Catalog

3.1 Introduction

- 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 rat, 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 continues till the metal comprises fully of new grains only.
- This process of formation of new grains is called as **recrystallization** and the corresponding temperature is the recrystallization temperature of the metal.
- Recrystallization temperature is the point which differentiates hot working and cold working.
- Mechanical working of metals above the recrystallization temperature, but below the melting or burning point is known as **hot working** whereas; below the recrystallization temperature, is known as **cold working.**

3.2 Hot working

- Hot working is accomplished at a temperature above the recrystallization 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 change in structure form hot working improves mechanical properties such as ductility, toughness, resistance to shock and vibration, % elongation, % reduction in the area, etc.

- The principal hot working process 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

Advantages

- Due to hot working, no residual stresses are introduced in the metal.
- Hot working refines grain structure and improves physical properties of the metal.
- Any impurities in the metal are disintegrated and distributed throughout the metal.
- Porosity of the metal is minimized by the hot working.
- During hot working, as the metal is in plastic state, large deformation can be accomplished and more rapidly.
- Hot working produces raw material which is to be used for subsequent cold corking operations.

Disadvantages

- As hot working is carried out at high temperatures, a raid oxidation or scale formation takes place on the metal surface which leads to poor surface finish and loss of metal.
- Due to the loss of carbon from the surface of the steel piece being worked, the surface layer loses its strength.
- This weakening of the surface layer may give rise to fatigue crack which results in failure of the part.
- Close tolerances cannot be obtained.
- Hot working involves excessive expenditure on account of high tooling cost.

3.3 Cold working

- The working of metals at temperatures below their recrystallization temperature is called as cold working.
- Most of the cold working process 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. Roll forming
11. Shot peening	12. High Energy Rate Forming (HERF)

Advantages

- 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.

Disadvantages

- Ductility of the metal is decreased during the process.
- Only ductile metals can be shaped through the cold working.
- Over-working of metal result 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.

3.4 Comparison between Hot working and Cold working

Sl.No.	Hot Working	Cold Working
1.	Hot working is carried out above the recrystallization temperature but below the melting point, hence deformation of metal and recovery takes place simultaneously.	Cold working is carried out below the recrystallization 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	The stress required to cause deformation is much higher.

	for deformation is less.	
4.	Hot working refines metal grains, resulting in improved mechanical properties.	Cold working leads to distortion of grains.
5.	No hardening of metal takes place.	Metal gets work hardened.
6.	If the process is properly perfumed, it does not affect ultimate tensile strength, hardness, corrosion and fatigue resistance of the metal.	It improves ultimate tensile strength, yield and fatigue strength but reduces corrosion resistance of the metal.
7.	It also improves some mechanical properties like impact strength and elongation.	During the process, impact strength and elongation are reduced.
8.	Due to oxidation and scaling, poor surface finish is obtained.	Cold worked parts carry better surface finish.
9.	Close dimensional tolerance cannot be maintained.	Superior dimensional accuracy can be obtained.
10.	Hot working is most preferred where heavy deformation is required.	Cold working is preferred where work hardening is required.

3.4.1 Warm working

Warm working refers to plastic deformation carried out at intermediate temperatures of hot and cold working. Thus, the temperature during warm working is above the room temperature and below the crystallization temperature. Also, the working temperature is usually about 0.3 to 0.5 times the melting temperature of metal. Warm working requires less force to perform an operation than cold working hence it is more preferable than the cold working.

3.5 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 workpieces.
- 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.
- Metal forming processes can be classified as follows:

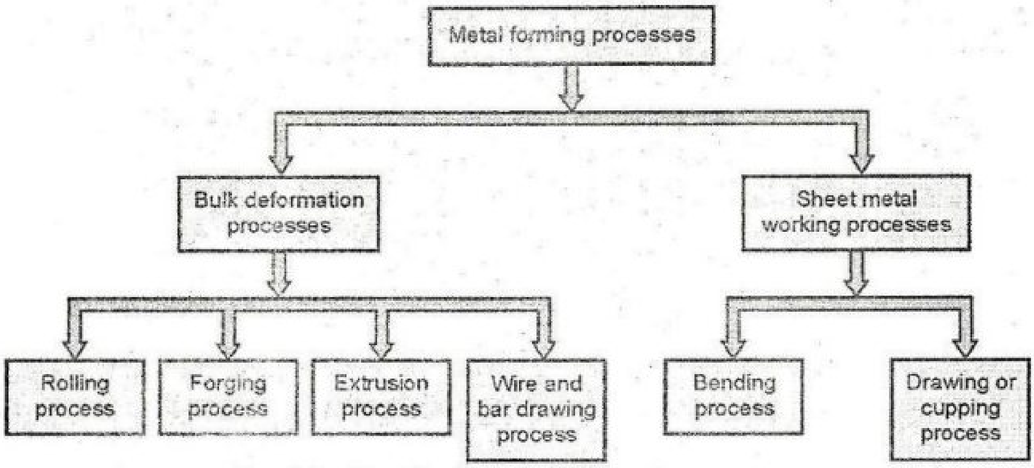


Fig. 3.1 : Classification of metal forming processes

3.5.1 Bulk Deformation Processes

These process are characterized by significant deformations and massive shape changes but the surface area to the volume of the work is relatively small. The workpieces which have this low area to volume ratio is called as bulk. Initial workpiece shape for bulk deformation processes include cylindrical billet (hot material) and rectangular bars. Figure 3.2 shows the basic operations in bulk deformation process.

1. Rolling

It is a compressive deformation process in which the thickness of a plate or slab (hot) is reduced by two opposing cylindrical rolls. The rolls rotate in order to draw the workpiece into the gap between them and squeeze the workpiece. Refer Figure 3.2 (a).

2. Forging

In this process, the workpiece is compressed between the two opposing dies in order to produce the die shapes on the workpiece. Refer Figure3.2 (b). It is generally a hot working process but sometimes it can be included in cold working also.

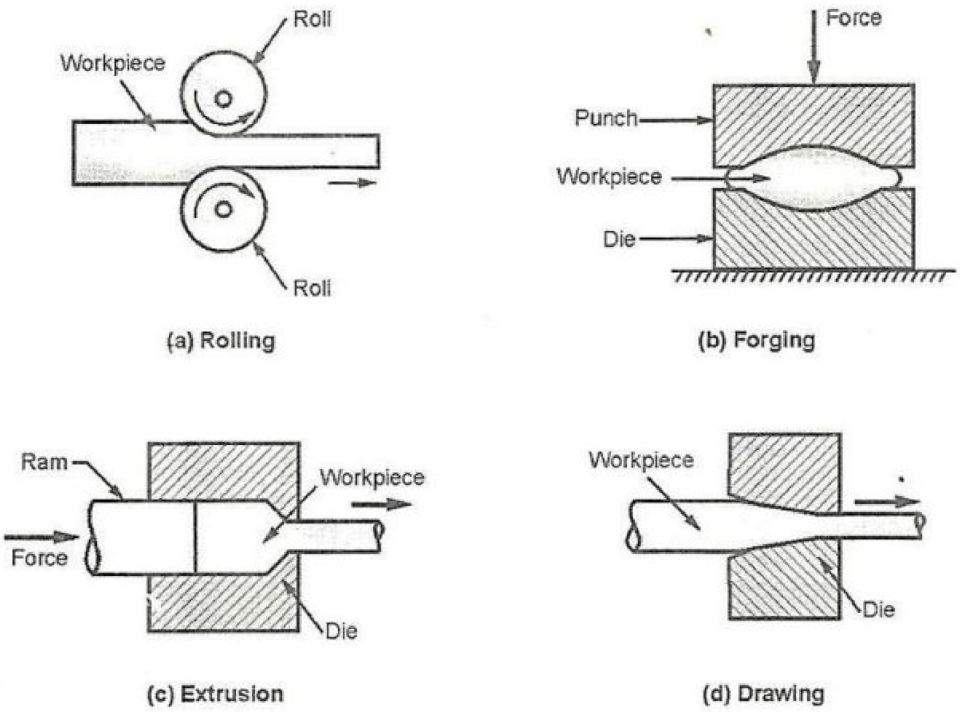


Fig. 3.2 : Basic bulk deformation processes

3. Extrusion

It is a compressive deformation process in which the work metal is forced to flow through a die opening as shown in figure3.2 (c). During the flow through a die, the work metal takes the shape of the opening as its cross-section.

4. Wire drawing

In this type of forming process, the diameter of a round bar (billet) is reduced by pulling it through a die opening. Figure 3.2 (d) shows the drawing process.

3.5.2 Sheet Metal Working Processes

In this type of metal forming processes, the operations are performed on metal sheets, strips and coils. In these processes, the surface area to volume ratio is high.

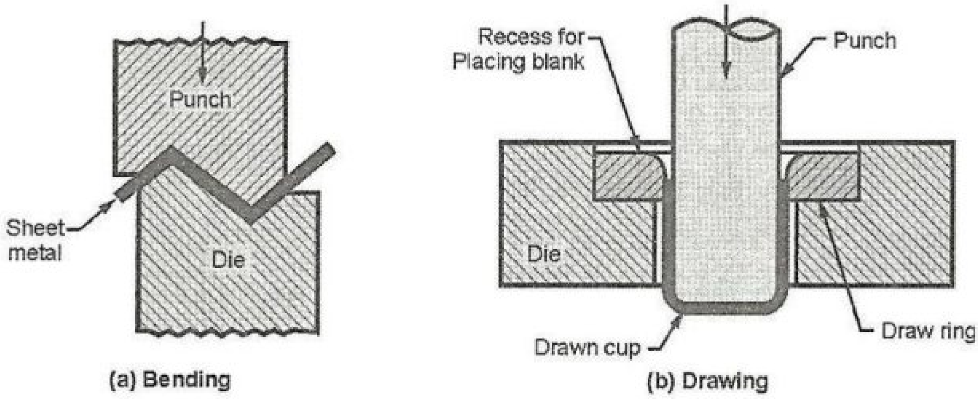


Fig. 3.3 : Basic sheet metal working operations

Generally, the sheet metal working processes are carried out on punching press machine, hence sheet metal working is also called as press working. A component produced by sheet metal working process is called as stamping. These operations are performed as cold working processes. The tools used for the operations is called as punch and die. The punch is a positive portion whereas the die is a negative portion of the tool set. Figure 3.3 shows the basic operations in sheet metal working process.

1. Bending

In this process, there is straining of metal sheet or plate to take an angle along a straight axis. Refer figure 3.3(a). The bending may be of V shape, U shape or any other shape.

2. Drawing or Cupping

It refers to the forming of a flat metal sheet into a hollow or concave shape like a cup by stretching the metal. During the process, a blank holder is used to hold the blank and the punch pushes into the sheet metal. Refer figure 3.3(b).

HOT WORKING PROCESSES

3.6 HOT ROLLING:

The process of rolling consists of passing the hot ingot through the two rolls, rotating in opposite directions, at a uniform peripheral speed. To confirm the desired thickness of the rolled section, the space between the rolls is adjusted and is always less than the thickness of the ingot being fed. Hence, to reduce the cross-section and increase the length of passing ingot, the rolls are squeezed. Refer Figure 3.4.

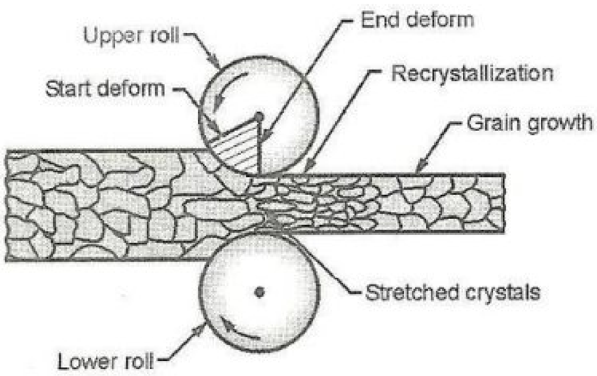


Fig. 3.4 : Hot rolling recrystallisation

When the metal passes through the rolls, there is change in its grain structure. Due to squeezing, the grains are elongated in the direction of rolling and the velocity of material at the exit is higher than that at the entry. After crossing the stress zone, the grains start refining.

3.6.1 Basic Definitions

The following are the basic terms used related to rolling process:

1. **Ingot:** Ingot is a large casting section of suitable shape made for further processing.
2. **Bloom:** A bloom is a square or rectangular piece formed after reducing ingots. The size of bloom ranges between 150 mm × 150mm to 250 mm × 250 mm. Rolling products from bloom: Structural shapes, Rails, etc.
3. **Billets:** Billets also formed after reducing ingot but have smaller cross sections. The size of billet ranges from 50 mm × 50 mm to 150 mm × 150mm. Rolling product from billets: Road, wires, etc.
4. **Slabs:** Slabs are metal pieces with rectangular cross section. It has thickness between 50-150 mm and width between 300-1500 mm. Rolling products from slabs: Sheets, plates, strips, etc.

3.6.2 Rolling of Various Sections

- The main purpose of rolling is to convert larger sections such as ingots into smaller sections, which can be used directly in as rolled state or stock for working through other processes.
- As a result of rolling, there is an improvement in physical properties of cast ingot such as strength, toughness, ductility, shock resistance, etc.

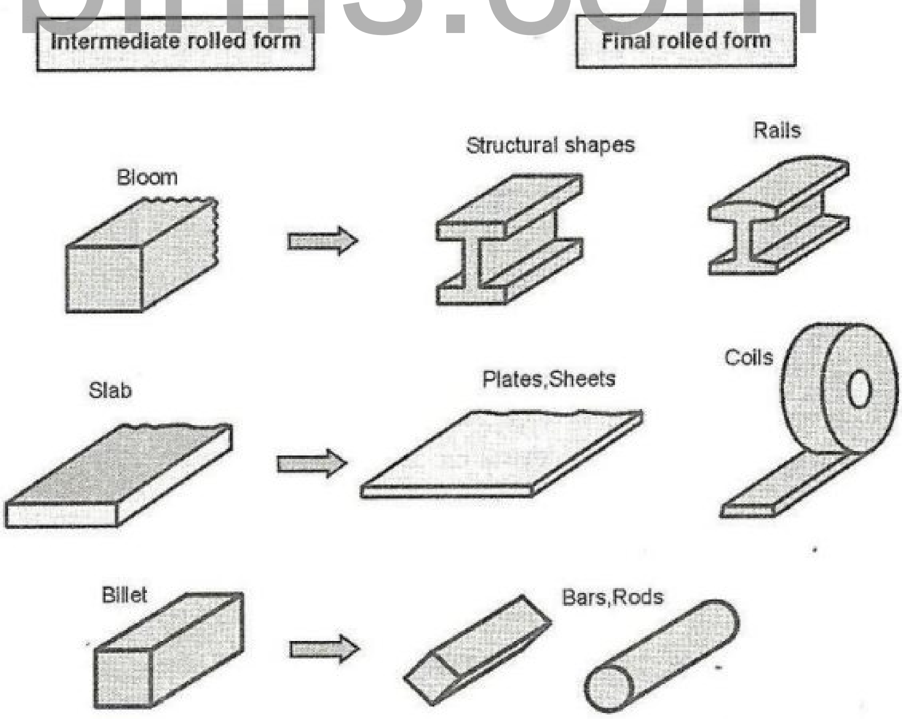


Fig. 3.5 : Steel components made from rolling

- Various useful articles like structural section, sheets, rails, plates and bars, etc. are produced through rolling.

- Figure 3.5 shows some commonly used rolled steel sections.
- The desired reduction in the cross-section of the billet and the required shape of the rolled section are not obtained in a single pass.

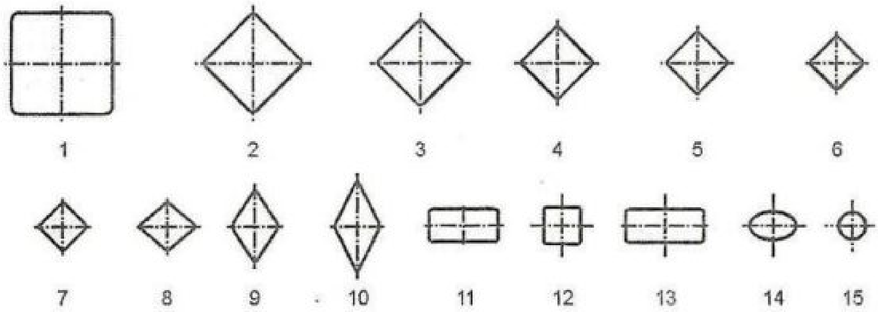


Fig. 3.6 : Various stages of rolling and number of passes for converting a steel billet into a round bar

- Figure 3.6 shows the sequence of rolling and the number of passes required to reduce the cross-section of a billet to a round steel bar.
- The process starts with the reduction of ingots which have been heated in a gas fired furnace up to a temperature of 1200 °C.
- The ingots are then taken to the rolling mill where they are rolled into immediate shapes as blooms, billets or slabs.
- A bloom has a square cross section with minimum size of 150 × 150 mm and a billet is smaller than bloom and it may have any square section from 38 mm up to the size of a bloom.
- Slabs have a rectangular cross section with a minimum width of 250 mm and minimum thickness of 38 mm.

3.6.3 Types of Rolling Mills

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

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 figure 3.7 (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 direction of rotation of the upper and lower rolls are same but the intermediate roll rotates in the opposite direction to each other. Refer figure3.7 (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.

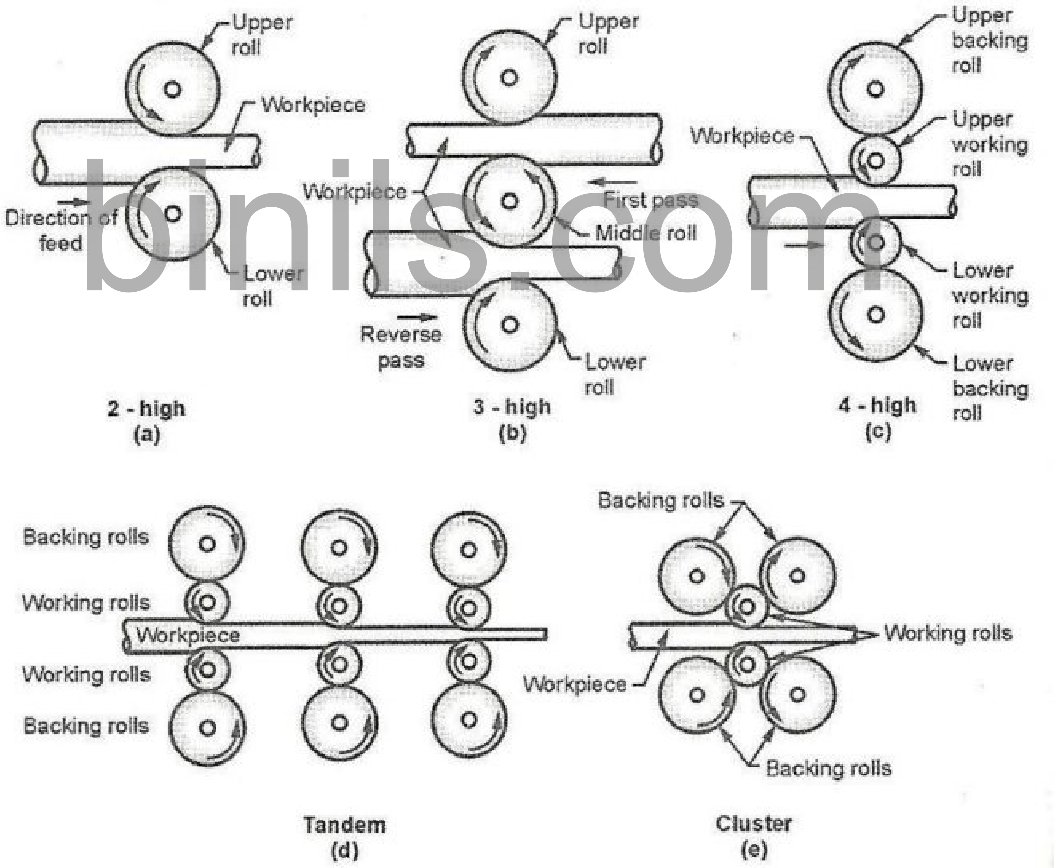


Fig. 3.7 : Types of rolling mills

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 figure 3.7 (c).
- The larger diameter rolls are called as 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 centre.
- 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.

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.
- Figure 3.7 (d) Shows the tandem rolling mill.

5. Cluster rolling mill

- It is a special type of four-high of rolling mill.
- In this, each of the two working rolls is backed up by two or more of the larger back up rolls. Refer Figure 3.7 (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 supports of the working rolls can be obtained by using a cluster 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.

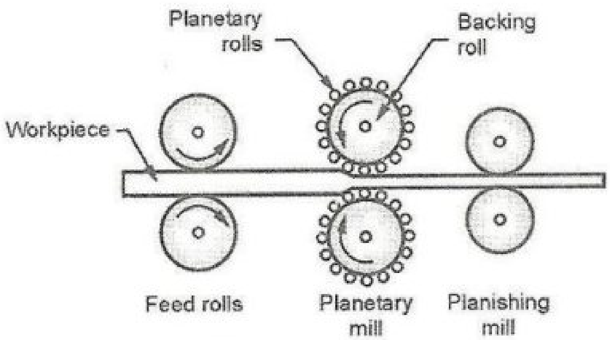


Fig. 3.7 (f) : Planetary rolling mill

- Planetary mill consists of a pair of heavy backing rolls surrounded by a large number of planetary rolls. Refer figure 3.7 (f).
- 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 follower 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 figure 3.7 (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.

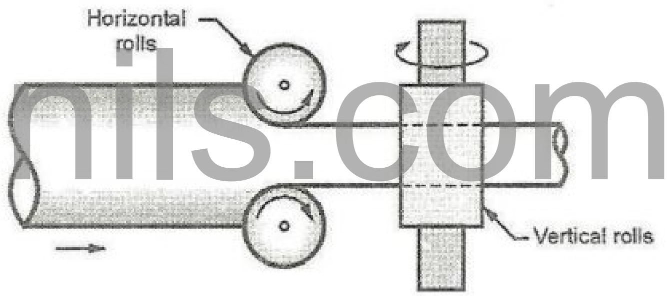


Fig. 3.7 (g) : Universal rolling mill

3.7 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 may be done by hand or by machine.
- Forging by machine involves the use of dies and is mostly used in mass production.
- In hand forging, hammering is done by hand.
- 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 be done in an open hearth, known as Smith's forge, for small jobs or in closed furnaces for bigger jobs.

- Now-a-days forging is an important industrial process used to make variety of high strength components for automobile, aerospace and other so many application.
- For example: Engine crankshafts, connecting rods, gears, jet engine and turbine parts, aircraft structural components, etc.

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 is 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

In this method of forging, the work piece is compressed between two flat dies which allows the metal to flow without constraint in a lateral direction relative to the die surfaces. Refer figure 3.8 (a).

b) Closed-die or impression-die forging

In this method, the die surfaces contain an impression or shape which is applied to the work piece during the compression. Refer figure 3.8 (b). During the operation, some portion of the work piece flows beyond the die impression to form a flash. (Flash is excess metal which is trimmed off at the end).

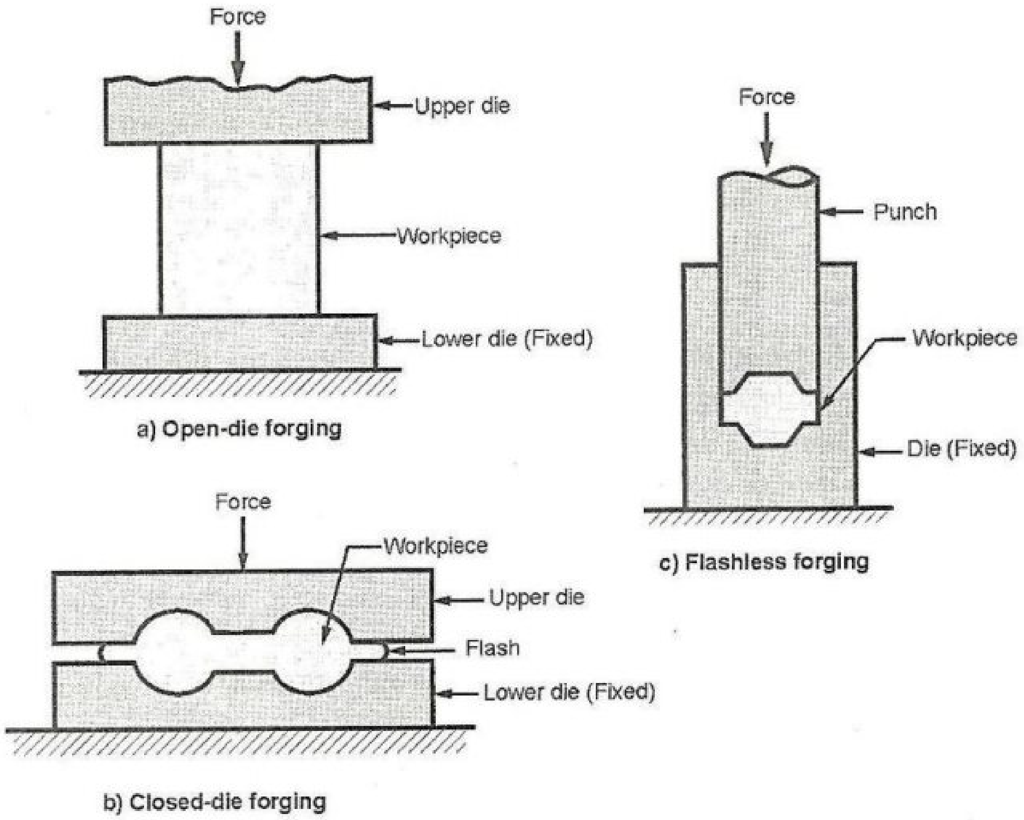


Fig. 3.8 : Types of forging operations

c) Flashless forging

In this method, the work piece is completely constrained within the die and no flash is produced. Refer figure 3.8 (c). The volume of the initial work piece much be controlled closely so that it matches with the volume of the die cavity.

3.8 OPEN-DIE FORGING

- It is the simplest and important forging process.
- The shapes generated by this process are simple like shafts, disks, rings, etc.

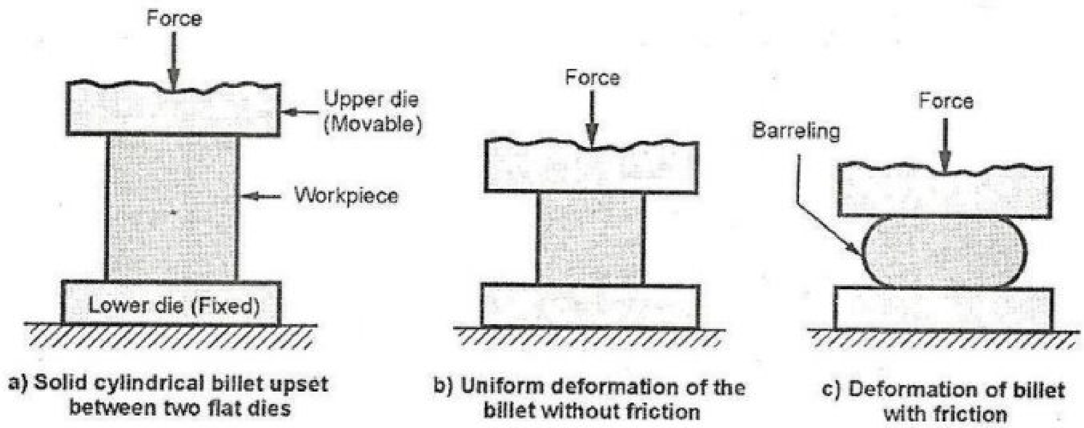


Fig. 3.9 : Open-die forging

- 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 operation produce produces 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. Refer figure 3.9.
- The deformation of the work piece is shown in Figure. Due to constancy of volume, any reduction in height of the work piece increases its diameter.
- In figure 3.9 (b) the work piece is deformed uniformly but practically the work piece develops a barrel shape which is called as pancaking or barreling.
- It is caused by the frictional forces at the die-work piece interfaces and it can be minimized by using an effective lubricant.

Some of the important operations performed in open-die forging process are as follows

1. Fullering

It is performed to reduce the cross-section and redistribute the metal in a work piece in preparation for subsequent shape forging. It is performed with dies of convex surfaces. Refer figure 3.10 (a).

2. Edging

Its working principle is similar to fullering operation, only the difference is that the dies have concave surfaces. Refer figure 3.10 (b).

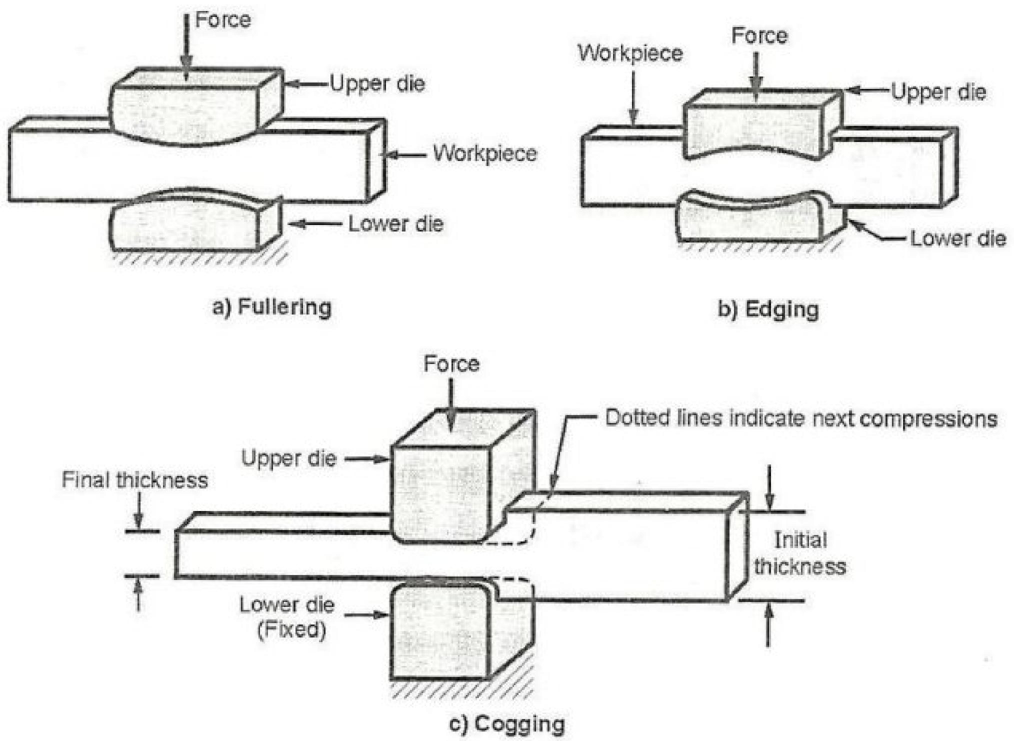


Fig. 3.10 : Open-die forging operations

3. Cogging

It consists of a sequence of forging compressions along the length of work piece to reduce the cross-section and to increase the length. Refer figure 3.10 (c). It is used to produce blooms, slabs, etc. from the cast ingots. The dies used in this operation are flat or have slightly contoured surfaces. This operation is also called as incremental forging.

3.9 IMPRESSION-DIE OR CLOSED-DIE FORGING

- Impression-die or closed-die forging is performed with dies which contain the invers of the required shape of the component. Refer figure 3.11.

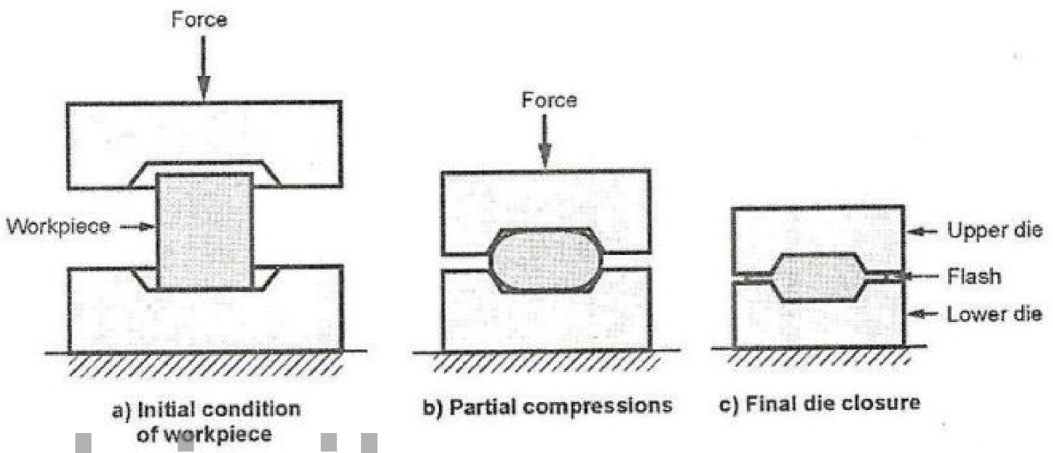


Fig. 3.11 : Closed or impression die forging

- 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.
- The initial steps in the process are used to redistribute the metal in the workpart 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 the flash is formed during the process, this process is used to produce more complex components by using dies.

3.9.1 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.

3.10 HAMMERS

Hammers are classified into different groups as show in Figure 3.12.

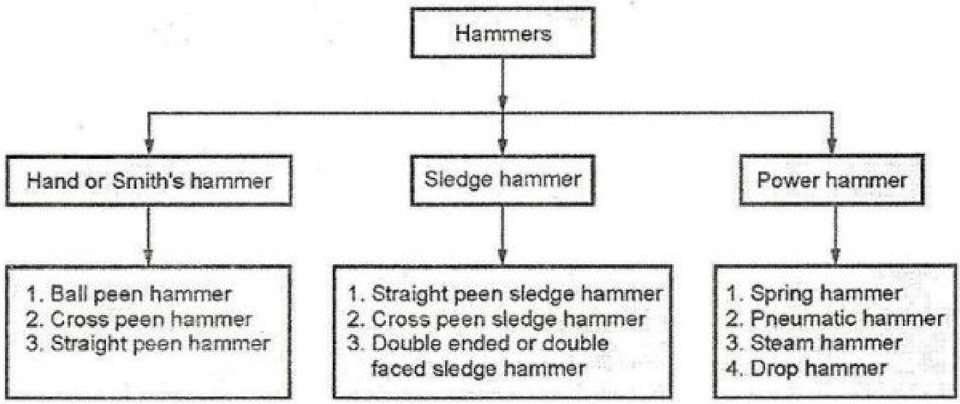


Fig. 3.12 : Types of hammers

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

3.10.1 Hand or Smith's 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 a tough cast steel or forged steel head which is fitted to a wooden handle. One end of the head is flat 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. Refer Figure 3.13 (a).

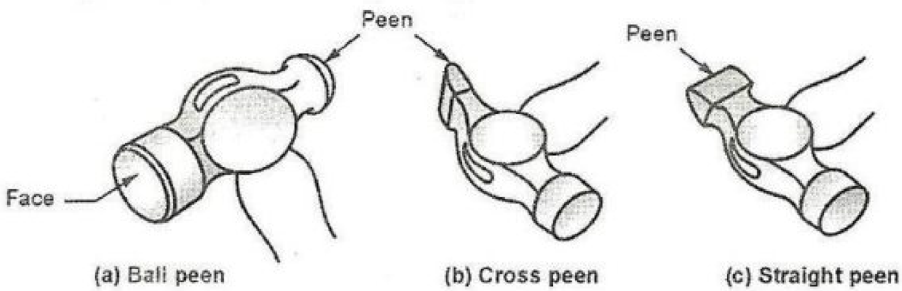


Fig. 3.13 : Hand or Smith's hammers

2. Cross Peen Hammer:

In this type of hammer, peen is at right angle to the axis of the handle of the hammer. It is used for heading, stretching and hammering into the inner portions of the component. Refer Figure3.13 (b).

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. Refer figure 3.13 (c).

3.10.2 Sledge Hammers

Sledge hammers are larger in size as compare to hand hammers and of following types:

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 workpieces.

- To avoid the damage of workpiece surface, the striking surface of the sledge hammer is made slightly convex and smooth.
- The construction of straight peen and cross peen hammers is similar as discussed in hand hammers. Refer figure 3.14 (a) and (b).
- If the hammer has no peen formation and instead carries flat faces at both ends, then it is called d as double ended or double faced hammer. Refer figure 3.14 (c).

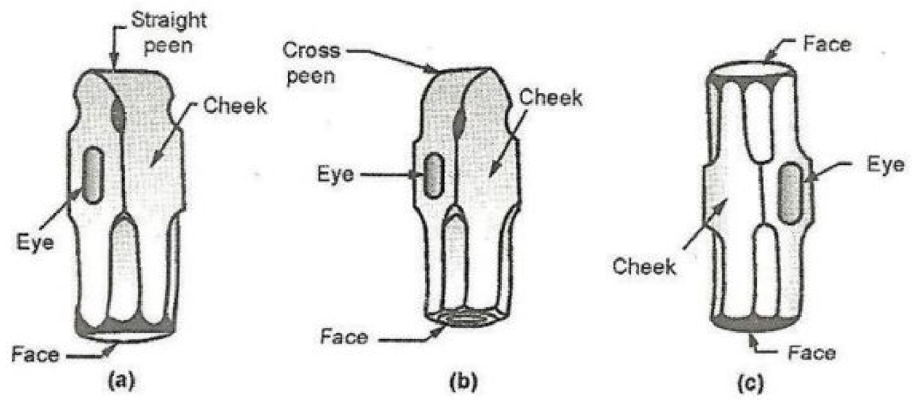


Fig. 3.14 : Sledge hammers

3.10.3 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 pressure are called as forging presses.

Forging or power hammers are of following types:

1. Spring hammer
2. Pneumatic hammer
3. Steam or air hammer
3. 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 acts 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 tup which reciprocates between fixed guides. Refer figure 3.15.
- The connecting rod is attached to on eccentric sheave, which is further connected to the crank wheel.

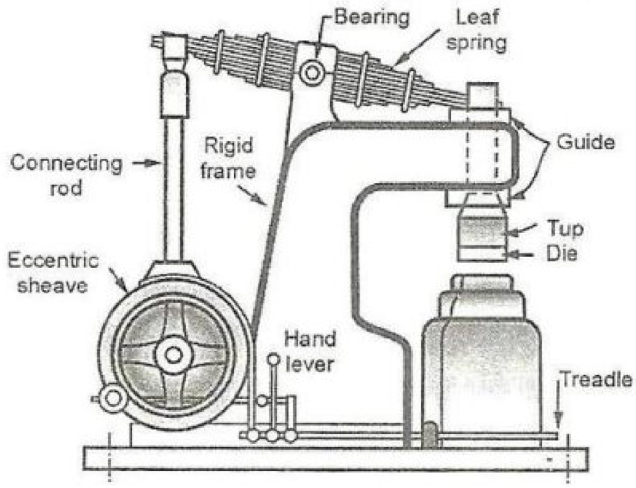


Fig. 3.15 : Spring hammer

- 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.
- Figure 3.16 shows a commonly used design of pneumatic hammers which consists of a compressor cylinder and ram cylinder.

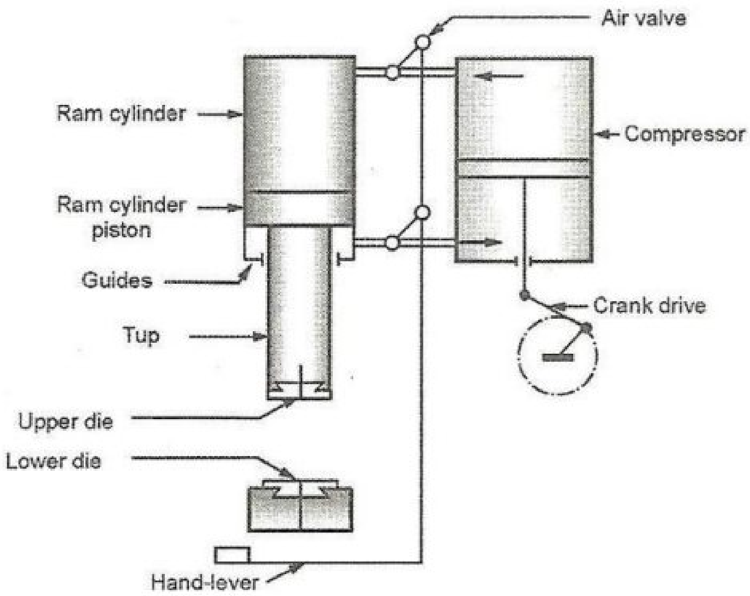


Fig. 3.16 : Pneumatic hammer

- 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 tup at it 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.
- Figure 3.17 (a) and (b) shows the working principle of single acting and double acting steam or air hammers.

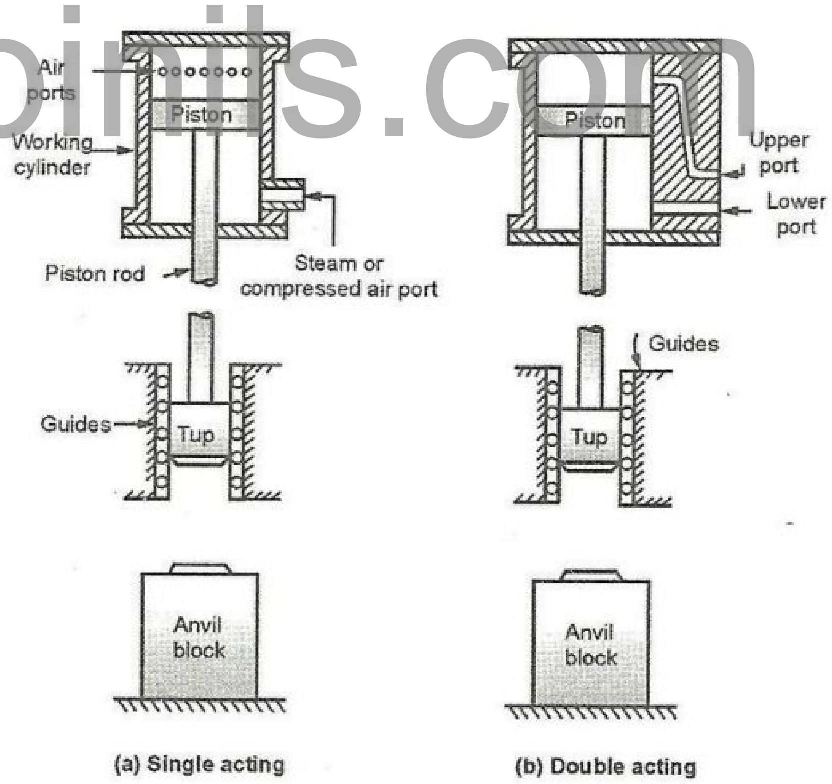


Fig. 3.17 : Steam or air hammers

- In single acting type, the air or steam is admitted into the cylinder through a part near its bottom which pushes the piston upwards.

- The steam supply is then cut off when the piston attains the required height and the tup falls 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.

4. Drop Hammer

- Drop hammer is a type of power hammer which is generally used in mass production of identical products.
- Drop hammers are similar in design and arrangement to steam or air hammer.
- Figure 3.18 shows the working principle of drop hammer.
- It consist of two halves of accurately made steel dies. One half is attached to the tup or hammer head and other half is fastened to anvil block at the bottom.
- The tup carrying upper die half is raised to a suitable height with the help of friction rolls or belt or rope as show in figure 3.18 (a).

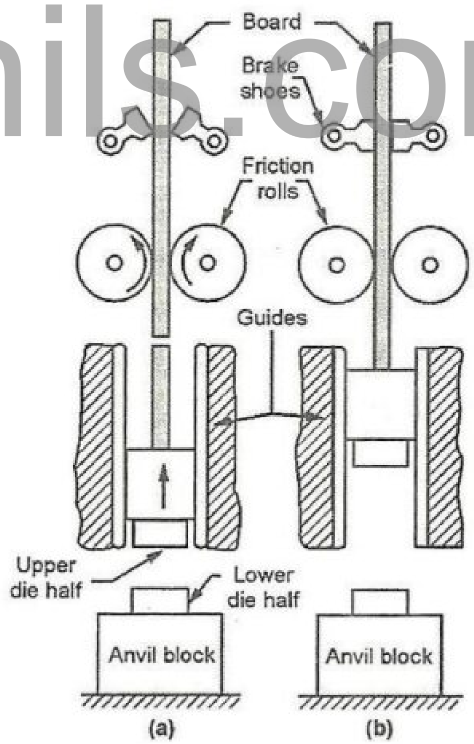


Fig. 3.18 : Drop hammer

- The heated metal is then placed on the lower die half.
- The hammer along with the upper die half is allowed to fall abruptly under gravity and its own weight hence known as drop hammer.

- The sudden fall of hammer causes the metal to shaped according to the formed cavities in the dies.
- Drop hammers are used for mass production of parts of steel or non-ferrous metals weighing upto 3500N.

3.10.4 Hand forgoing Tools:

To carry out hand forging operations, certain tools are used. They are also called as blacksmith's tools. The different hand forging tools are categorised as follows:

a) Anvil	b) Swage block	c) Tongs	
d) Hammers	e) Chisel and hardie	f) Swages	
g) Fullers	h) Flatters	i) Punches and drifts	j) Set hammer, etc.

a) Anvil

For performing forging operation successfully, a proper supporting device is required which a proper supporting device is required which should be capable of withstanding heavy blows applied to the workpiece. For this purpose anvil is used. Refer figure 3.19.

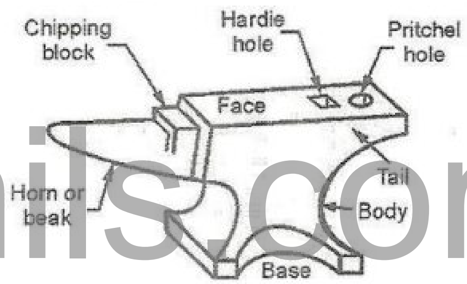


Fig. 3.19 : Anvil

Generally it is made of cast steel, mild steel or wrought iron provided with hardened top. The horn or beak is sued in bending the metal or for forming curved shapes. The flat step between the top and horn called as chipping block is sued to support workpiece while cutting. Tail is the flat projecting piece at the of anvil. It carries a square hole for accommodation of square shank of the bottom part of different hand tools like fullers, swages, etc. This square hole is called as hardie hole. Near the hardie hole a circular hole is provided which is called as pritchel hole.

b) Swage block

It is a solid rectangular block made up of either cast steel of forged steel. Refer figure 3.20. It carries a number of slots of different shapes and sizes (along it four side faces) and through holes (from its top face to bottom face) which also vary in shapes and sizes. It is used as a support in punching holes and forming various shapes. The workpiece to be given a required shape is kept on a similar shaped slot which acts as a bottom swage and then top swage is kept on another side of the workpiece. The holes provided in the top and bottom face are used for punching. It prevents the punch from damage by striking against a hard surface when the hole has been punched.

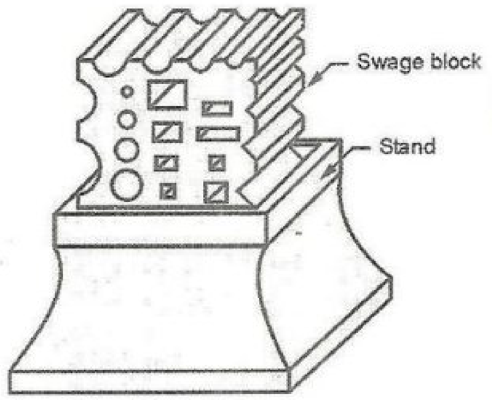


Fig. 3.20 : Swage block on stand

c) Tongs

Tongs are used by the smith for gripping and turning hot metal workpieces during forging. They have wide varieties of bit (mouth) shapes to hold different sized and shaped workpieces. Refer figure 3.21.

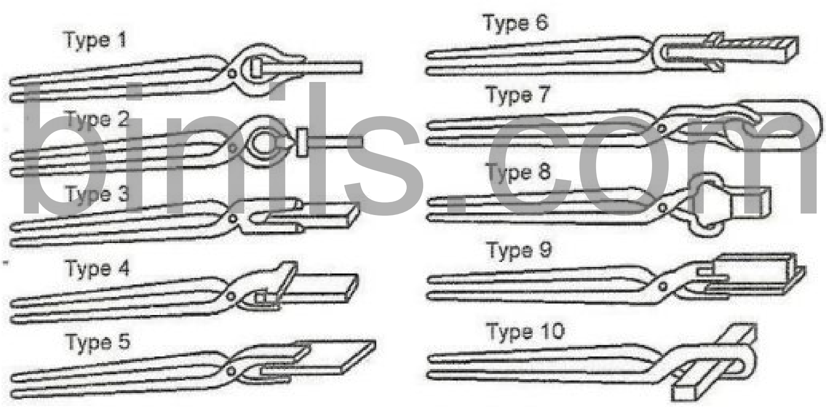


Fig. 3.21 : Types of tongs

Usually tongs are made of mild steel and they are made in two pieces, riveted together to form a hinge. The size of tongs vary as per the size and shape of the workpiece but commonly used lengths of tongs vary from 400 mm to 600 mm with the jaw opening (bit length) from 75 mm to 140 mm.

d) Hammers

For detail explanation of hammers and its types refer section 3.10.

e) Chisels and Hardie

Chisels are used to cut metals in hot as well as cold state. The chisels which are made for cutting the metal in hot state are called as hot chisels or hot set. Refer figure 3.22 (a). Similarly, the chisels which are made for cutting the metal in cold state are called as cold chisels or cold set. Refer figure 3.22 (b).

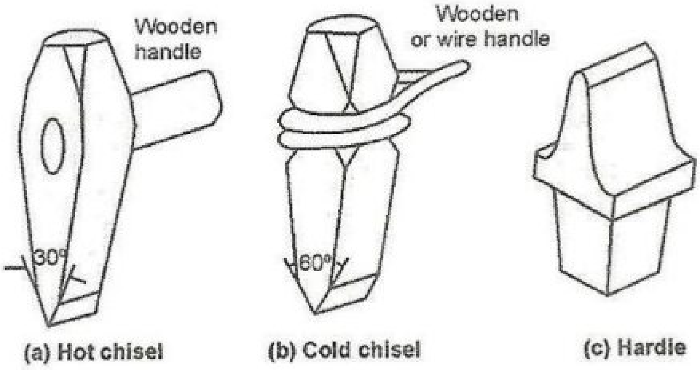


Fig. 3.22 : Chisels and hardie

Hot chisels are ground to an angle of 30°-35° whereas cold chisels are ground to an angle of 45°-60° for cutting the metals. Both hot and cold chisels are made of high carbon steel. These chisels are generally used together with a bottom cutting tools which is called as hardie. Refer figure 3.22 (c).

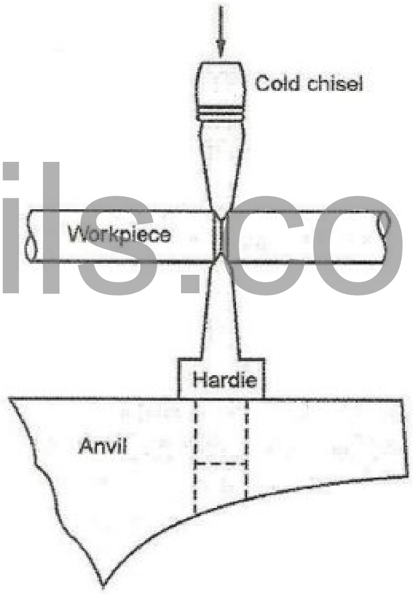


Fig. 3.23 : Cutting with chisel and hardie

It has a square shank and wedge shape which is mounted in the hardie hole of the anvil. Refer figure 3.23.

f) Swages

It consist of two parts called as top part and bottom part. These parts are either separate or connected by a steel strip handle. Refer figure 3.24.

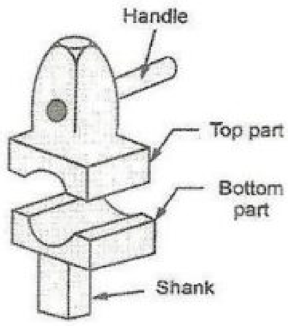


Fig. 3.24 : Swages

Swages are used to reduce and finish the workpiece to the size and shape (generally round or hexagonal). Usually swages are made of high carbon steel.

g) Fullers

Like swages, fullers are also made of high carbon steel in two parts called as bottom part and top part. Fullers are used to form grooves in the workpiece. They spread the metal and can reduce the thickness of workpiece. Like swages the top part of the fullers is provided with a handle and the bottom part has a square shank that fits into the square hole of the anvil. Refer figure 3.25.

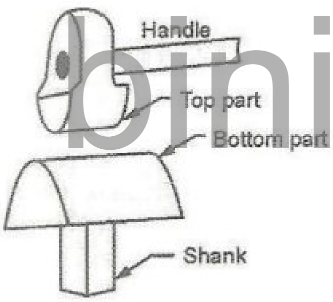


Fig. 3.25 : Fullers

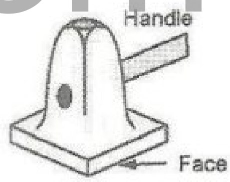


Fig. 3.26 : Flatter

h) Flatters

It is also called as flatteners or smoothers. It is made of high carbon steel and it has square body fitted with a handle as show in figure 3.26. It is used to finish off surfaces to a good surface especially when the surface area is large.

i) Punches and drifts

Punches are tapered tools available in different shapes and sizes. It is used for producing holes in the heated workpieces. Refer figure3.27 (a). A drift is a large sized punch used to expand the hole to the required size and shape after the punching is over. It carries a small taper near its tip only and the remaining part is of uniform cross section. Refer figure 3.27 (b).

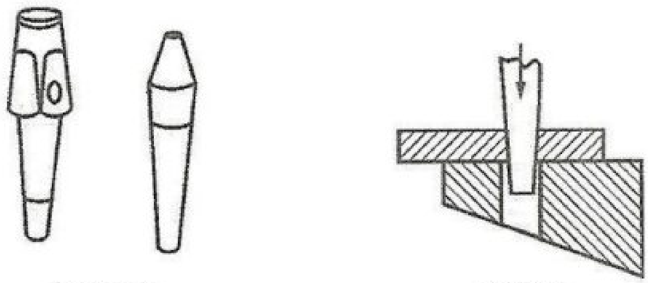


Fig. 3.27 : Punch and drift

j) Set hammer

It is used to finish off surfaces to a good smooth surface in restricted areas like corners. It is made of hardened tool steel. Its construction is similar to flatter but smaller in size and its bottom is also small.

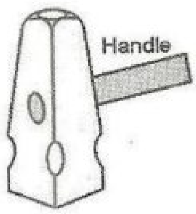


Fig. 3.28 : Set hammer

3.11 Drop Forging

- Drop forging differs from smith's forging as in drop forging closed impressions rather than open face of flat dies are used.
- This process utilises 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, forgoing 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:
    - Board or gravity hammer
    - Air – lift hammer
    - Power drop hammer or steam hammer
- Figure 3.29 shows the principle of a board or gravity hammer.

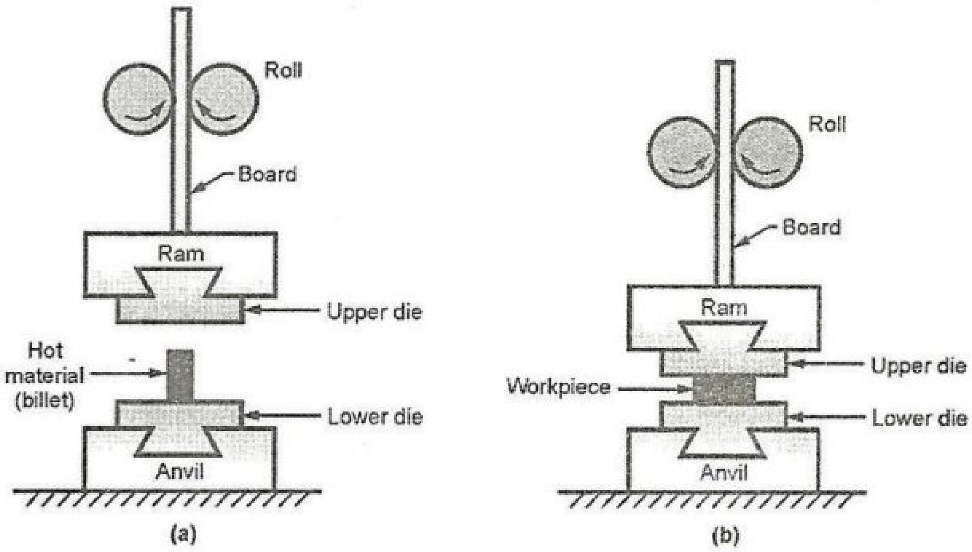


Fig. 3.29 : Principle of a board or gravity hammer

- The drop forging die consists of two halves i.e. lower half and upper half.
- The lower half of the die is fixed to the anvil of the machine while upper half is fixed to the ram.
- The heated stock or the workpiece is kept in the lower die while the ram delivers four to five blows on the metal in quick succession, so that the metal spreads and fills the die cavity.
- The force of the blow can be varied by changing the distance of the fall.
- The anvil which must absorb the blow is generally 20 times heavier than the hammer.
- A board hammer which works rapidly, gives overs 300 blows per minute.
- Board hammer can do a wide variety of work and they are less expensive as compared to the others.
- Components manufactured by drop forging are car axles, crankshafts, connecting rods, leaf springs, crane hooks, jet engine turbine dies and blades.

Disadvantages of Drop Forging

- The boards are liable to frequent breakage.
- The intensity of blow cannot be controlled during the stroke.
- Dimensional accuracy is less.

- The life of the hammers and dies is less.
- More noise and vibrations are produced during the operation.

3.11.1 Press Forging

- It is done in presses rather than by using hammers.
- The action is relatively slow squeezing instead of delivering heavy blows and penetrates deeply because it gives the metal time to flow.
- Press forgings are shaped at each impression with a single smooth stroke and they stick to the die impression more rigidly.

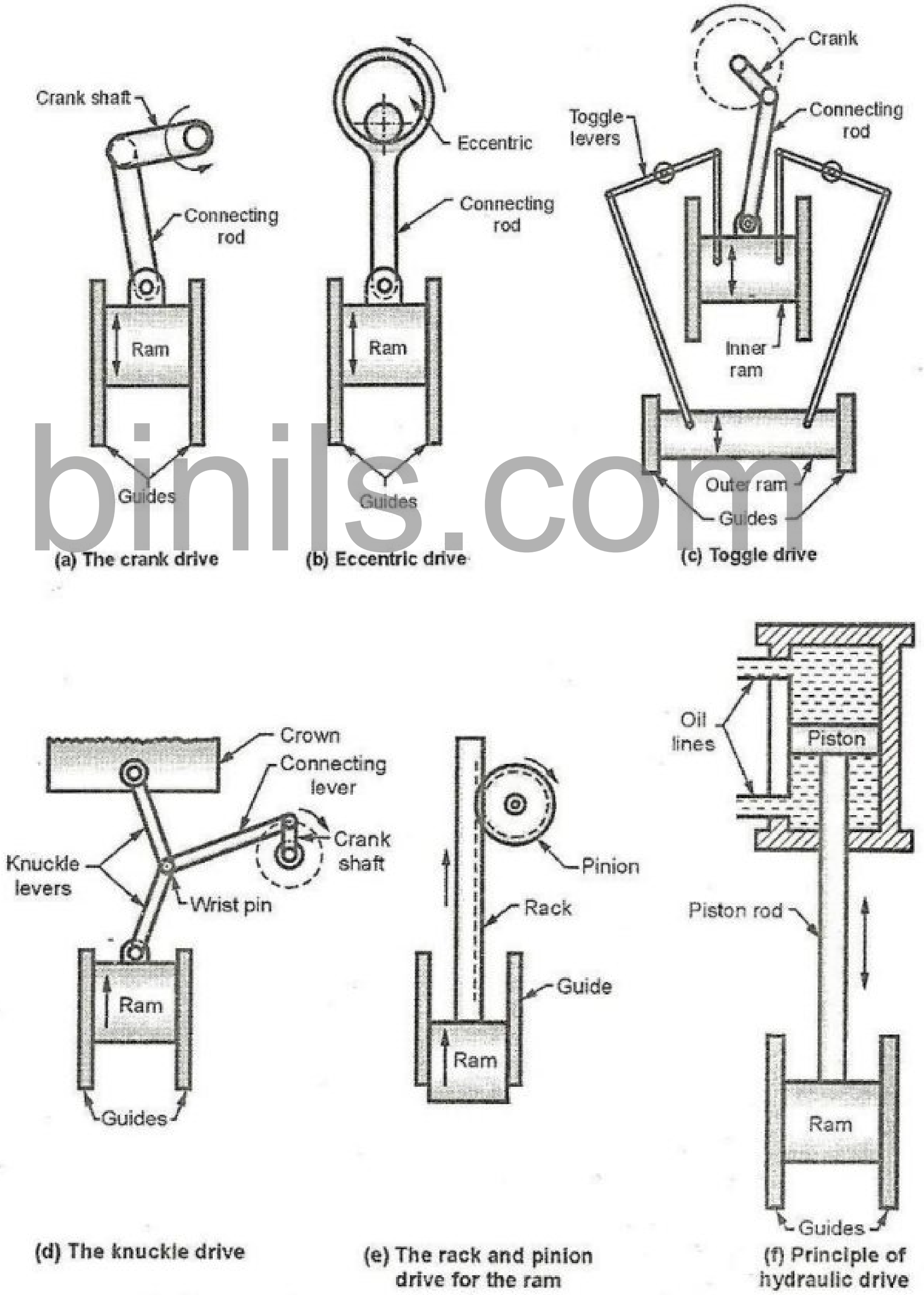


Fig. 3.30 : Ram driving mechanisms

- Press forgings are generally more accurate dimensionally than drop forgings.
- Press for forgings are generally more accurate dimensionally than drop forgings.
- Press for forgings may be of two types i.e. hydraulic and mechanical press.
- The dies used carry relatively less draft and hence more complicated shapes can be forged.
- The life of the presses and dies is longer than that of the hammer and dies used on them.
- The process does not require highly skilled operator because the speed, pressure and travel of the die are automatically controlled.
- There are less vibrations and noise as compared to hammering.
- Presses of 500 to 600 tonnes capacities are generally used.
- Press forging is used for the manufacturing of large levers, flanges, toothed wheels, crankshafts, propellers, hollow bodies, railway wheel disks, tank bottoms, panels and other bodies of air-craft and rocket bodies.
- Figure 3.30 shows different types of ram driving mechanisms.

Following table 3.1 gives the comparison between hydraulic and mechanical press:

Table 3.1: Comparison between hydraulic and mechanical press

Sl. No	Hydraulic press	Mechanical press
1.	Hydraulic presses are used for heavy work.	Mechanical presses are used for light work.
2.	Operating speed of hydraulic presses is slow.	Mechanical Presses operate faster than hydraulic presses.
3.	Hydraulic presses are designed to provide greater squeezing force.	Less squeezing force is applied by the Mechanical presses.
4.	Pressure can be changed at any point in the stroke by adjusting the pressure control valve.	Pressure cannot be changed during the process.
5.	Life of dies is short.	Life of dies is more.
6.	Initial cost of machine is high.	Initial cost of machine is low.

3.11.2 Comparison between press Forging and Hammer forging

Sr. No	Press forging	Hammer / Drop forging
1.	Press forging is slow as compared to hammer forging, but the reduction in the size of heavy parts is comparatively rapid.	Hammer forging is fast process, but a large number of blows are applied in rapid succession for reduction in the size of heavy parts.
2.	In press forging there is no restriction of the size of the components.	In hammer forging there is a restriction of the component size.
3.	The life of the presses and dies is more.	The life of the hammers and dies is less.
4.	Less vibrations and noise during the operation.	More vibrations and noise during the operation.
5.	The process does not require highly skilled operator.	Skilled operator is required for the process.
6.	More complicated shapes with better dimensional accuracy can be produced.	Less dimensional accuracy.
7.	The distance of the fall cannot be changed.	The force of the blow can be varied by changing the distance of the fall.

3.11.3 Machine or Upset Forging

- Machine forging is also called as hot heading.
- It consists of applying pressure longitudinally on a hot bar, which is gripped firmly between grooved dies, to upset a required portion of its length.
- All forgeable metals can be upset through this process.
- They may have any shape of cross-section, but round shape is most commonly used.
- The equipment used for this type of forging is known as forging machine or upsetter.
- The machine provides forging pressure in a horizontal direction.
- The dies are so designed that, the complete operation is performed in several stages and the final shape is attained gradually.
- The operation is performed by using die and punch which is called as heading tool, as shown in figure 3.31.
- The die is either made hollow to receive the round bar through it or in two parts to open out and receive the bar.

- Between the heading tool and the die, a mechanical stop is place which determines the correct projecting length of the bar.
- After the bar has been gripped firmly, with its correct length projecting outside, the stop is replaced and the heading tool is advanced into the die.

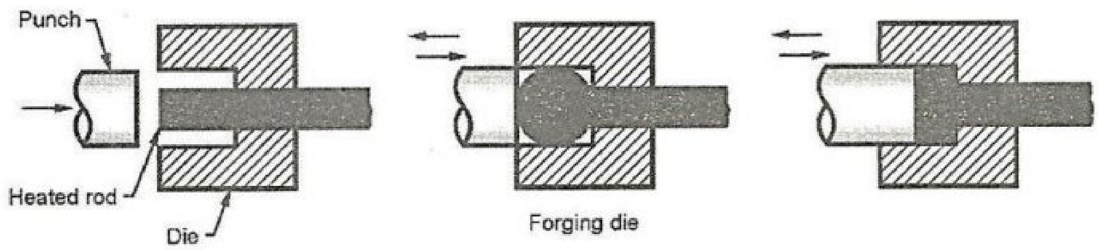


Fig. 3.31 : Upset forging

- Many such strokes are required to complete the upsetting.
- Forging of the ring and rod types with all kinds of heads and shoulders such as bolts, nuts, washers, collars, pinion gear blanks, etc. can be easily produced by this process.

Advantages of Machine forging

- The quality of machine forging is better than the other forging methods.
- The dies carry no draft, hence flash is not produced on the parts.
- Better dimensional accuracy can be obtained.
- With the help of this forging process piercing can also be done with considerable accuracy.
- Forging machines have higher productivity and their maintenance is less expensive than the other methods.
- The process can be automated.

Disadvantages of Machine Forging

- Due to material handling difficulties, heavier components cannot be forged easily.
- The components having diameter more than 250 mm cannot be forged by this process.
- Intricate and unsymmetrical components are difficult to be forged.
- Tooling cost is high.

3.11.4 Roll Forging

- Roll forging process consists of placing raw stock between two roll dies which are of semi-cylindrical form and are grooved to impart a desired shape to the workpiece being forged.
- The roll dies are carried on roll shafts and rotate continuously towards the operator.

- Figure 3.32 (a) shows the rolls in an open condition, with the heated workpiece in the tong and resting on the guide.
- In figure 3.32 (b) the rolls are brought together, with the stock gripped in the grooves of the rolls.

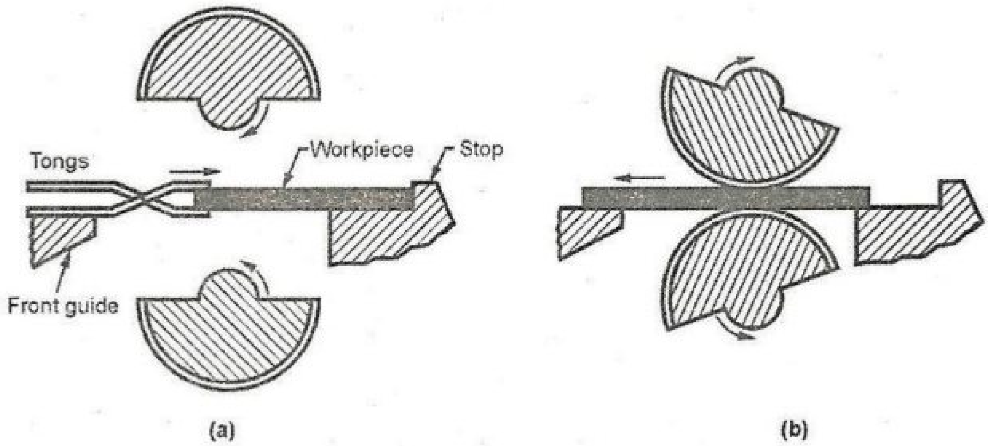


Fig. 3.32 : Principle of operation of a roll forging machine

- The rolling action forces the stock towards the operator.
- When the dies are again in an open condition the stock is placed in appropriate grooves of the rolls and the operations are repeated until the required shape is not obtained.
- This process is also used to make large reductions in the cross-section and distribution of the metal of a billet, hence saving considerable work in the forging hammer or press.
- By using roll forging, parts such as knife blades, automobile drive shafts, axles, leaf springs and gear-shift levers are made.

3.12 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 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.

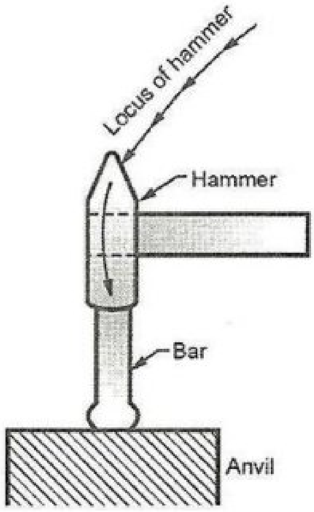


Fig. 3.33 : Upsetting a bar

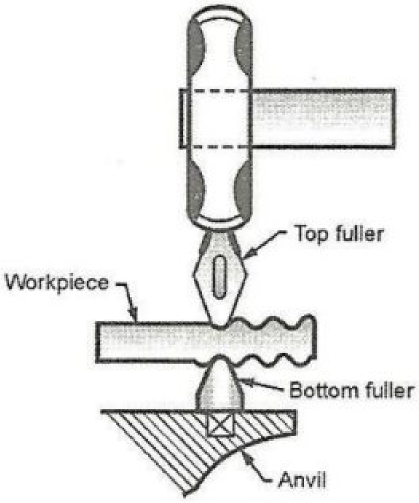


Fig. 3.34 : Drawing out

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.
- Figure3.34 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 workpiece must be turned 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.
- Figure 3.35 shows a round bar being bent to form a helical spring.

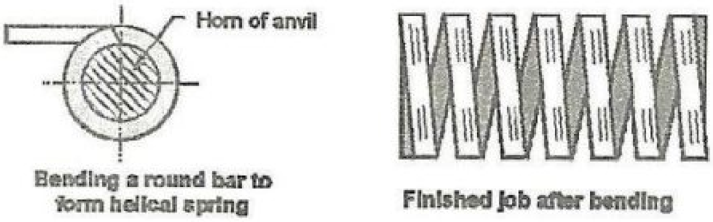


Fig. 3.35 : Bending a round bar to form a helical spring

5. Punching and Drifting

- The term punching refers to the operation in which a punch is forced though a workpiece to produce a hole.
- The workpiece is first heated and then placed on the anvil face.
- The punch is then forced into it upto about half its thickness.
- The workpiece is then turned upside down and placed over a tool called as bolster.
- The punch is again forced into the workpiece and made to pass through by hammering. Refer figure.
- Punching without using a die, is generally followed by drifting.
- In drifting, a tool known as drift, is made to pass through the punched hold to produce a finished hole of the require size.

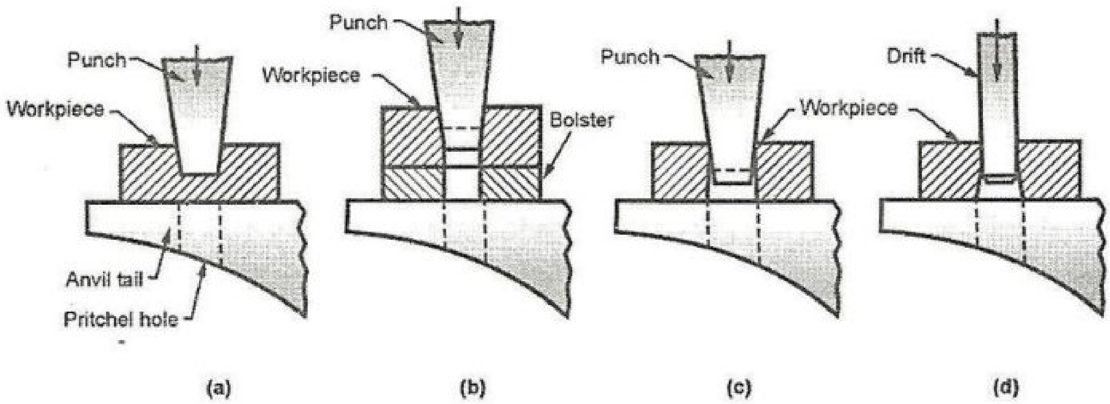


Fig. 3.36 : Punching and drifting operations

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 bards which have been formed to the corrected shape and heated to a welding temperature in a forge fire.
- The method of preparing the metal pieces for welding is called scarfing.

Following are the forms of welded joint which are commonly used:

a) **Lap scarf weld:** In this, the ends are prepared so that they may be welded one upon the other with the joint in an inclined position.

b) **Butt weld:** In this, the ends of the pieces to be joined are butted together, the weld being between the ends at right angles to the length of the piece.

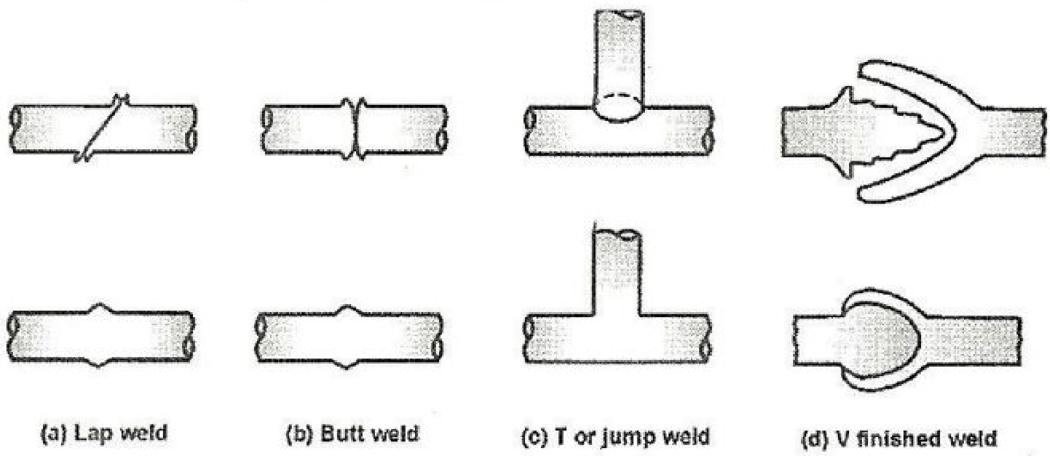


Fig. 3.36 : Forge welded joints

c) **T or Jump weld:** In this, one piece is place at the center of another at right angle to each other in the form of an inverted T.

d) **V-weld or Splice:** In this, the ends are first brought to the shape of fork and tongue respectively.

3.13 DEFECTS IN FORGING

The defects commonly observed in forged components are as follows:

1. Defective metal structure:

The main cause of this defect is defective original metal.

2. Presence of cold shuts or cracks at corners or surfaces

This defect is due to improper forging and faulty die design.

3. Incomplete components:

This is due to less metal used, inadequate heating of metal, improper forging design, faulty die design, metal not placed properly in the die and inadequate flow of metal.

4. Mismatched forging:

When the die halves are not properly aligned, forging will be mismatched.

5. Burnt and overheated metal:

This defect is because of improper heating.

6. Fibre flowlines discontinued:

The main cause of this defect is very rapid plastic flow of metal.

7. Scale pits:

Scale pits are formed by squeezing of scale into the metal surface while forging.

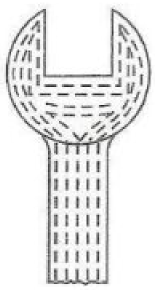
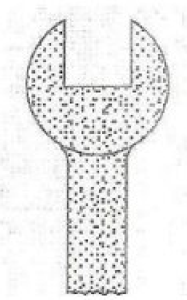
8. Oversized components

Worn out dies, incorrect dies, misalignment of die halves are the main causes of oversized components.

Forging defects can be removed as follows

- Shallow cracks and cavities can be removed by chipping out of the cold forging with pneumatic chisel.
- Surface cracks are removed from forgings by grinding on special machines. Care should be taken
- By taking into considerations, all relevant and important aspects die design should be made properly.
- To avoid mismatching of the dies, the parting line of a forgoing should lie in one plane.
- The mechanical properties of the metal can be improved by forging to correct fibre line and developed internal stresses are removed by annealing or normalising.

3.14 Comparison between Forging and Casting Processes

Sr. No	Forging	Casting
1.	In forging process, grain flow is continuous and uninterrupted Refer figure. 	In casting process, there is no grain flow. Refer figure. 
2.	Due to improved grain size and true grain flow, forging give greater strength and toughness.	Due to no grain flow and weak crystalline structure, casting is weak in withstanding working stresses.
3.	Requires minimum machine finish.	Requires more machine finish.
4.	Forged components have better mechanical properties like strength, toughness, resistance to shock and vibrations.	Cast components are brittle i.e. weak in tension. Also they have poor resistance to shock and vibrations.
5.	Welding of forged parts is easy.	Welding of cast parts is difficult.
6.	During the operation, cracks and blow holes are welded up.	Defects like cracks and blow holes make the casting weak and unsuitable for use.
7.	Accuracy is more.	Accuracy is less.
8.	Complicated shapes cannot be produced.	Complicated shapes can be produced.
9.	Generally used for large parts.	Generally used for small parts.
10.	Because of cost of dies, process is costly.	As there are not dies, hence casting is less expensive.

3.15 Roll Piercing of Seamless Tubing

- Roll piercing is a method of producing seamless tubes.
- Seamless tubing is a popular and economical raw stock for machining because it saves drilling and boring of parts.

- The piercing machine consists of two tapered rolls, called as piercing rolls.
- During the process, a round heated billet or steel is passed between these rolls over a mandrel.
- Both the rolls rotate in the same direction and the billet is provided with a small drilled hole at one end and uniformly heated to about 1100°C.
- It is then pushed into the two piercing rolls which impart axial and rolling movement to the billet and force it over the mandrel.

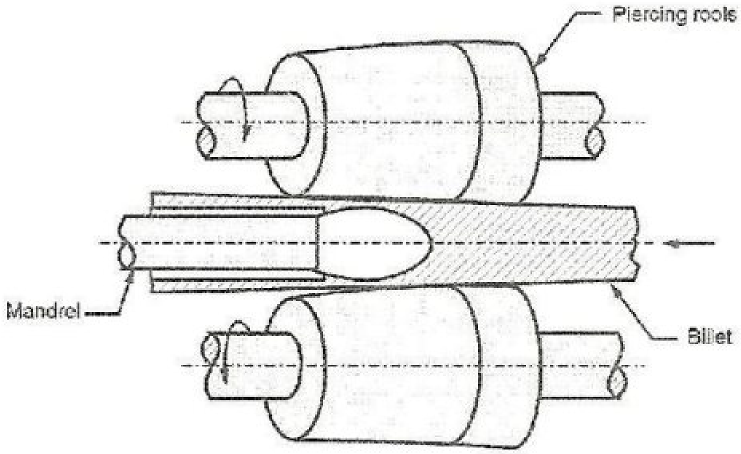


Fig. 3.38 : Tube piercing

- Hence, the combination of the revolving motion of billet and mandrel together with the axial advancement of the billet, provides a helical tubing effect on the material.
- For production of 12m length of upto 150 mm diameter rough tubing will take 10 to 30 seconds, whereas for tubing of larger diameter (upto 350 mm) second piercing operation is required.
- As above produced rough tubing is further subjected to rolling, reeling and sizing, to bring it to the correct shape and size for providing a find surface finish.
- Such tubes are produced in various metals and alloys such as steel alloys, aluminium brass, copper, etc.

3.16 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.
- The products made by extrusion process are tubes, rods, railing 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 tones 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

3.16.1 Direct Extrusion

- Direct or forward hot extrusion is most widely used and the maximum numbers of extruded parts are produced by this method.
- Figure 3.39 shows the direct extrusion process in which the raw material is a billet.

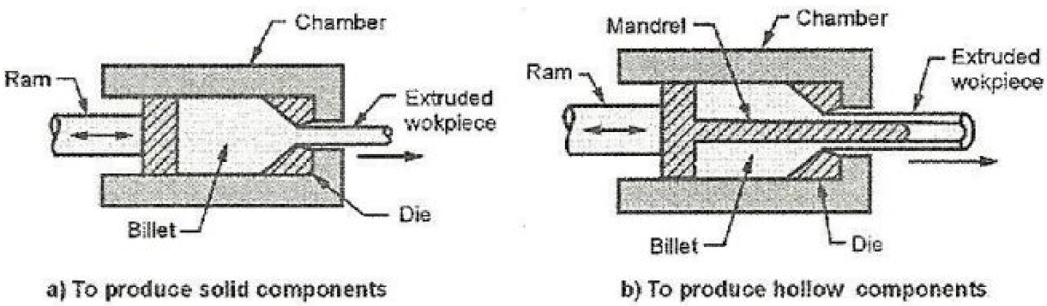


Fig. 3.39 : Direct extrusion

- 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.
- 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 workpiece 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 process is also used to produce hollow or semi-hollow sections.
- To produce hollow sections, by direct extrusion process, a mandrel is used. Refer figure 3.39 (b).
- When the billet is compressed, the material is forced to flow through the gap between the mandrel and die opening. This result in tubular cross-section.

3.16.2 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 backwall of the closed chamber, the metal is extruded back into the plunger, Refer figure 3.40.

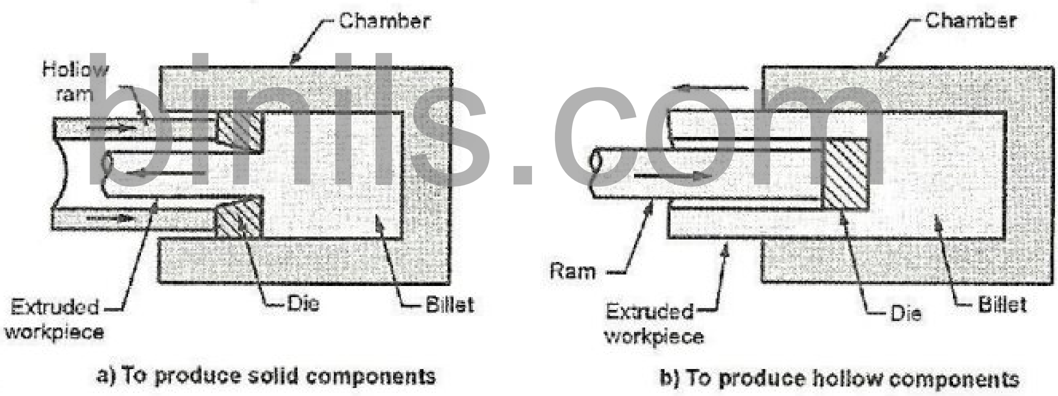


Fig. 3.40 : Indirect or backward or reverse extrusion

- 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 centre 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. Refer figure 3.40 (b).

3.16.3 Comparison between Direct and Indirect Extrusion

Sl. No	Direct / Forward Extrusion	Indirect / Backward Extrusion
1.	During the process a solid ram is used.	A hollow ram is used for the process.
2.	Flow of metal is in the same direction as the movement of the ram.	Flow of metal is in the opposite direction as the movement of the ram.
3.	A dummy block is used during the operation.	Dummy block may or may not be used. Die plays a part of the dummy block.
4.	Die is mounted on the cylinder or container.	Die is mounted over the bore of the ram.
5.	Because of relative motion between the heated metal billet and the cylinder walls, friction problem arises.	As the billet in the container remains stationary, there is no friction.
6.	Large amount of force is required to move the billet in the cylinder.	As the billet is stationary, process does not require large amount of force.
7.	Handling of extruded metal is very easy.	Handling of extruded metal is difficult.

COLD WORKING PROCESSES

3.17 COLD ROLLING:

Cold rolling is use for producing bars of all shapes, rods, sheets and strips. Cold rolling is generally employed for providing a smooth and bright surface finish to the 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. 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.

3.17.1 Comparison between Hot Rolling and Cold Rolling

Sl. 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 the rolls and stock is relatively lower.
4.	Heavy reduction is cross-sectional area is possible.	Heavy reduction is 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 upto 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.

3.18 Shape Rolling Operations

In shape rolling process various shapes like structural sectins (beams of I, T or C sections), sheets, rails, plates and bars are produced. Shape rolling process can be divided in two parts:

1. Ring rolling   2. Thread rolling

1. Ring Rolling

- Ring rolling is generally used for producing steel tyres of railway car wheels, rotating rights of jet engines, races, of ball bearings, etc.
- The initial material for ring rolling is a pierced billet for producing a thick walled ring.
- The ring is placed between driving roll and pressure as shown in figure 3.41.

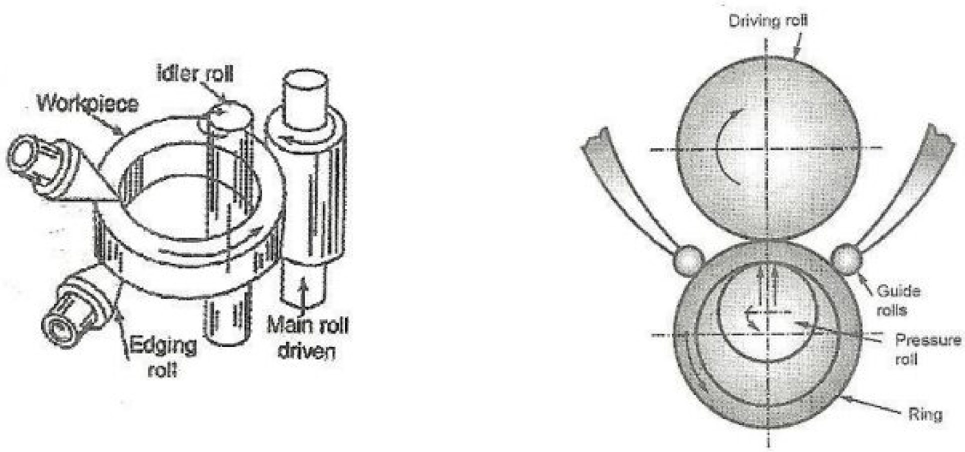


Figure 3.41 Ring Rolling

- The driving roll is fixe but it can rotate freely about its axis.
- The pressure roll applies pressure on the ring towards the driving roll.
- When the ring is gripped, it is caused to rotate and at the same time reduced in thickness continuously.

In order to ensure that a cirucular ring is rolled, a pair of guide rolls must be used.

Thread Rolling

- Thread rolling is the most economical and fastest method of making threads.
- It is actually a cold working process in which a plastic deformation takes place.
- No metal is removed and no chips are produced.
- Cold rolling strengthens the thread in tension, shear and fatigue.

Thread Rolling Machines

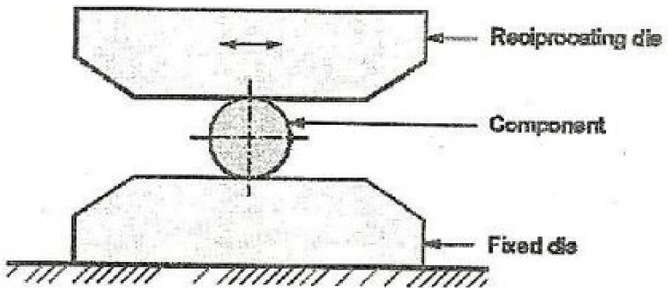
There are three types of thread rolling machines:

i. Reciprocating flat die machines.
ii. Cylindrical die machines.
iii. Rotary planetary machines having rotary die and one or more stationary concave-die segments.

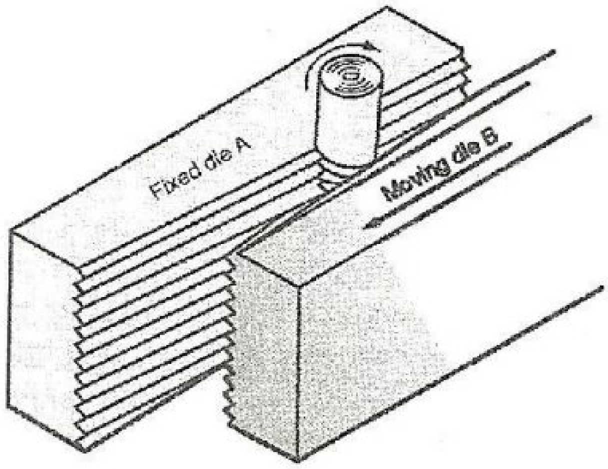
The choice of machine depends upon the size and design of the workpiece, The work material and the number pieces to be produced.

i) Reciprocating flat die machines

- In this process two dies are used. One of them is stationary and another is reciprocating.
- The component to be threaded is rolled between these dies. The moving die reciprocates in reference to the fixed die as shown in figure 3.42 (a) and (b).
- The reciprocating die stroke depends on thread diameter to be produced, as in one stroke the blank makes one complete revolution.
- In one complete revolution thread is completely formed.
- It is very popular machine, as both right and left hand threads can be rolled.
- This is mainly used for production of threads on nuts and bolts.



(a)



(b) Reciprocating flat die machine

Fig. 3.42 : Thread rolling

Advantages of Thread Rolling

- It is the fastest method of producing a thread, with production rate more than 2000 pieces per minute.
- Being a chipless forming process, there is lot of material saving (about 16 to 27%).
- During thread rolling, the material is strained plastically and work hardened, therefore it becomes stronger against tension and fatigue.
- A rolled thread is superior to one that has been cut since the process work hardens the thread surface and promotes a grain direction which adds to the strength of the thread.
- Surface finish is better than thread milling and it is in the order of 0.08 to 0.2 μm.

Limitations of Thread Rolling

- Best suitable only for diameters upto 20 mm.
- Necessary to hold close blank tolerance.
- Uneconomical for low quantities.
- Cannot roll material having a hardness exceeding RC37.
- Only external threads can be rolled.

Thread Rolling Applications

- To produce external thread, thread rolling is the best method.
- Electric light bulb, wood screws, machine screws, sheet metal screws, hooks and eyes of bolts are produced by this method.
- Thread rolling g is also used for producing threads on stamped parts.

3.19 Defects in Rolled Parts

There are following types of defects which can be observed in rolled components:

1. Surface defects 2. Internal structural defects 3. Other defects

1. Surface defects:

Surface defects include defects like scale, rust, cracks, scratches, gouges, etc. It occurs due to the impurities and inclusions in the original cast material and different conditions related to material preparation and rolling operation.

2. Internal structural defects: These type of defects include following defects:

i) Wavy edges ii) Zipper cracks iii) Edge cracks
iv) Alligatoring v) Folds vi) Laminations

- The defects of wavy edges and zipper cracks occur due to bending of rolls.

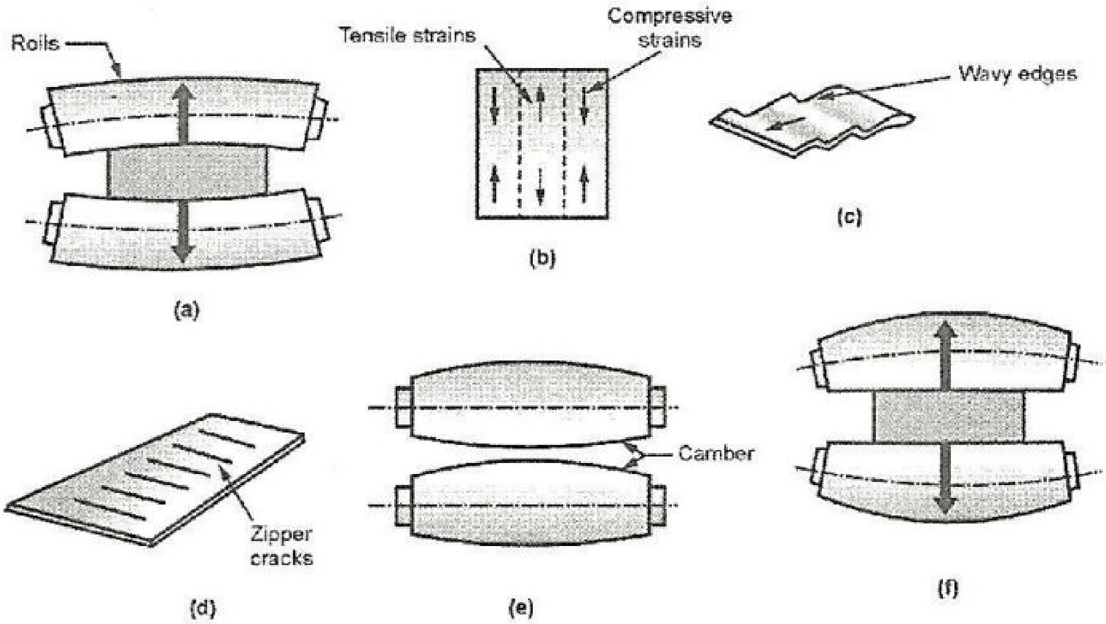


Fig. 3.43 : Rolling defects

- Rolls act as straight beams and due to rolling loads they deforms as shown in figure 3.43 (a). Due to this deformation, the edges of the workpiece get more compressed than the central region i.e. they form a shape of 'crown'.
- The reduction in thickness is converted into increase in length of the strip. Due to this, there are compressive strains on the edges and tensile strains at the centre as shown in figure3.43 (b).
- As the edges are restrained from expanding freely in the longitudinal direction, it results in wavy edges on the sheet as shown in figure 3.43 (c).
- Also, due to uneven ration of mean thickness to the length of the deformation zone, cracks may produce in the centre of the sheet. These cracks are called as **zipper cracks,** Refer figure 3.43 (d).
- To overcome these defects, generally the rolls are cambered i.e. their diameter is made slightly longer at the centre than at the edges as shown in figure 3.43 (e).
- Under loading action, the rolls will get flattened along the containing surface and provide a straight uniform gap to the strip as shown in figure 3.43 (f).

Folds: Folds are produced during plate rolling if the reduction per pass is very small.

Laminations: Due to incomplete welding of pipe and blow holes during rolling, internal defects like fissures are produced. Under severe conditions, these defects can result into small cracks or laminations which decrease the strength of material.

3. Other defects

i) Defects due to inhomogeneous deformation of elements across the width:

- When the workpiece passed through the rolls, the decrease in height results into increase in its length and there is lateral spread of the material.

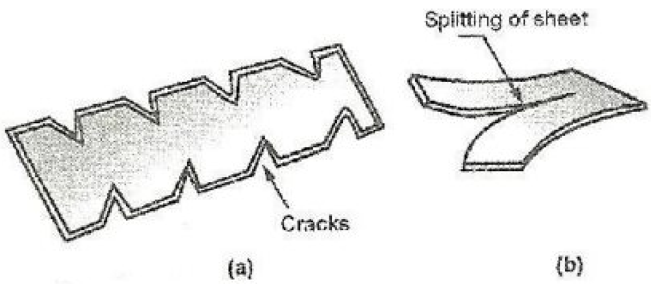


Fig. 3.44 : Other defects in rolling

- Due to continuity of material, the material near the edges will be under tension and near the centre will be under compression. This situation can lead to edge cracks as shown in figure 3.44 (a).

- Sometimes, these conditions may lead to split the sheet along the centre as shown in figure 3.44 (b).

ii) Defects due to inhomogeneous deformation in the thickness direction:

- While rolling, reduction in height is converted into increase in length of the sheet but all the elements do not undergo the same lateral deformation in the rolling direction. Due to this, barreled edge of the sheets is formed.
- With more sever conditions, the sheet-may rupture and follow the path of the respective rolls which results in **alligatoring** defect.

3.20 Cold Drawing

The most commonly used components which are cold drawn are tubes, bard, rods, wires and some typical shapes and items of novelties.

3.20.1 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.

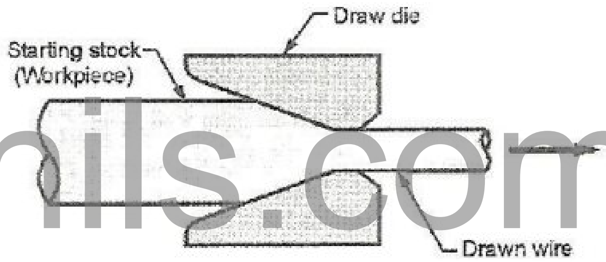
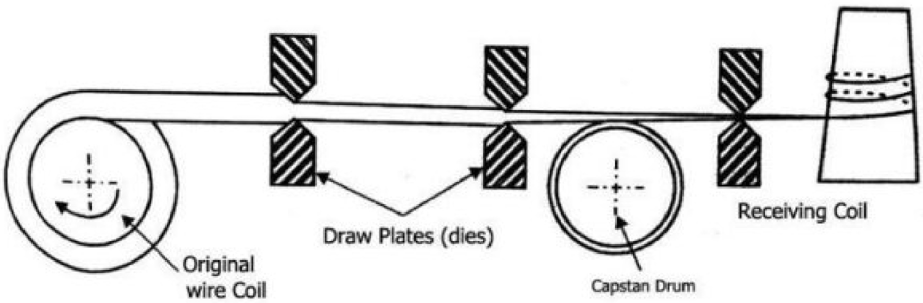


Fig. 3.45 : Wire drawing

- The general features of the drawing process are similar to extrusion. But the difference is that, in drawing the workpiece is pulled through the die whereas in extrusion workpiece is pushed through the die.
- During the process, tensile as well as compressive stress is 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.



- Wire size upto 0.03 mm can 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.
- 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.
- 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.

3.20.2 Tube Piercing

Tube piercing is the tube drawing with mandrel. In tube drawing, cylinders and tubes which are made by extrusion process is finished by drawing process.

Tube drawing is classified into:

1. Tube sinking
2. Tube drawing with plug, and
3. Tube drawing with mandrel

In tube sinking process, only the outer diameter of the tube is reduced. For reducing the inner diameter of the tube, the other two processes. i.e., tube drawing with plug or Tube drawing with mandrels is used.

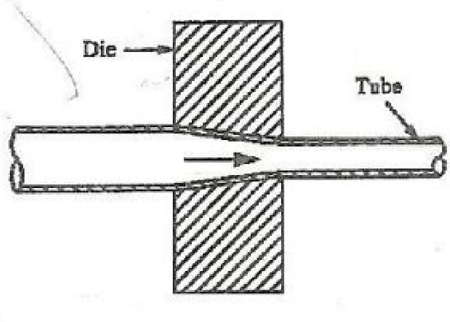


Figure 3.46 (a) Tube Sinking

In tube mandrel, the mandrel is place in the tube and the pull is given to the tube. It will reduce the inside diameter of the tube.

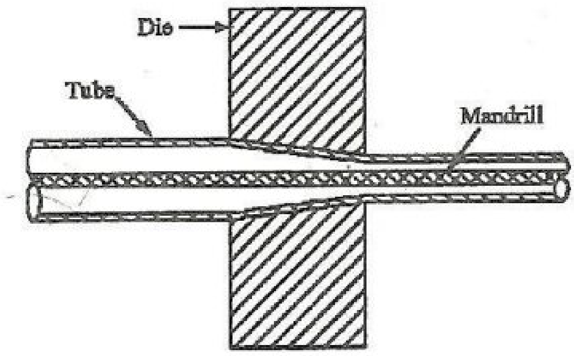


Figure 3.46 (b) Tube Mandrel

In plug drawing, both internal and external surfaces of the tube are controlled and the dimensional accuracy is good compared to other two methods. In this process, the plug is fixed or floating. The friction obtained in fixed plug is more than floating plug and drawing load is high is fixed plug and less in floating plug.

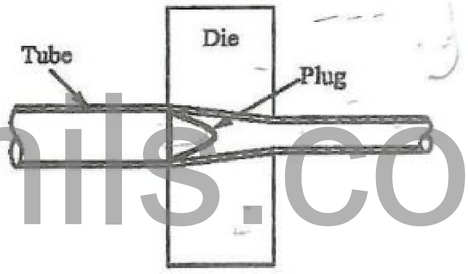


Figure 3.46 (c) Tube Plug

3.21 COLD FORGING AND SWAGING

3.21.1 Cold Forging

- Cold forging is a cold upsetting process adapted for large scale production of small cold upset parts from a wire stock. For example, small bolts, rivets, screws, pins, nails and small machine parts, small balls for ball bearing, etc.
- The machine used in the process is similar to hot forging.
- The dies are used for forming the required shapes.
- The rod is fed upto stops through straightening rolls, cut to size and pushed into the header die.
- The rod is gripped in the die and a punch operates on the projected part to apply pressure and form the head.
- During the process, a compressive force or impact causes the metal to flow in some determined shape of the die.

- Figure 3.47 shows the cold forming process in which the head will form in the punch, in the die, in punch and die or in between punch and die.

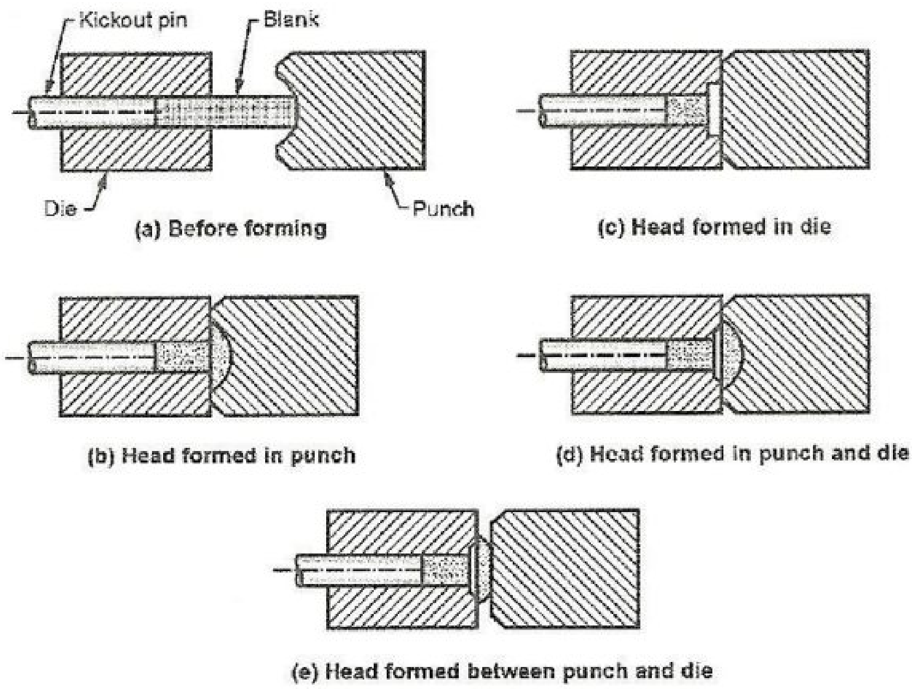


Fig. 3.47 : Cold forging process

3.21.2 Swaging

- Swaging term is applied to a number of metal forming operations.
- Swaging is also called as rotary forging.
- Swaging operations are generally performed on rotary swaging machines.
- Rotary swaging is a process of reducing the cross-sectional shape of bars, rods, tubes or wires by a large number of impacting blows with one or more pairs of opposed dies.
- The blows displace the metal and form the blank to the shape of the die.
- During the operation, as the die rotates around the workpiece, the final shaped is round.
- Swaging is an economical method for forming shapes usually confined to a portion of the total length of a given part, by pointing, tapering, reducing or sizing.
- The swaging process is also used for various joining and fastening operations.
- Figure 3.48 shows the principle of operation for a standard two-die rotary swager used for straight reduction of stock diameter or for producing taper and round stock.
- The die is engaged in a slot provided on the face of a spindle which rotates at a fairly high speed.
- Housing surrounds the spindle and a number of steel balls are provided between the spindle and the housing.

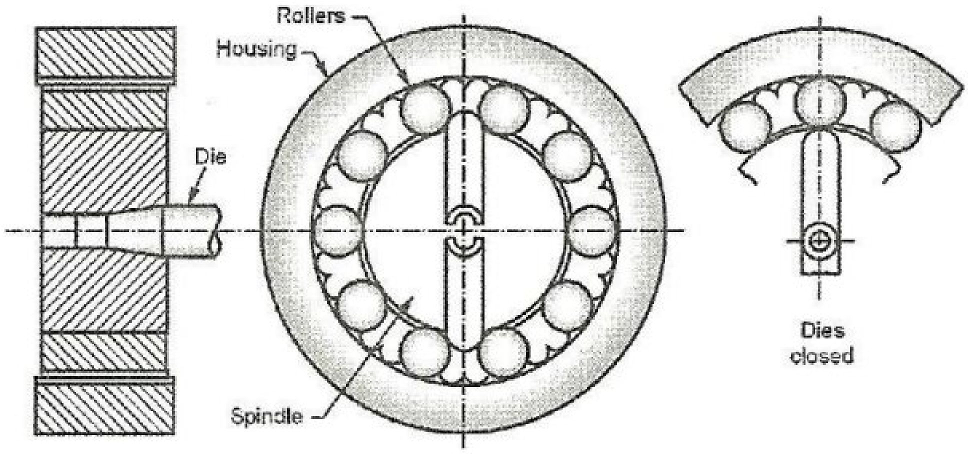


Fig. 3.48 : Operation of dies in a swaging machine

- As the spindle rotates the die passes between the pairs of opposite rolls, which close the dies.
- Hence, the dies are opened and closed alternatively as they pass between the gapes and rolls.
- Finally the metal is gradually squeezed to the desired shape and size.
- The metal gets hardened during the process because the swaging pressure is quite high and hence annealing has to be done.
- Commercial application of swaged parts includes various ratchets and sockets, various pins like guide pin, hinge pin, stop pin, shoulder pin, etc. Also, printed circuits, pen caps, shafts, spacers, umbrella components, mechanical pencils, metal chairs, table legs, etc.

Advantages of Swaging

- Tooling cost is high.
- Maintenance is easy.
- Initial investment is high.
- Semi-skilled operator is required, hence low labour cost.
- Production rate is high.
- Consistency of the product.

Limitation of Swaging

- Process is limited to parts of symmetrical cross-section only.

3.22 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 figure 3.49.

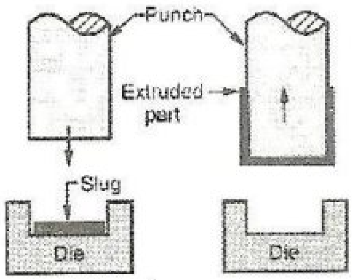


Fig. 3.49 : Principle of impact extrusion

- The metal flows up along the surface of the punch, forming a cup shaped 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, aluminium, zinc and some of their alloys.
- The main advantages of this process are its speed, product uniformity and no wastage.

3.22.1 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.
- Figure 3.50 shows the working principle of hydrostatic extrusion.
- Due to absence of wall friction, extrusion of very long billets or even wires and large reduction can be taken.

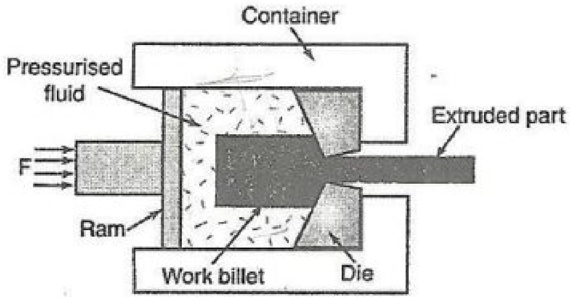


Figure 3.50 Hydrostatic Extrusion

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

Advantages

- The force required for hydrostatic extrusion is less as there is no friction between billet and container.
- Large billets and large cross-section can be extruded.
- This type of extrusion assures an even flow of material.
- High pressure in the operation improves ductility of metal.
- It allows for faster speeds, higher reduction ratios and lower billet temperatures.

Disadvantages

The billets must be prepared before use for extrusion. The entire billet must be machined to remove surface defects. It is difficult to handle fluid under high pressure.

3.22.2 Comparison between Hot and Cold Extrusion

Sl. No	Hot extrusion	Cold extrusion
1.	It involves working a metal above its recrystallization temperature.	It involves working a metal above its recrystallization temperature.
2.	It allows large amount of shape change.	It does not allow large amount of shape change due to stain hardening.
3.	It improves physical and mechanical properties of metal being extruded.	It does not improves physical and mechanical properties of metal being extruded.
4.	It is required to heat the workpiece before operation.	It is not required to heat the workpiece.

5.	Lower production rate than cold extrusion.	Higher production rate.
6.	Oxidation may takes place on the surface of workpeice.	There is no oxidation or scale formation on the surface of workpeice.
7.	Poor surface finish and accuracy of the part due to friction, wear and oxidation.	Higher accuracy and better surface finish.
8.	Hot extrusion is suitable for larger parts with more complex geometry.	Cold extrusion is suitable for smaller parts, less complex shapes and more workable metals.

3.23 Metal Forming Processes and Applications

Following table gives different metal forming processes along with their applications:

Sl. No	Metal forming process	Applications
1.	Rolling	It is used to produce articles like structural sections, sheets, rails, plates and bars.
2.	Extrusion	It is used to manufacture rods, tubes, various circular, square, rectangular, hexagonal rods and tubes both in solid and hollow form. Also for producing I,Z,T and sections.
3.	Drawing	It is used to produce bright drawn bards, solid drawn tubes and for the production of wires. Also for producing thicker walled seamless tubes and cylinders.
4.	Forging	Forged components are used in small tools, rail-road equipments and automobile and aviation industries. Also for production of rivets, screws, nuts, axles, leaf springs, gear blanks, engine housings, valve bodies, missile components, etc.