UNIT 6 SMITHYING AND FORGING

Structure

6.1 INTRODUCTION

In order to produce the desired shape or to improve the properties of any metal, shaping is done. Shaping process may be divided in two main groups as :

(a) cutting, and

(b) non-cutting.

Normally, the non-cutting shaping operation is referred to as mechanical working process. One such process is called smithying or forging.

Smithying is defined to handle relatively small jobs only such as those that can be heated in hearth or open fire, and the work is carried out by using of hand hammers or small power hammers.

Forging refers to the production of those jobs which must be heated in a closed furnace. The part of job where forging is done is termed as a forge. The work is normally performed by means of heavy hammers, forging machines, presses etc.

For obtaining certain desired properties in a metal or an alloy heat treatment is done. It is the operations or combination of operations of heating & cooling the metal in the solid state.

Objectives

After studying this unit, you should be able to

- explain the difference between smithying and forging,
- know about various tools, equipment, power hammers and presses etc.,

- identify which one is forgeable metal and which is not,
- describe in brief various operations which are performed in forging shops,
- know about rivet with its functions and classification,
- explain riveting process, and
- know the definition and function of heat treatment.

6.2 FORGING MATERIALS

In general practice, it is said that any metal or alloy which can be deformed in plastic stage through heating can be forged. The ability of material in getting forged is known as "Forgeability". For the material to be forgeable it should be ductile or in other words we can say that forgeable quality of any material is directly related to its ductility. Forgeability increases with temperature up to a point at which a second phase appears.

Wrought iron and different types of steels and steel alloys such as mild steel, carbon steel and tool steel, types of ferrous metals are the common raw materials for forging work. Low carbon steel responds better to forging work than the high carbon steel as the later requires greater care. The common non-ferrous metals and alloys used in forging work are copper, bronze, aluminum, brass and magnesium alloys etc.

6.3 TOOLS AND EQUIPMENT USED IN FORGING

To perform the different typical operations in forging shop, a number of tools and equipment are used as per their requirements and according to the nature of work. These are listed and discussed in detail below :

(a) Smith's forge
(b) Anvil
(c) Swage block
(d) Hammers
(e) Tongs
(f) Chisels
(g) Hardie
(h) Fullers
(i) Swage
(j) Flatters
(k) Punch and Drift
(l) Set Hammer

Smith's Forge or Hearth

It is used for heating purpose during the forging operation (Figure 6.1).

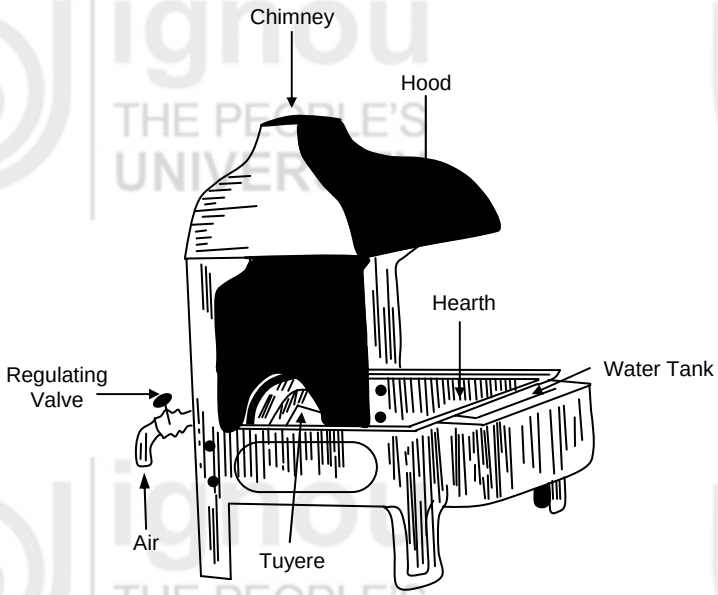

Figure 6.1 : Smith's Forge or Hearth

The structure of hearth is made of cast iron or cast steel. It has four-legged support, an hearth known as bottom, a chimney along with hood. A tuyere opening is also provided on the rear side of the structure to supply the air into the furnace. The hearth is covered by fire bricks lining. For quenching purpose, a water tank is also provided in front side of forge. Air under pressure is supplied to the furnace by the blower. A regulated valve is connected with the tuyere to control the supply of air to the furnace. It is specified according to the size of the hearth or by its weight.

Anvil

The Anvil (Figure 6.2) is used as a supporting device during hammering operation. The body of anvil is made of wrought iron or mild steel. At the top of the body, a hardened steel (High Carbon Steel) face is welded.

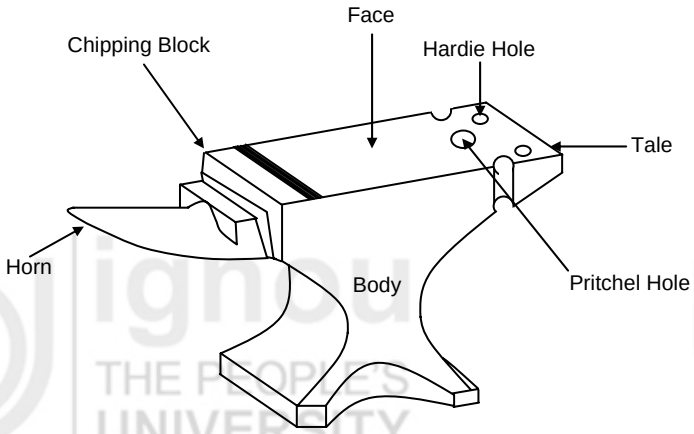

Figure 6.2 : Anvil

Face is used for general hammering work on job. Beak or horn part is used for bending or forming curved shapes. Between top face and horn, a chipping block is also provided which is used to support the job during cutting operation. The back part, known as tail, carries two holes which are hardie hole and pritchel hole.

The **hardie hole** is of square shape and is used for holding square shanks of swages fullers etc. while the **Pritchel hole** is of circular shape used for bending rods of small diameter and as a die for hot punching. The anvil is

supported either on an cast iron or hard-wooden base. Anvils are specified according to the weight and height of the top from the floor. Generally, by weight, 100-150 kg types of anvil are commonly used. Regarding the height it should stand about 0.75 meter.

Swage Block

It is a block of cast steel consisting of a number of slots of different shapes and sizes along its four side faces. It has through holes from top face to bottom face which vary in shapes and sizes (Figure 6.3). It is used for mainly squaring, sizing, heading, bending, punching and forming operations. The swage block is supported on a cast iron base. It is specified according to size of block or by weight.

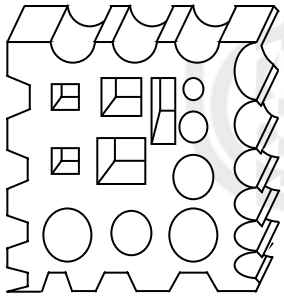

Figure 6.3 : Swage Block

Hammers

Hammers are the main striking tools made of forged steel, used in forging work. Generally, two types of hammer – hand hammer or smith's hammer and sledge hammers – are used in hand forging. Hand hammer is used by the worker himself while the sledge hammer is used by the striker.

Smith's Hammer

Hammer has four main parts, namely,

(a) Peen
(b) Cheek
(c) Eyehole
(d) Face

Figure 6.4(a) shows the different parts of hand hammer or smith's hammer.

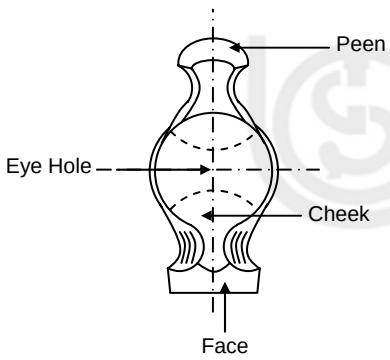

Figure 6.4(a) : Smith's Hammer

Hand Hammers may be classified as ball peen hammer, cross peen hammer and straight peen hammer.

Ball Peen Hammer

The peen has a shape of ball which is hardened and polished. Particularly this type of hammer is used for riveting and chipping purpose.

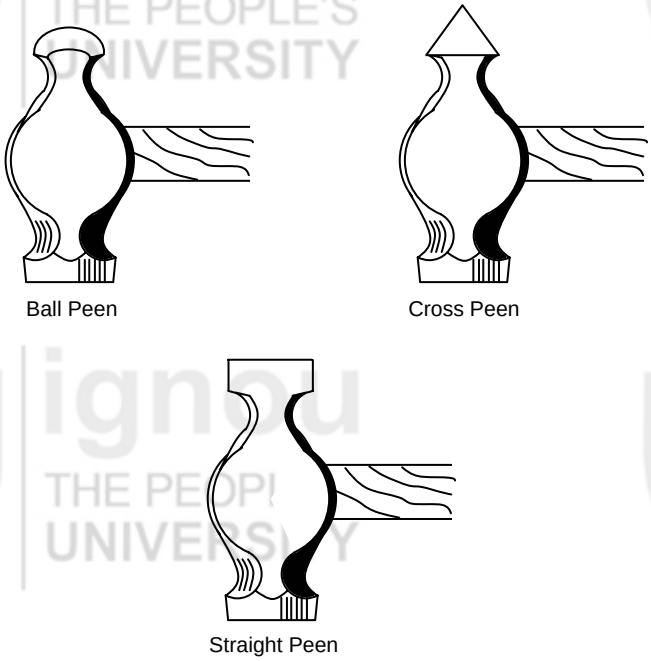

Figure 6.4(b) : Types of Hammer

Cross Peen Hammer

It is similar to ball peen hammer except the peen which is across the handle. It is mainly used for bending and hammering into shoulders etc.

Straight Peen Hammer

It has a peen straight with the handle that is parallel to the handle and is specially used for peening or stretching the metal.

Above mentioned hammers are shown in Figure 6.4(b).

Sledge Hammer

It has double faces on both ends as shown in Figure 6.4(c). Sledge hammers are comparatively heavier than hand hammers. Therefore, they are used for heavy type of forging work when heavy blows are needed.

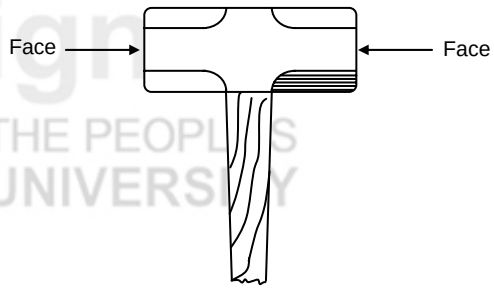

Figure 6.4(c) : Sledge Hammer

Hammers are made of cast steel and they are specified according to the weight and shape of peen (in case of hand hammer). As per weight, hand hammer vary from about 0.5 to 2 kg while the weight of sledge hammer from 4 to 10 kg.

Tongs

The work to be forged is generally held with various types of tong such as flat tong, round and square hollow tong, ring tong and GAD tong etc. Tongs are generally made of mild steel in two pieces, which are riveted together to form a hinge. One side of the hinge carries the holding jaws of different shapes and sizes while on other side, the longer portion is called arms. Jaws are used for holding the jobs while the movement of jaws for proper gripping of job is adjusted by applying suitable hand pressure on the arms. Generally, tongs are specified according to length of arm and shape of jaws opening.

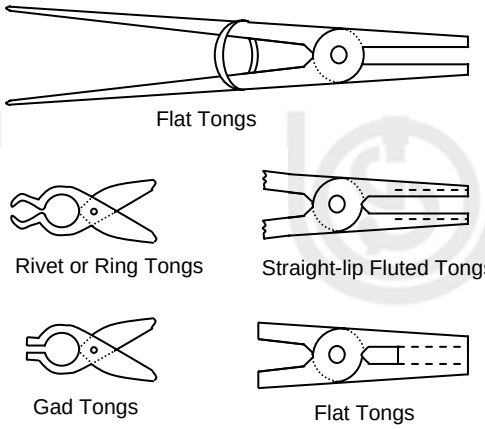

Figure 6.5 : Different Types of Tong

The tongs generally used for holding work are as shown in Figure 6.5.

Flat tong used for holding work is of rectangular section**. Straight lip fluted tongs** are used for circular, square or hexagonal section. **Ring tong** is used for rivet bolt and other work of circular section. **Gad tong** is used for pick up work for straight or tapered type of section.

Chisels

Chisels are used for cutting purpose. Two types of chisel – cold chisel and hot chisel – are commonly used in forging work as shown in Figure 6.6. It depends upon the nature of work what type of chisel is to be preferred. Cold chisel is made of high carbon steel, having an inclined angles of 60^o at the cutting edge. As it is used in cold stage, therefore it should be well hardened and tempered. Hot chisel is made of medium carbon steel with an inclined angle of about 30^o. As the hot chisel is used to cut the metal in plastic stage, there is no need of hardening it. The cutting edge is made slightly rounded for better cutting action. All these chisels are specified according to width of cutting edges.

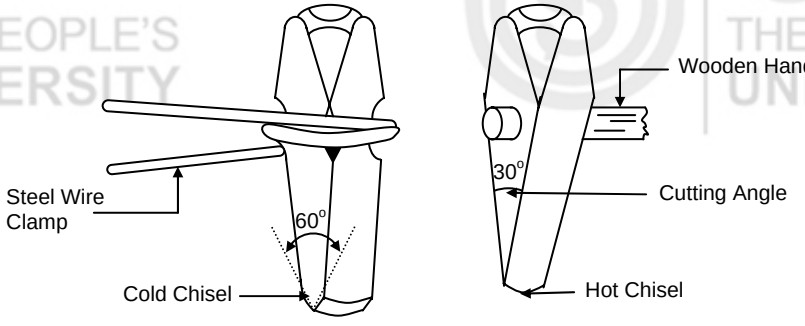

Figure 6.6 : Types of Chisel

Hardie

It is fitted in the hardie hole provided in the tail of anvil. It has a cutting edge at the top of body. During cutting or shearing operations, chisels are used in conjunction with this bottom cutting tool. It is made by high carbon steel.

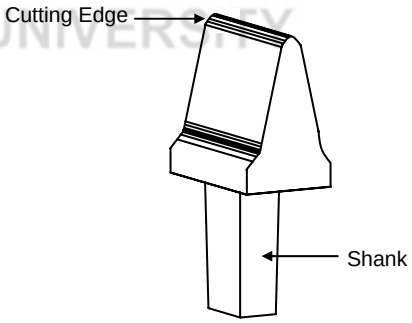

Figure 6.7 : Hardie

Fullers

These are also made of tool steel (high carbon steel). They are used in pairs (top and bottom). Bottom-one part of fuller is held in hardie hole of anvil with its square shape of shank. They are used for necking down or to reduce the cross section of a job. In some cases, they are also used in drawing out operation (Figure 6.8).

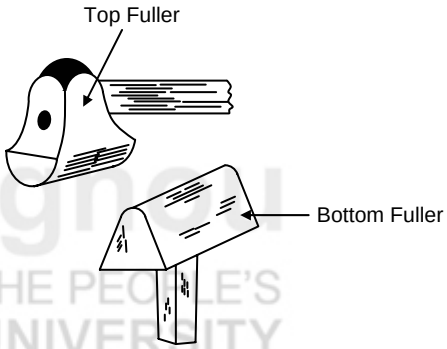

Figure 6.8 : Fullers

They are available in various sizes and shapes as per needs. The size of fullers is specified according to the width of fuller edge.

Swage

Just like fuller, these are also made in pairs that is top and bottom swages. The bottom part of swage is fitted in hardie hole of anvil. They are made by high carbon steel (Figure 6.9). The top part like fuller carries a wooden handle. After forging, finishing circular shape of job or for increasing the length of circular rod in circular shape, types of operation are performed by using swage.

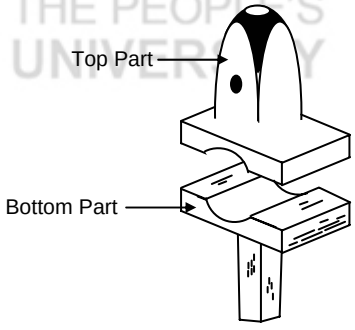

Figure 6.9 : Swage

Flatters

It is also made of high carbon steel. It has a flat square shape bottom as shown in Figure 6.10. A handle is fitted with body. These are used to give smoothness & accuracy to surfaces which have already been shaped by fullers and swages.

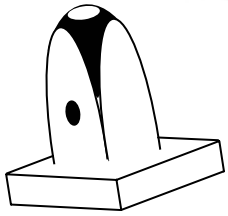

Figure 6.10 : Flatter

Punch and Drift

Both are made by high carbon steel. Punches are available in various shapes and sizes as per need of work. They are used for making the hole in a job which is at red hot condition.

After punching operation, drift is used to expand or open the hole up to required size. Drift is also a large sized punch.

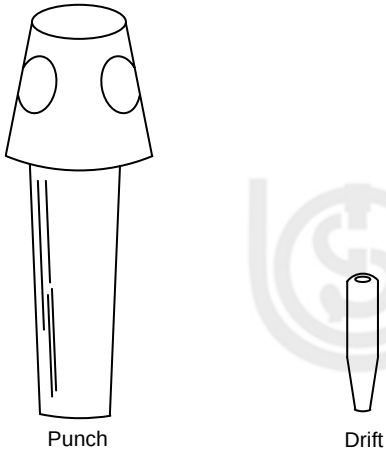

Figure 6.11 : Punch and Drift

Set Hammer

It is used for finishing corners and shouldered work where the use of flatter is inconvenient. It is made by high carbon steel and may also be used for drawing out purpose.

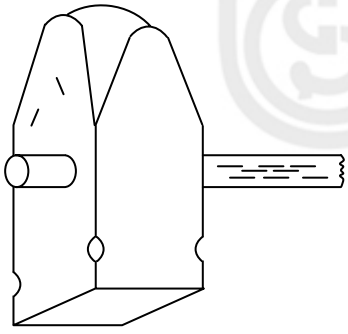

Figure 6.12 : Set Hammer

SAQ 1

(a) State the difference between smithying and forging.

(b) Name at least five numbers of smithying tools. Briefly state their uses.

(c) Name and explain, in brief, the common materials used for forging.

6.4 FORGING OPERATIONS

A number of operations are used in forging work for changing the shape of given raw material to the finished or required shape. They are listed and described below :

(a) Upsetting or Jumping

(b) Bending

(c) Cutting

(d) Drawing down

(e) Setting down

(f) Welding

(g) Punching and Drifting

(h) Fullering

Upsetting or Jumping

By using upsetting or jumping processes, the cross section or thickness of a workpiece is increased with a corresponding reduction in its length. During this process, the workpiece is heated up to plastic stage and then by applying the pressure with the help of hammer, the metal tends to increase in its dimensions at 90^{o} to the direction of application of force with a corresponding reduction in its dimensions parallel to the line of action of applied force.

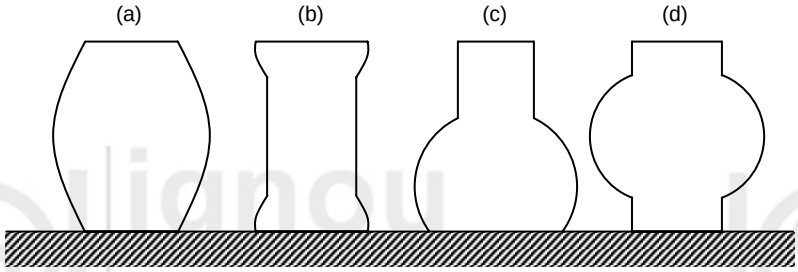

Figure 6.13

Figure 6.13 shows the upset forging operation when

(a) the upsetting is to be done throughout the entire depth,

(b) upsetting is done at both ends of the workpiece. The center part which is not to be jumped, cooled by quenching in water,

(c) jumping takes place at the lower part, and

(d) jumping takes place at the middle part.

Bending

Generally, two types of bending curvilinear and angular – are commonly used in practice. Bending operation is an important operation in forging shop. Bars and flats types of metallic job are bent into required shape by using this bending operation in forging shop.

Bending is done over the anvil face, over the anvil horn or over special forms or for bar stock, by inserting the end in the Pritchel hole of anvil and then bending the bar with a tong or wrench. During this bending operation, the layers of metal on the inside are shortened while on the outside are stretched.

For making an angular bending, the portion of the job, which is to be subjected in bending, is heated and then jumped on the outer surface. Additional metal must be worked to the place where the bend occurs. During bending operation this additional metal will try to make up the corners.

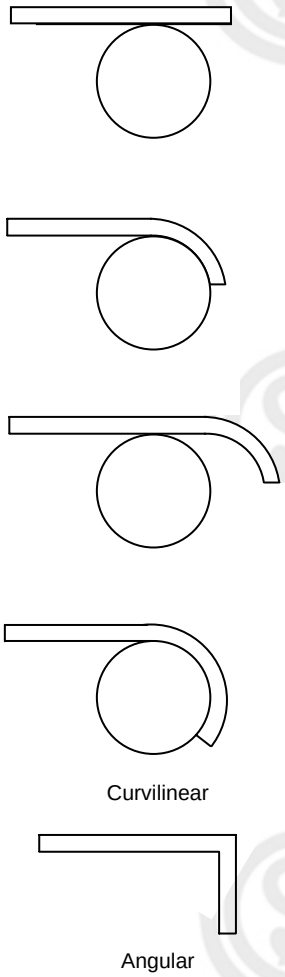

Figure. 6.14 : Stages in Bending

After bending outside edge formation is prepared by using a flatter and the inside edge by means of a set hammer. Figure 6.14 shows the stages in bending over the horn of anvil by using hammering.

Cutting

It is done in both hot and cold condition by using hot and cold types of chisel respectively. Cutting operation defined as a forging is separated from

its stock, a long piece metal is cut into several pieces of required length or in removing extra metal from the job before finishing it.

Cold cutting is preferred for thin flat or round sections while for hot cutting stock should be heated in a black smith's hearth or furnace to a light cherry red hot condition that is from 850^{o}C to 950^{o}C temperature. When cutting takes place by means of chisels, the hammer blows are directed on to the chisel head which must be slightly rounded.

A chipping block is also provided on the top of anvil head in between horn and face. It may also be used for cutting purpose.

Drawing Down

It is also known as swaging or drawing out. By this process the length of a bar stock may increased with a corresponding decrease or reduction in its thickness, width or both of a bar stock. In other words, it is exactly a reverse process to that of upsetting or jumping.

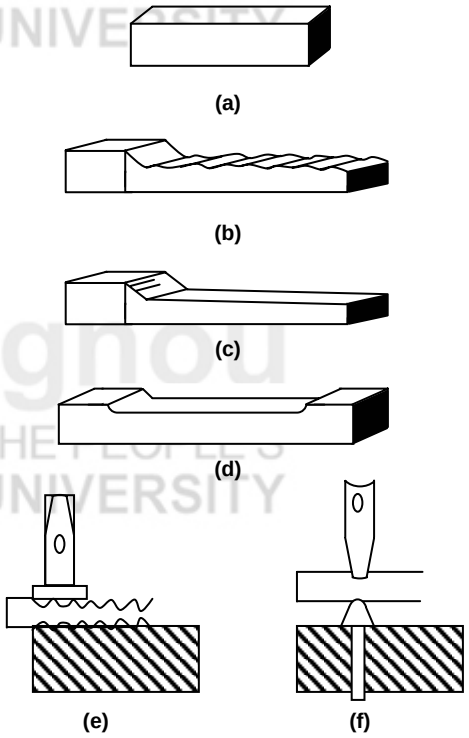

Figure 6.15

Figure 6.15 illustrates this operation. Figure 6.15(a) represents the original stock. Figure 6.15(b) shows the stock after hammering with a straight peen hammer or with a top and bottom fuller. Figure 6.15(c) shows the finished forging after the flatter has been used. In all cases, striking is done by sledge hammer.

Setting Down

Through this operation, roundness of a corner is changed to make it square, by using set hammer. Figure 6.15(d) illustrates the operation of local thinning down by using set hammer. Normally, the length will increase at the place where the setting down is used. Figure 6.15(e) shows the process of setting down both faces of a bar by using a top and bottom fuller and Figure 6.15(f) illustrates how the flatter may be used close to a shoulder.

It is also an important operation performed by smith's in forging shop. In this operation, two pieces of a same metal are joined together so that they may act as a single one. For it, given pieces are heated in the smith's hearth up to a required temperature and then they are withdrawn from the furnace and joined together by the application of external pressure through hammering. For the protection of heated metal from oxidation, borax is used as a flux. For getting a sound welded joint, following points are to be taken into consideration

(a) Surfaces to be joined should be quite clean and free from scale, dirt or ash as their presence will lead to the failure of the joint.

(b) Heating of job should be taken up to a required temperature as incorrect temperature will lead to the spoiling of the joint.

Punching and Drifting

As we know, it is a process of producing holes generally in round shape by using punch.

In this operation, stock of bar is placed on the pritchel hole of the anvil or over a correct hole of swages block (Figure 6.16) and then a punch in hot condition is used for producing the hole. External pressure on punch is given by using hammering.

Punching by using die, is usually followed by drifting. In this, drift as a tool is made to pass through the punched hole to produce a finished hole of a required size.

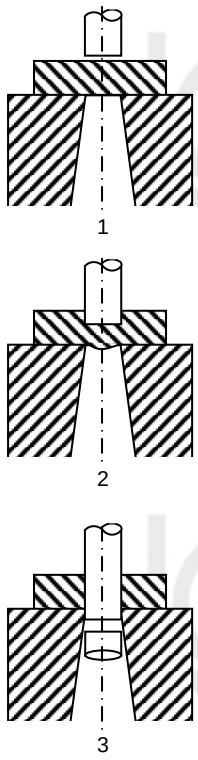

Figure 6.16

Fullering

In this operation main target is to increase the width along with a slight change in length. Fullering operation should always be started at the centre part of stock.

6.5 POWER HAMMERS AND PRESSES

6.5.1 Power Hammer

Main principle of operation for all power hammers is common, i.e. a falling weight striking the blow, with the entire energy being absorbed by the work. How much striking weight is required, it totally depends upon the nature of work. A 300kg hammer will be one of which the falling parts weight 300 kg. The heavier these parts and greater the height from which they fall, the higher will be intensity of blow the hammer will provide.

6.5.2 Classification of Power Hammers

Generally, there are three types of power hammer, which are widely used in forging work. These are :

(a) spring power hammer,

(b) steam or air power hammer, and

(c) pneumatic power hammer.

Spring Power Hammer

It is also known as mechanical power hammer. Being light in weight, it is best suited for small forging.

It consists of a heavy rigid frame, carrying vertical projection at its top. This projection works as housing for bearing in which the laminated spring oscillates. At the rear end of this spring carries a connecting rod while the front end, a vertical tup which carries weight and moves vertically up and down along with fixed guides, already provided for this purpose. The connecting rod at its bottom end is attached to an eccentric sheave which is directly connected to the crank wheel as shown in Figure 6.17.

For operating the hammer, the treadle is pressed in downwards position which rotate the sheave through the crank wheel and thus the laminated spring starts to oscillate in the bearing. Oscillation of spring causes the Tup to move up and bottom position and thus the required blows are provided on the job. These are built with ram weighing from 30-250 kg.

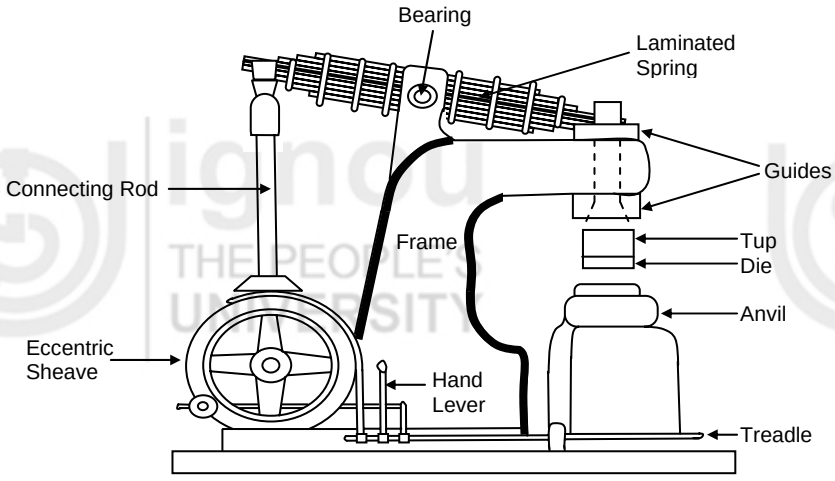

Figure 6.17 : Spring Power Hammer

Steam or Air Power Hammer

This type of power hammer is operated by steam or compressed air. The compression of steam or air takes place separately and not within the hammer. Hence, these types of hammer requires additional facilities for

applying high pressure steam or compressed air to raise the striker stroke. Steam power hammers are built in 400-8000 kg range.

Pneumatic Power Hammer

It consists of two cylinders, compressor cylinder and ram cylinder. Piston of compressor cylinder compresses the air and delivers it to the ram cylinder where it activates the cylinder which is an integral part of ram and thus delivers the blows to the work. The size of the pneumatic power hammer may vary in a range from 50-1000 kg.

6.5.3 Power Presses

Parts forged by using power press involves slow squeezing of plastic metal in closed impression dies, instead of applying repeated heavy blows by hammers.

Usually hydraulic type of presses are used for smithy work (Figure 6.18).

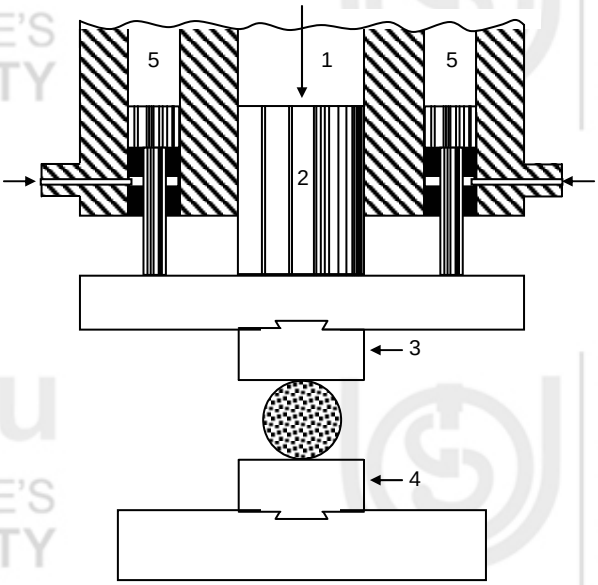

Figure 6.18

The water passes in starting from a large capacity tank to a pump and then is delivered on the press with the aid of an accumulator and distributor at a pressure of about 200-300 kgf/cm^2. The accumulated water pressure flows into a main cylinder and presses on the top of the large piston. Since cross sectional area of the piston in the main material is large, the press ram is forced down upon the material which is to be forged and lies on the anvil. As a result, the production of forging by presses is faster than that by hammers, because the whole operation is completed in a single squeezing action. Moreover the action goes deep into center of part since enough time is allowed to the part to flow.

6.6 RIVET

For permanent fastening or joining of two or more members so that they may act as a single one, rivet is used as an important permanent fastener. This joining process, where the rivets are used as an fastener, is known as riveting which is largely used in many works such as boiler work, ship building, chimney of workshop and structural construction works.

6.6.1 Specifications of Rivet

Rivets are made of mild steel, brass, copper and aluminum etc. They are specified according to the diameter of shank and shape of head.

6.6.2 Classification of Rivet

All the rivets are classified according to their heads as shown in Figure 6.19. Cup headed, pan headed, counter sunk headed and conical headed types of rivet are widely used. The snap headed or cup headed rivet is the most commonly used form and shows a very strong joint.

Pan headed provides the maximum strength and therefore used where strength is a primary consideration such as heavy steel structure.

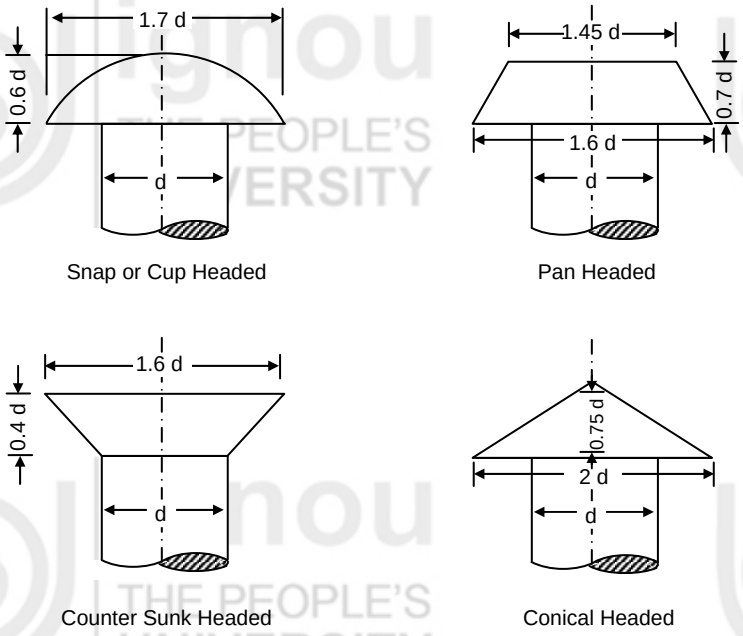

Figure 6.19 : Types of Rivet

Counter sunk headed rivet provides a flush head and therefore does not project from the work surface generally used in ship buildings.

Conical headed is used for small job and the head is formed by hand hammer.

6.6.3 Method of Riveting

The parts to be joined are laid against each other for being drilled together. This rivet hole must be such that the rivet may be inserted into the hole easily. The inserted rivet is pulled tight and the tail part of shank is formed in shape of head by hammering. Two types of riveting process – cold riveting and hot riveting – are in practice.

What type of riveting process is preferred depends upon the diameter of rivet shank. Moreover up to 10 mm diameter of rivet shank, cold riveting is used. Hot riveting is referred for the diameter above 10 mm.

SAQ 2

(a) What operations are performed in smithying or forging?

(b) What are the different types of power hammer you know?

(c) What is press forging? Explain in brief.

(d) What is forgeability? Differentiate between hand forging and power forging.

(e) How many types of rivet you know? Why riveting is done?

6.7 HEAT TREATMENT

Heat treatment is the operation or combination of operations of heating and cooling of metal or an alloy in the solid state to produce certain desired properties. Heat treatment process consists of three main steps as given below :

(a) Heating of metal to the predetermined temperature.

(b) Soaking of the metal at that temperature until the whole structure becomes uniform throughout the mass.

(c) Cooling of metal at predetermined rate to cause the formation of desirable structure within the metal as per requirement.

6.7.1 Objectives of Heat Treatment

Various objectives of heat treatment are given below :

(a) improve the mechanical properties such as hardness, toughness, ductility and strength,

(b) change the grain size,

(c) increase the resistance to heat and corrosion,

(d) relieve internal stresses,

(e) improve machinability,

(f) change the chemical composition, and

(g) modify the electrical and magnetic properties.

6.7.2 Different Processes of Heat Treatment

The aforesaid purposes of heat treatment may be served by one or more of the following selected processes of heat treatment :

(a) Annealing

(b) Normalizing

(c) Hardening

(d) Tempering

(e) Case hardening

Annealing

The purpose of Annealing is to improve one or more of the following properties :

(a) To improve machinability,

(b) To refine grain size,

(c) To relieve internal stresses, and

(d) For softening the metal.

Annealing process may be classified as Full Annealing and Process Annealing which are described below :

Full Annealing

Full Annealing is the process of heating at 30^{o} to 50^{o}C above the higher critical point for hypoeutectoid steel and by the same amount above the lower critical point for hypereutectoid steel for an appreciable period of time and then cooling it slowly. The name full annealing is due to the fact that it wipes out all traces of previous structure by complete phase recrystallisation. It is also known as high temperature annealing.

Process Annealing

Processes Annealing consists of heating the steel at a temperature range from 550^{o}C to 650^{o}C for a considerable period of time and then cooling slowly. It relieves internal stresses resulting from any previous heat treatment. It is also known as a low temperature annealing.

Normalizing

Normalizing is used particularly to

(a) improve the mechanical properties,

(b) remove internal stresses that may have caused by working, and

(c) refine the structure of steel.

This process of heat treatment involves the heating of steel to a temperature about 50^{o} C above the higher critical point and then allow it to cool in the air.

Hardening

The operation of hardening is applied to all cutting tools and some important machine parts intended for specially heavy duty service as well as to all machine parts made of alloy steel. The purposes of hardening are to :

(a) develop high hardness to resist wear and to enable it to cut other metals, and

(b) improve toughness, strength, ductility and elasticity properties.

Process of hardening consists of heating the steel to a temperature about 30^{o} to 50^{o}C above the higher critical point for a considerable period and then followed by cooling it suddenly in a liquid (water, oil or molten salt bath). This type of sudden cooling is known as quenching.

Tempering

As stated above during hardening process quenching is done to cool the heated metal. Due to this rapid cooling, it will become hard and brittle and will have severe unequally distributed internal stresses besides other unfavourable characteristics. In general, tempering restores ductility and reduces hardness. Basic objects of tempering are, therefore, to

(a) reduce internal stresses produced during previous heating,

(b) increase the ductility of metal, and

(c) improve the toughness, make the metal shock resistance.

In this operation, the hardened steel metal piece is reheated to suitable temperature below the lower critical point and then cool it slowly.

Case Hardening

Through this process, a hard wearing surface is produced on steel having a tough core inside. In case of hardening process, the metallic piece is heated to red hot condition and then force the carbon contents into its surface structure so that a certain depth all along its surface becomes rich in carbon, then it is hardened as usual. In other words, this process is also known as carburising or carbonising. It is mainly employed for wrought iron and mild steel specially for the metal containing comparatively low carbon contents.

Alloy steel are usually quenched in oil and carbon steel in water. This treatment will produce a hard fine grained case, while the core of the structure will retain the properties of low carbon steel.

SAQ 3

(a) Define the term heat treatment. For what reasons may steel be heat treated?

(b) Give a list of all heat treatment processes.

(c) What is the purpose of annealing and how is it done?

6.8 SUMMARY

Smithying is termed to handle relatively small size of jobs which can be heated in an open fire or hearth and the shop in which the work is carried out is known as the smithy or smith's shop. Generally, various types of operation are performed by using of different types of hand tool.

For the production of those parts which must be heated in a close furnace, forging is referred. The portion of part, in which forging is done, is denoted as forge and the work is commonly performed by means of heavy hammers and presses.

By using heat treatment, we can change the energy state in some metal by adding or taking away the heat. Through this heat treatment operation, certain desired properties can be produced.

6.9 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in section 'Further reading' to get the answers of SAQs.