- 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.

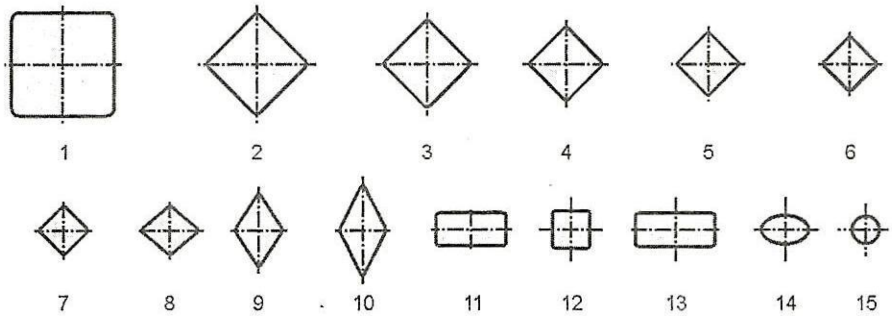

Fig. 3.6 : Various stages of rolling and number of passes for converting a steel billet into a round bar

- 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.

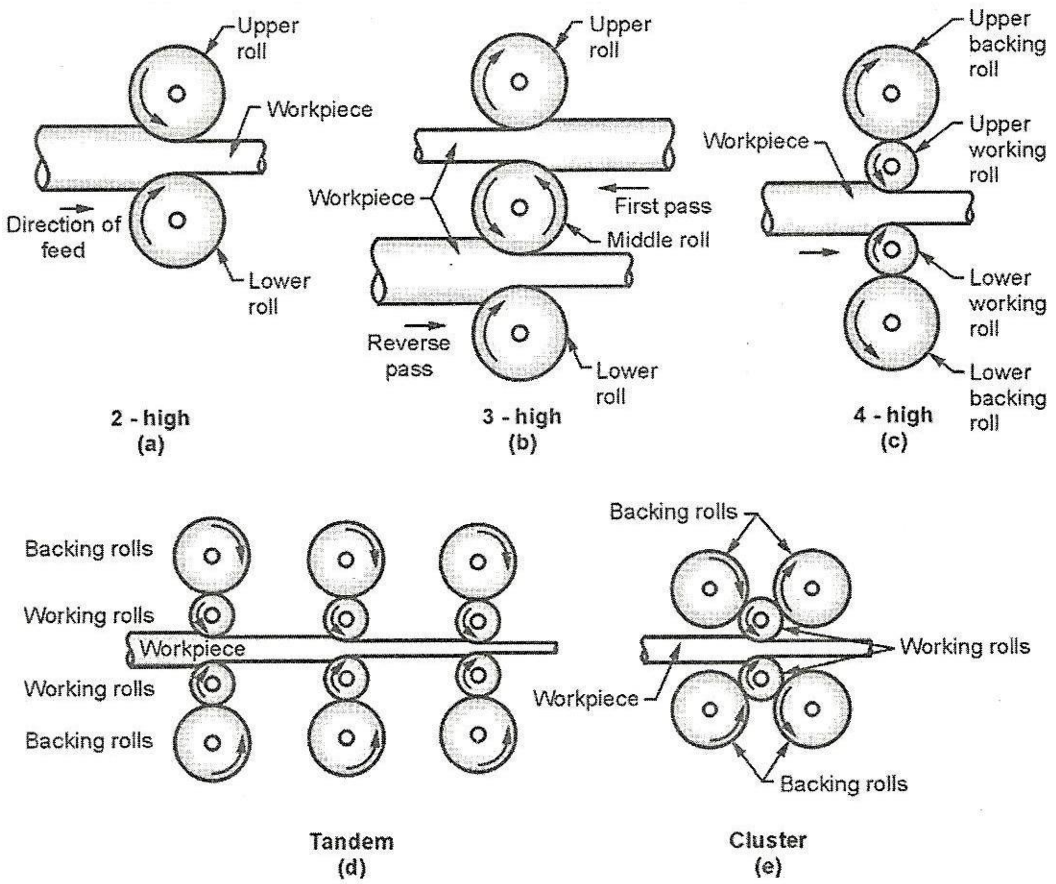

Fig. 3.7 : Types of rolling mills

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.

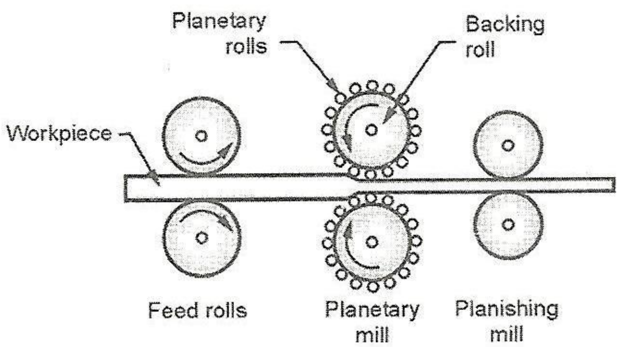

Fig. 3.7 (f) : Planetary rolling mill

- 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.

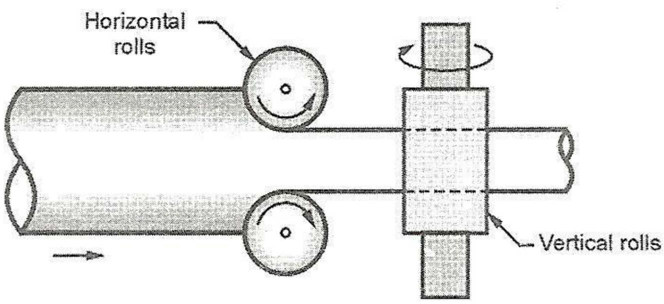

Fig. 3.7 (g) : Universal rolling mill

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).

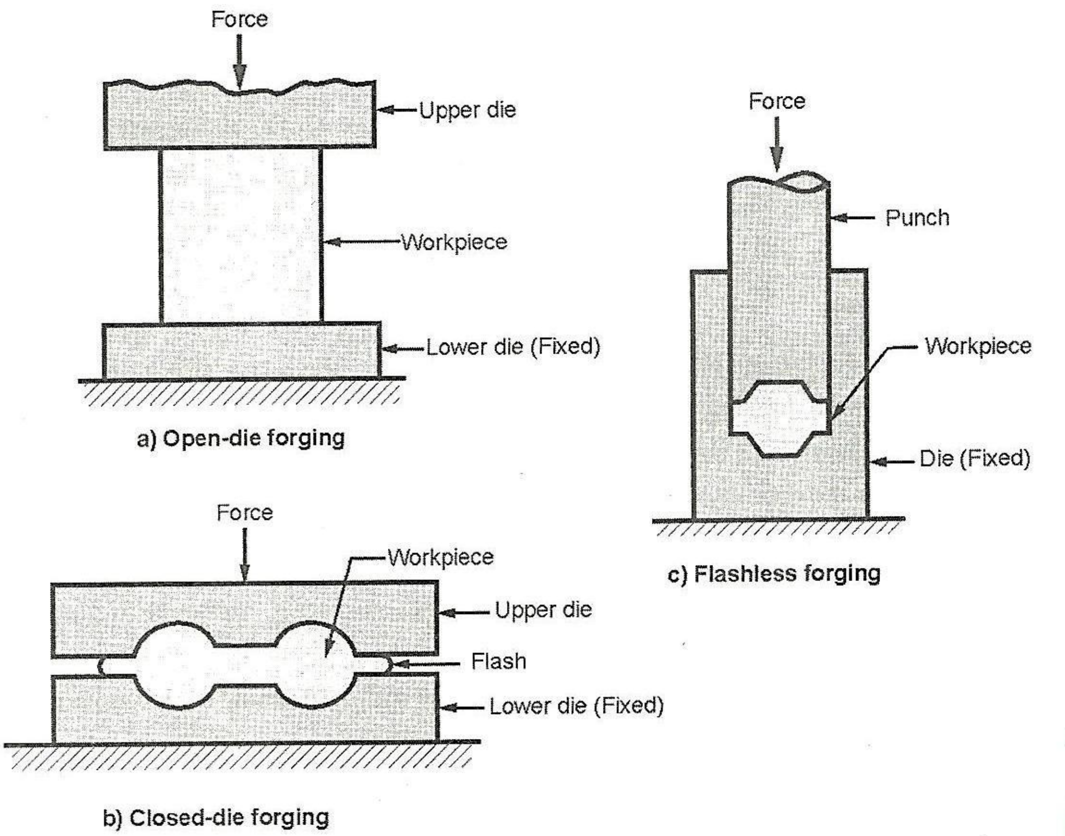

Fig. 3.8 : Types of forging operations

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.

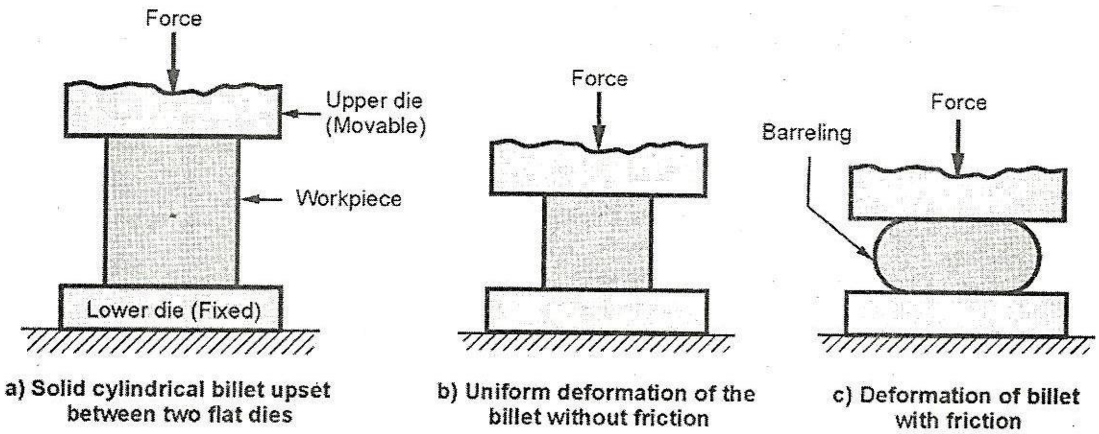

Fig. 3.9 : Open-die forging

- 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).

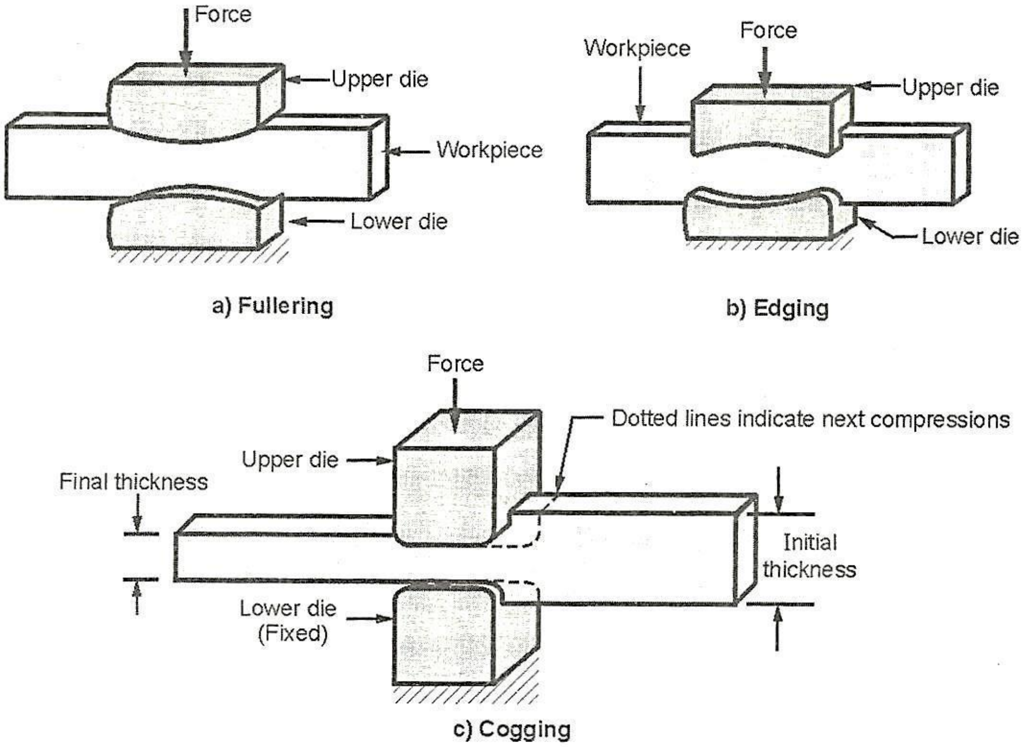

Fig. 3.10 : Open-die forging operations

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.

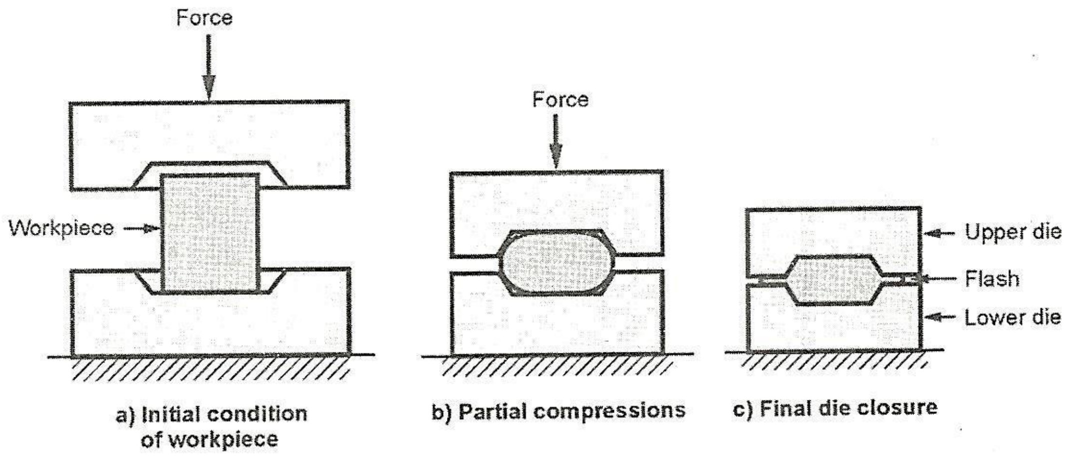

Fig. 3.11 : Closed or impression die forging

- 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.

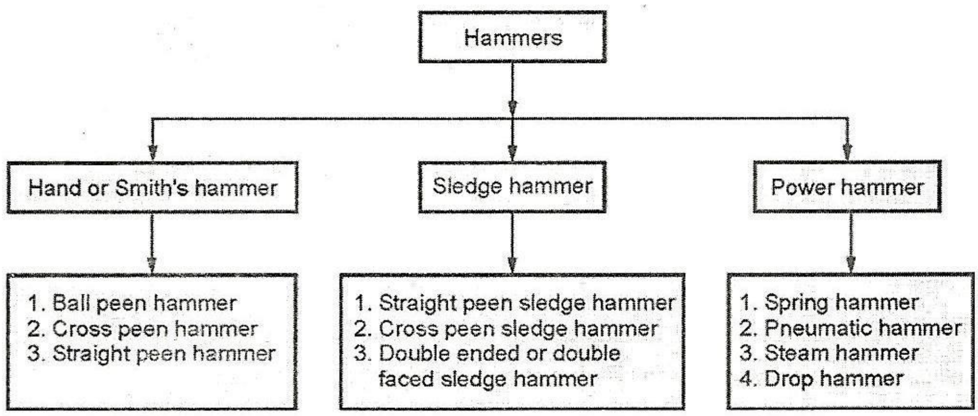

Fig. 3.12 : Types of hammers

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