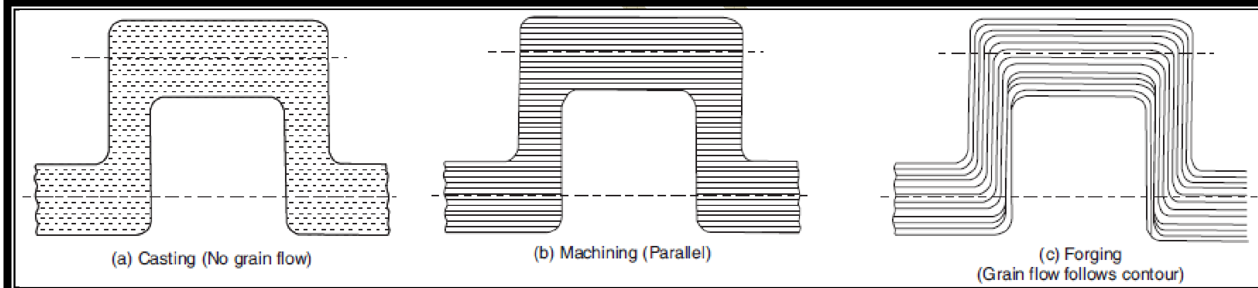
Syllabus covered in this notes:

Smithy and Forging (half part of UNIT-II):
Basic operation e.g. ***upsetting***, ***fullering***, ***flattening***, drawing and ***swaging***: tools and appliances: drop forging, press forging.

ADVANTAGES OF MECHANICAL WORKING PROCESSES

1. Mechanical working improves the mechanical properties of material like ultimate tensile strength, wear resistance, hardness and yield point while it lowers ductility. This phenomenon is called "***strain hardening***".
2. It results in grain flow lines being developed in the part being mechanically worked. The grainflow improves the strength against fracture when the part is in actual use. This is best explained by taking illustration of a crankshaft. If the crankshaft is manufactured by machining from a bar of large cross-section, the grain flow lines get cut at bends whereas in a crankshaft which is shaped by forging (which is a mechanical working process), the grain flow lines follow the full contour of the crankshaft making it stronger.
   This is shown in following figure.
   During mechanical working, the grains of the metal get deformed and lengthen in the direction of metal flow. Hence they offer more resistance to fracture across them. Hence mechanically worked components have better mechanical strength in a certain orientation *i.e.*, across the grain flow.



FORGING

In forging, metal and alloys are deformed to the specified shapes by application of repeated blows from a hammer.
It is usually done hot; although sometimes-cold forging is also done.

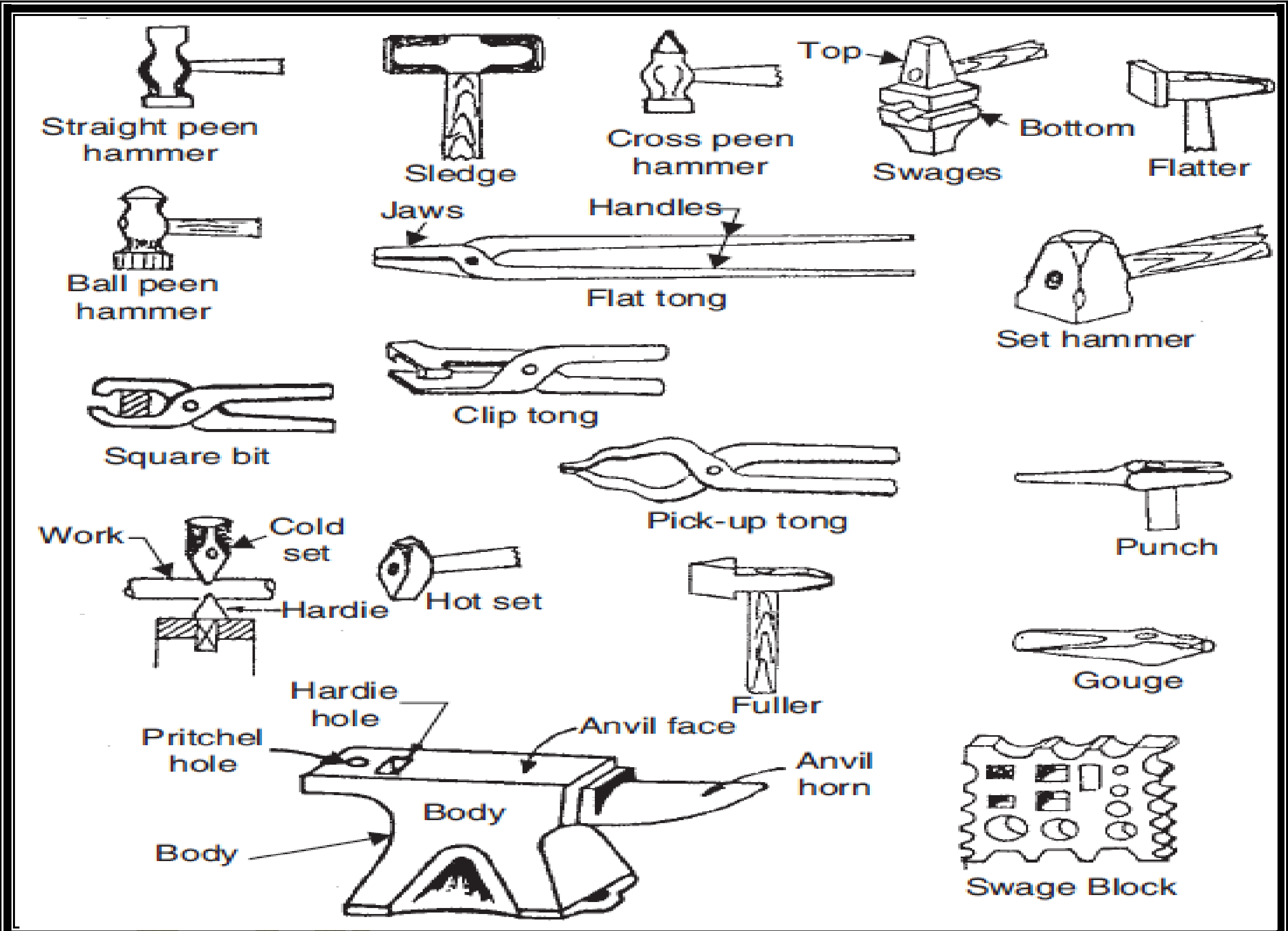
CLASSIFICATION OF FORGING:

(*a*) **Hand Forging:**

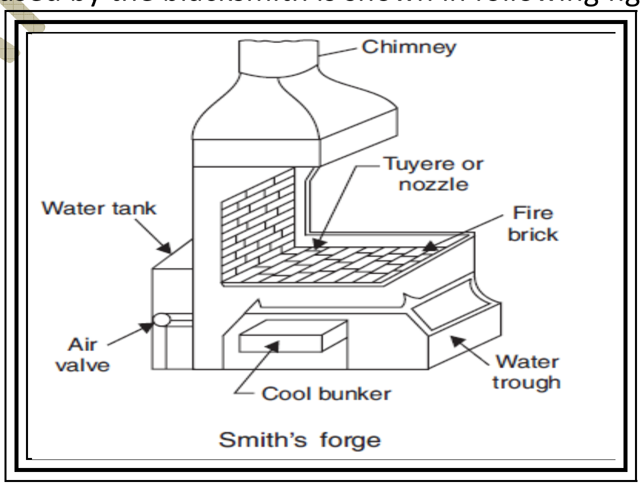
Under the action of the compressive forces due to hammer blows, the material spreads laterally *i.e.*, in a direction at right angles to the direction of hammer blows.
Obviously brittle material like cast iron cannot be forged as it will develop cracks under the blows from hammer.
An ordinary blacksmith uses an open-hearth using coke (or sometimes steam coal) as fuel for heating the metal and when it has become red-hot, blacksmith's assistant (called striker

on hammerman) uses a hand held hammer to deliver blows on the metal piece while the blacksmith holds it on an anvil and manipulates the metal piece with a pair of tongs. This type of forging is called "***hand forging***" and is suitable only for small forgings and small quantity production.

A blacksmith's ancillary equipment and tools used by the blacksmith are shown in following figure.



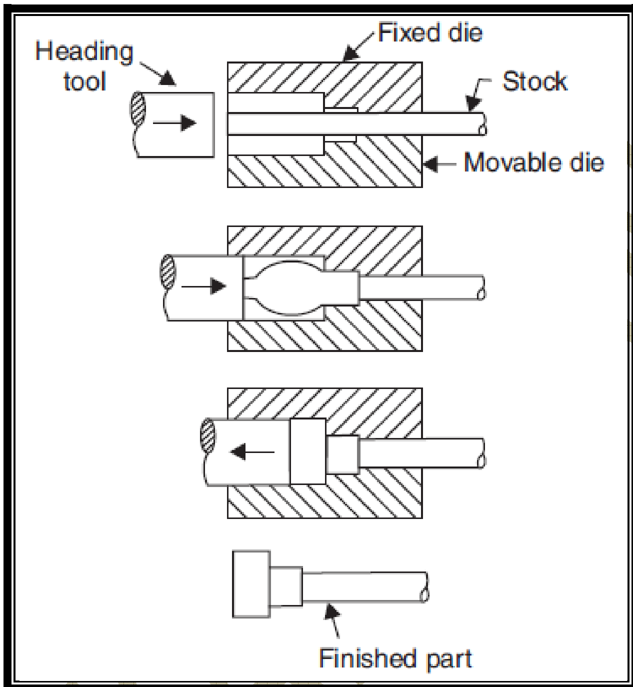
A blacksmith's hearth used by the blacksmith is shown in following figure:



Smith's forge

Basic forging operations employed in giving required shape to the work piece are described below:

(i) **<u>Upsetting</u>**: It is the process of increasing the cross-section at expense of the length of the work piece.



(ii) ***<u>Drawing down:</u>*** It is the reverse of upsetting process. In this process, length in increased and the cross-sectional area is reduced.

(iii) ***<u>Cutting:</u>*** This operation is done by means of hot chisels and consists of removing extra, metal from the job before finishing it.

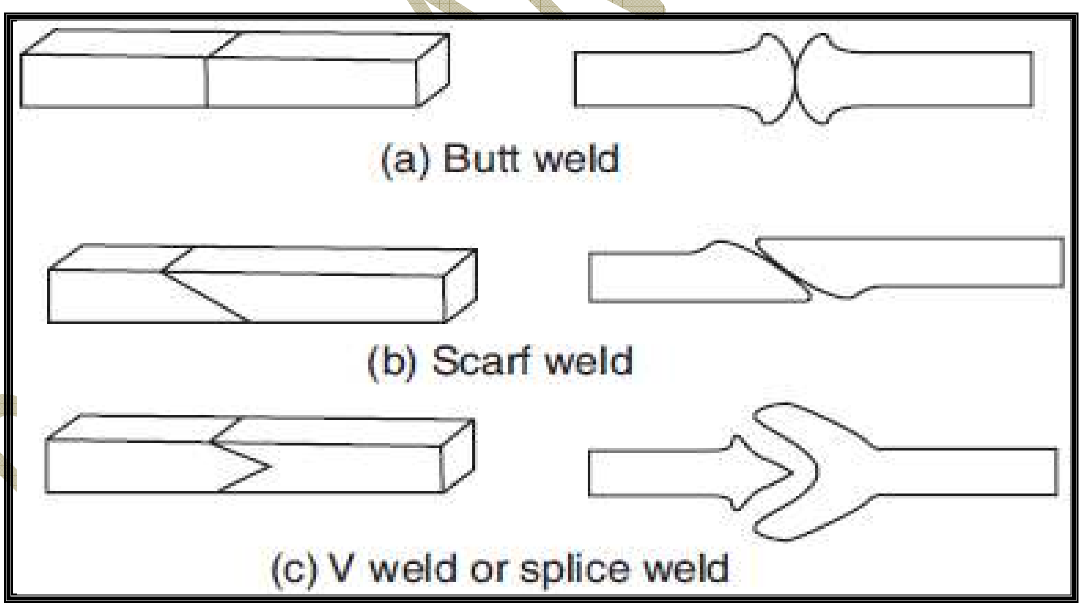
(iv) ***<u>Bending:</u>*** Bending of bars, flats and other such material is often done by a blacksmith. For making a bend, first the portion at the bend location is heated and jumped (upset) on the outward surface. This provides extra material so that after bending, the cross-section at the bend does not reduce due to elongation.

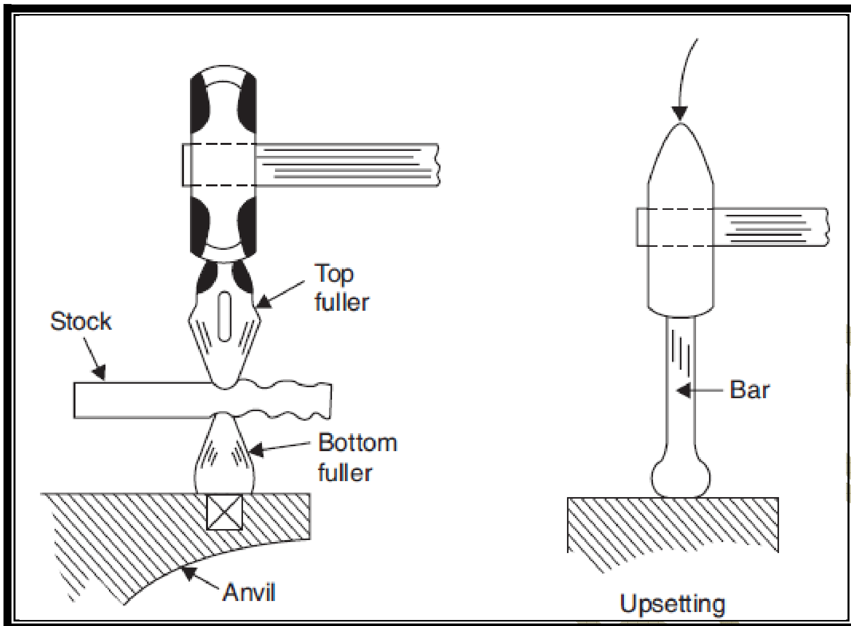
(v) ***<u>Punching and drifting:</u>*** Punching means an operation in which a punch is forced through the work piece to produce a rough hole. The job is heated, kept on the anvil and a punch of suitable size is forced to about half the depth of the job by hammering.
The job is then turned upside down and punch is forced in from the otherside, this time through and through.
Punching is usually followed by *<u>drifting</u> i.e.*, forcing a drift in the punched hole through and through. This produces at better hole as regards its size and finish.

(vi) ***Setting down and finishing:*** Setting down is the operation by which the rounding of a corner is removed to make it a square.
It is done with the help of a set hammer. Finishing is the operation where the uneven surface of the forging is smoothened out with the use of a flatter or set hammer and round stems are finished to size with the use of swages after the job has been roughly brought to desired shape and size.

(vii) ***Forge welding*****:** Sometimes, it may become necessary to join two pieces of metal. Forge welding of steel is quite common and consists of heating the two ends to be joined to white heat (1050°C – 1150°C).
Then the two ends of steel are brought together having previously been given a slight convex shape to the surfaces under joining. The surfaces are cleaned of scale. They are then hammered together using *borax as flux.*
The hammering is started from centre of the convex surface and it progresses to the ends. This results in the slag being squeezed out of the joint. Hammering is continued till a sound joint is produced.
Several types of joints can be made viz., ***butt joint, scarf joint or splice joint.***

Various forging operations described above and forge welding joints are shown in following Figures:



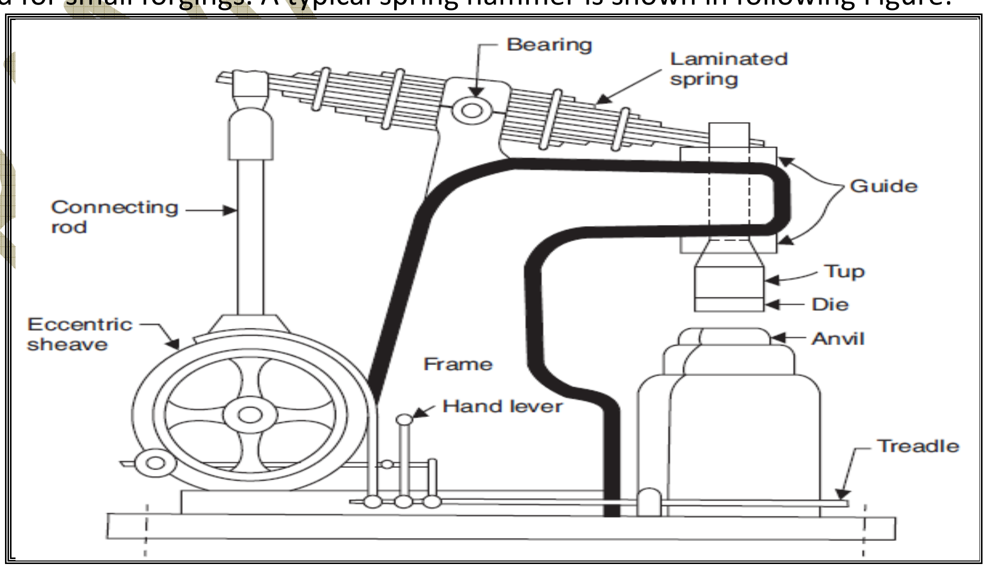


Fullering and Upsetting

(*b*) **Forging with Power Hammers:**

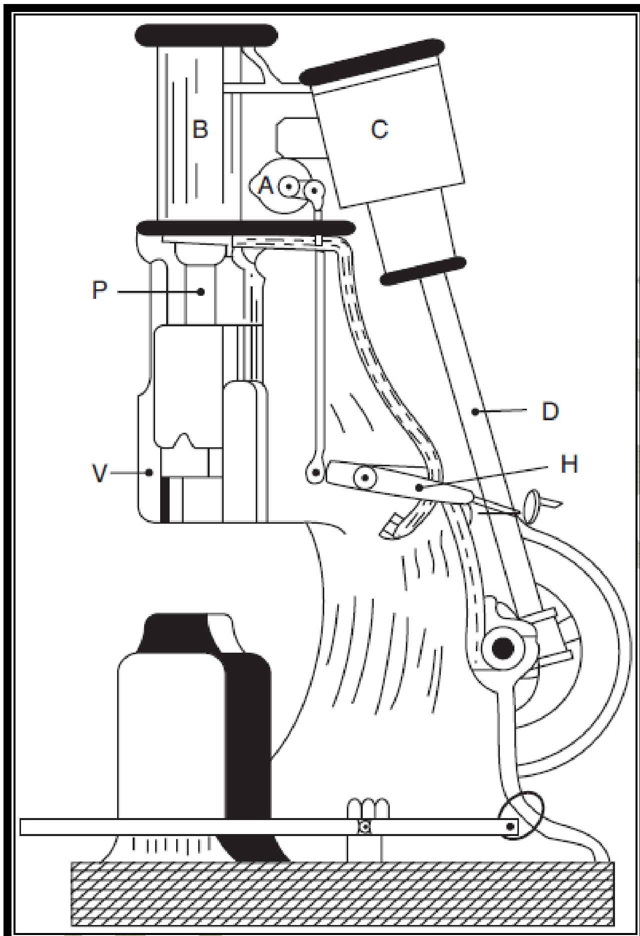
The use of hand forging is restricted to small forgings only. When a large forging is required, comparatively light blows from a hand hammer or a sledge hammer wielded by the striker will not be sufficient to cause significant plastic flow of the material. It is therefore necessary to use more powerful hammers. Various kinds of power hammers powered by electricity, steam and compressed air (*i.e.*, pneumatic) have been used for forging. A brief description of these hammers is now given.

(*i*) **Spring hammer:** It is a light hammer powered by an electric motor and gives repeated blows when it is operated by a foot operated treadle. This type of hammer is now obsolete and was best suited for small forgings. A typical spring hammer is shown in following Figure:



(*ii*) ***Pneumatic power hammers:***

A typical form of pneumatic hammer is shown in following figure:



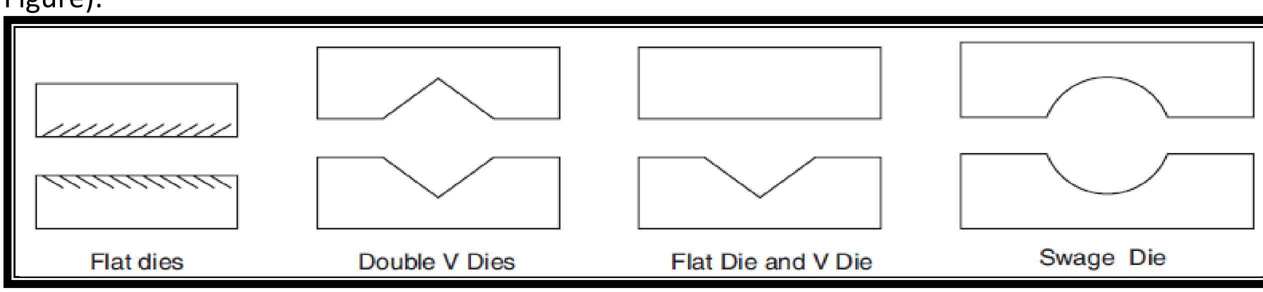
Typical Hot Working Temperatures:

Steels	650–1050°C
Copper and alloys	600–950°C
Aluminium and alloys	350–485°C

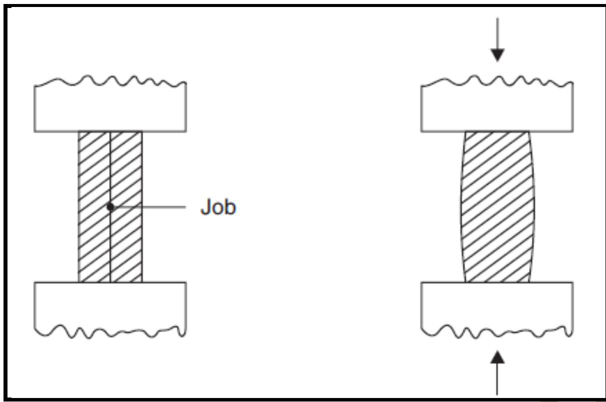
OPEN DIE FORGING

In this type of forging, the metal is never completely enclosed or confined on all sides. Most open dies forgings are produced on flat, V or swaging dies.

Swaging dies are usually round but may also be of other shapes *e.g.*, double V. (Refer following Figure):



The common "***upsetting***" operation done on a hammer can also be considered as an example of
open die forging with two flat dies as shown in following figure:



Advantages claimed for open die forging are:

(i) Simple to understand and operate

(ii) Inexpensive tooling and equipment as no die-sinking is involved and

(iii) Wide range of work piece sizes can be accommodated.

The *main disadvantage is low volume of production and difficulty in close size control*.

IMPRESSION DIE FORGING

Here half the impression of the finished forging is made in the top die and other half of the impression is sunk in the bottom die.
In impression die forging, the work piece is pressed between the dies.
As the metal spreads to fill up the cavities sunk in the dies, the requisite shape is formed between the closing dies.
Some material which is forced out of the dies, is called "*flash*". The flash provides some cushioning for the dies, as the tup strikes the anvil.
For a good forging, the impression in the dies have to be completely filled by the material.
This may require several blows of the hammer, a single blow may not be sufficient.
To facilitate the production of good forgings, the work piece may be given a rough shape by hand forging before die forging is done.

CLOSED DIE FORGING

Closed die forging is very similar to impression die forging, but in true closed die forging, the amount of material initially taken is very carefully controlled, so that no flash is formed. Otherwise, the process is similar to impression die forging. It is a technique which is suitable for mass production.

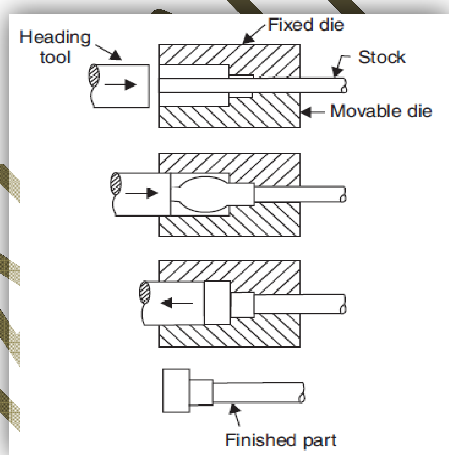
FORGING PRESSES

Occassionally, high capacity hydraulic presses are used for forging and the metal is shaped by squeezing action of the press rather than hammering action of hammer.

- Closed dies are used with impressions sunk in both dies, the upper die is fixed on the ram and the lower die is fastened to the platen of the press.
- Presses are usually of a vertical configuration. Presses produce forgings of a superior structural quality.

MACHINE FORGING (PRACTICAL APPLICATION OF FORGING)

For specific jobs like mass manufacture of bolts and nuts from bar stock, special forging machines have been developed. These machines work alongside a furnace in which one end of bar is heated for some length. The heated end of bar is than fed into the machine. With the help of dies and a heading tool, the hexagonal head of the bolt is forged by "upsetting". These machines are in reality horizontal mechanical presses which can be operated by a foot pedal. The die consists of two halves and a heading tool.
The sequence of operations can be understood from figure shown below:



FORGING DEFECTS

The common forging defects can be traced to defects in raw material, improper heating of material, faulty design of dies and improper forging practice.

<u>Most common defects present in forgings are:</u>

1. ***<u>Cold shuts or Laps</u>***: Cracks at corners i.e. at right angles to the surfaces
   It`s caused due to following over of a layer of material over another surface.
   Improper forging and faulty die design cause these defects.
2. ***<u>Incomplete forging or incomplete filling of Dies:</u>*** It is caused either due to less material or inadequate or improper flow of material.
3. ***<u>Scale pits</u>*** due to squeezing of scales into the metal surface during hammering action.

Scale is metal not removed or cleaned from dies.

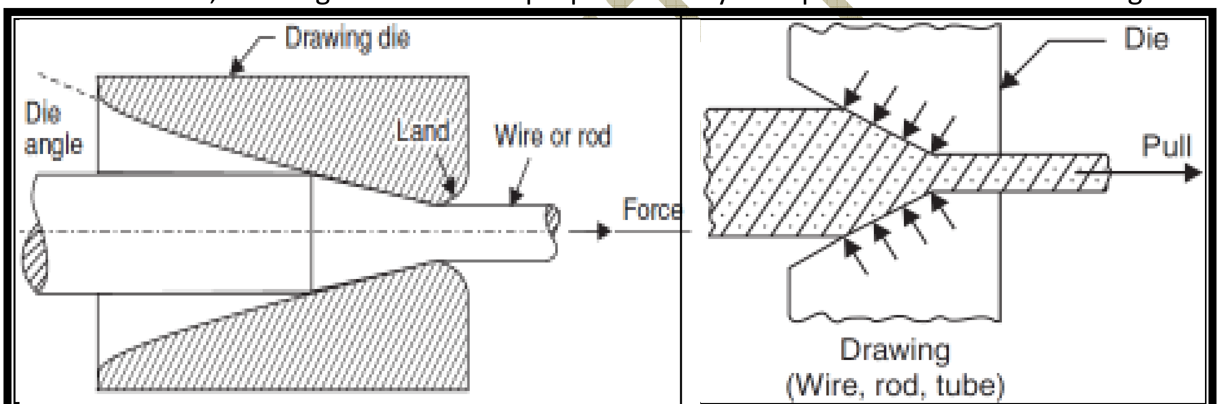
4. ***Mismatched forging*** due to improperly aligned die halves.
   It also give rise to *incorrect size of forging*.
5. ***Burnt or overheated metal***—due to improper heating.
6. Internal ***cracks*** in the forging which are caused by use of heavy hammer blows and improperly heated and soaked material.
7. ***Fibre flow lines disruption*** due to very rapid plastic flow of metal.
8. ***Blow Holes:*** blow holes if present in ingots then may also arise in forged piece or forging, but are eliminated to the large extent during forging.

DRAWING

Wire drawing is a simple process. In this process, rods made of steel or non ferrous metals and alloys are pulled through conical dies having a hole in the centre. The included angle of the cone is kept between 8 to 24°.

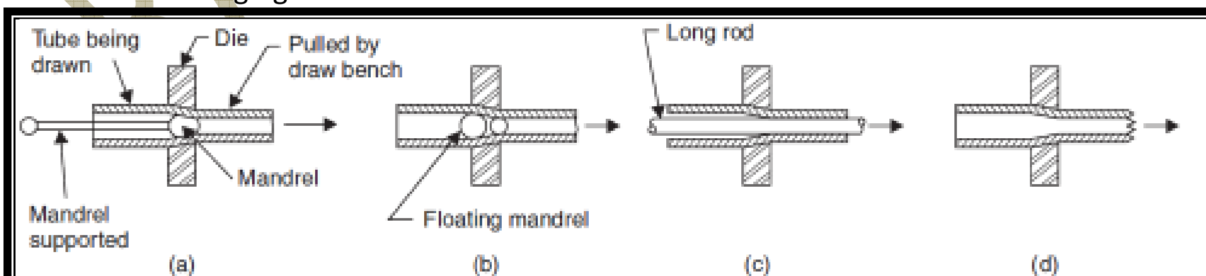
As the material is pulled through the cone, it undergoes plastic deformation and it gradually undergoes a reduction in its diameter.

At the same time, the length is increased proportionately. The process is illustrated in Fig. 4.7.



The 'drawing' process can also be used for *Tube drawing*.

Tube drawing does not mean manufacturing a tube from solid raw material. It means lengthening a tube reducing its diameter. Various arrangements used for tube drawing are shown in following figure:



- Method (*a*) is most commonly used.
- Method (*b*) uses a floating mandrel which adjusts itself to the correct position because of its stepped contour.

SOME OF THE OPERATIONS PERFORMED WITH PRESSES:

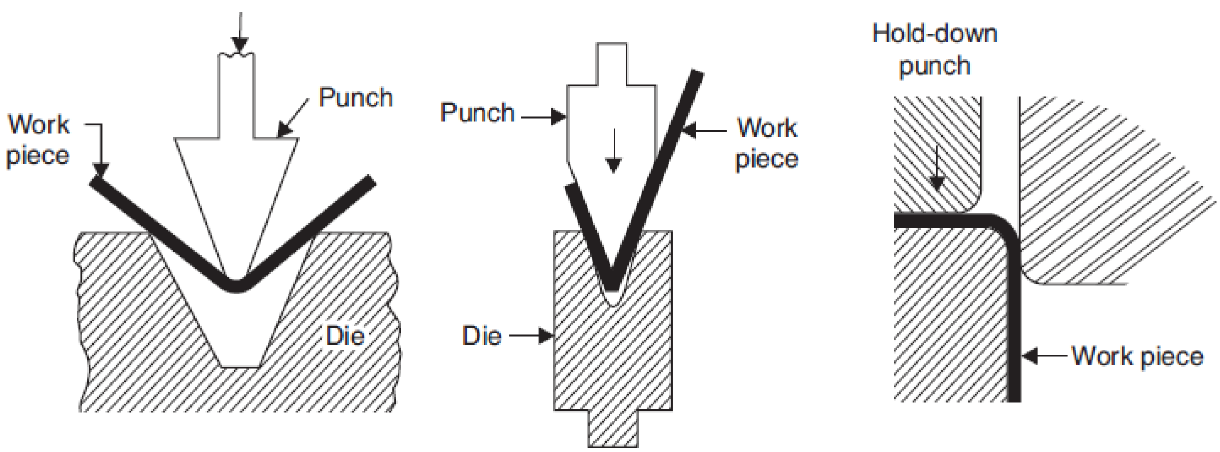
(*i*) Bending,
(*ii*) Deep drawing,
(*iii*) Coining, and
(*iv*) Embossing.

These operations are described briefly.

BENDING

Bending means deforming a flat sheet along a straight line to form the required angle. Various sections like angles, channels etc., are formed by bending, which may then be used for fabrication of steel structures.

Three common methods of bending are illustrated in following figure:



(a) Air bending (b) Die bending (c) Wiper bending

The operation of bending is done with the help of a V-shaped punch, a die and press specially designed for such work. The stroke of such presses can be controlled at operator's will and such presses are called press brakes.

In V-bending, a V-shaped punch forces the metal sheet or a flat strip into a wedge-shaped die. The bend angle will depend upon the distance to which the punch depresses. Bends of 90° or obtuse as well at acute angle, may be produced.

Wiper bending is used only for 90° bends. Here the sheet is held firmly down on the die, while the extended portion of sheet is bent by the punch.

Spring back: At the end of the bending operation, after the punch exerting the bending force is retrieved, due to elasticity, there is a tendency for the bend angle to open out. This is called "spring back".

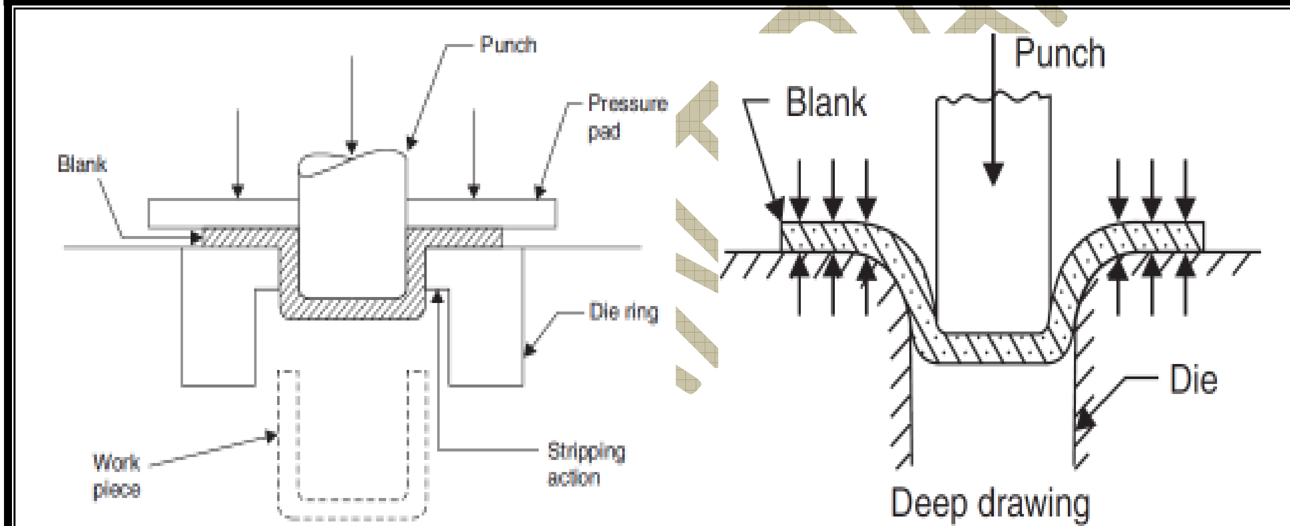
The effect of spring back may be offset by slight overbending in the first place.
For low carbon steels spring back is 1– 2°, while for medium carbon steel it is 3–4°.

DEEP DRAWING

In deep drawing process, we start with a flat metal plate or sheet and convert it into cupshape by pressing the sheet in the centre with a circular punch fitting into a cup shaped die.
In household kitchen, we use many vessels like deep saucepans (or BHAGONA), which are made by deep drawing process.
If the depth of cup is more than half its diameter, the process is termed as deep drawing and with a lesser depth to diameter ratio, it is called shallow drawing.

H > ½ D	DEEP DRAWING
H < ½ D	SHALLOW DRAWING

The deep drawing process is illustrated in following figures:



During the drawing process, the sheet metal part is subjected to a complicated pattern of stress.
The portion of the blank between the die wall and punch surface is subjected to pure tension, whereas the portion lower down near the bottom is subject both to tension and bending. The portion of metal blank, which forms the flange at the top of the cup is subjected to circumferential compressive stress and buckling and becomes thicker as a result thereof.
The flange has therefore to be held down by a pressure pad, otherwise, its surface will become buckled and uneven like an orange peel.
Deep drawing is a difficult operation and the material used should be specially malleable and ductile, otherwise it will crack under the induced stresses. The wall thickness of a deep drawn component does not remain uniform. The vertical walls become thinner due to tensile stresses. But the thinnest portion is around the bottom corner of the cup all around. This thinning of sheet at these locations is called "***necking***".
After deep drawing, the component may be subjected to certain finishing operations like "*irowing*", the object of which is to obtain more uniform wall thickness.

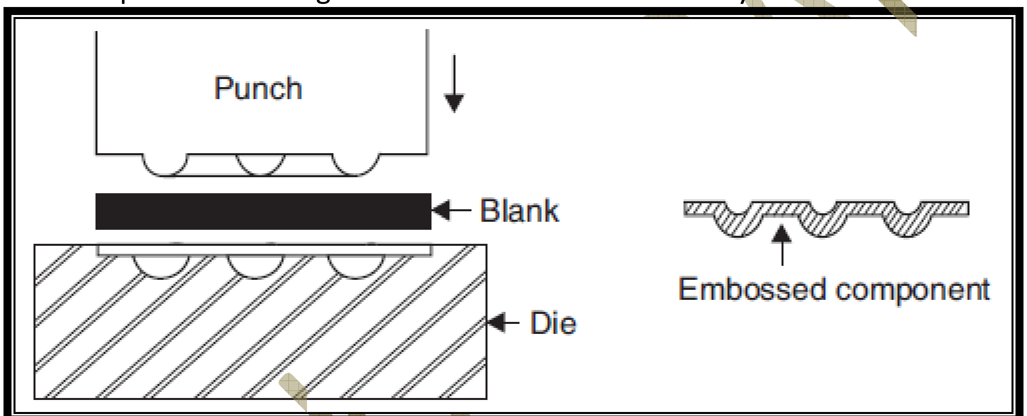
COINING AND EMBOSSING

Both coining and embossing operations are done 'cold' and mechanical presses with punch and die are used for these operations.

In ***embossing***, impressions are made on sheet metal in such a manner that the thickness of the sheet remains uniform all over even after embossing has been done. It means that if one side of the sheet is raised to form a design, there is a corresponding depression on the other side of the sheet.

Basically it is a pressing operation where not much force is needed. The sheet is spread on the bottom die and the stroke of the punch is so adjusted that, when it moves down to its lowest position, it leaves a uniform clearance between the impressions carved in the punch and the die which is equal to the thickness of the sheet being embossed.

Many decoration pieces with religious motifs are made in this way.



COINING

In coining process, a blank of metal which is softened by annealing process is placed between two dies containing an impression.

The blank is restricted on its circumference in such a manner, that upon the two dies closing upon the blank, the material cannot flow laterally *i.e.,* sideways. The material is only free to flow upwards (as a result of which it fills up the depressions in the upper die) and downwards (when it fills up depressions in the bottom die).

The result of the coining operation is that the design engraved on the top and bottom dies gets imprinted on the corresponding faces of the blank in relief (*i.e.,* raised material) without the size of the blank-circumference changing. Coins used as money in daily usage are manufactured in this manner. Here forces required are much higher, enough to cause plastic-flow of material.

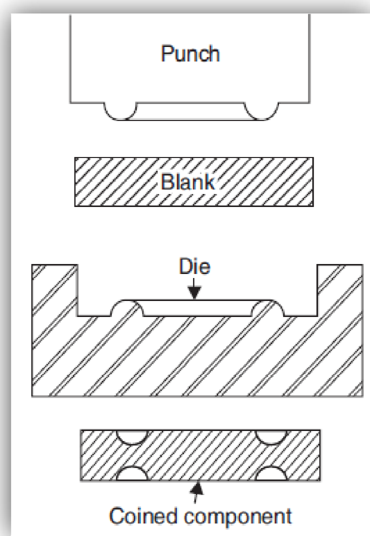
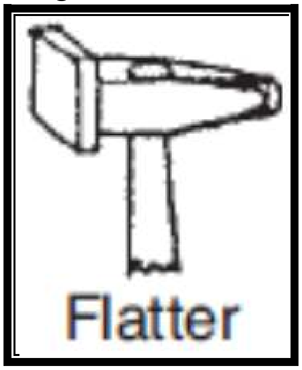
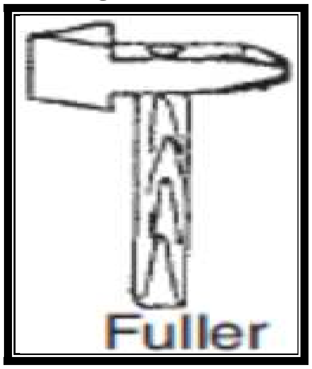


FIGURE: COINING PROCESS:

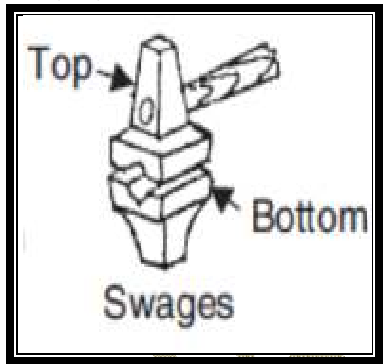
Flattening tool:



Fullering tool:



Swaging tool:



Anvil: