UNIT II

Metal Forming&Forging

Metal Forming: Introduction

- Nature of plastic deformation
- Hot and cold working of metals
- Mechanics of metal forming
- Rolling: Principle
- Types of rolling mill and products,
- Roll passes, forces in rolling and power requirements

Extrusion: Basic extrusion process

- Extrusion process characteristics,
- Hot extrusion
- Cold extrusion,
- Wire drawing,

  Tube drawing.
- **Forging:**
- Principles of forging
- Tools and dies.
- Typesof forging
- Smith forging
- Drop forging
- Forging hammers
- Rotary forging
- Forging defects

Sheet metal forming:

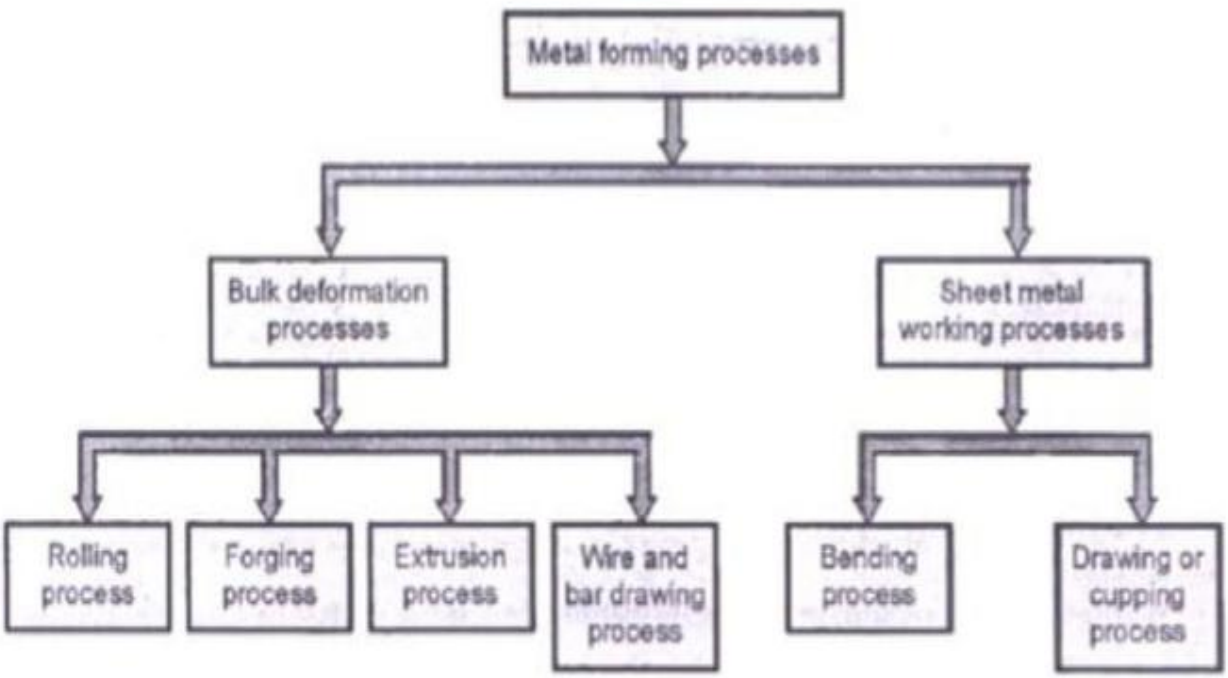
- Mechanics of sheet metal working
- Blanking
- Piercing
- Bending
- Stamping

Metal Forming

- Metal forming includes a large number of manufacturing processes in which plastic deformation property is used to change the shape and size of metal work pieces.
- During the process, for deformation purpose, a tool is used which is called as die. It applies stresses to the material to exceed the yield strength of the metal.
- Due to this the metal deforms into the shape of the die. Generally, the stresses applied to deform the metal plastically are compressive.
- But, in some forming processes metal stretches, bends or shear stresses are also applied to the metal. For better forming of metal, the desirable properties of metal are low yield strength and high ductility.
- These properties are highly affected by the temperature. When the temperature of the metal is increased, its ductility increases and yield strength decreases.

  The other factors which affect the performance of metal forming process are, strain rate, friction, lubrication, etc.

Classification of metal forming processes



What Is Bulk Deformation?

- Operations that induce shape changes on the metal work piece by plastic deformation under forces applied by various tools and dies.
- Starting forms: cylindrical bars and billets, rectangular billets and slabs, and similar shapes.
- These processes work by stressing metal sufficiently to cause plastic flow into desired shape.
- The cross-section of work piece changes without volume change.
- **BULK DEFORMATION:**
- **Rolling:**
- Compressive deformation process in which the thickness of a plate is reduced by squeezing it through two rotating cylindrical rolls

- **Forging:**
- The work piece is compressed between two opposing dies so that the die shapes are imparted to the work.
- **Extrusion:**
- The work material is forced to flow through a die opening taking its shape.
- **Wire and Bar Drawing:**
- The diameter of a wire or bar is reduced by pulling it through a die opening (bar drawing) or a series of die openings (wire drawing).
- **SHEET METAL WORKING PROCESS**
- **Bending:**
- In bending operations, the sheet metal is subjected to both tensile and compressive stresses.
- During the operation, plastic deformation of material takes place beyond its elastic limit but below its ultimate strength.
- **Drawing:**
- itis the process of making a cup shaped parts from sheet metal blanks.
- The blank is first heated then placed in position over the die or cavity. The punch descends through the die to form a cup

Introduction Mechanical working of a metal

- Mechanical working of a metal is a simply plastic deformation performed to change the dimensions, properties and surface conditions with the help of mechanical pressure.
- Depending upon the temperature and strain rate, mechanical working may be either hot working or cold working, such that

recovery process takes place simultaneously with the deformation.

- The plastic deformation of metal takes place due to two factors i.e. deformation by slip and deformation by twin formation.
- During deformation the metal is said to flow, which is called as plastic flow of the metal and grain shapes are changed.
- If the deformation is carried out at higher temperatures, then the new grains start growing at the locations of internal stresses.
- When the temperature is sufficiently high, the grain growth is accelerated and continue still the metal comprises fully of new grains only.
- This process of formation of new grains is called as recrystallisation and the corresponding temperature is the recrystallisation temperature of the metal.
- Recrystallisation temperature is the point which differentiates hot working and cold working.
- Mechanical working of metals above the recrystallisation temperature, but below the melting or burning point is known as hot working whereas; below the recrystallisation temperature, is known as cold working.
- **Plastic Deformation**
- – Any external or internal forces cause stresses in the material resulting into deformation.
- – Deformation is of two basic types :
- o Elastic Deformation : Stress is below the elastic limit,
- o Plastic Deformation: Stress is above the elastic limit.

- – When the body regains its original shape on the removal of externally applied force the deformation is called as elastic deformation.
- Elastic deformation occurs upto the maximum value of stress upto which the deformations are elastic or temporary.
- Stress required during elastic deformation is lower than plastic deformation.
- The plastic deformation is an important property of metals and non-metals, due to which materials can be deformed permanently and shaped as per the requirement.
- Plastic deformation can be done through forming, rolling, drawing, forging, etc.

Plastic deformation may occur by :

- Slip or
- Twinning or
- Both acting simultaneously

Plastic deformation is permanent and takes place when the applied stress level exceeds a certain limit known as yield stress[value of stress at a yield point or at the yield strength . Refer Fig. 4.1

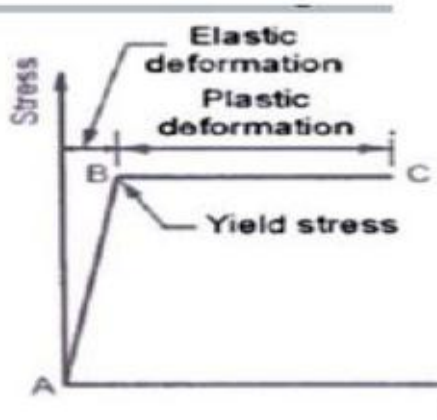


Fig. 4.1: Ideal plastic deformation preceded by ideal elastic deformation

Work Hardening

- It is the phenomenon by which metals become **harder and stronger during mechanical working** or straining i.e. during plastic deformation of the metal.
- After initial work hardening or straining, more and more stress is required to further deform the material.
- E.g. During the operation of hammering a nail, quite often the nail bends. This bending of nail induces stress development inside the nail.
- The nail gets plastically deformed and work hardened or strained.
- Now if we try to straighten the nail, it requires more force than that required to bend it.
- Work hardening or Straining occurs below the re-crystallization temperature

Hot Working

- Hot working is accomplished at a temperature above the recrystallisation temperature but below the melting or the burning point of the metal, because above the melting or the burning point, the metal will burn and become unsuitable for use.
- Every metal has a characteristic hot working temperature range over which hot working may be performed.
- The upper limit of working temperature depends on composition of metal, prior deformation and impurities within the metal.

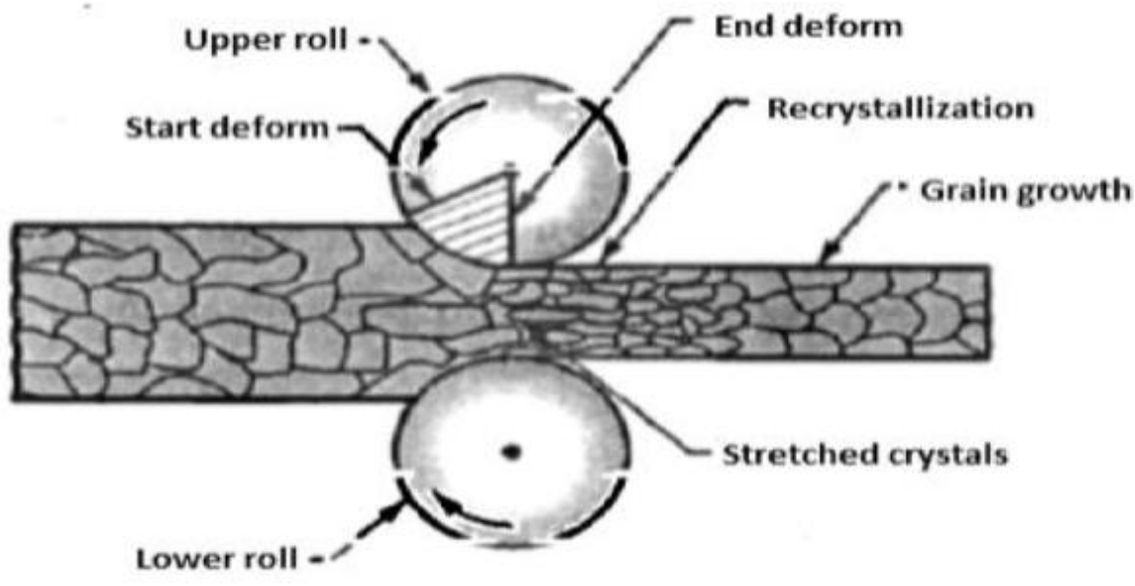
- The changes in structure from hot working improves mechanical properties such as ductility, toughness, resistance to shock and vibration, % elongation, % reduction in area, etc.

  The principal hot working processes applied to various metals are as follows :

1. Hot rolling
2. Hot extrusion
3. Hot spinning
4. Roll piercing
5. Hot drawing
6. Hot forging .

1.Rolling:

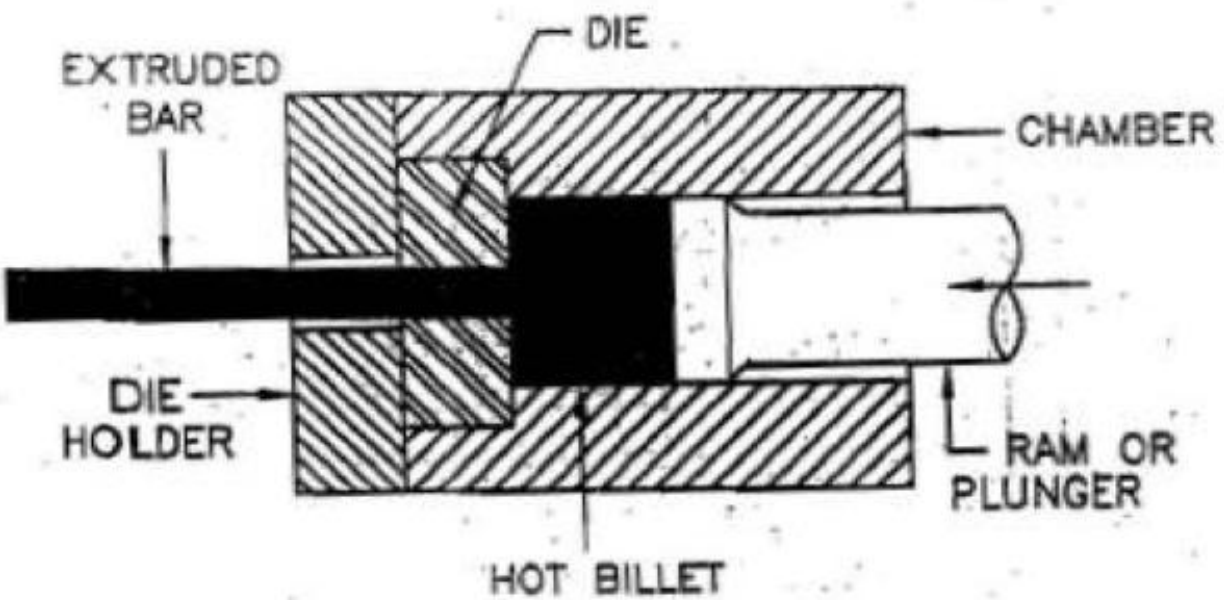
The plastic deformation of metal takes place as it passes through a pair of rolls rotating in opposite direction.This isdue to squeezing action of rolls. In this reducing the cross- sectional area takes place. The hot rolling is used to produce bars, plates, sheets, rails and girders



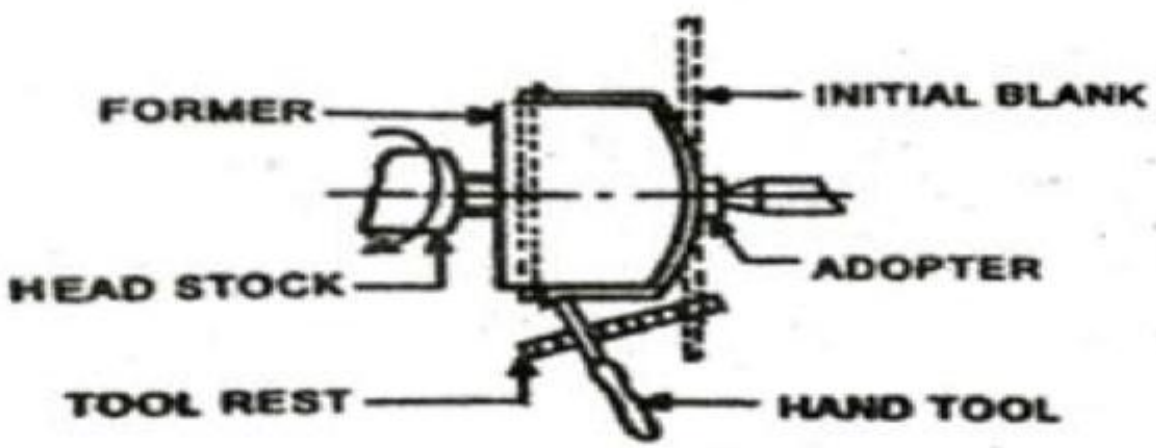
2. Extrusion: direct and indirect extrusion

In this the metal billet is heated to plastic state and placed in a container. The billet is forced through a die by the pressure applied from the ram. The billet moves relative to the container.

Ex: Tubes, cables, air craft parts etc.

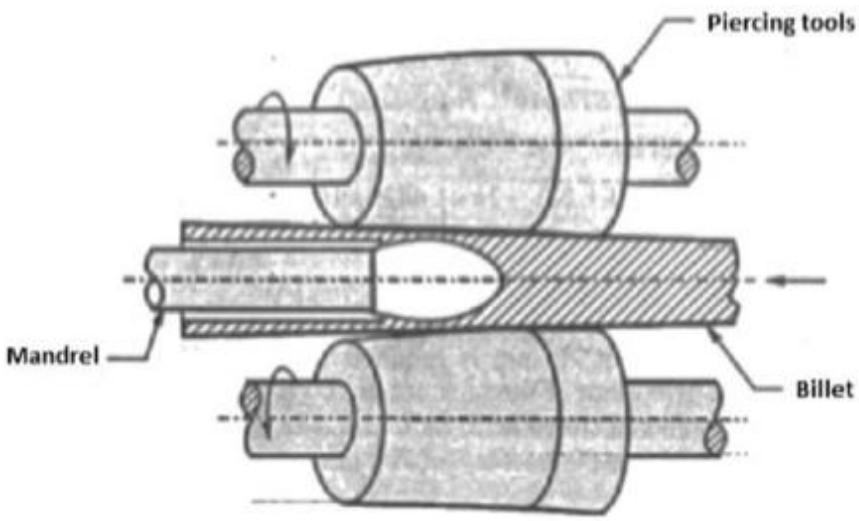


3. Spinning: It is the process of shaping thin sheets of metal by pressing against a rotating former. The blank is held between the former and adopter. The blank rotates with the former. A specially shaped tool is pressed against the blank and slowly moved to cover the former.



4. piercing: [a small hole]

Hot piercing is used to produce seam (smooth) less tubes. A small hole is made at the end of the heated billet. It is feed between two piercing rolls rotating in the same direction. As a result seamless tube is produced.



5. Drawing or Cupping:

Drawing is the process of making a cup shaped parts from sheet metal blanks.

The blank is first heated then placed in position over the die or cavity. The punch descends through the die to form a cup.

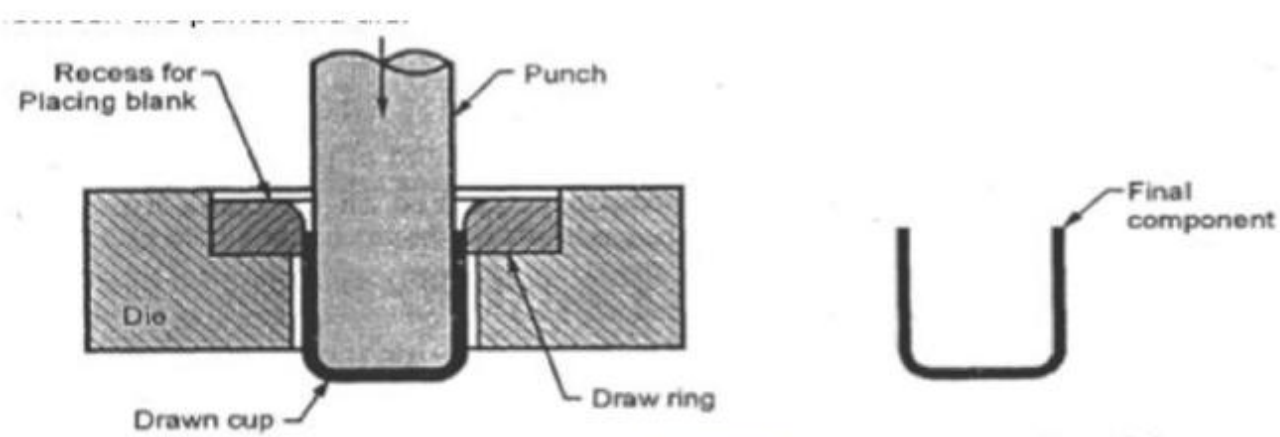
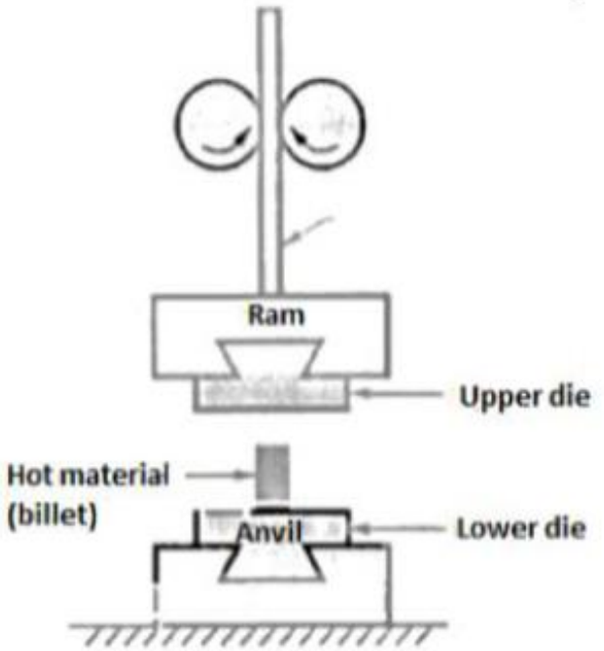
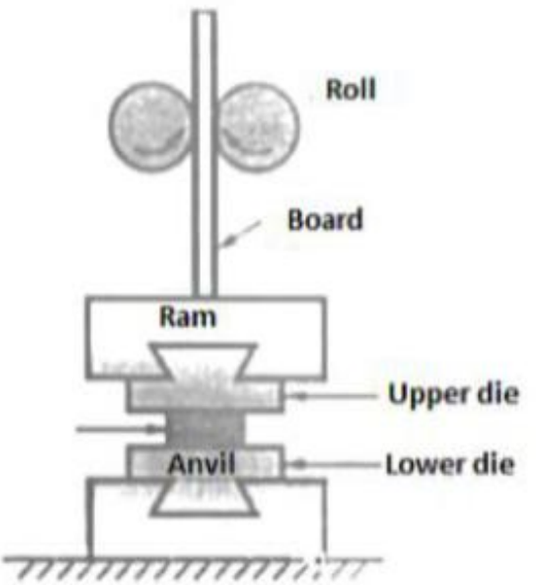


Fig. 5.17: Drawing

6.Forging

In this process, the work piece is compressed between the two opposing dies in order to produce the die shapes on the work piece





Advantages of Hot working process:

1.The grain structure is refined remove impurity and unwanted elements.

2. Less force is enough to shape the metal into desired shape.

3. Strength and hardness of metal decreases.

4. Porosity of metal eliminated.

5. Ductility and toughness increases.

6. Energy consumption is less.

7. Uni-directional fiber structure is obtained.

8. This process is easy and economical.

9. Larger deformation is possible with less force.

Dis-advantages of Hot working process:

1. At high temperature scales are formed, so poor surface finish.
2. Close tolerance cannot be maintained.
3. Tooling and handling costs are high.
4. Tool life is less due to work at high temperature.
5. The steel work piece loose carbon,

Cold Working

- The working of metals at temperatures below their recrystallisation temperature is called as cold working. – Most of the cold working processes are performed at room temperature.
- Unlike hot working, it distorts the grain structure and does not provide an appreciable reduction in size. – Cold working requires much higher pressure than hot working.
- If the material is more ductile, it can be more cold worked.
- Residual stresses are setup during the process, hence to neutralize these stresses a suitable heat treatment is required.

The principal methods of cold working are as follows :

1. Cold rolling
2. Cold drawing
3. Cold spinning
4. Stretch forming
5. Cold forging and swaging
6. Cold extrusion
7. Coining
8. Embossing

9. Cold bending

10. Reeding

11. Squeezing

1.Cold Rolling

- Cold rolling is used for producing bars of all shapes, rods, sheets and strips.
- Cold rolling is generally employed for providing a smooth and bright surface finish tothe previously hot rolled steel.
- It is used to finish the hot rolled components, to close tolerances and improve their hardness and toughness.
- Before cold rolling, the hot rolled articles are cleaned through pickling[surface treatment used to remove the impurities]and other operations.
- The same types of rolling mills, as in hot rolling, are used for cold rolling.
- The part being rolled is generally annealed[anneling is a heat treatment process used to increase ductility & reduce hardness]and pickled before the final pass is made, so as to bring it to accurate size and obtain a perfectly clean surface.
- **2.Drawing:**
- It is the process to reduce the large diameter of metal in to required low diameter. In this die is used.
- The metal is passed through the die, by applying force the metal comes out from die.

3.Spinning:

- It is the process of shaping thin sheet metal by pressing against the form which is rotation.
- This process is suitable for soft metals. 4.**Stretch forming :**
- Stretch forming strains the metal beyond elastic limit to give work piece a permanent set.
- This prevents the metal from spring back

5.Cold forging

- For certain products like bolts, rivets, screws, pins, nails, etc. cold forging is also very common.
- It increases the strength which results from the strain hardening of the component.

6.Extrusion:

It is the process of pushing the billet of metal through an orifice in the die.

The punch is passed on metal. Then the metal extruded into die shape

7. Coining (Squeezing):

- In coining operation, the metal having good plasticity and of proper size is placed within the punch and die and a tremendous pressure is applied on the blank from both ends. Refer Fig. 5.20.

7. Coining (Squeezing):

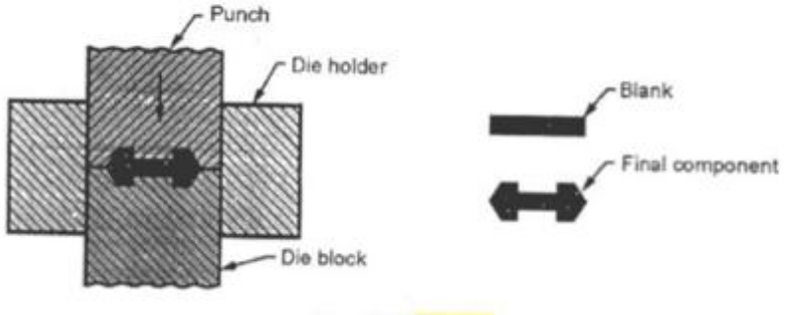


Fig. 5.20: Coining

- Under severe compressive loads, the metal flows in the cold state and fills up the cavity of the punch and die. – This

operation is used .in the manufacturing of coins, medals, ornamental parts, etc.

Embossing

- – With the help of this operation, specific shapes or figures are produced on the sheet metal.
- – It is used for decorative purposes or giving details like names, trade marks specifications, etc. on the sheet metal. Refer Fig. 5.18.

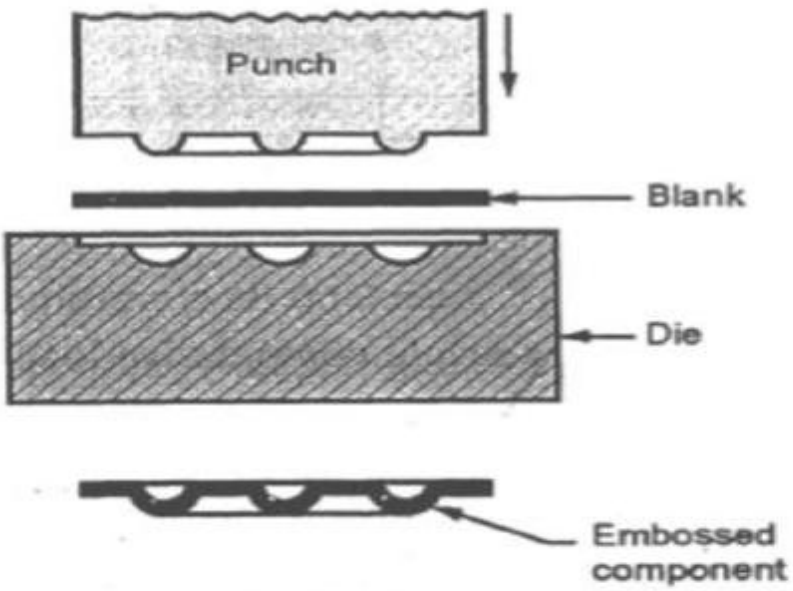


Fig. 5.18: Embossing

Bending

- It is a metal forming operation in which the straight metal sheet is transformed into a curve· form.
- In bending operations, the sheet metal is· subjected to both tensile and compressive stresses.
- During the operation, plastic deformation of material takes place beyond its elastic limit but below its ultimate strength.

The bending methods which are commonly used are as follows :

a. U-Bending b. V-bending c. Angle bending

d. Curling e. Roll bending

f. Bending in a 4-slide machine g. Edge bending

10. Reeding:

It is the process of intending[indentation a deep]large quantities of steel shots in to the surface of metal.

This is done by air blast. By this indentation compressive stresses are developed at outer layer. Due to this the metal surface is slightly hardened

11.Squeezing:

It requires large amount pressure to get required shape. For this a cavity of die and punch are required.

Ex: bolts, screws, rivets.

Advantagesof cold working process:

- Better dimensional control is possible because there is not much reduction in size.
- Surface finish of the component is better because no oxidation takes place during the process.
- Strength (tensile strength and yield strength) and hardness of metal are increased.
- It is an ideal method for increasing hardness of those metals which do not respond to the heat treatment.

Disadvantagesof cold working process:

- Ductility of the metal is decreased during the process.
- Only ductile metals can be shaped through the cold working.
- Over-working of metal results in brittleness and it has to be annealed to remove this brittleness.

- To remove the residual stresses setup during the process, subsequent heat treatment is mostly required

Comparison between Hot Working and Cold Working

4.5.1 Comparison between Hot Working and Cold Working

Sr. No.	Hot working	Cold working
1.	Hot working is carried out above the recrystallisation temperature but below the melting point, hence deformation of metal and recovery takes place simultaneously.	Cold working is carried out below the recrystallisation temperature and as such there is not appreciable recovery of metal.
2.	During the process, residual stresses are not developed in the metal.	During the process, residual stresses are developed in the metal.
3.	Because of higher deformation temperature used, the stress required for deformation is less.	The stress required to cause deformation is much higher.
4.	Hot working refines metal grains,	Cold working leads to distortion of grains.

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Types of Rolling Mills

According to the number and arrangement of the rolls, rolling mills are classified as follow:

1. Two-high rolling mill
2. Three-high rolling mill
3. Four-high rolling mill
4. Tandem rolling mill
5. Cluster rolling mill
6. Planetary rolling mill
7. Universal rolling mill

1. **Two-high rolling mill**:

- It consists of two heavy horizontal rolls placed exactly one over the other.
- The space between the two rolls can be adjusted by raising or lowering the upper roll, whereas the position of the lower roll is fixed.
- Both the rolls rotate in opposite direction to each other. Refer Fig. 4.8 (a).
- In this type, their direction of rotation is fixed and cannot be reversed.
- There is another type of two-high rolling mill which incorporates a drive mechanism that can reverse the rotation direction of the rolls.
- This type of rolling mill is called as two-high reversing mill

2. Three-high rolling mill:

- It consists of three horizontal rolls positioned directly one over the other.
- The directions of rotation of the upper and lower rolls are same but the intermediate roll rotates in the opposite direction to each other. Refer Fig. 4.8 (b).
- All the three rolls revolve continuously in the same fixed direction and they are never reversed.
- The work piece is fed in one direction between the upper and middle rolls and in the reverse direction between the middle and lower rolls.
- This results in high production rate than the two-high rolling mill.

3. Four-high rolling mill:

- It consists of four horizontal rolls i.e. two of smaller diameter and two of larger diameter arranged directly one over the other. Refer Fig. 4.8 (c).
- The larger diameter rolls are called back-up rolls and they are used to prevent the deflection of the smaller rolls, which otherwise would result in thickening of rolled plates or sheets at the center.
- The smaller diameter rolls are called as working rolls, which concentrate the total rolling pressure over the metal.
- The common products of these mills are hot or cold rolled sheets and plates.

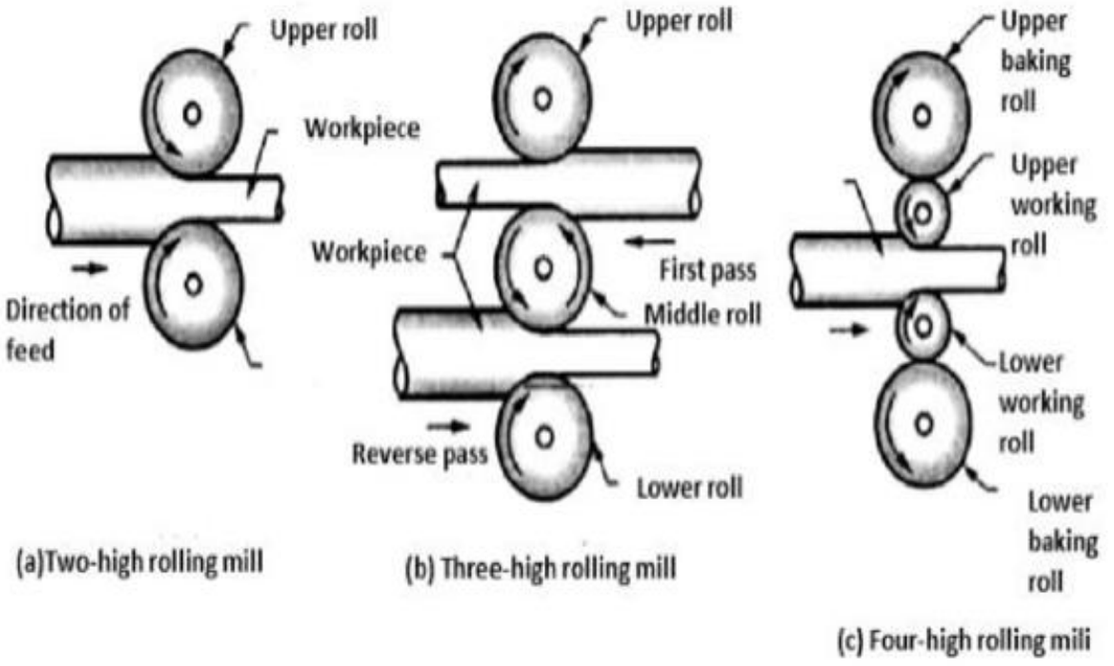
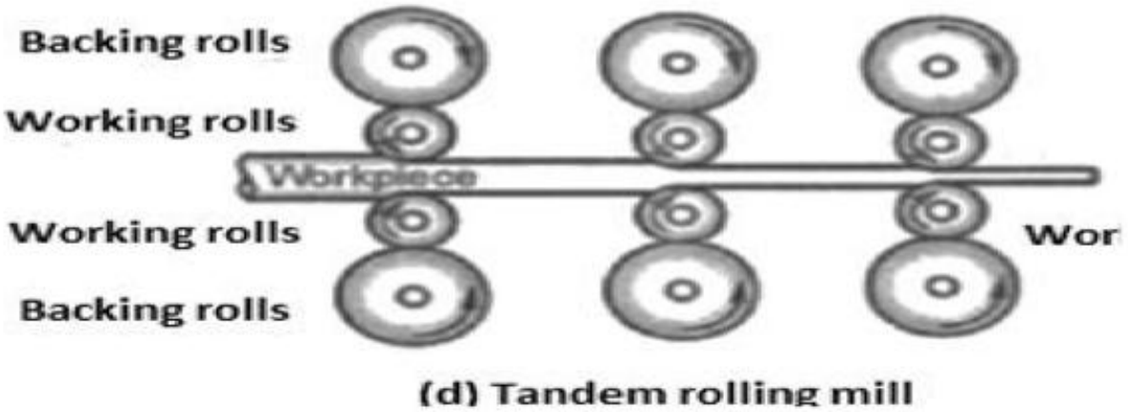


Fig. 4.8: Types of rolling mills

4. Tandem rolling mill:

- It is a set of two or three stands of rolls set in parallel alignment.
- This facilitates a continuous pass through each one successively without change of direction of the metal or pause in the rolling process.

Fig. 4.8 (d) shows the tandem rolling mill.

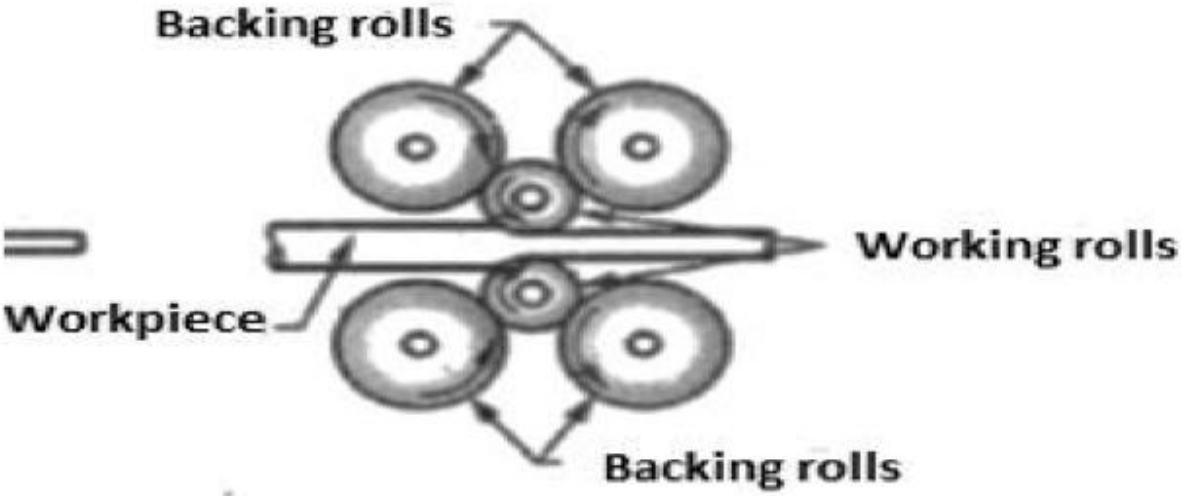


(d) Tandem rolling mill

5. Cluster rolling mill:

- It is a special type of four-high rolling mill.
- In this, each of the two working rolls is backed up by two or more of the larger backup rolls. Refer Fig. 4.8 (e).

- For rolling hard thin materials, it is necessary to employ work rolls of very small diameter but of considerable length.
- In such cases, adequate support of the working rolls can be obtained



(e) Cluster rolling mill

6. Planetary rolling mill:

- For the rolling arrangements requiring large reduction, a number of free rotating wheels are used instead of a single small roll.
- Planetary mill consists of a pair of heavy backing rolls surrounded by a large number of planetary rolls. Refer Fig. 4.8 (f).

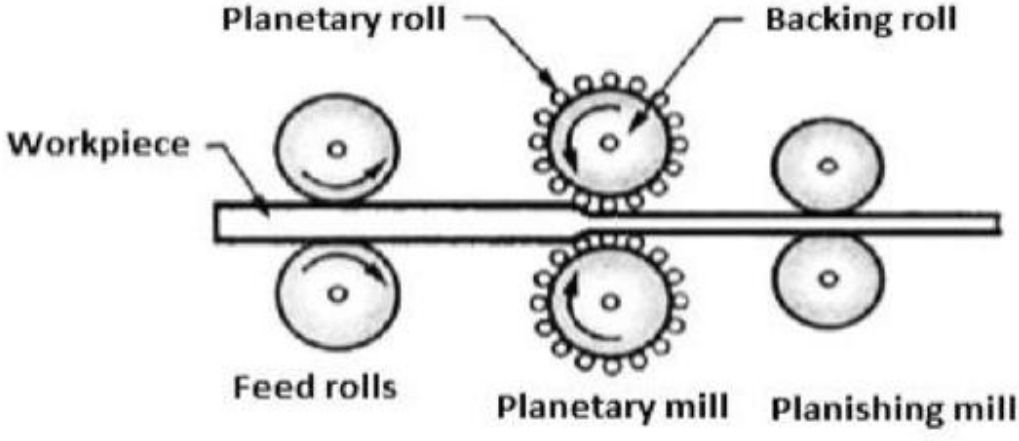


Fig. 4.8 (f): Planetary rolling mill

6. Planetary rolling mill:

- The main feature of this mill is that, it reduces a hot slab to a coiled strip in a single pass.
- Each pair of planetary rolls gives an almost constant reduction to the slab.
- The total reduction is the sum of a series of such small reductions following each other in rapid succession.
- The feed rolls are used to push the slab through a guide into planetary rolls.
- On the exit side planning mill is installed to improve the surface finish.

7. Universal rolling mill:

- In this type of rolling mill, the metal is reduced by both horizontal and vertical rolls. – Refer Fig. 4.15 (g).
- The vertical rolls are mounted either on one side or on both sides of horizontal roll stand which makes the edges of bar even and smooth.
- The horizontal rolls may be either two-high, three-high or four-high arrangement

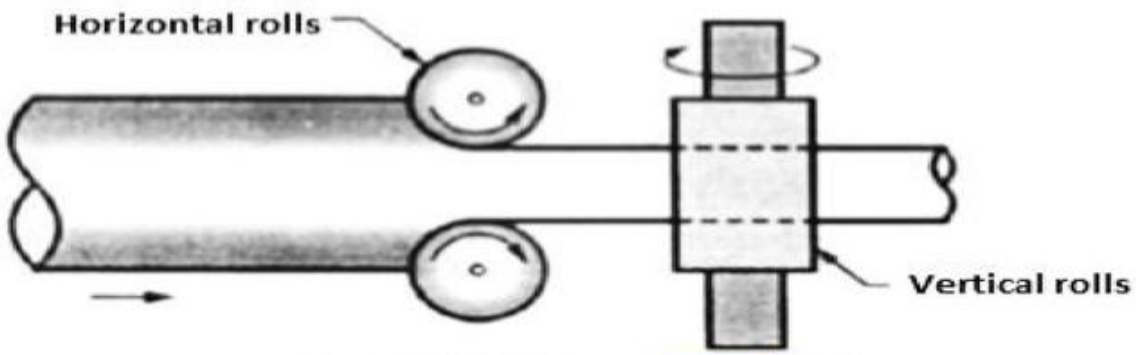


Fig. 4.8 (f): Universal rolling mill

Principle of Roll Pass

- In addition to flat rolling, different shapes can be produced by shape rolling.
- Straight and long structural shapes like solid bars of different cross-sections, channels, – I-beams, rails, etc. are produced by passing the stock through specially designed rolls.
- The shape cut into one roll is called as groove and the shape formed when the grooves of the mating rolls are matched together is called as pass.
- As the materials cross-section is to be reduced non-uniformly, the design of series of rolls requires considerable experience to avoid external and internal defects.
- By rolling the metal consequently through the passes, the initial square or rectangular cross section of the ingot (bloom or billet) can be gradually changed to produce a bar of final desired shape.
- As per the designation, passes are divided into the following three groups :

a. Roughing or breakdown or roll down passes

b. Leader passes

c. Finishing passes

Cold Rolling

- Cold rolling is used for producing bars of all shapes, rods, sheets and strips.
- Cold rolling is generally employed for providing a smooth and bright surface finish tothe previously hot rolled steel.
- It is used to finish the hot rolled components, to close tolerances and improve their hardness and toughness.

- Before cold rolling, the hot rolled articles are cleaned through pickling and other operations. **pickling[surface treatment used to remove the impurities]**
- The same types of rolling mills, as in hot rolling, are used for cold rolling. The part being rolled is generally annealed and pickled before the final pass is made, so as to bring it to accurate size and obtain a perfectly clean surface.

4.10.1 Comparison between Hot Rolling and Cold Rolling

Sr. No.	Hot rolling	Cold rolling
1.	Metal is fed into the rolls after being heated above recrystallisation temperature.	Metal is fed into the rolls when its temperature is below recrystallisation temperature.
2.	Hot rolled metal does not show work hardening effect.	Cold rolled metal shows work hardening effect.
3.	Coefficient of friction between the rolls and stock is higher.	Coefficient of friction between rolls and stock is relatively lower.
4.	Heavy reduction is cross-sectional area is possible.	Heavy reduction in cross-sectional area is not possible.
5.	Close dimensional tolerances cannot be obtained.	Section dimensions can be finished to close tolerances.
6.	Very thin sections cannot be obtained.	Aluminum foils up to 0.02 mm can be made.
7.	Poor surface finish with scale on it.	Smooth and oxide free surface can be obtained.
8.	Roll radius is larger.	Roll radius is smaller.

Extrusion

- Extrusion is a compression process in which the work metal is forced to flow through a small opening which is called as die to produce a required cross-sectional shape.
- The extrusion process is similar to squeezing toothpaste or cream from a tube.
- Almost any solid or hollow cross-section may be produced by extrusion process.

- As the geometry of the die remains same during the operation, extruded parts have the same cross-section.
- During the process, a heated cylindrical billet is placed in the container and it is forced out through a steel die with the help of a ram or plunger.

Extrusion

- The products made by extrusion process are tubes, rods, railings for sliding doors, structural and architectural shapes, door and window frames, etc.
- Extrusion process is suitable for the non-ferrous alloys, steel alloys, non-ferrous metals, stainless steel, etc.
- Extrusion process is carried out on horizontal hydraulic press machines which are rated from 250 to 5500 tonnes in capacity.

Extrusion process is classified as follows :

1. According to physical configuration

   a. Direct (Forward) extrusion

   b. Indirect (Backward) extrusion

   2. According to working temperature

   a.Hot extrusion

   b. Cold extrusion

Direct Extrusion

- Direct or forward hot extrusion is most widely used and the maximum numbers of extruded parts are produced by this method.
- Fig. 4.28 shows the direct extrusion process in which the raw material is a billet.

- A billet is heated to its forging temperature and fed into the machine chamber.
- Pressure is applied to the billet with the help of ram or plunger which forces the material through the die.
- The length of extruded part will depend on the billet size and cross-section of the die.

Direct Extrusion

- The extruded part is then cut to the required length.
- As the ram approaches the die, a small portion of billet remains which cannot be forced through the die opening.
- This extra portion is known as butt which is separated from the product at the end.
- When the billet is forced to flow through the die opening, there is friction between the work piece and chamber walls.
- This friction is overcome by providing additional ram force. This is the major problem with this process.
- To overcome this problem oxide layer is provided on the billet or dummy block is used between the ram and billet.

Direct Extrusion

- Direct extrusion process is also used to produce hollow or semi-hollow sections.
- To produce hollow sections, by direct extrusion process, a mandrel is used. Refer Fig. 4.28
- When the billet is compressed, the material is forced to flow through the gap between the mandrel and die opening. This results in tubular cross-section.

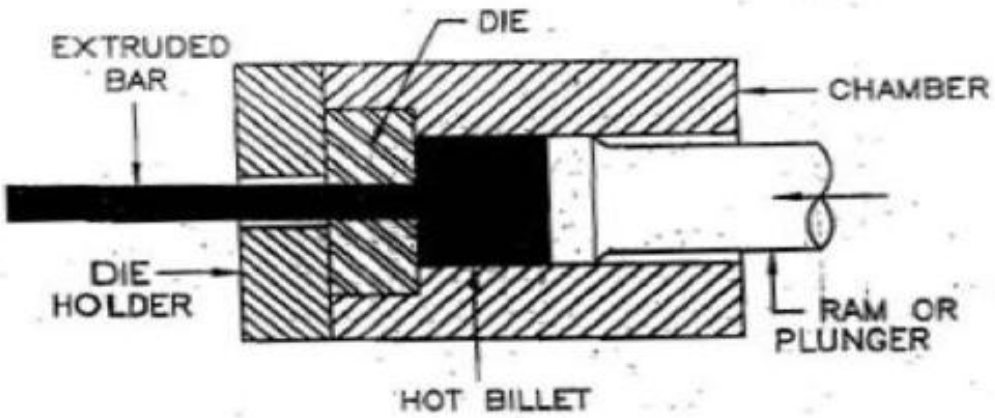


Fig. 4.28: Direct extrusion

Indirect Extrusion

- Indirect extrusion is also called as backward extrusion.
- In this type, the ram or plunger used is hollow and as it presses the billet against the back wall of the closed chamber, the metal is extruded back into the plunger. Refer Fig. 4.29.
- It involves no friction between the metal billet and the chamber because the billet does not move inside the chamber. As compared to direct extrusion, less total force is required in this method.
- But the equipment used is mechanically complicated in order to support the passage of the extruded shape through the center of the hollow ram.
- Indirect extrusion is also used to solid as well as hollow components. For producing solid parts ram is hollow whereas for producing hollow parts ram is solid.

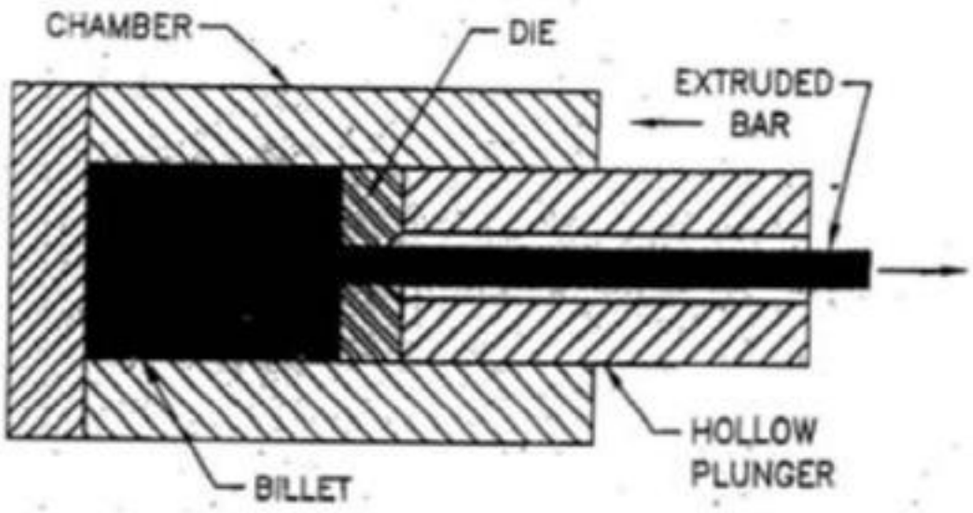


Fig. 4.29 : Indirect or backward or reverse extrusion

Cold Extrusion (Impact Extrusion)

- The most common cold extrusion process is impact extrusion.
- Various daily use products such as tubes for shaving creams, tooth paste and paints, condenser cans and such other thin walled products are impact extruded. The raw material is in slug form which have been turned from a bar or punched from a strip.
- By using punch and dies, the operation is performed.
- The slug is placed in the die and struck from top by the punch operating at high pressure and speed. Refer Fig. 4.30.

- The metal flows up along the surface of the punch, forming a cup shaped

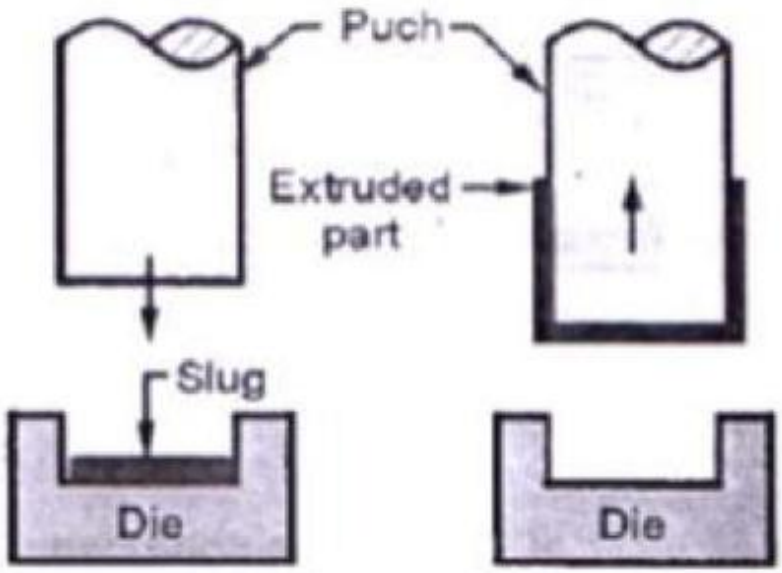


Fig. 4.30: Principle of impact extrusion

component

- When the punch moves up, to separate the component from the punch compressed air is used.
- At the same time, a fresh slug is fed into the die.
- The rate of production is fairly high i.e. 60 components per minute.
- This process is used only for soft and ductile materials such as lead, tin, aluminum, zinc and some of their alloys.
- The main advantages of this process are its speed, product uniformity and no wastage.

Hydrostatic Extrusion

- In this type of extrusion process, the billet is surrounded by a working fluid which is pressurised by the ram to apply the extrusion force.
- In this process, hydraulic fluid remains between the billet and the chamber walls hence eliminating the contact between

them. Also, it avoids the friction between the metal billet and the walls of the chamber.

- Fig. 4.31 shows the working principle of hydrostatic extrusion.
- Due to absence of wall friction, extrusion of very long billets or even wires and large reductions can be taken.
- During the process, the ram does not directly act on the billet, instead of that, it acts on the hydraulic fluid which forces the billet through the die and produces the extrusions.

The materials which cannot be extruded successfully by conventional methods can be extruded by this process

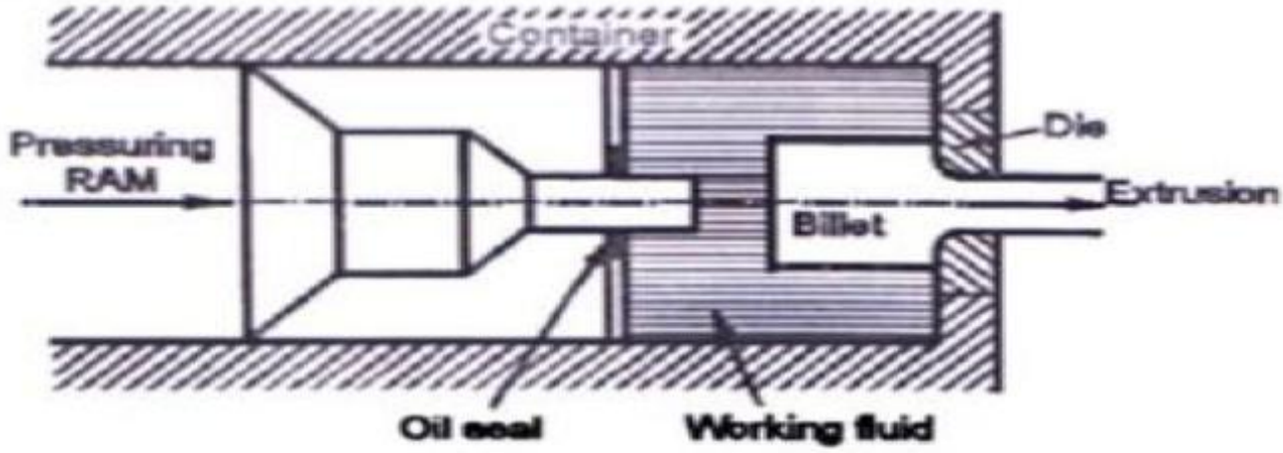


Fig. 4.31: Hydrostatic extrusion

Defects in Extrusion

Following are the three basic categories of extrusion defects :

i. Center cracking

ii. Surface cracking

iii. Piping defect

i. **Center cracking**

- It is commonly called as internal breakage, cheveron cracking, arrowhead fracture and center burst.

- As the work piece is being extruded from the die, stresses in the work break the material.
- It causes cracks to form along the central axis of extruded part.
- This defect occurs due to difference in metal flow of central region and outer region.

ii.Surface cracking

- In surface cracking, excessive stresses on the surface of the extruded part cause the breakage on the surface. Refer Fig. 4.60.
- These cracks usually occur along the grain boundaries. – Surface cracking occurs due to high extrusion temperature, friction and speed.

iii. Piping defect

- Piping defect is commonly called as tail pipe or fish tailing defect and occurs during direct extrusion at the end opposite to the die.
- Piping defects results due to improper metal flow during the extrusion operation.
- A funnel shaped void of material at the end of the work is seen in this defect.

Wire Drawing

- Drawing is an operation in which the cross-section of a bar, rod or wire is reduced by pulling it through a die opening.
- The general features of the drawing process are similar to extrusion. But the difference is that, in drawing the work piece is pulled through the die whereas in extrusion work piece is pushed through the die.

- During the process, tensile as well as compressive stresses are produced in the material.
- The main difference between the bar drawing and wire drawing is the stock size(workpiece size). Bar drawing is used for large diameter (bar and rod) stock whereas wire drawing is used for small diameter stock

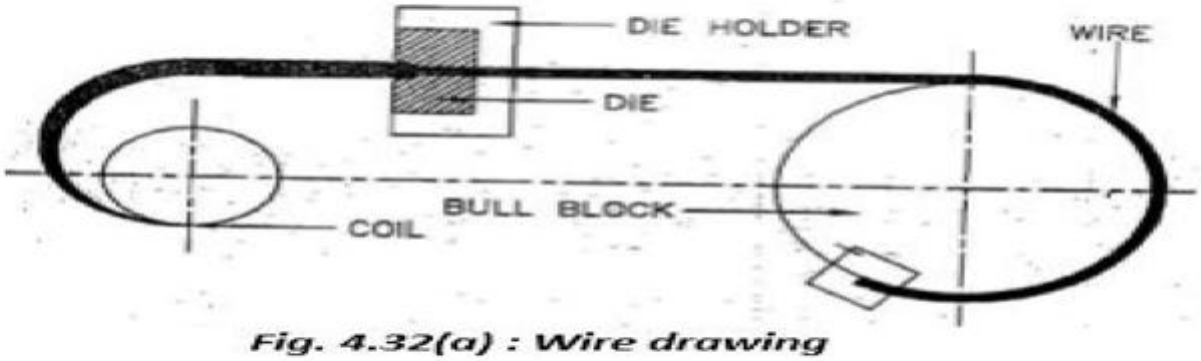


Fig. 4.32(a) : Wire drawing

- Wire sizes upto 0.03 mm can be drawn by wire drawing process.
- The process consists of pulling the hot drawn bar or rod through a die of which the bore size is similar to the finished product size. Depending upon the material to be drawn and the amount of reduction required, total drawing can be accomplished in a single die or in a series of successive dies.
- One end of the rod to be drawn into wire is made pointed, entered through the die and gripped at the other end by using tongs

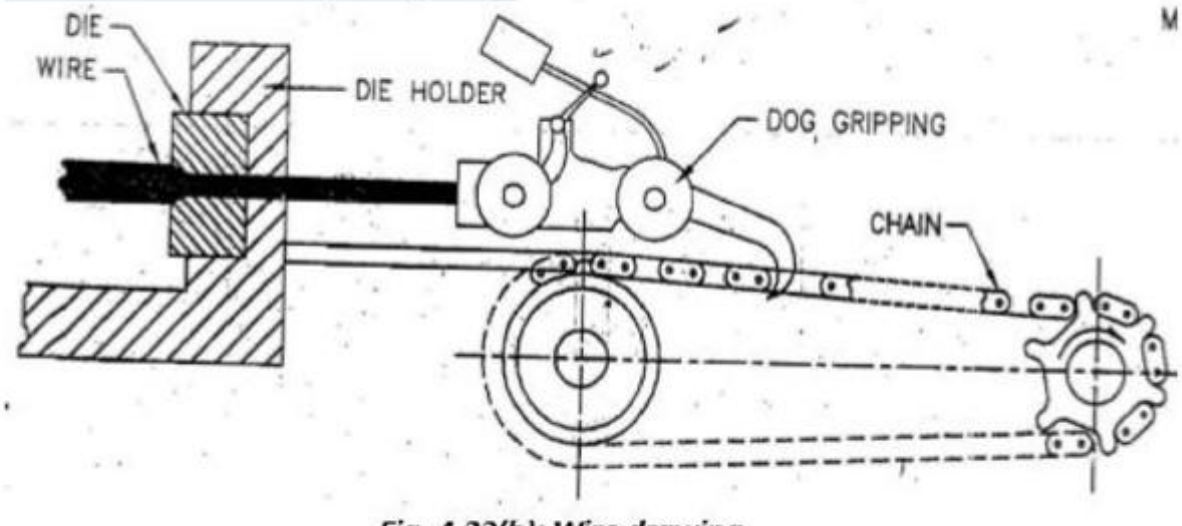


Fig. 4.32(b): Wire drawing

- After pulling a certain length, this end is wound to a reel or draw pulley.
- When the pulley or reel is rotated, the rod is pulled through the die and its diameter reduces.
- Refer Fig. 4.32 (a) & (b)
- The die is made of highly wear resistant material.
- Generally, tungsten carbide is used for die making.
- The die made of tungsten carbide is suitably supported in a die holder which is made of mild steel or brass.

Tube Drawing

- As the initial tubing has been produced by other processes like extrusion, drawing can be used to reduce the diameter or wall thickness of seamless tubes and pipes.
- Tube drawing can be carried out either with mandrel or without mandrel

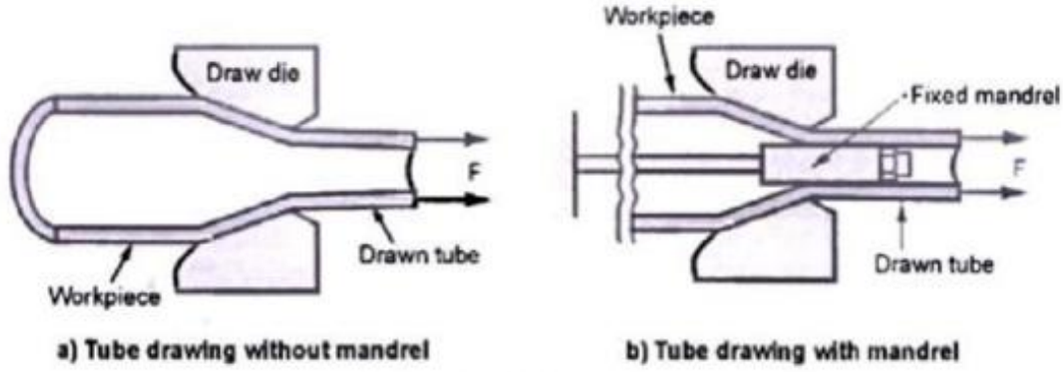


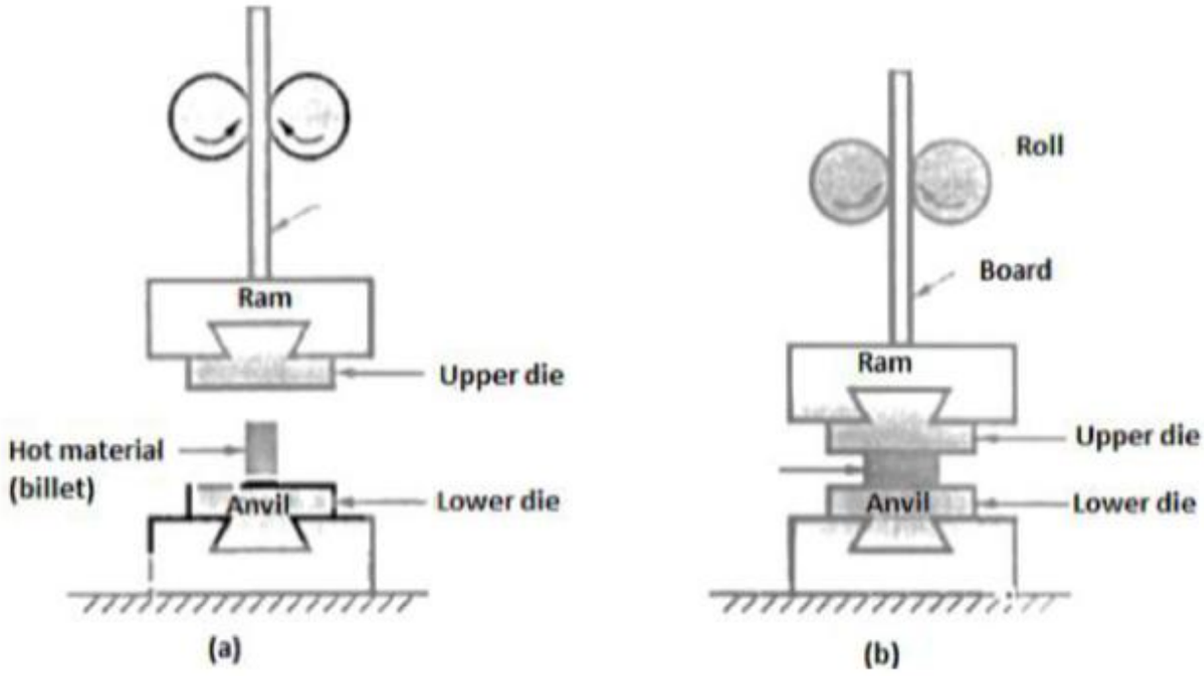
Fig. 4.33: Tube drawing

- The simplest method of producing tubes and pipes is shown in Fig. 4.65 (a) in which mandrel is not used. This method is also called as tube sinking.
- In tube sinking method there is no control over the inner diameter and wall thickness of tube.
- To overcome this drawback, mandrels are used in the process

- Fig. 4.33(b) shows tube drawing with mandrel. In this method, mandrel is fixed and attached to a long support bar to produce inside diameter and wall thickness during the process.

Forging:

- Forging is the process of shaping heated metal by the application of sudden blows(hammer forging) or steady pressure (press forging) and makes use of the characteristic of plasticity of the material.
- Forging is metal forming process which may be done by hand or by machine.
- In case of hand forging, hammering is done by hand; whereas forging by machine involves the use of dies and it is mostly used in mass production.



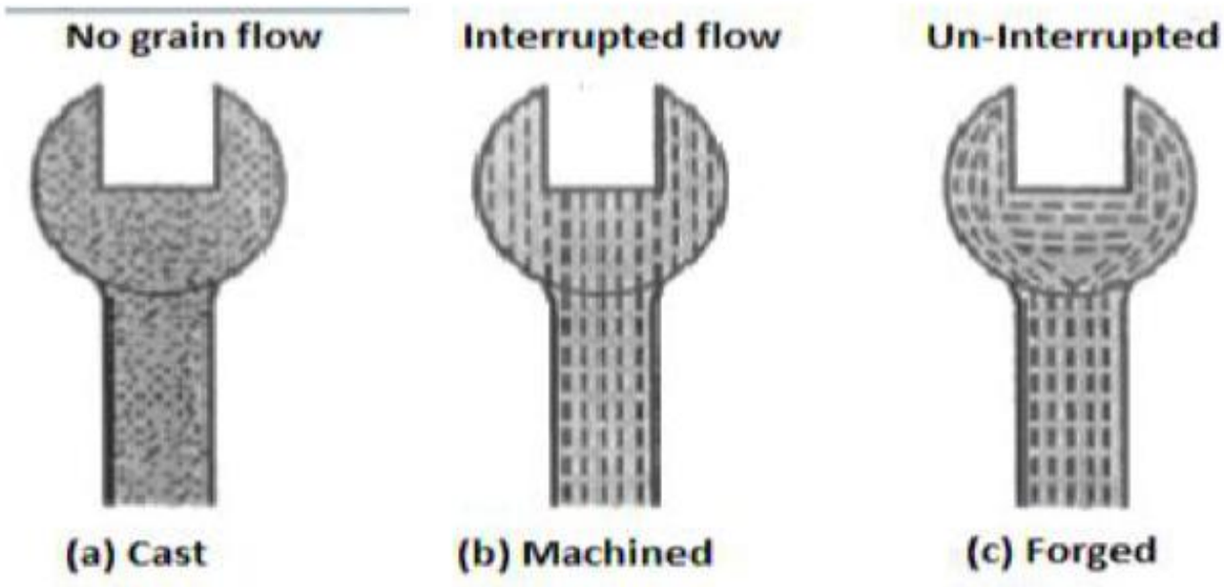
- Whatever may be the method of applying pressure for shaping the metal, the primary requirement is to heat the metal to a definite temperature to bring it into the plastic state. This may done in an open hearth, called as Smith's forge for small jobs or in closed furnaces for large jobs.
- The shop in which the work is carried out is called as Smithy or Smith's shop.

- The metals which are used in forging process must possess the required ductility.
- We know that ductility refers to the capacity of a material to undergo deformation, under tension without failure.
- The commonly used forging materials are :
- Aluminum alloys, copper alloys, low carbon steels, alloy steels, nickel alloys, tungsten alloys, magnesium alloys, titanium alloys, beryllium, etc.

Advantages of Forging Process

- In forging process, grain flow is continuous and uninterrupted. It gives greater strength and toughness to the forged components. Fig. 4.12 shows three spanners, produced through three different methods casting, machining and forging. The cast spanner is the weakest of all, the machined spanner is relatively stronger and the strongest will be the forged spanner Forged components requires minimum surface finish.
- The forging process gives the high dimensional accuracy.
- Forged components have better mechanical properties like strength, toughness, etc.
- Forged components have better resistance to shock and vibrations.

Welding of forged parts is easy.



Spanners produced through three different methods

Disadvantages of Forging Process

- Complicated shapes cannot be forged easily.
- Forging process is mostly suitable for large parts.
- Forging of brittle materials is difficult.
- Due to high cost of forging dies, forging process is costly.
- More noise and vibrations are produced during the process.

Applications of Forging Process

- Forging process is used in the manufacturing of following components :
- Car axles, crankshafts, connecting rods, leaf springs, crane hooks, jet engine turbine dies and blades.
- Levers, flanges, propellers, hollow bodies, railway wheel disks, tank bottoms
- Air-craft and rocket parts, knife blades, bolts, nuts, washers, collars, gear blanks, etc.

Types of Forging process

Forging process is classified as follows :

1. **According to the working temperature**

a. Hot forging

b. Cold forging

2. According to the method of applying the blows

a. Impact forging

b. Gradual pressure forging

3. According to the degree to which the flow of work piece is constrained by the dies

a. Open-die forging

b. Closed-die or impression-die forging

– Forging process is classified as follows :

1. **According to the working temperature**

a. **Hot forging**– Most of the forging operations are performed above the recrystallization temperature but below the melting point of the metals.

During the process there is deformation of the metal which reduces the strength and increases the ductility of metal.

b. Cold forging

– For certain products like bolts, rivets, screws, pins, nails, etc. cold forging is also very common.

– It increases the strength which results from the strain hardening of the component.

2. According to the method of applying the blows

a. **Impact forging**

– In this method of forging, a machine that applies impact load on the work piece is called as forging hammer.

b. **Gradual pressure forging**

– In this method of forging, a machine that applies gradual pressure on the work piece called as forging press.

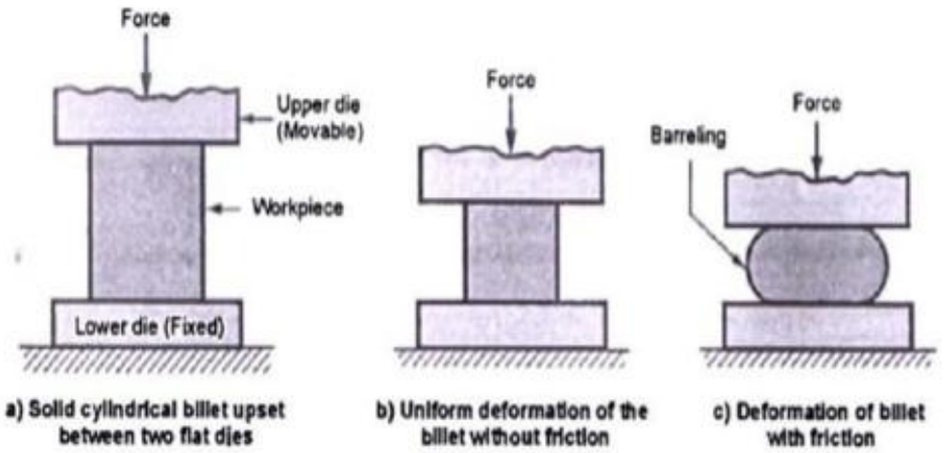
3. According to the degree to which the flow of work piece is constrained by the dies

a. Open-die forging

b. Closed-die or impression-die forging

a. Open Die Forging

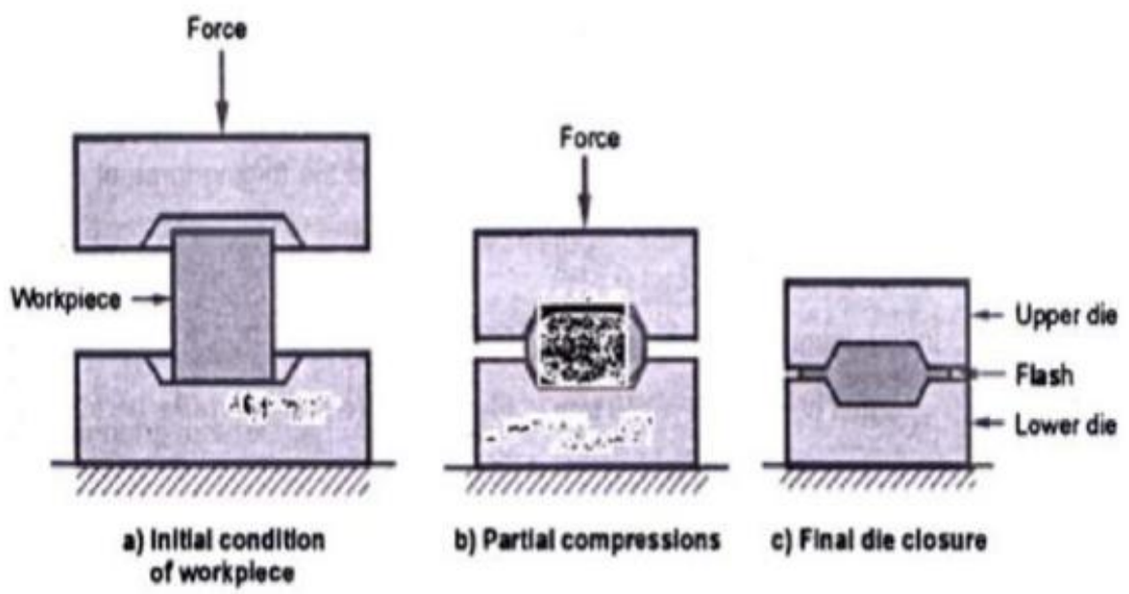
- It is the simplest and important forging process.
- The shapes generated by this process are simple like shafts, disks, rings, etc.
- An example of open-die forging in the steel industry is the shaping of a large square cast ingot into a round cross-section.
- Open-die forging operations produce rough forms of work piece hence, subsequent operations are required to refine the parts to final shape.
- Open-die forging process can be depicted by a solid work piece placed between the two flat dies (lower die is fixed and upper die is moving) and reduced in height by compressing it. This process is called as upsetting or flat-die forging.



Open-die forging

Impression Die or Closed Die Forging:

– Impression-die or closed-die forging is performed with dies which contain the inverse of the required shape of the component.



Impression Die or Closed Die Forging:

- Initially the cast ingot is placed between the two impressed dies. As the die closes to its final position, flash is formed by the metal.
- This flash flows beyond the die cavity and into the small gap between the die plates.
- The formed flash must be cut away from the final component in a subsequent trimming operation but it performs an

important function that, it increases the resistance to the deformation of the metal.

Impression Die or Closed Die Forging:

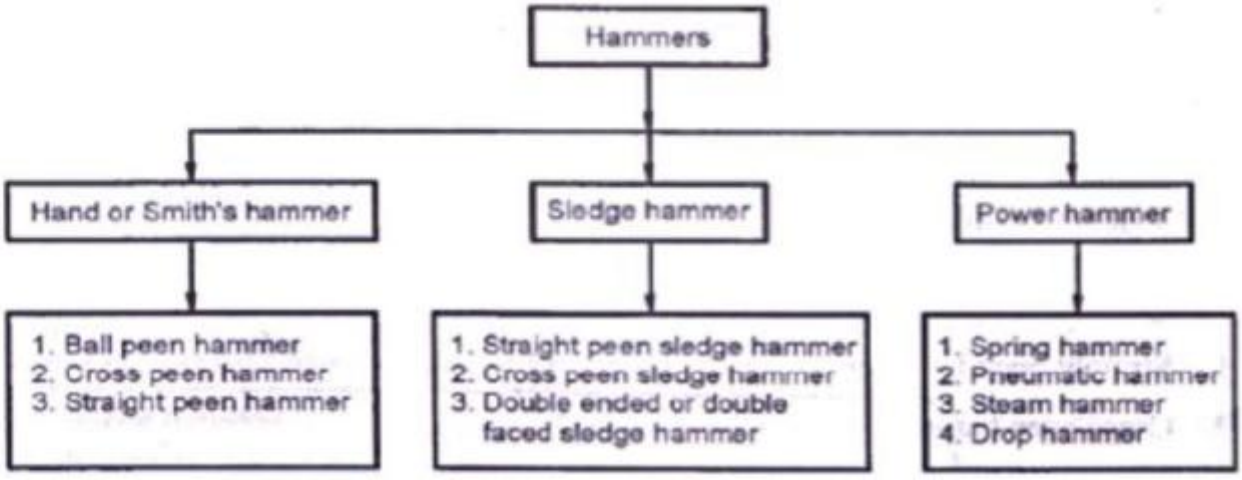
- The initial steps in the process are used to redistribute the metal in the work part to achieve a uniform deformation and required metallurgical structure in the subsequent steps.
- The final steps bring the component to its final geometry. Also, when drop forging is used, number of blows of the hammer may be used for each step.
- As flash is formed during the process, this process is used to produce more complex components by using dies

Comparison between Open-die and Closed-die Forging

Sr. No.	Open-die forging	Closed-die forging
1.	In this method, the workpiece is compressed between the two flat dies.	In this method, the workpiece is compressed between the two impressed dies.
2.	The cost of dies is low.	The cost of dies is high.
3.	The process is simple.	The process is complex.
4.	During the process there is poor utilization of the material	During the process there is better utilization of the material.
5.	After the process, machining of components is required.	After the process, machining of components is not required.
6.	The dimensional accuracy of obtained products is not good.	The dimensional accuracy of obtained products is good.
7.	This process is used for low quantity production.	This process is used for high quantity production.
8.	It is suitable only for production of simple components.	It is suitable for production of simple and complex components.

Hammers are classified into different groups as shown in Fig.

– The hammers are used by a Smith in order to give the desired shape to the heated metal piece.



Types of hammers

Smith's hand hammers are small in size and of following types :

1. Ball peen hammer

   2.Cross peen hammer

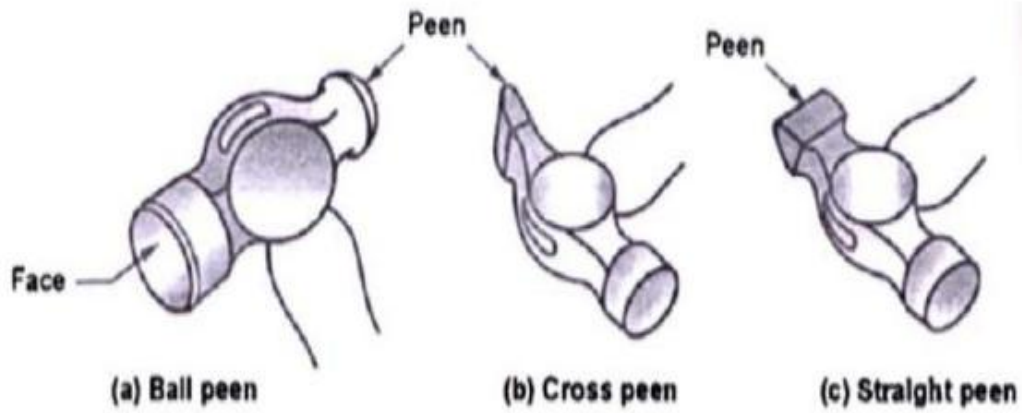
   3.Straight peen hammer

1. Ball Peen Hammer:

It is most suitable hammer for hand forging operations.

It has cast steel or forged steel head which is fitted to a wooden handle.

One end of the he called as face i.e. hardened and polished. It is used for general striking and hammering purpose. Another end is half ball shaped called as peen i.e. used for riveting or burring over purpose.



Hand or Smith's hammers

Smith's hand hammers are small in size and of following types :

2**. Cross Peen Hammer:** In this type of hammer, peen is at right angle to the axis handle of the hammer. It is used for heading, stretching and hammering into the inner of the component.

3. Straight Peen Hammer: In this type of hammer, peen is parallel to axis of handle of the hammer. It is used for stretching the metal.

Sledge Hammers

– Sledge hammers are larger in size as compare to hand hammers and of following type

1. Straight peen hammer

2. Cross peen hammer

3. Double ended or double faced hammer.

– Due to large size, weight of sledge hammers is also more than the hand hammers.

– These hammers are used when heavy blows are required to be imparted to the work piece.

To avoid the damage of work piece surface, the striking surface of the sledge hammer is made slightly convex and smooth.

Sledge Hammers

– The construction of straight peen and cross peen hammers is similar as discussed in hand hammers. Refer Fig. 4.19 (a) and (b).

– If the hammer has no peen formation and instead carries flat faces at both ends, then it is called as double ended or double faced hammer. Refer Fig. 4.19 (c).

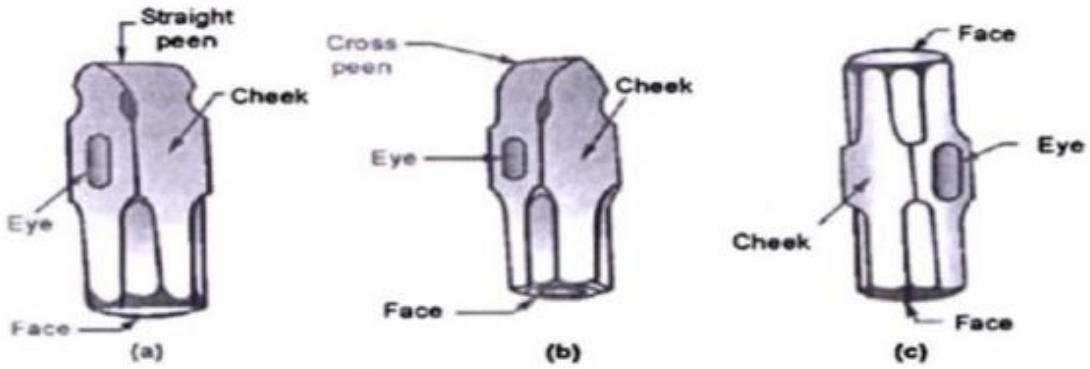


Fig. 4.19: Sledge hammers

Power Hammers

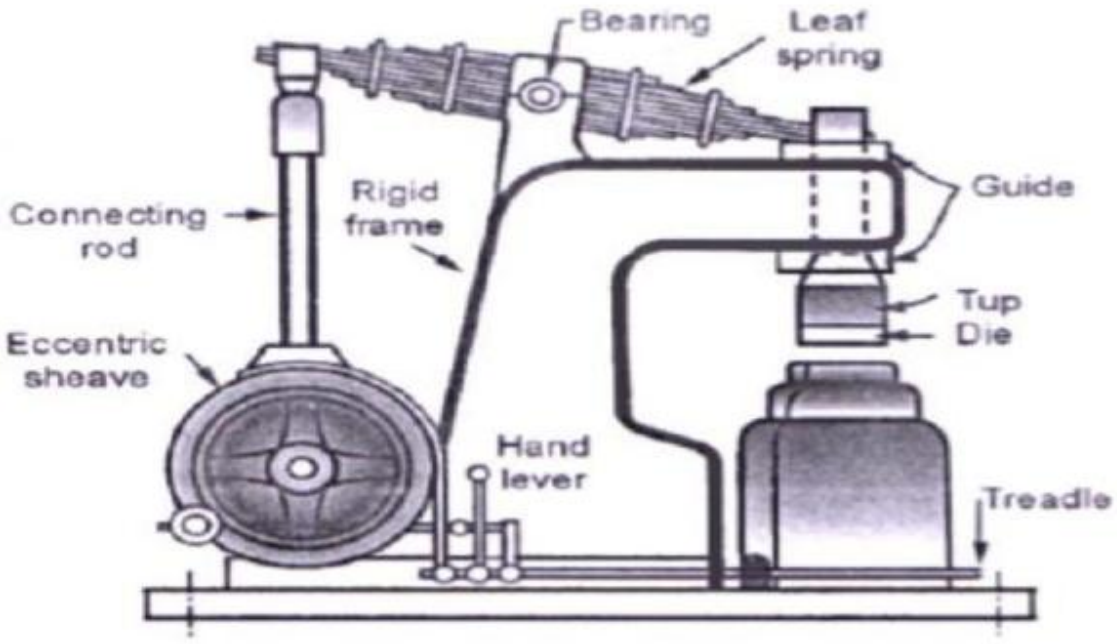
- During forging, heavy components require a great degree of deformation which is not possible by using hand hammers.
- When forging with power machines, the deformation of the heated metal takes place either under the action repeated blows or the action of gradually applied pressure.
- Machines which work on the principle of repeated blows are called as forging hammers or power hammers, whereas those apply gradual pressures are called as forging presses.

Forging or power hammers are of following types :

1. Spring hammer
2. Pneumatic hammer
3. Steam or air hammer
4. Drop hammer

1. **Spring Hammer :**

- It has a simple design to regulate the speed and force of its blows.
- It is very light type of power hammer and suitable for small forgings.
- It consists of a heavy rigid frame carrying a vertical projection at its top which act as a housing for bearing in which leaf or laminated spring oscillates.
- One end of this spring is connected to the connecting rod and other end is connected to a vertical up which reciprocates between fixed guides.

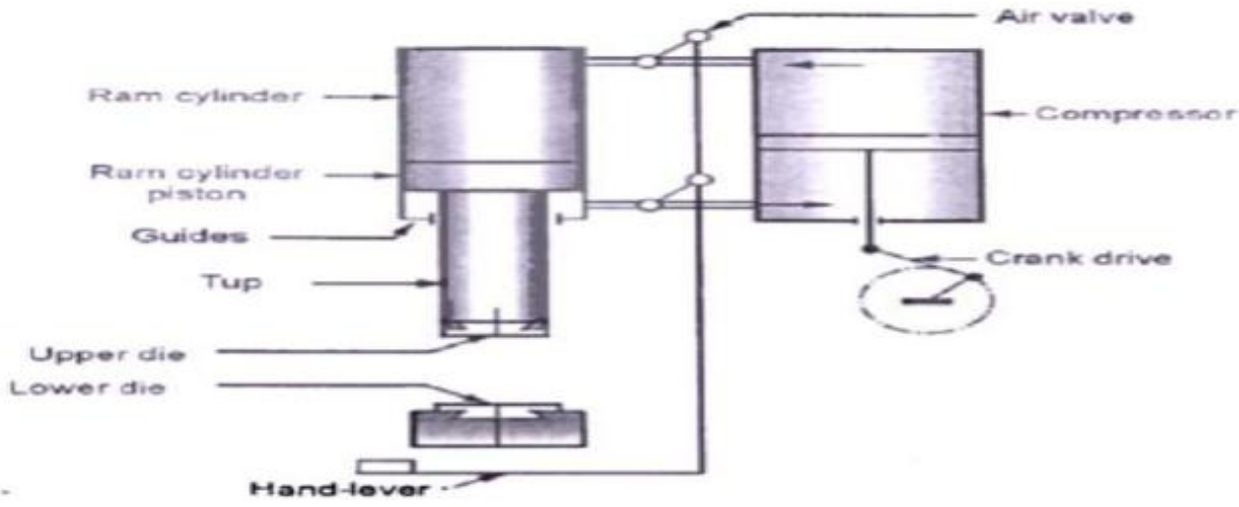


- The connecting rod is attached to on eccentric sheave, which is further connected to the crank wheel.
- To operate the hammer, treadle is pressed downwards that makes the sheave to rotate through the crank wheel and hence, leaf spring starts oscillating in the bearing.
- This oscillation of spring causes the reciprocating motion of the tip and thus, required blows are provided on the work piece.

- To adjust the stroke of the connecting rod and intensity of blows, hand lever is used.

2. Pneumatic Hammer :

- – Design of pneumatic hammer varies with the different manufacturers.
- – Fig. 4.21 shows a commonly used design of pneumatic hammers which consists of compressor cylinder and ram cylinder.
- – In these hammers, the compressor cylinder compresses the air and delivers it to the ram cylinder. By using this compressed air pressure, the ram cylinder piston is actuated. – A hand lever operates an air valve provided on the air passage from compressor cylinder to ram cylinder.
- – Piston of ram cylinder carries up at its bottom which can slide inside the fixed guides.



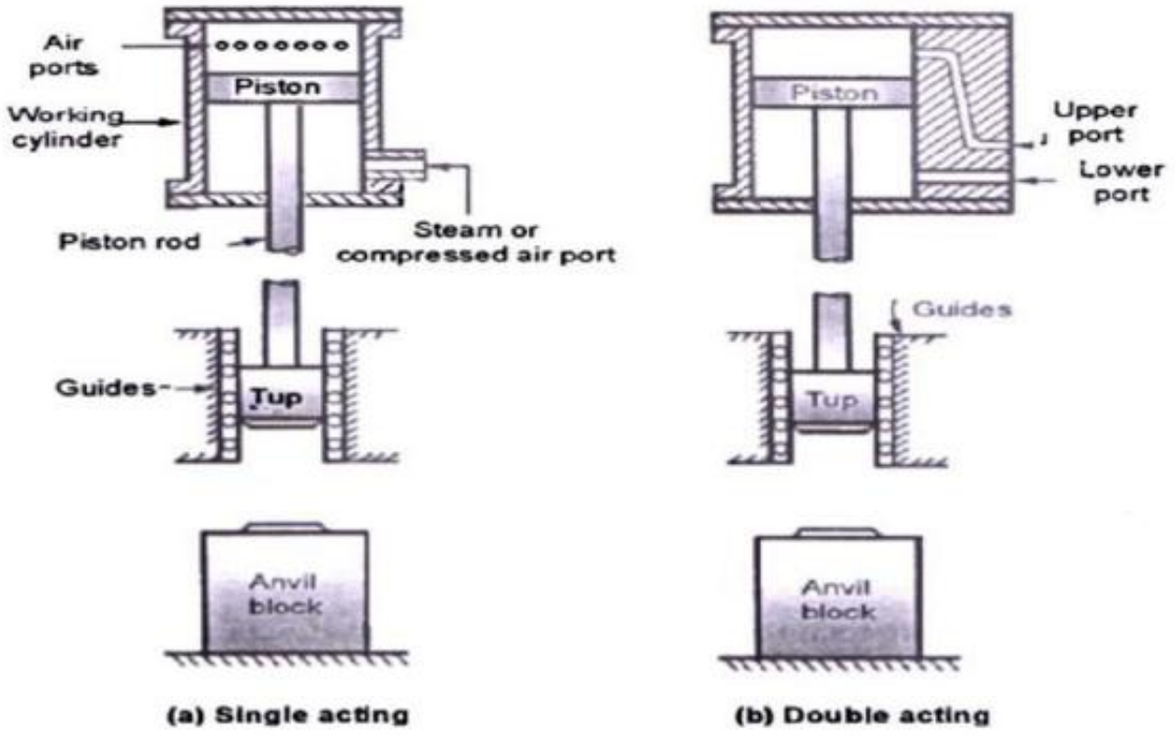
The compression of the reciprocating cylinder is obtained with the help of crank drive which is operated by a reduction gear drive. – Pneumatic hammer can produce 70 to 200 blows/minute.

3. Steam Hammer :– Steam or air hammers are similar in design to the pneumatic hammers.

– Steam or air hammers are normally consists of double acting cylinder i.e. steam or air is admitted on both sides of the piston.

– Hence, both the strokes are initiated and performed by the pushing action of compressed air or steam.

– In this type of hammer, compression of air or steam takes place separately and not within the hammer. – In single acting type, the air or steam is admitted into the cylinder through a part near its bottom which pushes the piston upwards..



(a) Single acting (b) Double acting

– The steam supply is then cut off when the piston attains the required height and the outfalls under the gravity on the anvil.

– Before the end of upward stroke, air from atmosphere is admitted into the cylinder through the air ports, which provides cushioning action and lowers the speed of upward moving piston.

– In case of double acting type, steam or air is admitted under pressure on both sides of the piston and both the strokes are operated by the fluid.

Drop forging

– Drop forging is different from smith's forging as in drop forging closed impressions rather than open face of flat dies are used

– This process utilizes closed impression die to obtain the required shape of the component.

– The dies are matched and separately attached to the movable ram and the fixed anvil.

– The forging is produced by impact or pressure, which compels hot and pliable metal to confirm to the shape of the dies.

– During the operation, there is a drastic flow of metal in the dies caused by repeated blows of hammers on the metal.

To ensure proper flow of the metal during the intermittent blows, the operation is divided into a number of steps.

– Each step changes the metal form gradually, controlling the flow of the metal until the final shape is obtained.

– The number of blows required varies according to the size and shape of the part, forging quality and required tolerances.

– The equipment used for applying the blows is called as drop hammer.

Three types of drop hammers are used in making drop forgings :

o Board or gravity hammer

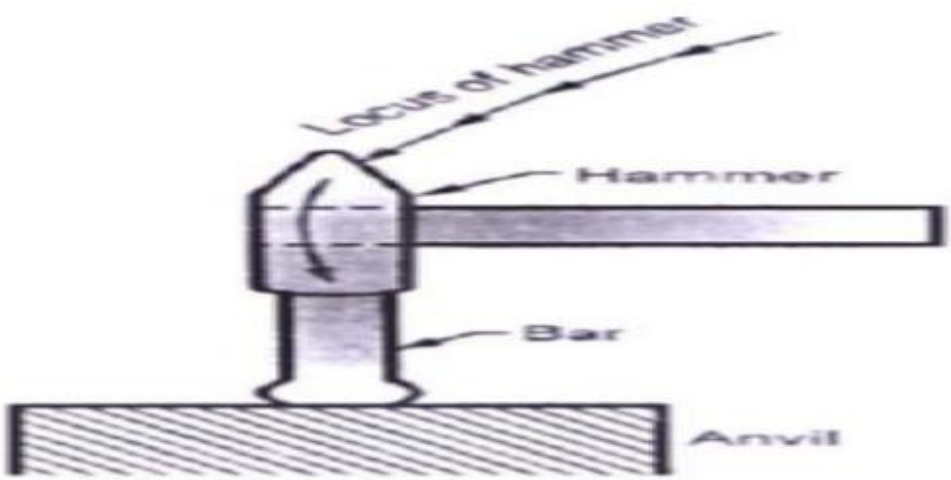
o Air-lift hammer

o Power drop hammer or steam hammer

Forging Operations – A number of operations are used to change the shape of the raw material to the finished form. A typical smith forging operations are as follows :

1. Upsetting
2. Drawing out or drawing down
3. Cutting
4. Bending
5. Punching and Drifting
6. Setting down
7. Welding

1. Upsetting :



Upsetting is also called as jumping or heading.

– It is a process through which the cross-section of a metal piece is increased with a corresponding increase in its length.

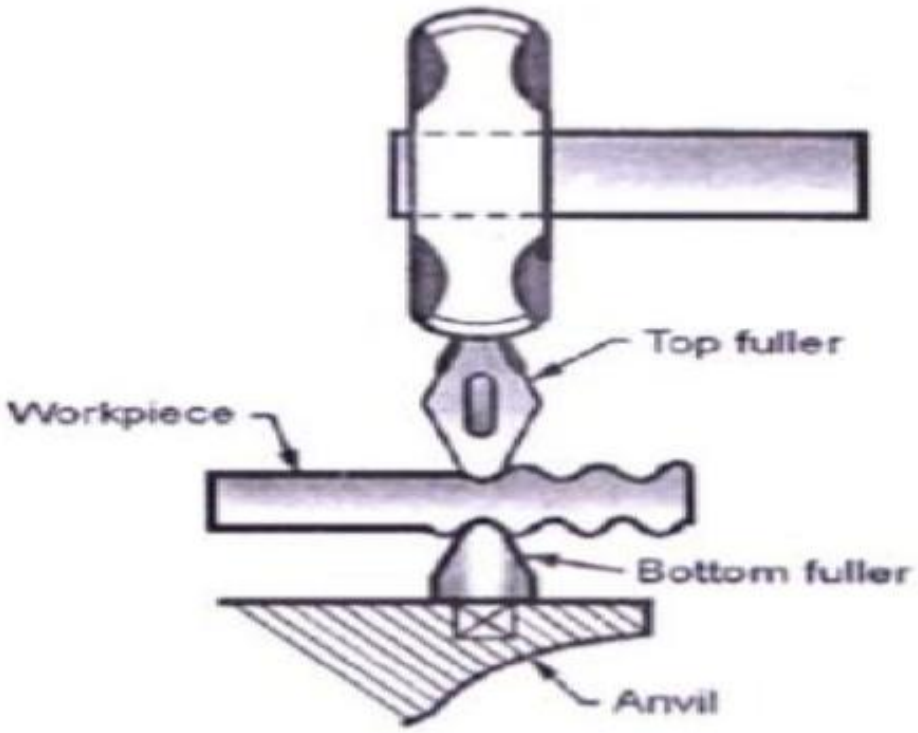
– When a metal is sufficiently heated, it acquires the plastic stage, so that it becomes soft.

– If some pressure (blows) is applied to it, then the metal tends to swell or increase in its dimensions at right angles to the

direction of application of force with corresponding reduction in its dimensions.

This is what actually takes place during upsetting or jumping a metal part

2. Drawing out or drawing down :



Drawing out is exactly a reverse process to that of upsetting.

– It is employed when a reduction in thickness, width of a bar is desired with a corresponding increase in its length.

– The desired effect is obtained by the use of either the peen of a cross peen hammer, a set of fullers or a pair of swages.

– Fig. 4.51 shows the drawing out operation by using top and bottom fullers.

3. Cutting :

– Cutting-off is a form of a chiseling whereby a long piece of stock is cut into several specified lengths, or a forging is cut-off from its stock.

– A notch is first made about one half the thickness or diameter of the stock.

– After that, the work piece must be turned through an angle of 180° and the chisel is placed exactly opposite the notch.

– The required length of metal can then be cut-off by giving the chisel a few blows with a sledge hammer

4. Bending :

– Bending is an important operation in smith forging and it is very frequently used.

– It may be classified as angular or curvilinear.

– Any required angle or curvature can be made through this operation.

– Bending operation is carried out on the edge of the anvil or on the perfectly square edge of a rectangular block.

– For making a right angle bend, particular portion of the stock is heated and jumped on the outer surface.

– When metal is bent, the layers of metal on the inside are compressed and those on the outside are stretched.

5. Punching and Drifting :

– The term punching refers to the operation in which a punch is forced though a work piece to produce a hole.

– The work piece is first heated and then placed on the anvil face.

– The punch is then forced into it up to about half its thickness.

– The work piece is then turned upside down and placed over a tool called as bolster.

– The punch is again forced into the work piece and made to pass through by hammering.

– Punching without using a die, is generally followed by drifting.

– In drifting, a tool known as drift, is made to pass through the punched hole to produce a finished hole of the required size.

6. Setting down :

– Setting down is the operation through which the rounding of a corner is removed, to make it square by using a set hammer.

– By putting the face of the hammer over the round portion, formed by bending or fullering of the corner and hammering it at the top a local reduction in thickness takes place resulting in sharp corner.

– Hence, finishing operation is performed through which the unevenness of a flat surface is removed by using a flatter or a set hammer.

7. Welding :

– Welding or shutting is the principle operation performed by the smith.

– The metal which remains pasty over a wide range of temperature is most easily welded.

– For production of sound weld, the surfaces in contact must be perfectly clean, both mechanically and chemically, so that cohesion will take place when the metal is in a plastic state.

– A protection to the metal is a coating of flux which covers the surfaces of the metal and prevents oxidation.

– A forge weld is made by hammering together the ends of two bars which have been formed to the corrected shape and heated to a welding temperature in a forge fire.

Sheet metal

– Sheet metal work is very useful trade in engineering work and for our day-to-day needs.

– Many articles-(household and engineering) whose production by other methods will be uneconomical and complicated are made from metal sheets.

– It is necessary to understand the construction and working of hand tools, sheet metal working machines and basic principles of different operations, to attain proficiency in the trade.

– For successful working in the trade, we must have a good knowledge of projective geometry, development of surfaces and properties of different metals.

Metal Forming Operations

– In metal forming operations, the sheet metal is stressed below the ultimate strength of the metal.

– In these operations, no material is removed hence there is no wastage.

– Metal forming operations include fol1owing operations

1. Bending
2. Drawing
3. Embossing·
4. Forming
5. Coining (Squeezing)

Bending

– It is a metal forming operation in which the straight metal sheet is transformed into a curve form.

– In bending operations, the sheet metal is· subjected to both tensile and compressive stresses.

– During the operation, plastic deformation of material takes place beyond its elastic limit but below its ultimate strength.

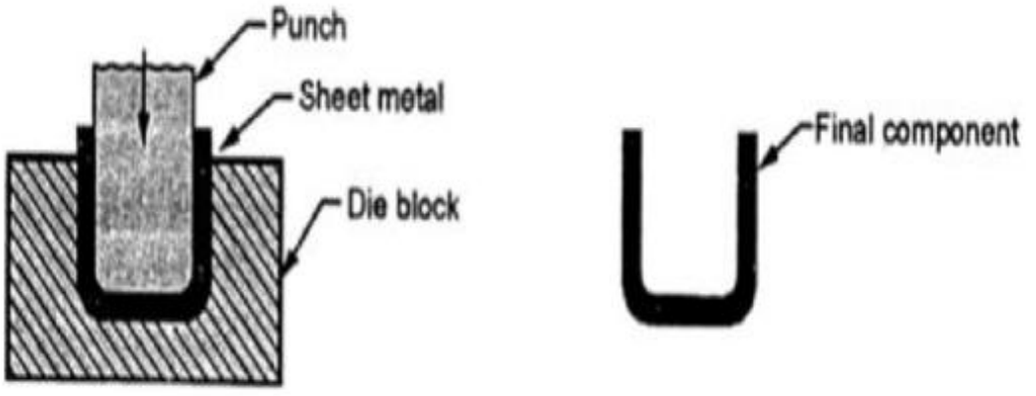
The bending methods which are commonly used are as follows :

a. U-Bending b. V-bending c. Angle bending d. Curling e. Roll bending f. Bending in a 4-slide machine g. Edge bending

a. U-bending:

– U-bending operation which is also called as channel bending.

– In this operation, the die cavity is in the form U, due to which component forms the Shape of U.

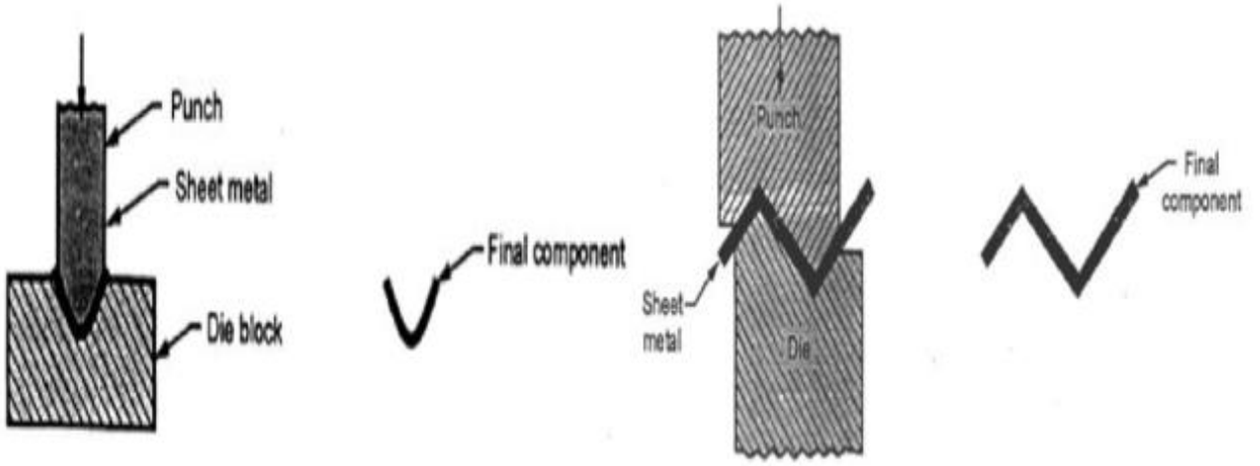


b. V-bending

– V-bending operation in which wedge shape punch is used.

– The angle of V may be acute, 90° or obtuse.

b. **Angle bending**– In this operation, there is a bending of a sheet metal at a sharp angle



V-bending **Angle bending**

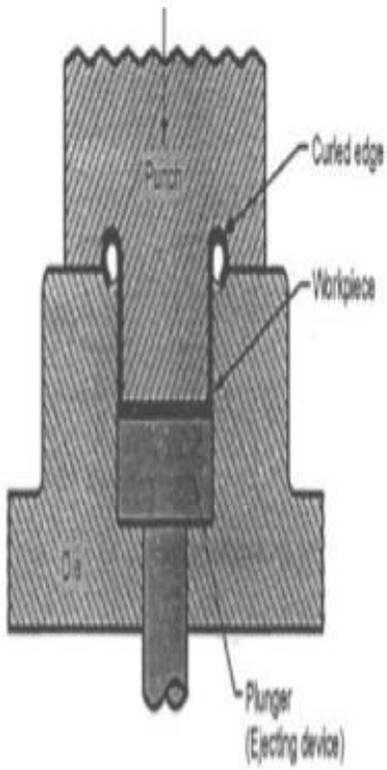
d. Curling

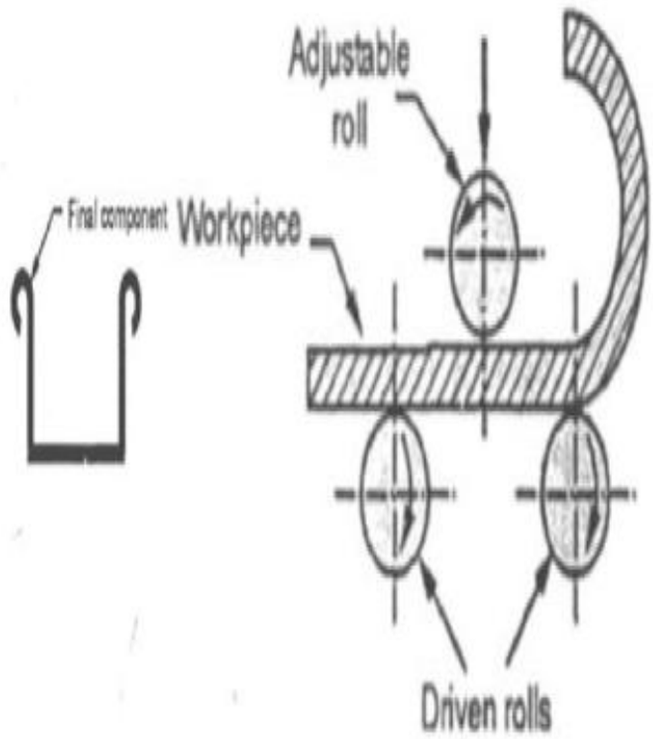
– In this operation, the edge of a sheet metal is curled around.

– The punch and die both are made to contain the cavity for cutting partially.

– After the operation, punch moves up and work piece is ejected out with the help of plunger

– This process is used in the manufacturing of drums, pots, vessels, pans, etc.





Curling **Roll bending**

e. Roll bending

– It is an operation in which generally large sheet metal parts are formed into curved sections with the help of rolls.

– When the sheet passes between the rolls, the rolls are brought towards each other to a configuration that achieves the required radius of curvature on the work piece

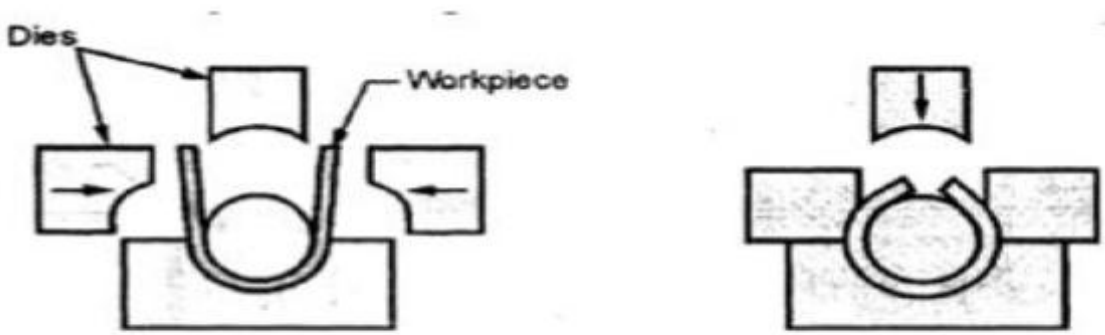
– It is used for fabrication of large storage tanks, pressure vessels, etc. Also used to bend metal plates, tubes, structural shapes etc.

f. Bending in a 4-slide machine

– This type of machine is used for bending of relatively short pieces .

– These types of machines are available in different designs.

– The lateral movements of the dies are controlled with the vertical die movement to form the part of desired shapes.



g. Edge bending

– It involves cantilever loading of sheet metal.

– In this method a pressure pad is used to hold the base of the work piece against the die whereas the punch forces the work piece to yield and bend over the edge of the die.

– The edge bending operation is limited to bend 90° or less. – The dies used for edge bending is called as wiping dies. They can also be designed for bend angles greater than 90°. – Due to pressure pad, wiping dies are more complicated and costly than the V-dies.

– These dies are used for high production work.

2. Drawing:

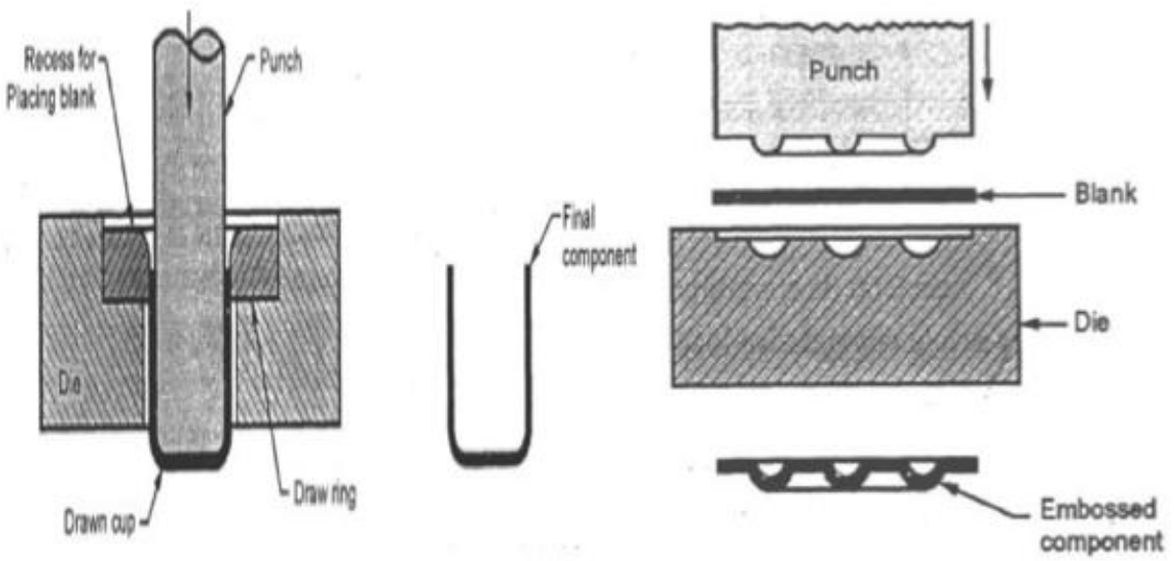
– In this operation, punch forces a sheet metal blank to flow plastically into the clearance between the punch and die.

– Finally, the blank takes a shape of cup

3. Embossing

– With the help of this operation, specific shapes or figures are produced on the sheet metal.

– It is used for decorative purposes or giving details like names, trade marks specifications, etc. on the sheet metal



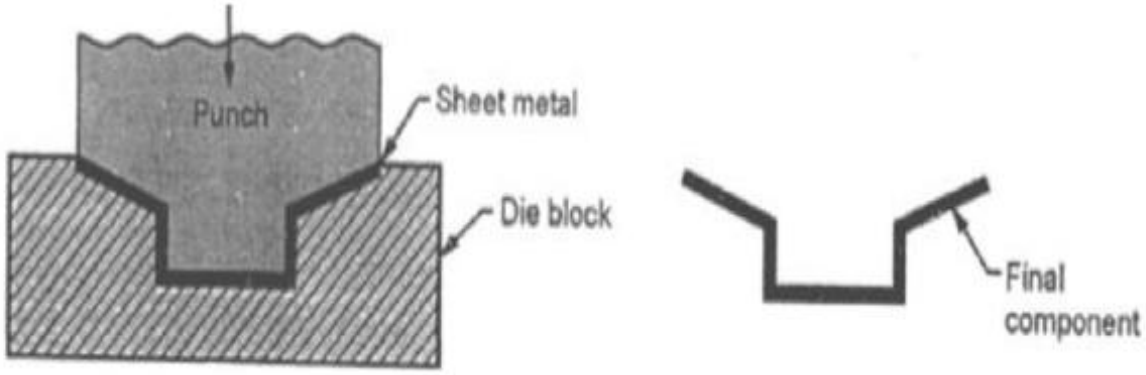
Drawing **Embossing**

Forming:

– In forming operation, sheet metal is stressed beyond its yield point so. that it takes a permanent set and retains the new shape.

– In this process, the shape of punch and die surface is directly reproduced without any metal flow.

– This operation is used in the manufacturing of door panels, steel furniture, air-craft bodies, etc.



5. Coining (Squeezing)

– In coining operation, the metal having good plasticity and of proper size is placed within the punch and die and a tremendous pressure is applied on the blank from both ends. Under severe compressive loads, the metal flows in the cold state and fills up the cavity of the punch and die.

– This operation is used .in the manufacturing of coins, medals, ornamental parts,etc.