horizontal milling machine.

Main Parts of a Horizontal Milling Machine

1. Base: It is a heavy casting on which column and other parts are mounted. It may be bolted to the floor strongly.

2. Column: There are guideways on the front face of the column in which the knee slides. It houses power transmission units such as gears, belt drives and pulleys to give rotary motion to the arbor.

3. Knee: It supports the saddle, table, workpiece and other clamping devices. It moves on guideways of the column. It resists the deflection caused by the cutting forces on the workpiece.

4. Saddle: It is mounted on the knee and can be moved, by a handwheel or by power. The direction of travel of the saddle is restricted to be towards or away from the column face.

5. Table: It is mounted on the saddle and can be moved by a handwheel or power. Its top surface is machined accurately to hold the workpiece and other holding devices. It moves perpendicular to the direction of saddle movement.

6. Arbor: Its one end is attached to the column and the other end is supported by an over arm. It holds and drives different types of milling cutters.

7. Spindle: It gets power from gears, belt drives, to drive the motor. It has provision to add or remove milling cutters onto the arbor.

Working Principle: The workpiece is holding on the worktable of the machine. The table movement controls the feed of workpiece against the rotating cutter. The cutter is mounted on a spindle or arbor and revolves at high speed. Except for rotation the cutter has no other motion. As the workpiece advances, the cutter teeth remove the metal from the surface of workpiece and the desired shape is produced.

Working:

First the cutting tool is set at the arbor which is connected to the spindle. The knee is moved downward. Now the work piece is clamped on the table by using clamping screw. All the controlling points are set to zero like knee position, saddle position etc. Now the spindle starts to rotate which further rotates the cutting tool. As the tool is moving, we move the work piece as required by moving the knee, saddle and table. The controlling axis move the work piece and cut the desire shape on it. The tool remains stationary and only in rotary motion.

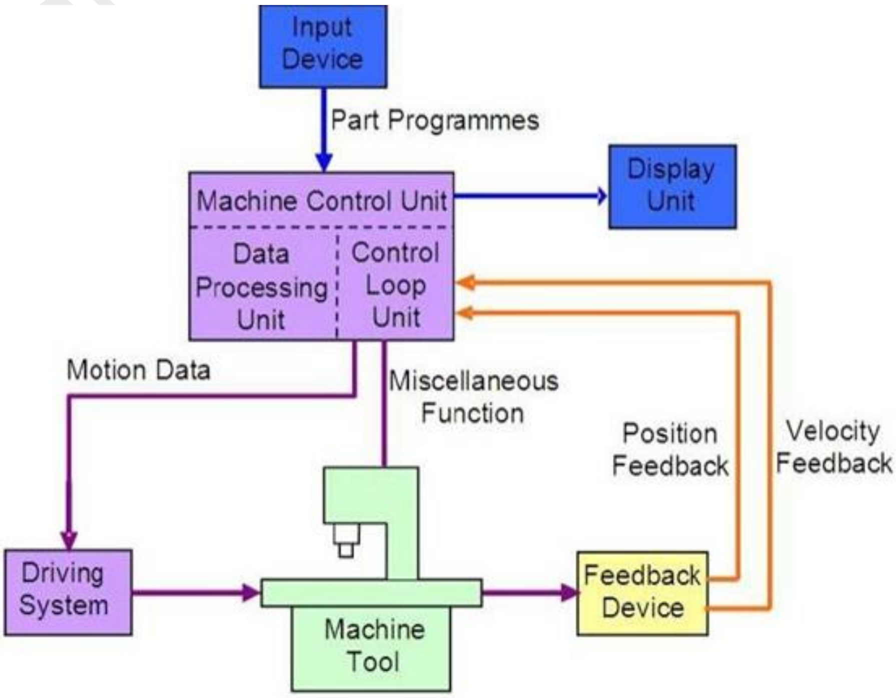
CNC MACHINE

In CNC (Computer Numerical Control) machines, a dedicated computer is used to perform the most of basic NC machine functions. CNC (Computer Numerical Control) machine is a NC machine which uses a dedicated computer as the machine control unit. The entire program is entered and stored in computer memory. The machining cycle for each component is controlled by the program contained in the computer memory. The stored part program listing can be used for future production also.

Components of CNC machine tool system

The main components of CNC machine tools are as follows :

- Input / Output Console.
- Microprocessor Based control unit.
- Memory.
- Feedback unit.
- Machine Tool.
- Interfaces.



- **Input / Output Console**: It is the unit through which part program is fed to the CNC machine tool system and required output is taken out. It basically consists of monitor and Keyboard.
- **Microprocessor**: This controller takes input from Input / Output device, Feedback from feedback unit and actuates the drives as well as the tool of the machine tool.
- **Memory**: It consists of RAM & ROM. The RAM stores part program, while ROM stores the programs for machine control.
- **Feedback unit**: The feedback unit takes input from machine tool and transfers it to control unit for necessary corrections.
- **Machine tool**: Machine tool is operated by the control unit.
- **Interfaces**: They are the connections between the different components of the CNC machine tool system.

Working

The part program is fed into the CNC machine tool through input console. The microprocessor (control unit) takes the input from the input console and actuates the drives as well as the tool of the machine tool according to the program in memory unit. A feedback unit is provided to take the input from machine tool and transfer it to control unit for necessary corrections. This process is continued till the required operation is done.

Advantages & Limitations of CNC machine tools

Advantages

- Ease of program input.
- Multiple program storage.
- Online part programming and editing.
- Automatic tool compensation.
- Auto generation of part program for existing components.

- Higher investment cost.
- Higher maintenance cost.
- Requires specialised operators.

Principle of CAD/CAM, Rapid and Additive manufacturing.

CAD/CAM

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. ***CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.*** CAD is an important industrial art extensively used in many ***applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more.***

CAD is used as follows:

- To produce detailed engineering designs through 3-D and 2-D drawings of the physical components of manufactured products.
- To create conceptual design, product layout, strength and dynamic analysis of assembly and the manufacturing processes themselves.
- To prepare environmental impact reports, in which computer-aided designs are used in photographs to produce a rendering of the appearance when the new structures are built.

Computer-aided manufacturing (CAM) is the use of computer systems to plan, manage, and control the operations of a manufacturing plant through direct or indirect computer interface with plant's resources. CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage. ***Its primary purpose is to create a faster production process and components and tooling with more precise dimensions and material consistency, which in some cases, uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption.*** CAM is a subsequent computer-aided process after computer-aided design (CAD) and sometimes computer-aided engineering (CAE), as the model generated in CAD and verified in CAE can be input into CAM software, which then controls the machine tool.

Need for CAD/CAM

- To increase productivity of the designer
- To improve quality of the design
- To improve communications
- To create a manufacturing database
- To create and test tool paths and optimize them
- To help in production scheduling and MRP models
- To have effective shop floor control

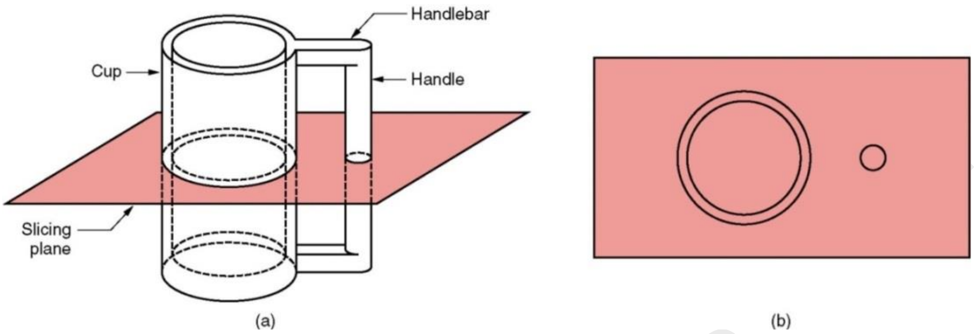
The key benefits of CAD/CAM

- Increased range of design ideas
- Improved accuracy
- Ease of modification
- Repeatability of output
- Quality of output
- Reduction of wastage

RAPID PROTOTYPING (RP)

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Rapid prototyping is a family of fabrication processes developed to make engineering prototypes in minimum lead time based on a CAD model of the item.

Traditional method is machining and may require significant lead-times – several weeks, depending on part complexity and difficulty in ordering materials. RP allows a part to be made in hours or days, given that a computer model of the part has been generated on a CAD system.



RP – Two Basic Categories:

1. **Material removal RP** - machining, using a dedicated CNC machine that is available to the design department on short notice.

Starting material is often wax.

- Easy to machine
- Can be melted and re-solidified

2. **Material addition RP** - adds layers of material one at a time to build the solid part from bottom to top

Steps in Rapid Prototyping

1. **Geometric modeling** - model the component on a CAD system to define its enclosed volume
2. **Tessellation of the geometric model** - the CAD model is converted into a computerized format that approximates its surfaces by facets (triangles or polygons)
3. **Slicing of the model into layers** - computerized model is sliced into closely-spaced parallel horizontal layers

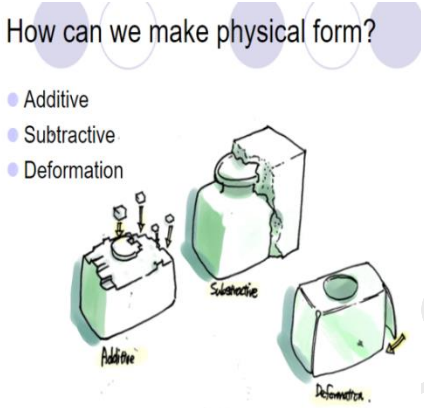
Rapid Prototyping – Applications

- Building of real physical model in minimum time
- Can be used for engineering analysis and planning

- Can be employed in tooling and manufacturing

Rapid Prototyping – Advantages

- Speed: part or product designed and tested in a short timeframe.
- Cost: most cost-effective among the forms of prototyping.
- Full-scale model can be prepared in minimum time
- Less waste: Because only the material that is needed is used, there is very little (if any) material wasted.



Additive/ Layered Manufacturing

Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. It is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. By contrast, when you create an object by traditional means, it is often necessary to remove material through milling, machining, carving, shaping or other means.

The term "additive manufacturing" references technologies that grow three-dimensional objects one superfine layer at a time. Common to AM technologies is the use of a computer, 3D modeling software (Computer Aided Design or CAD), machine equipment and layering material. ***Once a CAD sketch is produced, the AM equipment reads in data from the CAD file and lays downs or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object. Each successive layer bonds to the preceding layer of melted or partially melted material***

The term AM encompasses many technologies including subsets like 3D Printing, Rapid Prototyping (RP), Direct Digital Manufacturing (DDM), layered manufacturing and additive fabrication. AM application is limitless.

Additive manufacturing applications

- Aerospace, Automotive, Healthcare, Product Development etc.

Additive manufacturing - Advantages

- Allows the creation of lighter, more Complex geometries
- It is possible to make alterations on the run. .
- Lead times are frequently reduced.
- Parts once created from multiple assembled pieces are now fabricated as a single, assembly-free object.
- It enables a design-driven manufacturing process
- Few constraints: Anything you can dream up and design in the CAD software, you can create with additive manufacturing.
- Less waste: Because only the material that is needed is used, there is very little (if any) material wasted.
- Infinite shades of materials: Engineers can program parts to have specific colors in their CAD files, and printers can use materials of any color to print them.

Additive Manufacturing - Disadvantages

- Limited Material Selection
- Differences in Material Properties of different materials used in layers
- High Initial Investment and Required Maintenance Expertise
- Limited production scale.

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