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DEPARTMENT OF COLLEGIATE AND TECHNICAL EDUCATION

STUDY MATERIAL

ON

MANUFACTURING PROCESS

(20ME33P)

For III Semester Diploma in Mechanical Engineering

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UNIT-2

METAL FORMING PROCESS

Types of forging

Forging is done by two processes:

1. Hand forging
2. Machine forging

1. Hand Forging:

The work piece is heated in the furnace after heating Keep the heated work piece (with the support of blacksmith tongs) onto the anvil and take the hammer and strike on it, make the required shape and size.

2. Machine Forging:

The processes, in which forging is done by machines are known as machine forging. Machine forging is useful for heavy and complicated jobs requiring large forces.

Machine forging can be classified in as

(i) Mechanical board hammer:

- It is a stroke restricted machine.
- Repeatedly the board (weight) is raised by rolls and is dropped on the die.
- Rating is in terms of weight of the ram and energy delivered.

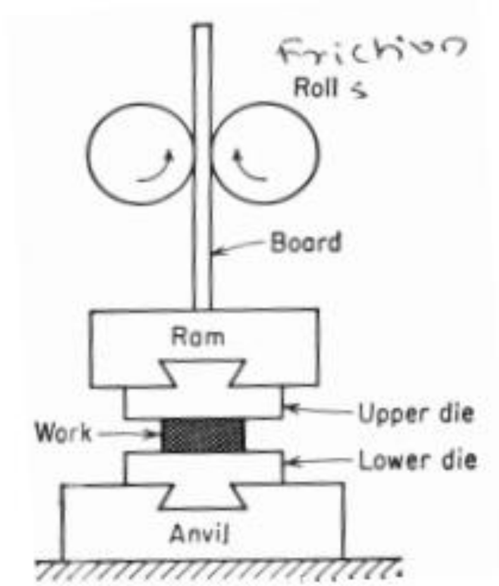


Fig2.4 Mechanical board hammer

(ii) Steam Hammer (Power Hammer) Range: 5 kN to 200 kN

- It uses steam in a piston and cylinder arrangement.
- It has greater forging capacity.

- It can produce forgings ranging from a few kgs to several tonnes.
- Preferred in closed die forging

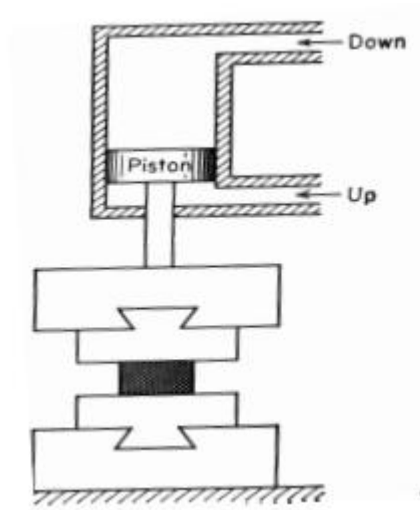


Fig.2.5 Steam Hammer

(iii) Hydraulic Press:

- It is a load restricted machine.
- It has more of squeezing action than hammering action.
- Hence dies can be smaller and have longer life than with a hammer.

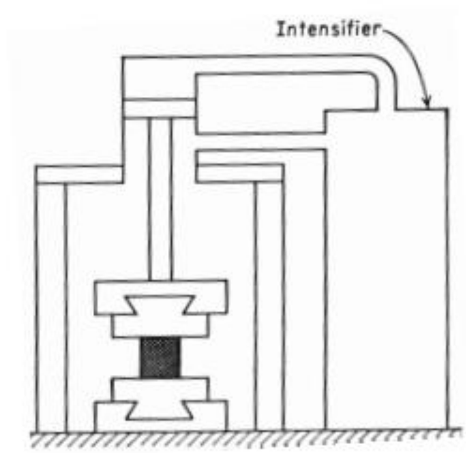


Fig 2.6 Hydraulic Press

Forging operations

The various smith forging operations are

1. Drawing down
2. Upsetting
3. Flatting and Setting down
4. Bending
5. Punching

6. Drifting
7. Forged Welding
8. Edging
9. Cutting

1. Drawing down

Drawing down is a process of elongate the length and reduce the cross section area of work piece. Simply in this operation, the length of work piece increases and the cross section area decreases. In this process, a compressive force is applied at perpendicular direction of its length axis. If a tensile force is applied to change its length at parallel to its length axis, this process is known as wire drawing.

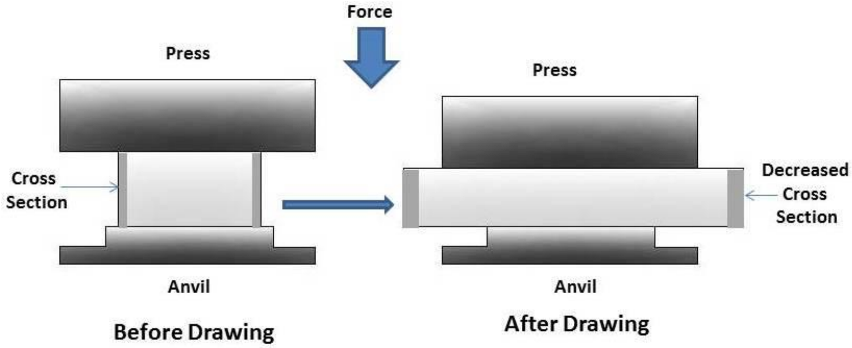


Fig.2.7 Drawing down

Swaging

This forging operation is done to reduce the finished work into desired size and shape, usually either round or hexagon. In this operation, the top and bottom pairs are added for small jobs, where the swag block can be used for larger jobs.

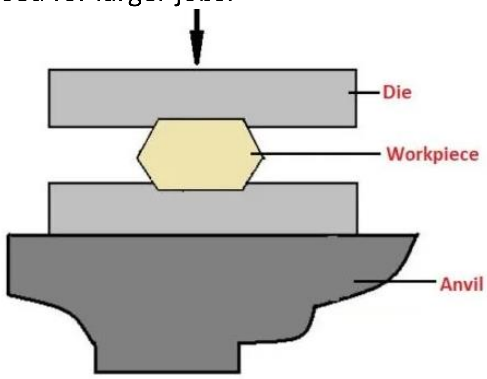
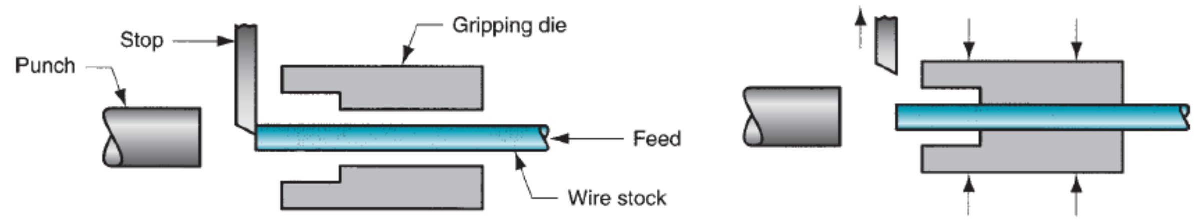


Fig.2.8 Swaging operation

Upsetting

This is the operation of increasing the thickness of a bar at the expense of its length and is brought about by end pressure (or) In this operation the length of work piece decreases and its cross section area increases. The pressure may be obtained by driving the end of the bar against the anvil, by supporting on the anvil and hitting with the hammer, by placing in swage block hole and hitting with the hammer or by clamping in vice and then hammering.

Upset forging is widely used in the fastener industries to form heads on nails, bolts, and similar products.

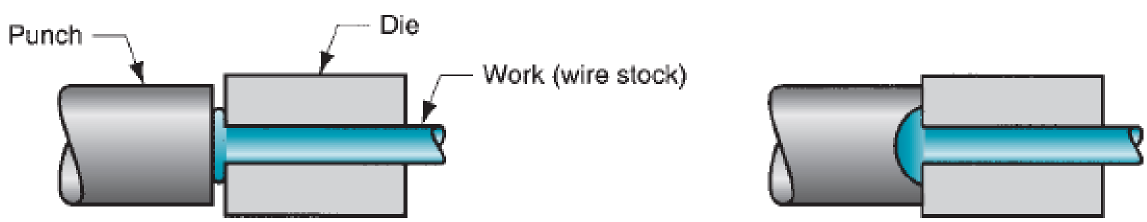


Feeding of work piece Gripping of work piece and retracting of stop

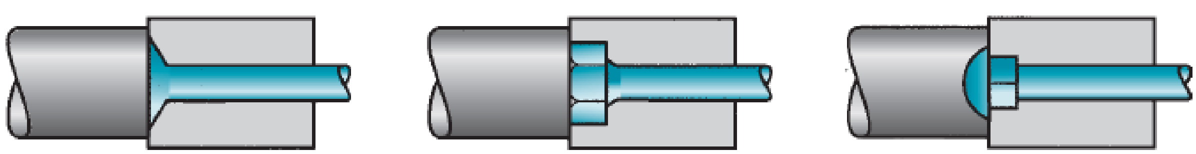
Forward movement of punch and upsetting Forging operation completes

Fig.2.9 Upsetting sequence of operations

The following figure shows variety of heading operations with different die profiles. The maximum length that can be upset in a single blow is three times the diameter of the initial wire stock.



Heading a die using open die forging Round head formed by punch only



Head formed inside die only Bolt head formed by both die and punch

Fig.2.10 Different bolt heads formed by upsetting process

Flatting and Setting down

Fullering leaves a corrugated surface on the job. Even after a job is forged into shape with a hammer, the marks of the hammer remain on the upper surface of the job. To remove hammer marks and corrugation and in order to obtain a smooth surface on the job, a flatter or set hammer is used.

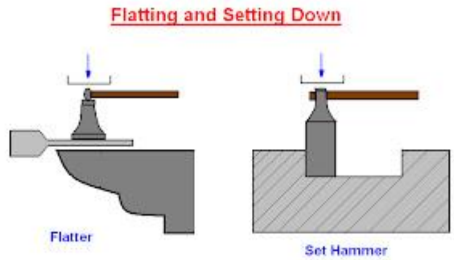


Fig.2.11 Flatting and Setting down

Bending

Bending is very common forging operation. It is an operation to give a turn to metal rod or plate. This is required for those which have bends shapes. Bending classified as angular or curvilinear.

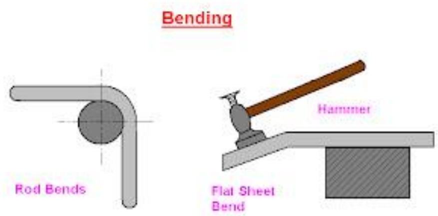


Fig.2.12 Bending operation

Punching

This forging operation is done to produce holes one the workpiece. The workpiece is placed on a hollow cylindrical die, placing the punch to the area that a hole is required.

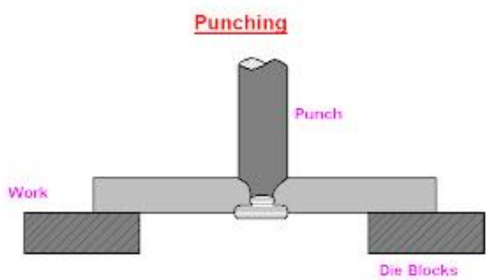


Fig.2.13 punching operation

Drifting

It is a process of finishing and enlarging the hole. The process is similar to punching. To continue punching without using a die is called to be as drifting but in this case a tool known as drift is used.

Forged Welding

It is a process of joining two metal pieces to increase the length. By the pressing or hammering then when they are at forging temperature. The first essential to the production of a sound weld is that 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.

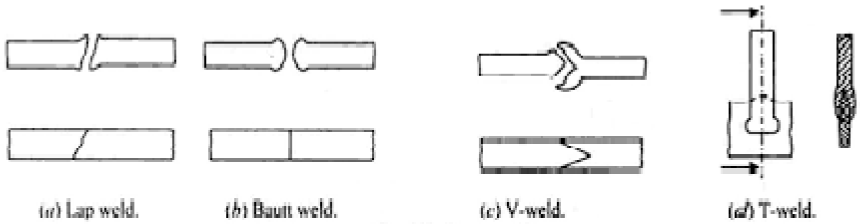


Fig.2.14 Forge welding operation

Figure shows four types of joints made by forge welding. In the lap weld the ends are tapered so that they may be placed one upon the other and forged. The joint is in an inclined direction. In the butt weld the straight ends are butted together and forged. The joint will be at right angle to the length of the workpiece.

In the V finished weld, the end of one part is made like a fork, the other end of the other part is made like a tongue. The tongue shape is inserted inside the fork shape and forged together. Similarly, T shape weld is also done but workpieces placed at right angles.

Edging

This forging operation is performed by striking or forcing the metal plate to the desired shape. The workpiece is forced between two die edges.

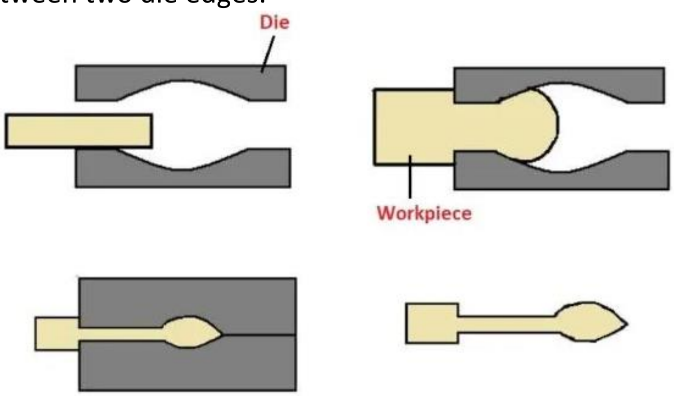


Fig.2.15 Edging operation

Cutting

To make small of long metal rods and plates is known as cutting. This can be done both in cold or hot condition. For cold metals, the chisel of cutting angle is used. For hot metals, the chisel of cutting angle is used. Metal beyond the thickness of 20mm should be cut only after heating it.

Power hammers

Power hammers are mechanical forging hammers that use an electrical power source or steam to raise the hammer preparatory to striking and accelerate it into the work being hammered.

It uses some form of pressure that first creates force, the strike is much faster and with greater force than if you were using a hammer or even a hydraulic press. Power hammers are also much larger in size than other tools. The greater the force required, the larger the machinery and old models can take up to more space in your shop or more.

Types of Power Hammers

Types of forging power hammers used in forging shop:

1. Lever-Spring hammers
2. Pneumatic hammers
3. Steam or air hammers
4. Helve hammers
5. Hydraulic hammers

Lever-Spring Hammer

It is a very light type of power hammer and it is used for small forgings. It consists of a heavy frame with a vertical projection at its top. This projection acts as a housing to bearing in which the laminated spring oscillates.

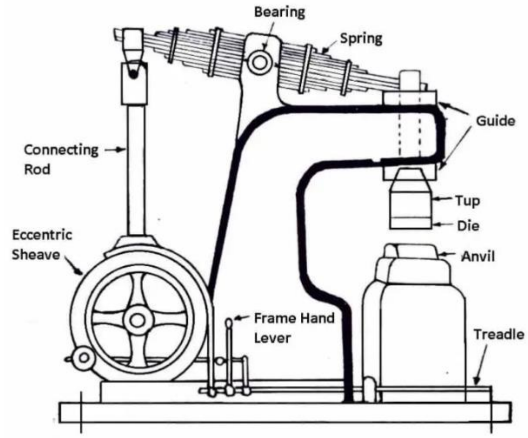


Fig.2.16 Lever-Spring Hammer

One end of this spring carries a connecting rod and the other end a vertical tup. The tup carries weight and moves vertically up and down between fixed guides. The connecting rod is attached to an eccentric sheave as its lower end.

Eccentric sheave is further connected to the crank wheel. For operating the hammer, the treadle is pressed downwards. This makes the sheave rotate through the crank wheel and hence the laminated spring starts oscillating in the bearing.

This oscillation of the spring causes the tup to move up and down. Thus, the required blows are provided on the job. The hand lever is operated to adjust the stroke of the connecting rod and hence the intensity of blows.

Pneumatic Power Hammer

A typical form of the pneumatic hammer is shown in the figure. It carries a cylinder (C). A piston works inside this cylinder. The piston is connected to the main motor shaft by means of a crank and connecting rod mechanism.

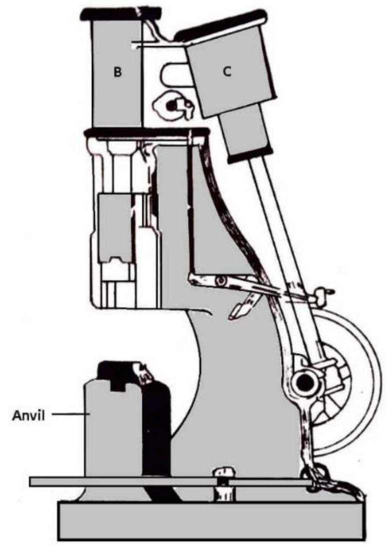


Fig.2.17 Pneumatic Power Hammer

A hand lever operates an air valve. The air valve is provided on the air passage from cylinder (C) to cylinder (B). Another piston works inside the cylinder (B). This piston carries tup at its bottom and it is made to slide fixed guides.

Let the tup be resting on the anvil. To start the motion of the tup, the piston in the cylinder (C) is moved downwards creating the vacuum above the piston in the cylinder (B). This provides a suction effect on the piston and hence the tup starts lifting.

A little before the end of the upward stroke of the piston, in-cylinder (B), the air is forced from cylinder (C) to cylinder (B). In cylinder (B), the air is compressed due to the upward stroke of the piston.

This in turn forces the piston and hence the tup downwards with a high velocity. This operation is repeated again and again and the required blows are obtained.

Steam or Air Power Hammer

A steam-power hammer can be performed by either steam or compressed air. It includes a moving ram, rod, and piston, a lifting tool, a double-acting high-pressure steam cylinder, housing or frame, and anvil.

In these types of forging power hammers, initially, steam is entering the bottom of the cylinder and the piston is lifted upward, along with other moving parts. The velocity of force is about 3m/sec, while the mass of the moving parts is up to 5000kg.

When a required blow needed, the lever is energized, and the top sliding value is open to receive steam on the above of the cylinder and the exhaust steam remains on the bottom. Hence, the required blows are obtained.

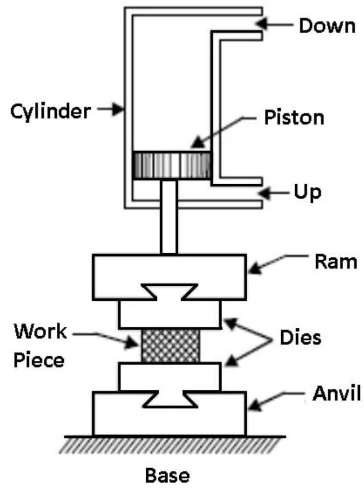


Fig.2.18 Steam or Air Power Hammer

Hydraulic Power Hammer

The hydraulic hammers also known as hydraulic presses. It uses 200 to 300 times higher oil pressure than the atmospheric pressure in the hydraulic cylinder. Hydraulic presses are applied in heavy forgings.

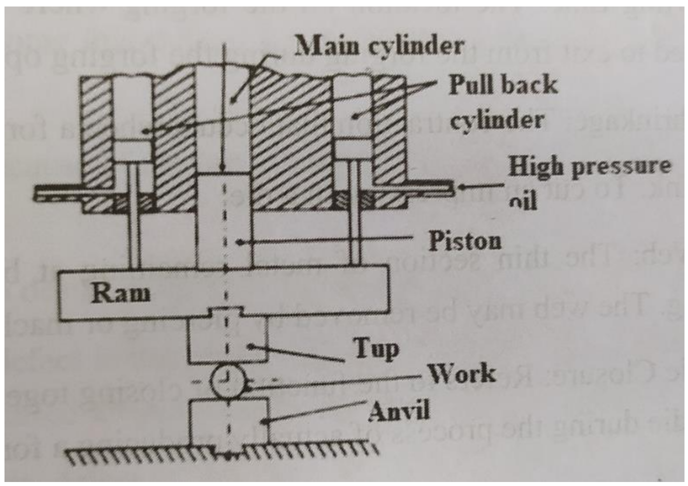


Fig.2.19 Hydraulic Power Hammer

It consists of a press and hydraulic drive. The rate of production in hydraulic presses is normally faster than other hammer forgings, as the entire operation is completed in a single squeezing action. Unlike mechanical presses and other hammers, the hydraulic hammer has low noise and vibration. In these presses, the speed, blow pressure and die travel are automatically controlled.

Presses that can provide a force of 75000 tons are pretty common. Hydraulic presses are used in forging industries almost ranges from 1000 tons to 10,000 tons. These presses are used for the production of nuts, bolts, screws, and rivets.

Important forging terms

1. Forging die: It may be defined as a complete tool consists of a pair of mating members for producing work by hammer or press. Die pair consists of upper and lower die halves having cavities.
2. Billet: A slug cut from rod to be heated and forged.
3. Blocker: Preform die or impression, used when part cannot be made in a single operation.
4. Cavity: The impression in upper and lower die.
5. Draft Angle: The taper on a vertical surface to facilitate the easy removal of the forging from the die or punch. Internal draft angles are larger (70 -100), whereas external draft angles are smaller (30 -5 0).
6. Fillet: It is a small radius provided at corners of die cavity to ensure proper and smooth flow of material into die cavity. It helps to improve die life by reducing rapid die wear.
7. Flash: The excess metal that flows out between the upper and lower dies which is required to accomplish a desired forging shape.
8. Gutter: A slight depression surrounding the cavity in the die to relieve pressure and control flash flow.
9. Parting Line: The location on the forging where excess material in the form of flash is allowed to exit from the forging during the forging operation.
10. Shrinkage: The contraction that occurs when a forging cools.
11. Sink: To cut an impression in a die.
12. Web: The thin section of metal remaining at bottom of a cavity or depression in a forging. The web may be removed by piercing or machining.
13. Die Closure: Refers to the function of closing together the upper and lower members of a forge die during the process of actually producing a forging

Forging Defects

When a forge shop begins to experience defects in their process, they should try to find the root cause of the problem, initiate corrective action and implement procedures to prevent its recurrence.
Description of defects and their remedial methods is given below:

1. **Incomplete forging penetration:** This defect arises due to incomplete forging. it is due to light or rapid hammer blow. Actual forging takes place only at the surface.
   Cause- Use of light or rapid hammer blows.
   Remedy- To use forging press for full penetration.
2. **Surface cracking:** Surface cracking occurs due to exercise working on surfaces at low temperature. Many cracks appear on the work piece as a result of this defect.
   Cause- Excessive working on the surface and too low temperature.
   Remedy- This defect can be removed by proper control on working temperature.
3. **Cracking at the flash:** This crack penetrates into the interior after flash is trimmed off.
   Cause- Very thin flash
   Remedy- Increasing flash thickness, relocating the flash to a less critical region of the forging, hot trimming and stress relieving.
4. **Cold shut (Fold):** Cold shut includes small cracks at corners. These defects occur due to improper design of forging die.
   Cause- It is due to sharp corner, and excessive chilling in forge product.
   Remedy- The fillet radius of the die should be increase to remove these defects.
5. **Unfilled Section:** Some section of die cavity not completely filled by the flowing metal.

Cause- Improper design of the forging die or using forging techniques, less raw material, poor heating.
Remedy- Proper die design, Proper raw material and Proper heating.

6. **Die shift (Mismatch):** Die shift forging defects occur when the upper and lower dies are not aligned with each other. As a result, the product's dimensions will be off or Misalignment of forging at flash line.
   Cause- Misalignment of the die halves.
   Remedy- Proper alignment of die halves. Make mistake proofing for proper alignment for eg. provide half notch on upper and lower die so that at the time of alignment notch will match each other or provide alignment pins at top and bottom dies.
7. **Scale Pits (Pit marks):** These forging defects occur as a result of improper cleaning of the forged surface. Scale pits are common in open-air forging.
   Cause- Improper cleaning of the stock used for forging. The oxide and scale gets embedded into the finish forging surface.
   Remedy- Proper cleaning of the stock prior to forging.
8. **Flakes:** These are Internal cracks form as a result of improper cooling of forge product. When the forge product cools quickly, these cracks are commonly formed, reducing the forge product's strength.
   Cause- Improper cooling of forging. Rapid cooling causes the exterior to cool quickly causing internal fractures.
   Remedy- Follow proper cooling practices.
9. **Improper Grain Growth:** This defect occurs due to improper flow of metal in casting which changes predefine grain structure of product.
   Cause-
   Remedy- It can be removed with the right die design.
10. **Residual Stresses in Forging**
    Residual stress problems are generally occurring in cold working forging.
    Cause- Too much rapid cooling is main causes of this type of defects.
    Remedy- Residual stress is reduced when work piece is heated up to recrystallization temperature and then cool slowly.

Causes of Forging Defects

Common defects in forging are found in metals that have been subjected to more or less plastic shaping shown as follows:

1. Defects, resulting from the melting practice such as dirt or slag, blow holes, etc.
2. Ingot defects such as seams, piping, cracks, scales or bad surface and segregation.
3. Defects resulting from improper heating and cooling of the forging such as burnt metal, decarburization, and flakes.
4. Defects resulting from improper forging such as seams, cracks, laps, etc.
5. Faulty forging design.
6. Faulty die design.
7. Improper placement of the metal in the die causing mismatched forging

Forging Defects Removal

To avoid this forging defect, care should be taken during the operation and the smith must have experience in forging. Defects in forging can be removed as follows:

1. Shallow cracks and cavities can be removed by chipping out of the cold forging with pneumatic chisel or with hot sets during the forging processes.
2. Surface cracks and decarburized areas are removed from important forgings by grinding on special machines. Care should also be taken to see that the workpiece is not under heated, decarburized, overheated and burnt.
3. Die design should be properly made taking into consideration all relevant and important aspects that may impair forging defects and ultimate spoilage.
4. The parting line of a forging should lie in one plane to avoid mismatching.
5. Destroyed forgings are straightened in presses, if possible.
6. The mechanical properties of the metal can be improved by forging to correct fiber line, and finally internal stresses, developed due to heating and cooling of the workpiece, are removed by annealing and or normalizing.

Forging losses

The losses expected in forging are

1. Scale loss
2. Flash loss
3. Tong hold loss
4. Sprue loss
5. Shear loss

Scale loss

When the material used in forging, iron is heated at a high temperature in atmospheric conditions a thin film od iron oxide is formed all-round the surface of the heated metal. The iron oxide film from the surface of the metal on being beaten up by the hammer.

Flash loss

This is a loss related to die forging or machine forging. There is a certain quantity of metal which comes between the flash surfaces of the two dies after the die cavity has been filled in.

Tong hold loss

This is the loss of material due to a projection at one end of the forging to be used for holding it with a pair of tongs and turning it round and round to give the required cross section in drop forging.

Sprue loss

The connection between the forging and tong holds is called or runner. The material loss due to this portion of the metal used as a contact is called sprue loss. The sprue must heavy enough to permit lifting the work piece out of the impression die without bending.

Shear loss

In forging the long bars or billets are cut in to required length by means of a swaging machine. The material consumed in the form of saw-dust or pieces of smaller dimensions left as defective pieces is called shear loss.

Estimation procedure or Estimation of forging cost

The cost for producing forgings depends on many factors, such as material, die, labor, equipment, inspection, heating and overhead costs etc. These charges may vary from plant to plant and also from product to product with in an individual plant. The cost of forged component consists of following elements

1. Cost of direct materials
2. Cost of direct labour
3. Direct expenses such as due to cost of die and cost of press.
4. Overheads.

1. Direct martial cost

Cost of direct materials used in the manufacture of a forged component are calculated by first determine the net weight based on component drawing and then adding expected losses.

a. The net weight of the forging

Net weight of the forged component is calculated from the drawings, first calculating the volume and then multiplying it by the density of the metal used.

Net weight = volume of forging (V) x Density of metal (ρ)

$$m = V\ x\ \rho$$

b. Gross weight

Gross weight is the weight of forging material required to make the forged component. Gross weight is calculated by adding expected losses

Gross weight = Net weight + material loss in the process.

In case of smith or hand forging, only scale loss and shear loss are to be added to net weight but in case of die forging other machine related losses are also to be taken into account.

c. Diameter and length of the stock

The greatest section of forging gives the diameter of stock to be used and

$$Legth\ of\ stock\ = \frac{Gross\ weght}{sectional\ area\ X\ density\ of\ material}$$

$$Legth\ of\ stock\ = \frac{Volume\ X\ density\ of\ material}{sectional\ area\ X\ density\ of\ material}$$

If the density of material same then the above equation becomes

$$Legth\ of\ stock\ = \frac{Volume}{sectional\ area}$$

d. Direct material cost

The cost of direct material is calculated by multiplying the gross weight by the price of raw material

$$Direct\ material\ cost = Gross\ weight\ X\ price/Kg$$

2. Direct labour cost

Direct labour cost is calculated by the following formula

$$Direct\ labour\ cost = L\ x\ T$$

L= Labour rate per hour

T = Time for forging per piece (in hrs)

3. Direct Expenses

Direct expense include the expenditure incurred on dies and other equipment, cost of using machines and any other items, which can be directly identified with a particular product.

$$Die\ cost/\ component\ = \frac{x}{y}$$

Where x = cost of die

y= no of components can be manufactured with the die

4. Overheads expenses

The overheads include supervisory charges, depreciation of plant and machinery, consumables, power and lighting charges, office expenses ect., The overheads can be expressed as percentage of direct labour cost or machine hours.

Total cost: The total cost of forging is calculated by adding the direct material cost, direct labour cost, direct expenses and overheads.