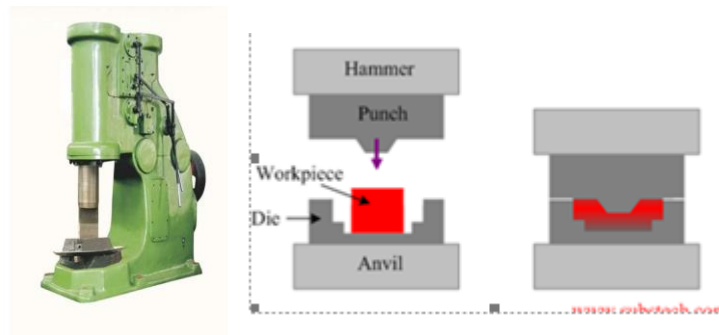


Mechanics

Level II

Based on March, 2022, Curriculum Version I,



Module Title: Performing Hammer Forging

Module Code: IND MCS2 M07 0322

Nominal duration: 60 hours

Prepared By: Ministry of Labor and Skill

**September, 2022
Addis Ababa, Ethiopia**

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Acronyms

CVJB: Constant Velocity Joint Body

PPE: Personal Protective Equipment

TTLM: Teaching, Training and Learning Materials

OHS: Occupational Health and Safety

Introduction to the Module

Forging hammers are used in the drop forging to form the metal between two dies. The first half of the die is attached to the anvil and the second part to the hammer. The material is placed in the lower die and then hammered with the upper one until the hot metal flows in all directions, filling the die cavity.

This module is designed to meet the industry requirement under the irrigation and drainage occupational standard, particularly for the unit of competency: **Perform hammer forging.**

Module unit

- Hand forging work
- Tools and material
- Hammer forging techniques
- Assure quality work.

Learning objectives of the Module. At the end of this session, the students will able to:

- Analyze and plan hand forging work
- Prepare and select tools and material
- Perform hammer forging techniques
- Confirm assure quality work

Module Learning Instructions:

1. Read the specific objectives of this Learning Guide. Follow the instructions described below.
2. Read the information written in the information Sheets
3. Accomplish the Self-checks
4. Perform Operation Sheets
5. Do the “LAP test”

Unit One: Hand Forging Work

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Drawing for swaging, bending, upsetting, spreading, punching and drifting techniques
- Material calculations for oxidization and shrinkage
- Forging temperatures and heat specifications.
- Drafting work plan.

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Interpreted drawing for swaging, bending, upsetting, spreading, punching and drifting techniques is in compliance with specification.
- Making Material calculations for oxidization and shrinkage.
- Applied forging temperatures and heat specifications are applied to for various materials requirement
- Drafted work plan according to specifications.

1.1 Drawing for swaging, bending and punching drifting technique

A. Swaging

Swaging is used to produce a bar with a smaller diameter (using concave dies). It is a special type of forging in which metal is formed by a succession of rapid hammer blows. Swaging provides a reduced round cross section suitable for tapping, threading, upsetting or other subsequent forming and machining operations. It is a process of finishing a round or hexagonal section of bar between a pair of swages of the appropriate size. These may be separate tools for top and bottom or these may be held to gather by a long spring handle as shown in figure.

The process involves:

- Heating the metal
- Placing the metal between the top and bottom swages;
- Striking the top swage while rotating the work

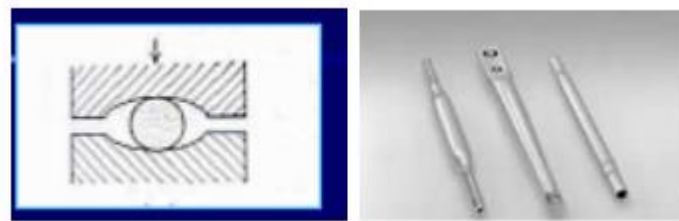


Figure 1.1 Swaging

B. Bending

It is one of the most important processes of forging and is very frequently used. Bends may be classified a sharp cornered bends or more gradual bends. The operation is performed by hammering the metal over the edge of the anvil or over a block of metal held in vice. When the metal is bending by hammering, the outer and inner surface does not remain same. The inside surface is shortened while the outer surface is stretched which causes bulging of the side at the inner surface and a radius on the outer surface of a sharp corner is required an additional metal is required at the place where the bend occur in order to permit stretching of metal at outer surface.

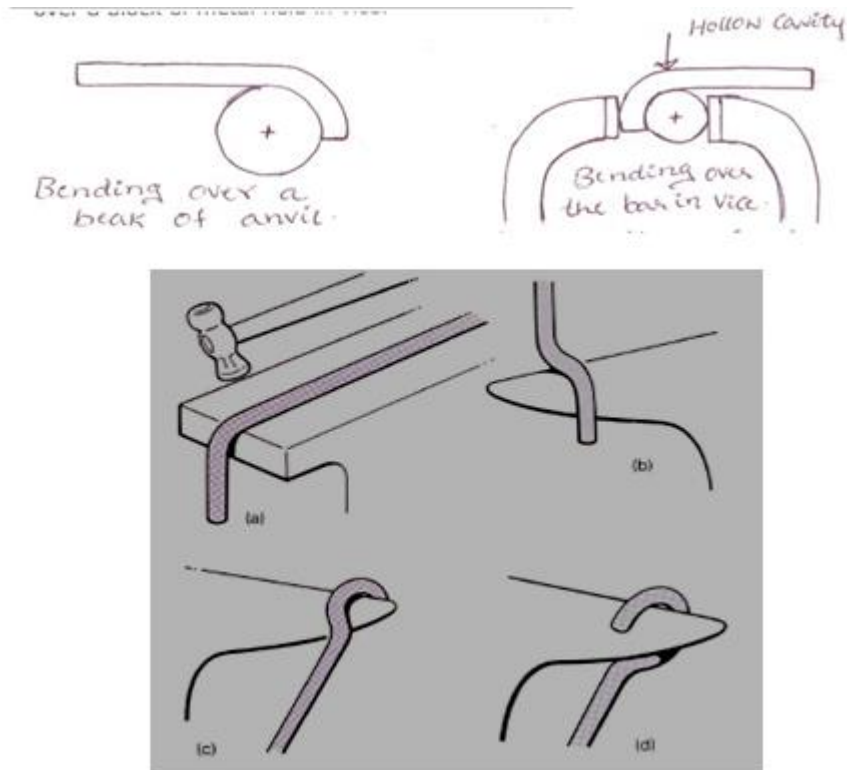


Figure 1.2 Bending

C. Upsetting

When upsetting, the height is reduced and a cross-section of the body is increased. This is just opposite to drawing and involves increasing of the cross-sectional area usually by pressing or hammering in the direction parallel to the original ingot axis. Only the part to be upset is heated to forging temper and the bar or work is then struck at the end, usually between the hammer and the axis as shown in figure. Upsetting is the most demanding forging operation as for the force and energy. The purpose of upsetting is to increase the grade of through-forging, to reduce the anisotropy of mechanical properties, to achieve the radial grain, and to produce forgings with a larger cross section than corresponds to the initial semi-product and get rough forgings suitable for subsequent punching or lengthening

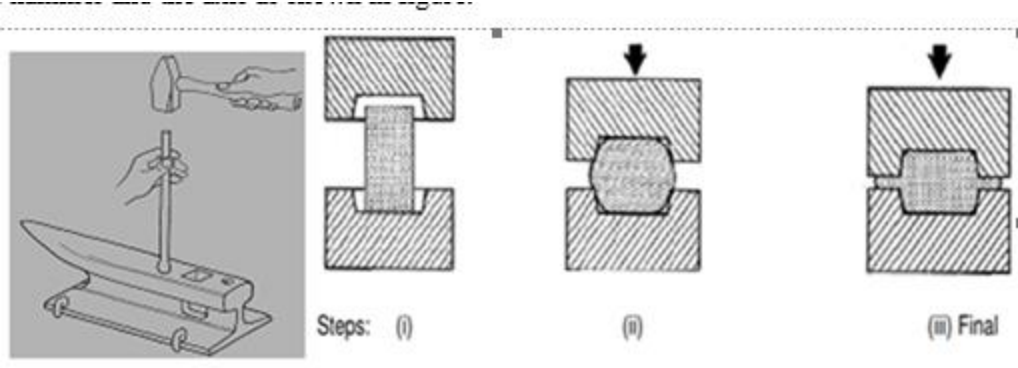


Figure 1.3 Upsetting

D. Spreading,

The operation of spreading or thinning action and is accomplished by striking the work piece with flat dies. Due to impact of die on metal its thickness is reduced and length is increased.

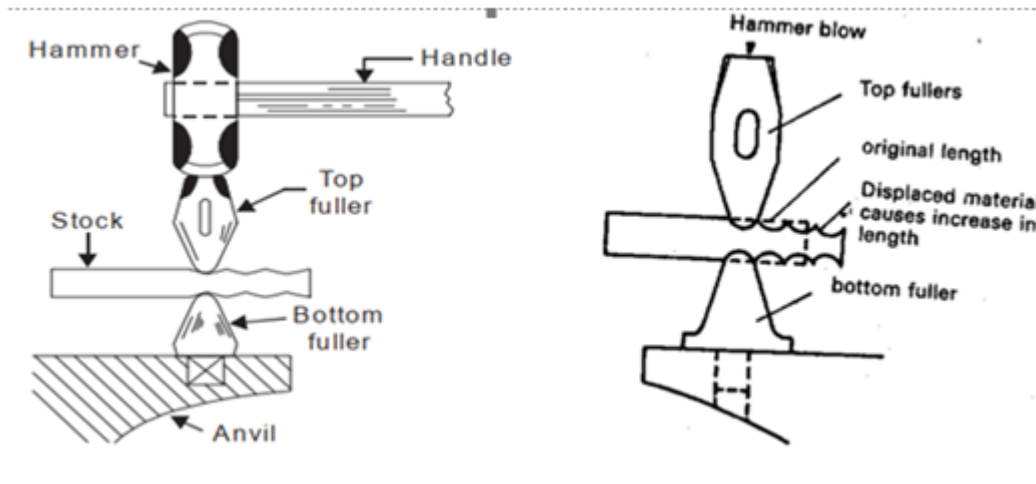


Figure 1.4 Spreading

E. Punching

It is the process of producing hole generally cylindrical by using a hot punch over a cylindrical die.

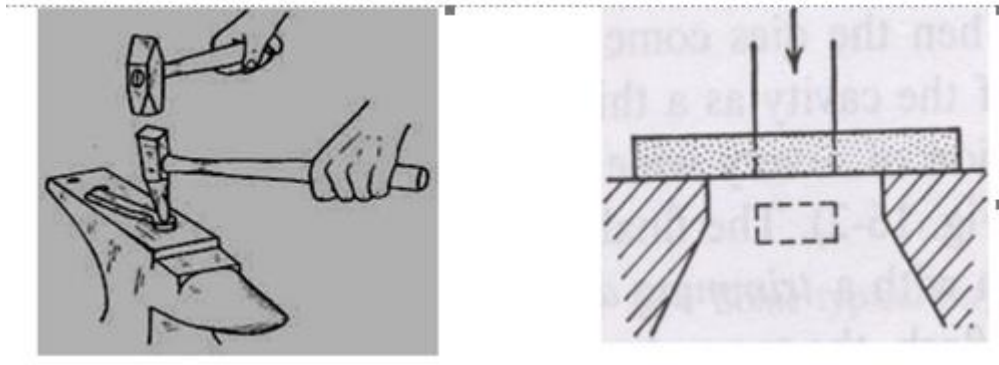


Figure 1.5 Punching

E. Drifting techniques

Drifting techniques is, the operation of forming or enlarging a hole by use of a tapered punch.

Drop forging — A forging made in closed or impression dies under a drop or steam hammer.

Drop hammer — A term generally applied to forging hammers wherein energy for forging is provided by gravity, steam, or compressed air.

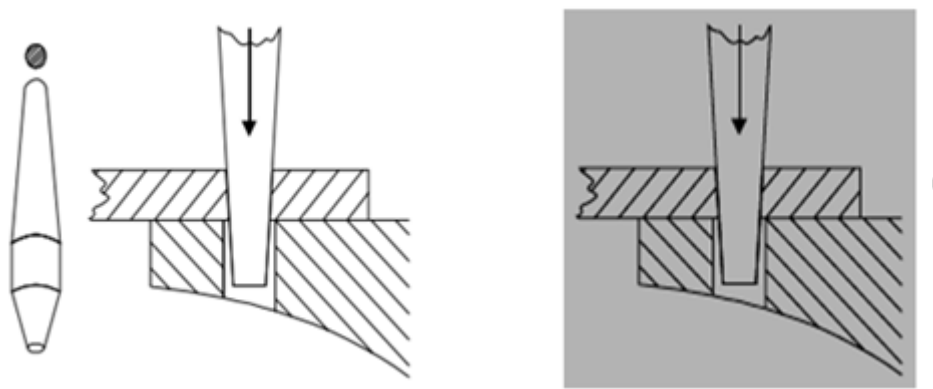


Figure 1.6 Drifting techniques

1.2 Material calculations for oxidization and shrinkage

In material requirements planning and product costing, material quantity calculation is used to calculate the material and operation quantities that are, for example, necessary for reservations or direct cost statements. In the process order, material quantity calculation determines the order-specific quantities in material requirements planning and product costing, material quantity calculation is used to calculate the material and operation quantities that are, for example,

necessary for reservations or direct cost statements. In the process order, material quantity calculation determines the order-specific quantities. The term oxidation was originally used to describe reactions in which an element combines with oxygen. Example: The reaction between magnesium metal and oxygen to form magnesium oxide involves the oxidation of magnesium. An oxidizing material is a chemical that has the ability to easily decompose to release oxygen or an oxidizing substance. Oxidizing materials can be a hazard when they are added to a fire. They will provide the fire with more oxygen, which will cause the fire to expand. Shrinkage is an internal or external change in volume that occurs during a phase change in a metal's transition from a liquid state to a solid state at the exposed surface. This phenomenon occurs in processes like casting and concrete solidification.

1.2.1 Forging Estimation Procedure

Estimation procedure varies from shop to shop and person to person but for a general procedure, following factors may be considered:

The procedure for estimation of net weight of the forged component

- Break up the job drawing into suitable geometrical section, whose volumes can easily be calculated by using Mensuration.
- Next, find the value of each section, neglecting rounded corners and taking suitable assumptions.
- Now, find total volume of material required by subtracting volume of the hollow spaces.
- Lastly, calculate the weight of the component by multiplying the total volume with its density.

1.2.3 Cost calculation on forging

Product cost estimation of forging is basically the process of determining the cost of a product. Forging is a commonly used production method, here materials are deformed plastically & shaped. Main industries like automotive & defense industry use forgings or buy forgings from forging companies. The items that form up forging costs like; Material cost, labour cost, tooling cost, and Equipment cost, etc are calculated each time.

1.2.4 Design of the forging part & the forging process

- Material losses
- Forging equipment selection
- Forging die design

Manufacturing of forging dies

- Material Losses
- Tong Loss
- Scale Loss
- Flash Loss
- Sprue Loss
- Shear Loss
- Flash Loss

It is the surplus metal, which comes out between the two meeting surfaces of the dies. For getting finished product, this surplus metal is required to be trimmed off. This loss may be calculated by assuming it to be 20mm wide and 3mm thick all around the periphery of the dies. Thus, volume of flash loss = periphery x 20x 3 cu mm nearly. OR, Flash thickness $T_f = 0.015\sqrt{A_t}$: For ax symmetrical forging flash thickness $T_f = 0.016D$ Flash land ratio is $W_f/T_f = 63/\sqrt{D}$

Where, D=maximum diameter of the forging

A_t =projected area of forging

Scale Loss: The outer surface of the hot metal is generally oxidized, and when hammering is done oxidized film is broken and falls down in the form of scale. It reduces the dimensions of the job, and therefore, this loss must be considered for estimation purposes. Generally, it is taken as 6% of the net weight.

Tong Loss: While performing forging operations, some length of stock is required for holding the job in tong. This length is an extra length, which is removed after completion of the job. For estimation purposes, the weight of the extra length is also considered and is known as Tong loss. 2-3 cm of the stock length.

Shear Loss: The required sizes of work piece for forging operations are obtained from long bars by sawing or shearing. In sawing operation, some material is always lost. If last piece of bar is not to be required length, it is rejected. This loss of material is taken as 5% of the net weight.

Sprue Loss: The portion of metal between the length held in the tong and the material in the die is called sprue. This is also a metal loss and can be taken as 7% of the weight. Thus, we can see that nearly 15-20% of the net weight of metal is lost during forging. Therefore, in estimation their consideration is very essential and total weight will be net weight of job plus sum of the weight of different losses occurred during forging. Thus, this gives the amount of weight of material required for forging.

Forging Equipment Selection:

Forging equipment depends on the material & geometry of the forging.

- To calculate forging load, For simple forging, $F_t = 0.0354 * (W_f / (T_f * h_m))^{0.025} * A_t$
- For complex forging, $F_t = 0.0538 * (W_f / (T_f * h_m))^{0.009} h_m$ h_m = height of forging excluding the flash, Where, F_t = total load on forging W_f = Flash land ratio

Forging cost items

- material cost
- forging equipment cost
- forging die cost
- labour cost
- overhead cost

Material cost:

- Gross weight \times Price per kg (Net weight + Material loss in the process) \times Price per kg

Equipment cost:

- $KP = CP / PR$, Where, CP: The equipment usage cost per unit time,

PR: the production rate; pieces/time)

Forging labour cost: $t \times l$

Where t = time for forging per piece (in hours)

l = labour rate per hour.)

Forging die cost:

- the die costs are about 10% of the forging

Overhead cost:

- The overheads include supervisory charges, depreciation of plant and machinery, consumables, power and lighting charges, office expenses etc.

Division of Total Costs for Steel Forging Die (10% 16% 10% 11% 53%)

- Equipment cost
- overhead cost
- Quality cost
- Material cost

The cost of a forged component

Cost of Direct Material

- Calculate the Net weight = Volume of forging \times Density of material
- Calculate the gross weight = Net weight + Material loss in the process
- Calculate the Length of stock = Gross weight / (Cross-sectional area of stock \times Density of material)
- Direct material cost = Gross weight \times Price per kg.

Cost of Direct Labour

- Direct labour cost is estimated as follows:
- Direct labour cost = $t \times l$

Where t = time for forging per piece (in hours)

l = labour rate per hour.

Direct Expense Cost of press per component = Rs. $A/1920 n N$

- Cost of press = Rs.
- A Life of press = n years
- No. of components produced per hour = N

Overheads

- The overheads are generally expressed as percentage of direct labour cost.
- It includes supervisory charges, depreciation of plant & machinery, consumable, power and lighting charges, offices expenses.

Example1. Given (a) (b) (c) (d) 20 50 20 25 50 Φ 40 Φ 30 Φ 20 Φ

(a)=50 mm diameter of

(b)=40 mm diameter of

(c)=30 mm diameter of

(d)=20 mm

- Density of material is 7.86 gm/cc.
- Material cost = Rs. 150 per kg
- Labour cost = Rs. 50 per piece
- Overheads = 150 percent of labour cost.

Solution:

Net volume of forged component $= \pi/4 [(5)^2 \times 3 + (4)^2 \times 3.5 + (3)^2 \times 3 + (2)^2 \times 5] = \pi/4(178) = 139.73$ cc
Net weight $= 139.73 \times 7.86 = 1098$ gm = 1.098 kg

Losses: Scale loss = 6% of net weight $= 6/100 \times 1098 = 65.88$ gm = 0.065kg
 Taking flash width = 20 mm and Flash thickness = 3 mm

Flash loss = (periphery of parting line) $\times 2 \times 0.3 \times 7.86 = [2(3 + 3.5 + 3 + 5) + 2 + (3 - 2) + (4 - 3) + (5 - 4) + 5] \times 2 \times 0.3 \times 7.86 = 39.0 \times 2 \times 0.3 \times 7.86 = 183$ gm = **0.183 kg**

Tong loss $= 2 \times \text{Area of cross-section of bar} \times 7.86 = 2 \times \pi/4 \times (2)^2 \times 7.86 = 197.44$ gm = 0.197 kg

Sprue loss = 7 % of net weight $= 7/100 \times 1098$ gm = 76.86 gm = **0.076 kg**

Total material loss $= 54.9 + 65.88 + 183 + 197.44 + 76.86 = 578$ gm

Gross weight = Net weight + Losses $= 1098 + 578 = 1676$ gm = **1.676 kg**

New length of 14 mm of bar required per piece = Volume of forging/ (Area of X – Section of bar) $= 139.73 \div \pi/4 \times (2)^2 = 44.5$ cm

Direct material cost $= (1676/1,000) \times 15 =$ **Rs. 25.14**

Direct labour cost = Rs. 50 per piece
 Overheads = 150 percent of labour cost $= 1.5 \times 50 =$ **Rs. 75**

Cost per piece $= 25.14 + 50 + 75 =$ **Rs. 150.14**

Product cost estimation is basically the process of determining the cost of a product. Cost estimation is very critical and important in all types of manufacturing processes. In forging cost estimation, determination of the forge volume is very critical to find the required press or hammer capacity, flash allowance, scale loss, billet weight and the forging material cost. Computer aided cost estimation software has been developed.

1.3. Forging temperatures and heat specifications.

1.3.1 Forging Temperatures

Forging temperature is the temperature at which a metal becomes substantially softer, but is lower than the melting temperature. Bringing a metal to its forging temperature allows the metal's shape to be changed by applying a relatively small force, without creating crack

Before forging, the metal work piece is heated to a proper temperature so that it gains required plastic properties before deformation, which are essential for satisfactory forging. Excessive temperatures may result in the burning of the metal, which destroys the cohesion of the metal. Insufficient temperatures will not introduce sufficient plasticity in the metal to shape it properly by hammering etc. For forging, a metal must be heated to a temperature at which it will possess high plastic properties both at the beginning and at the end of the forging process, e.g. temperature to begin the forging for soft, low carbon steels is 1250 to 1300°C and finishing temperature is 800 to 850°C.

Moreover, under these conditions, the cold working defects (e.g., hardening, cracking etc.) are liable to come into product. The finishing temperature of the work piece should be that at which no grain growth takes place, so that the work piece possesses a fine-grained structure.

Table 1.1. Forging Temperatures

Metal / Alloy	Forging Temperatures, °C (Approx.)	
	Starting	Finishing
1. Mild steel	1300	800
2. Medium carbon steel	1250	750
3. High carbon steel	1150	825
4. Wrought iron	1275	900
5. Aluminium and Manesium alloys	500	350
6. Copper, Brass and Bronze	950	600

Material	Forging temperature (°C)
Carbon steel and alloy steels	850 – 1150
Stainless steel	1100 – 1250
Aluminium alloys	400 – 550
Magnesium alloys	250 – 350
Cooper alloys	600 - 900
Titanium alloys	700 - 950
Nikel alloys	1000 - 1200

1.3.2 Thermal expansion/contraction

Thermal expansion occurs when you heat a material and it gains more internal energy, and as the atoms within the material move around faster, and the material expands. Thermal contraction occurs when you cool the material down, and the atoms don't have that much energy.

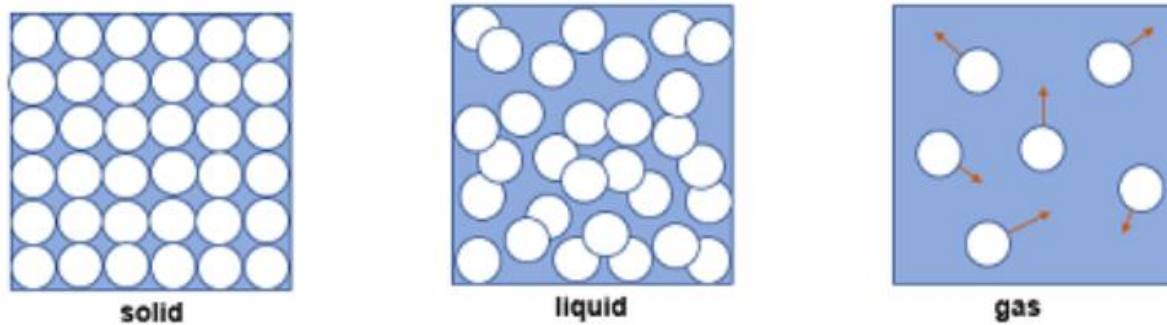


Figure 1.7. The molecular arrangement of a solid, liquid, and gas

Thermal contraction, or shrinking of materials, occurs when materials are subjected to a decrease in temperature. It occurs in all types of matter, whether it is solid, liquid, or gas. When subjected to a decrease in temperature at constant pressure, atoms and molecules move slower due to a decrease in their kinetic energies. As a result, the distances between the molecules decrease, and the object's dimensions, such as its length and width, also decrease by a relatively small amount.

Most materials expand when they are heated and contract when they are cooled. As mentioned in the previous section, contraction and expansion occur because of the change in internal energy (specifically the kinetic energy of the atoms and molecules) due to temperature change. The change in kinetic energy allows the molecules to move faster or slower and, in turn, either reduces or increases the average particle-to-particle distances within a material.

1.3.3 Thermal Expansion Measurement and Coefficient

Thermal expansion occurs in one, two, and three dimensions. **Linear thermal expansion** is characterized by an increase in length. For solids, length either increases or decreases as the temperature changes. **Area thermal expansion**, on the other hand, refers to the expansion of material in two dimensions. Consider a metal square punched with a circular hole. What would

happen to the size of the hole as the temperature increases? Since the area increases so that both the length and the width of the square increase, the area of the circular hole also increases. Lastly, **volume thermal expansion** describes an expansion in three dimensions. Solids, liquids, and gases expand in all directions when there is an increase in temperature. The amount of thermal expansion, specifically the amount of linear expansion depends on the original length of the material (l_0), the change in temperature (ΔT), and the coefficient of linear expansion (α). The relationship between these materials is expressed as:

$$\Delta l = \alpha l_0 \Delta T \text{ or } l = l_0(1 + \alpha \Delta T).$$

Thermal expansion in two dimensions is expressed as

$$\Delta A = 2\alpha A_0 \Delta T,$$

Where ΔA is the change in the area, A_0 is the initial area, and ΔT is the change in temperature.

Thermal expansion in three dimensions is given by

$$\text{Thermal expansion in three dimensions is given by } \Delta V = \beta V_0 \Delta T,$$

Where β is the coefficient of volume expansion. The coefficient of volume expansion is simply three times the coefficient of linear expansion ($\beta = 3\alpha$). When a material undergoes thermal contraction, its dimensions become smaller, thus Δl , ΔA , and ΔV would be negative.

The value of the coefficient of linear expansion, α varies from one material to another. It also varies slightly depending on temperature; that is why most resources indicate the temperature at which the material was measured.

1.4 Drafting work plan

The Draft work plan will give details on but not limited to: the primary information needs, the methodology to be used, the budget required, and the work plan/work schedule of roles and responsibilities of World Vision and that of the consultant as agreed upon by the two parties.

1.4.1. Working steps in making the Forging Job

- Calculate the final length of the model to be forged
- Place the given round rod in the Hearth furnace in suitable place.
- Switch on the blower and set the temperature range as required
- The job is heated to red hot temperature.
- Place the heated job in between open-faced Bottom & Top Die, which is set on Anvil.
- Draw down the heated work piece to calculated length with the help of hammer, tong & flatter.
- The process is carried approximately until the circular rod is transformed into desired shape and with desired dimensions
- The work piece is re-heated to carry out bending operation.
- Bending is carried out on Leg vice as per dimensions.
- With the help of flatter, open faced dies finish the work piece to the final dimension and surface finish; cool the specimen by dipping in water.

1.4.2. Equipment & materials

Materials and Equipment means all materials, supplies, apparatus, equipment, components, and machinery required for the Project to the extent such are within the Scope of Work of the Contractor, but excluding Construction Aids. Based on these various materials and equipment:

- Forge Hearth,
- Tongs, Anvil,
- Sledge,
- Flatter Hammer,
- Steel Rod.

1.4.3. Report The Following

- Sketches depicting major step in processing.
- Give the weight loss during the hot forging in your object.
- Problems associated with heating of steel prior to forging.
- Applications of the open die cold forging
- Precautions to be taken.

Self-Check -1

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

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I. choose the correct answer for given alternative (5 point each)

1. Which one of the following is used to produce a bar with a smaller diameter (using concave dies).

A) hammer die B) Swaging C) None

2. Which one of the following is one of the most important processes of forging and is very frequently used.

A) power bending B) Bending C), section of upsetting

3. Which one of the following is just opposite to drawing and involves increasing of the cross-sectional area usually by pressing or hammering in the direction parallel to the original ingot axis

A) Swaging B) Upsetting C) Bending

II. Answer the following questions (3point each)

1. What is the difference between bending and upsetting

2. Define hammer Forging

3. Explain Punching

III. Say true or false (5 point each)

1. Drifting techniques is, the operation of forming or enlarging a hole by use of a tapered punch.

2. Material requirements planning and product costing, material quantity calculation is used to calculate the material and operation quantities

3. Drop hammer generally applied to forging hammers wherein energy for forging is provided by gravity, steam, or compressed air.

OPERATION SHEET

Operation Title: - Making S-Hooks

Instruction: follow the following instruction to make S-blocks within available material and dimension.

Purpose: To make an S-hook from a given round rod, by following hand forging operation.

Required tools and equipment: - smith's forge, Anvil, 500gm and I kg ball-peen hammers, Flatters, Swage block, Half round tongs, Pickup tongs, Cold chisel.

Precaution:

- Hold the job carefully while heating and hammering
- Job must be held parallel to the face of the anvil.
- Wear steel-toed shoes.
- Wear face shield when hammering the hot metal
- Use correct size and type of tongs to fit the work.

Procedure:

Steps 1: One end of the bar is heated to red hot condition in the smith's forge for the required length.

Steps 2: Using the pick-up tongs; the rod is taken from the forge, and holding it with the half round tongs, the heated end is forged into a tapered pointed end.

Steps 3: The length of the rod requires for S-hook is estimated and the excess portion is cut-off, using a cold chisel.

Steps 4: One half of the rod towards the pointed end is heated in the forge to red hot condition and then bent into circular shape as shown. The other end of the rod is then heated and forged into a tapered pointed end.

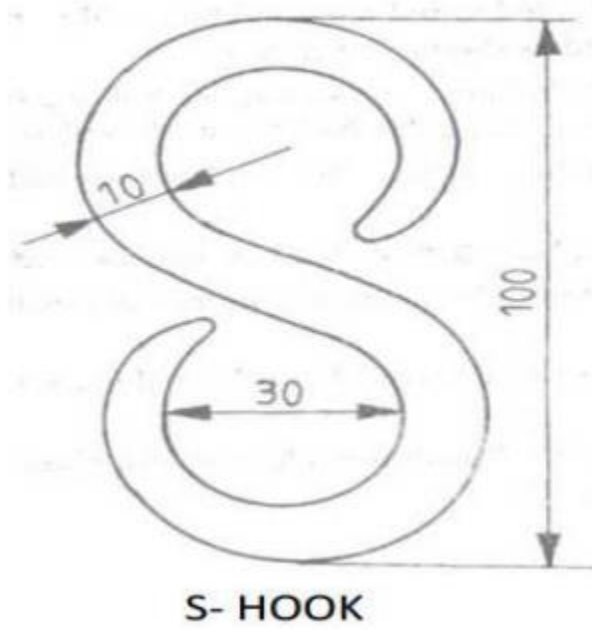
Steps 5: The straight portion of the rod is finally heated and bent into circular shape as required.

Steps 6: Using the flatter, the S-hook made as above, is kept on the anvil and flattened so that, the shape of the hook is proper.

NOTE: In-between the above stage, the bar is heated in the smith's forge, to facilitate forging operations..

Quality Criteria: Dimensional accuracy and Surface finish.

Making S-Hook



LAP Test

Name: _____

Date: _____

Time started: _____

Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 10 hours.

Task 1: Check based on the specification of S-Hooks.

Unit Two: Select Tools and Material

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Hammer tools and formers.
- Setting up forging machine.
- Selecting materials.
- OHS measures.

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Making hammer tools and formers.
- Setting up forging machine.
- Selecting materials.
- Following OHS measures.

2.1 Hammer tools and formers

A hammer is a tool, most often a hand tool, consisting of a weighted "head" fixed to a long handle that is swung to deliver an impact to a small area of an object. Hammering is use of a hammer in its strike capacity, as opposed to prying with a secondary claw or grappling with a secondary hook. Carpentry and blacksmithing hammers are generally wielded from a stationary stance against a stationary target as gripped and propelled with one arm, in a lengthy downward planar arc downward to add kinetic energy to the impact pivoting mainly around the shoulder and elbow, with a small but brisk wrist rotation shortly before impact; for extreme impact, concurrent motions of the torso and knee can lower the shoulder joint during the swing to further increase the length of the swing arc (but this is tiring). War hammers are often wielded in non-vertical planes of motion, with a far greater share of energy input provided from the legs and hips, which can also include a lunging motion, especially against moving targets. There is some of hammering tool:

Hammer tools and formers are correctly selected according to the job specification

- Smith's forge
- Anvil
- Swage block
- Hammers
- Tongs
- Chisels
- Hardie
- Fullers
- Swage
- Flatters
- Punch and Drift
- Set Hammer

There is some hammering tool listed below:

A. Flatters

This is used to flatten and smoothen metal flatters are used under a sledge hammer to flatten the metal particularly after its thickness has been reduced using fullers

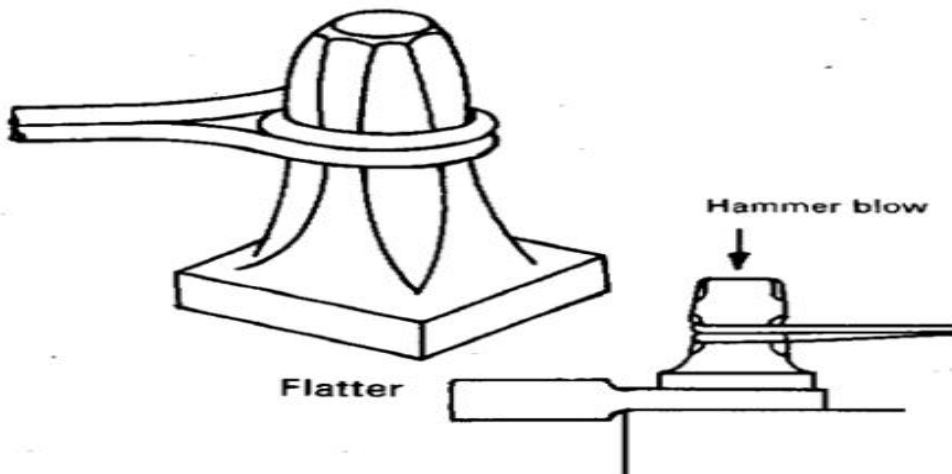


Figure 2.1 Flatter

B. Hammers

A hammer is a tool used to deliver an impact to an object. Hammers are mostly used to drive nails, fit parts, or break up objects. There are many types of hammers designed for specific uses, which vary in shape and structure. Most hammers include a handle and a head, with most of the weight in the head. The strongest, safest hammers have heads made of tough alloy (two or more metals) or drop-forged steel. The two main types of hammers are claw and ball peen.

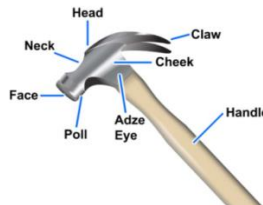


Fig.2.2. Parts of a claw hammer

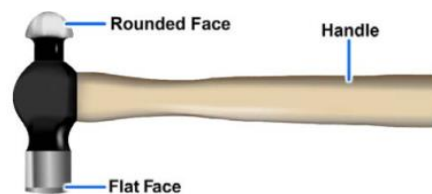


Fig.2.3 ball peen hammer

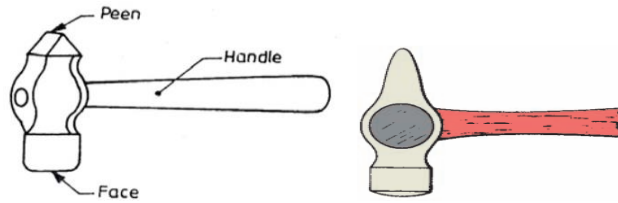


Fig. 2.4 cross peen hammer

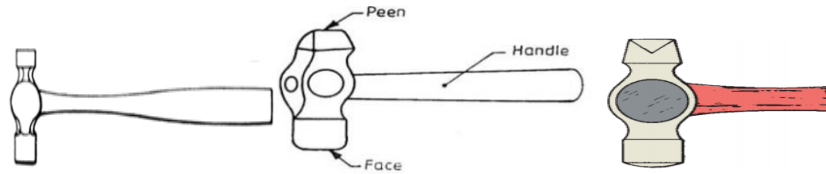


Fig.2.5. straight peen hammer

C. Set Hammers

The set hammer is most often used for setting in shoulders, while the flatter is a good finishing tool and should be used only to impart a good finish to flat surfaces. This tool is cone-shaped and fitted with a handle. It is used for rounding up small rings or for stretching them to size. It is really a form of flattery. A set hammer is used for finishing corners in shouldered work where the flatter would be inconvenient to use.

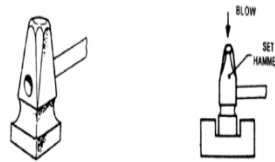


Fig 2.6 Set Hammers

D. Hot and cold set

The “cold” setting of a variable spring support refers to the installed position and the associated load being carried by the support at that time. The “hot” setting refers to the operating position and subsequently the associated load being carried by the support at that time.

Cold set: a chisel ground to a flat edge and used in metalworking especially for flattening seams. Used in a method of printing in which ink is kept fluid by heat until it contacts the cold paper when it quickly solidifies. Cold forging improves the strength of the metal by hardening it at room temperature

Hot set: is a heat treatment by which shape retention, crease resistance, resilience, and elasticity are imparted to the fibers. It also brings changes in strength, stretchability, softness, dyeability, and sometimes on the color of the material. Hot forging results in optimal yield strength, low hardness, and high ductility by hardening the metal at extremely high temperatures.

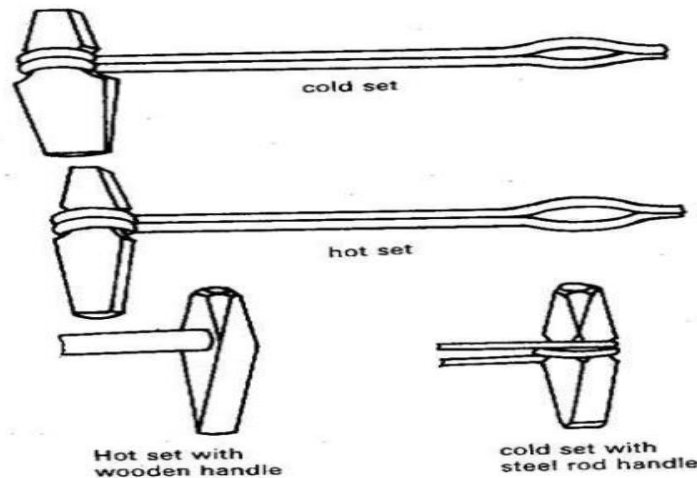


Figure 2.7 Hot and cold set

E. Swages

Swaging is a forging process in which the dimensions of an item are altered using dies into which the item is forced. Swaging is usually a cold working process, but also may be hot worked. A swaging machine works by using two or four split dies which separate and close up to 2,000 times a minute. This action is achieved by mounting the dies into the machine's spindle which is rotated by a motor. The spindle is mounted inside a cage containing rollers (looks like a roller bearing)

Swaging Process

In this process, the diameter of a rod or a tube is reduced by forcing it into a confining die. A set of reciprocation dies provides radial blows to cause the metal to flow inward and acquire the form of the die cavity. The die movements may be of in – and – out type or rotary. The latter type is obtained with the help of a set of rollers in a cage, in a similar action as in a roller

bearing. The workpiece is held stationary and the dies rotate, the dies strike the workpiece at a rate as high as 10 – 20 strokes per second.

In tube swaging, the tube thickness and / or internal die of tube can be controlled with the use of internal mandrels. For small – diameter tubing, a thin rod can be used as a mandrel; even internally shaped tubes can be swage by using shaped mandrels.

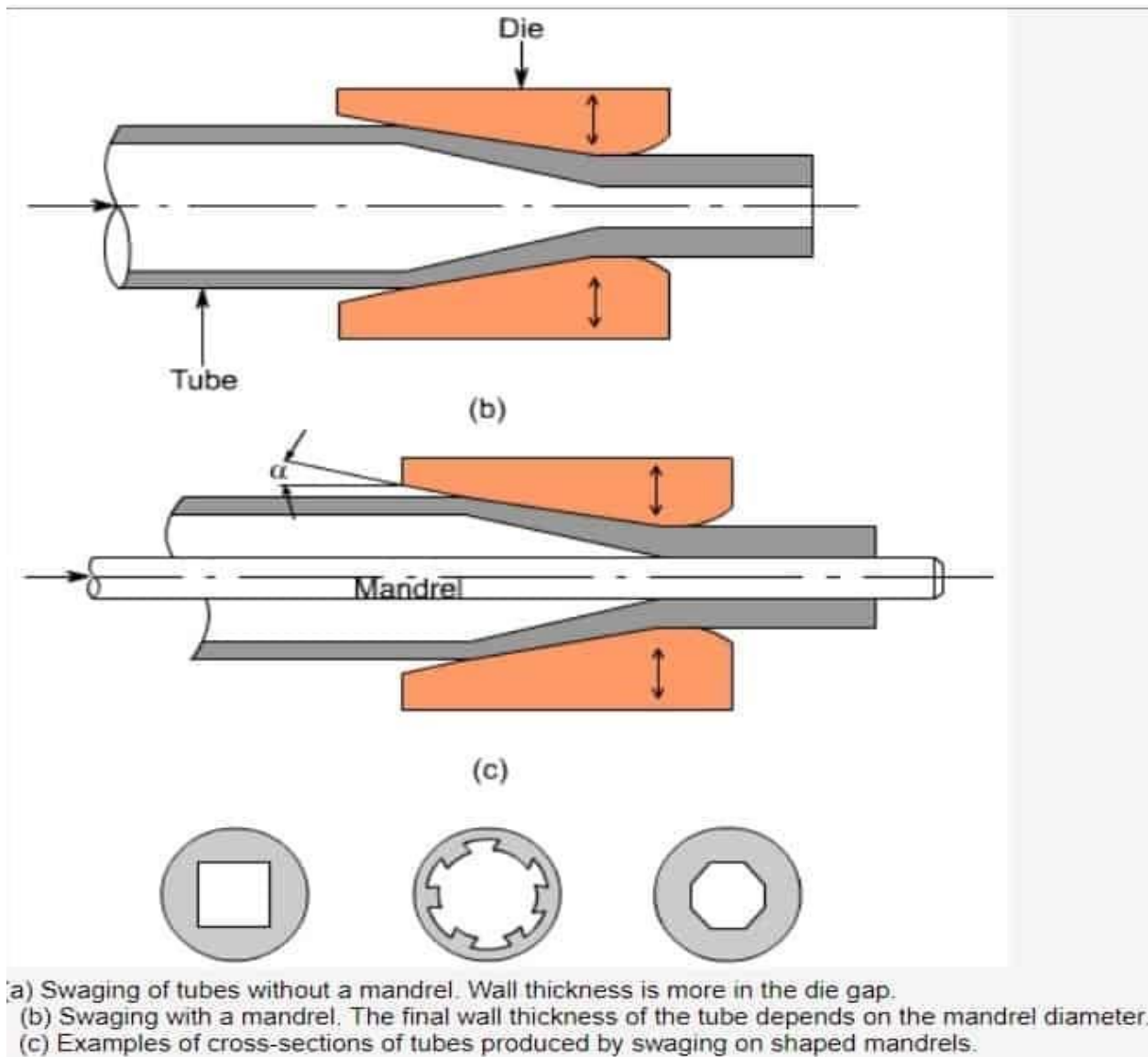


Figure 2.8 Swage tube mandrel

The process is quite versatile. The maximum diameter of work piece that can be swaged is limited to about 150 mm; work pieces as small as 0.5 mm diameter have been swaged. The production rate can be as high as 30 parts per minute depending upon the complexity of the part shape and the part handling means adopted.

The parts produced by swaging have tolerance in the range ± 0.05 mm to ± 0.5 mm and improved mechanical properties. Use of lubricants helps in obtaining better work surface finish and longer die life. Materials, such as tungsten and molybdenum are generally swaged at elevated temperatures as they have low ductility at room temperature. Hot swaging is also used to form long or steep tapers, and for large reductions.

Swaging is a noisy operation. The level of noise can be, however, reduced by proper mounting of the machine or by the use of enclosure

2.2 Setting up forging machine

2.2.1 Forging Hammers

Many forgings are produced at present by machinery. These are used to forge the small parts. To forge the large parts, continuous blows or gradually applied pressure is required which is not possible for the hand forgings. Hence forging hammers came into existence which works on the same principle of providing continuous blows to the metal piece in order to get the large parts forgings. Nowadays the tradition of Pneumatic forging hammer is also in use. The pneumatic forging hammer mallet is one of most highly loaded parts in machinery and is made by forging, using the low alloyed steel for tempering Č4731 - JUS C.B9.021 (34CrMo4 - EN 10083/1).

There are various types of forging hammers available to us like drop hammer, Counterblow hammer, Air or Steam hammer, Pneumatic hammer, lever Spring hammer, water or electricity. Based on this some of forging hammer operation are:

A. Drop hammer

The drop hammer is provided with a pair of dies made of cast steel, one upper and one lower, having suitably shaped depression made in them for forming the forgings. The lower die is held stationary on a heavy weight or hammer. This is raised perpendicularly and allowed to drop upon the material, which is held on the fixed die by the smith, thus forming the forging.

Process variations

Presses can be mechanical, hydraulic or drop hammer type.

- Closed die forging: series of die impressions used to generate shape.
- Open die forging: hot material deformed between a flat or shaped punch and die. Sections can be flat, square, round or polygonal. Shape and dimensions largely controlled by operator.
- Roll forging: reduction of section thickness of a doughnut-shaped preform to increase its diameter. Similar to ring rolling (see PRIMA 4.2), but uses impact forces from hammers.
- Upset forging: heated metal stock gripped by dies and end pressed into desired shape, i.e., increasing the diameter by reducing height.
- Hand forging: hot material reduced, upset and shaped using hand tools and an anvil. Commonly associated with the blacksmith's trade, used for decorative and architectural work.
- Precision forging: near-net shape generation through the use of precision dies. Reduces waste and minimizes or eliminates machining

Hammers are either gravity type or power assisted. With a gravity drop hammer, the upper die is attached to a ram and is raised by either a board, belt, or air (Figure 2.10). It is then allowed to fall freely to strike the workpiece. In power-assisted drop hammers, air or steam is used against a piston to supplement the force of gravity during the downward stroke. The energy used to deform the workpiece is obtained from the kinetic energy of the moving ram and die. Because hammers are energy-restricted machines, multiple blows (usually three) are required at each stage (i.e., for each die) during the forging process.

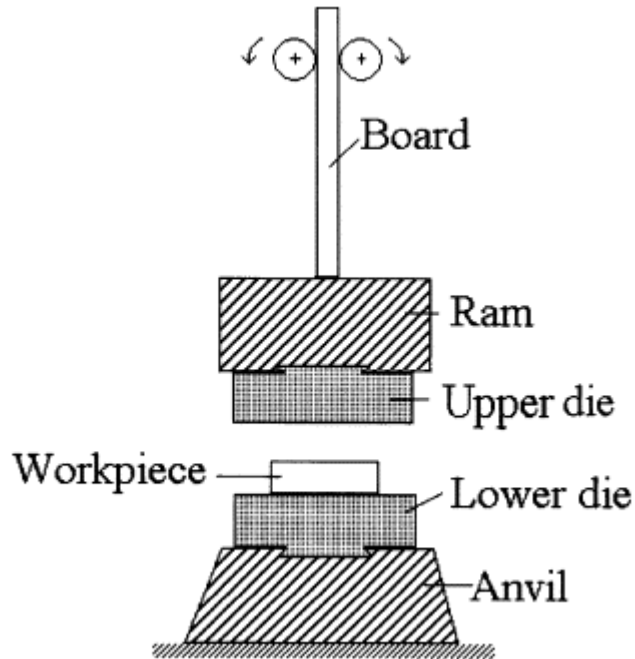


Figure 2.9. A gravity drop hammer

Operation of gravity drop hammer

With a gravity drop hammer, the upper die is attached to a ram and is raised by either a board, belt, or air (Figure 2.10). It is then allowed to fall freely to strike the workpiece. In power-assisted drop hammers, air or steam is used against a piston to supplement the force of gravity during the downward stroke.

B. The steam hammer (Power Hammer)

A steam hammer, also called a drop hammer, is an industrial power hammer driven by steam that is used for tasks such as shaping forgings and driving piles. Typically the hammer is attached to a piston that slides within a fixed cylinder, but in some designs the hammer is attached to a cylinder that slides along a fixed piston.

Steam Hammer Range: 5 KN to 200 KN. Of the various machines that have been devised for the smith's use, to relieve him of the laboriousness of pounding metal into shape, there is none that could take the place of this invention. Numerous shapes and forms can be produced more accurately and rapidly by the steam hammer than by the use of hand methods.

Before proceeding any further, a few words of warning and advice may not be out of place. The power of steam will always exert its utmost force when liberated, so do not let in too much steam at first unless the material is held horizontally and flat on the die, the blow will jar the hands badly and will bend the materials. All tools such as cutters and fullers should be held firmly but lightly, so that they may adjust themselves to the die and the descending blow. After the hammer has been put into motion, the blows

- 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 tones.
- Preferred in closed die forging

Operating system:

Steam hammer is raised by the pressure of steam injected into the lower part of a cylinder and drops under gravity when the pressure is released. With the more common double-acting steam hammer, steam is also used to push the ram down, giving a more powerful blow at the die.

$$W = \frac{1}{2}mv^2 + pAH = (mg + pA)H$$

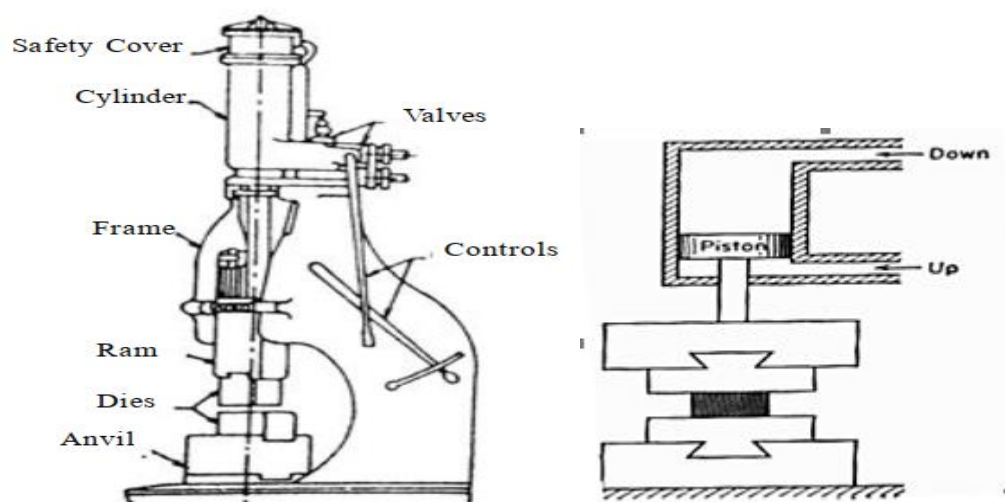


Figure 2.10 Steam hammer

- Where m = mass
- v = velocity of ram at start of deformation
- g = acceleration of gravity
- p = air or steam pressure acting on ram cylinder on down stroke
- A = area of ram cylinder
- H = height of the ram drop

C. 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.

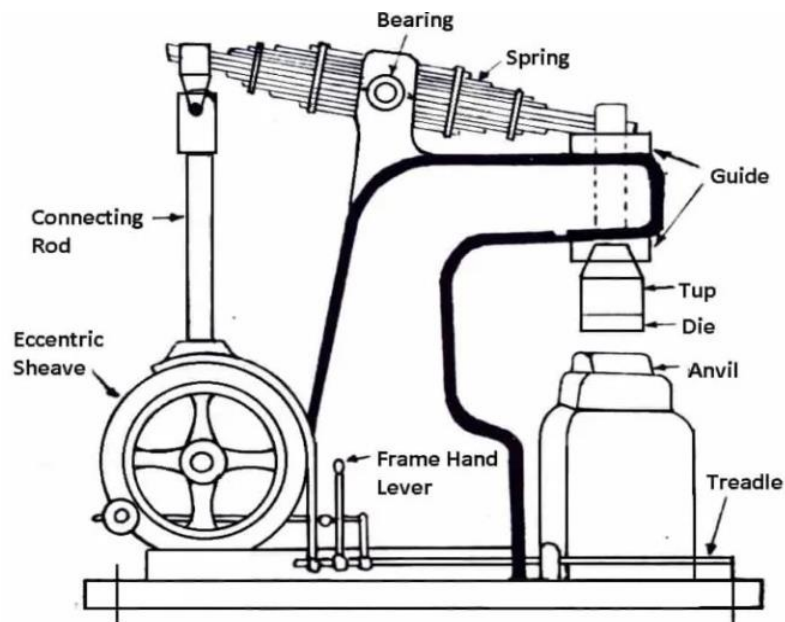


Figure 2.11 Lever-Spring Hammer

Operation of 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

D. Pneumatic Power Hammer

Pneumatic hammer may refer to: Air hammer (fabrication), a pneumatic hand tool. Jackhammer, a pneumatically driven tool used to break up rock and pavement. Nail gun, a pneumatically powered tool used to set nails. Pneumatic hammer (forging), a pneumatically driven forging 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. The motor for the power hammer moves the rod of the back cylinder or compressor and the compressed air goes to the front cylinder through the valves that control the stroke displacement. No need for any external compressor. They are manufactured in welded and mechanized steel sheet

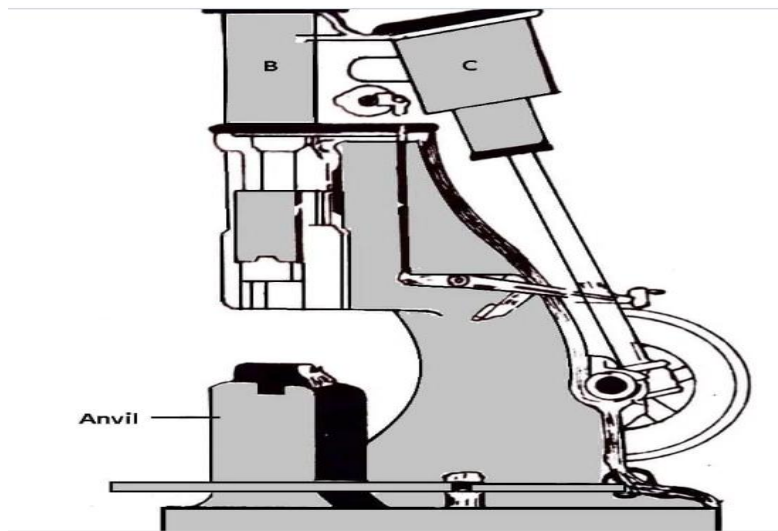


Figure 2.12 Pneumatic Power Hammer

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.

E. Hydraulic press forging

- Using a hydraulic press or a mechanical press to forge the metal, therefore, gives continuous forming at a slower rate.
- Provide deeper penetration
- Better properties (more homogeneous)
- Better properties (more homogeneous)
- Equipment is expensive.

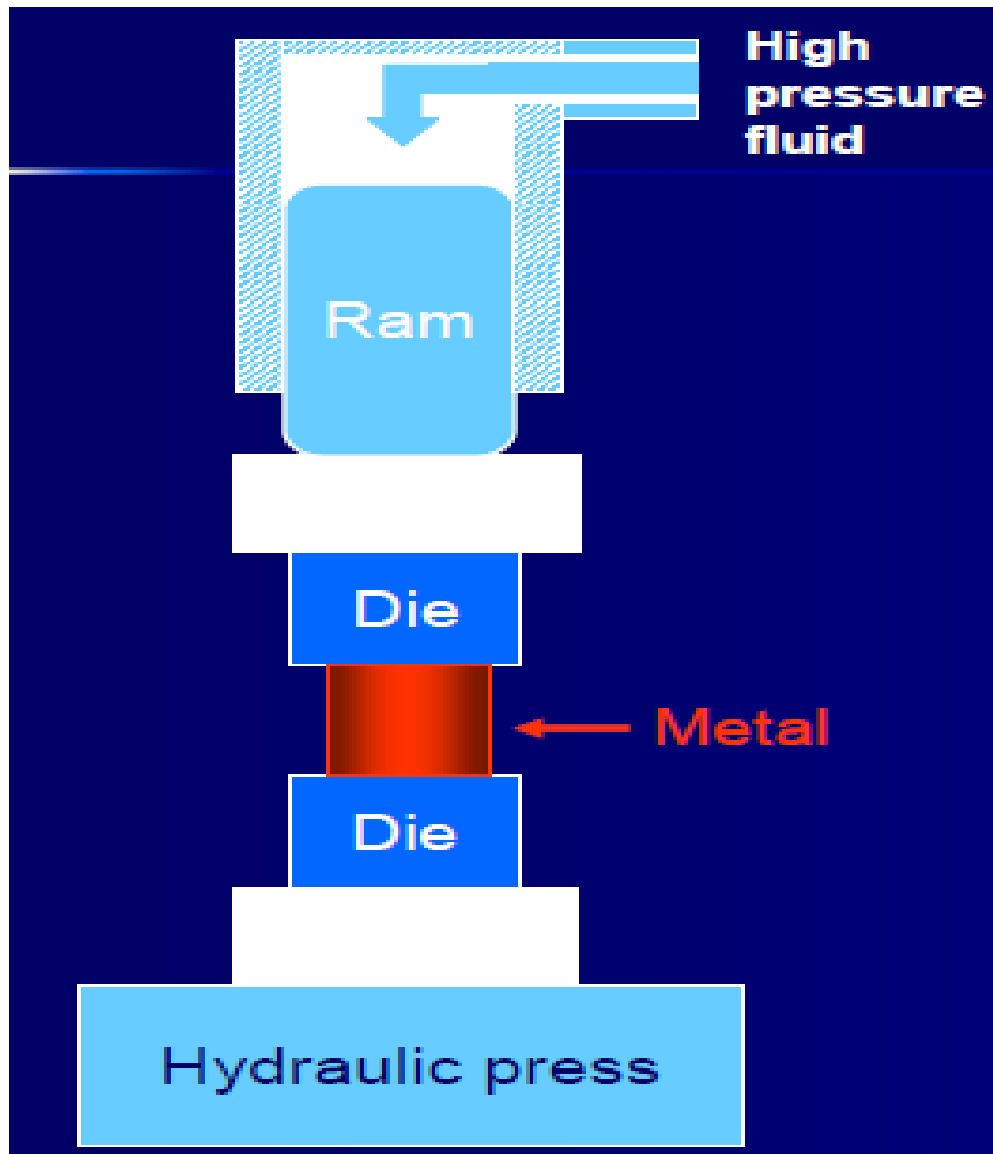
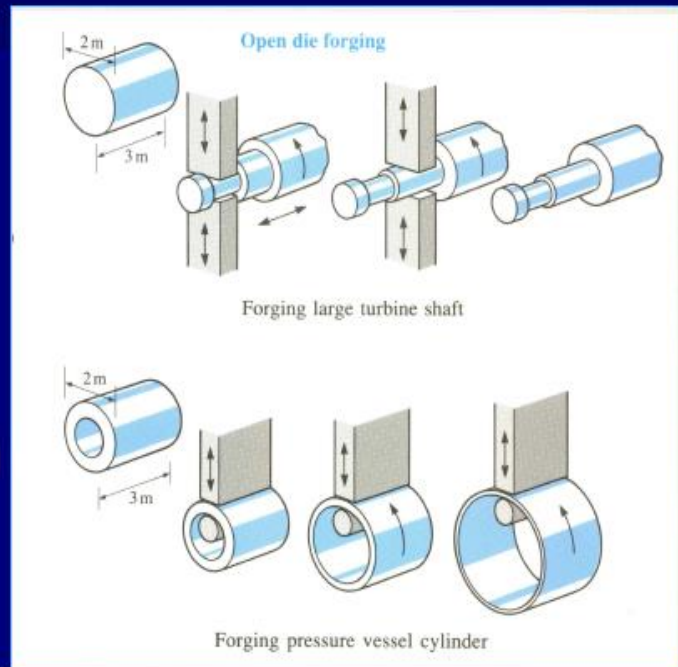


Figure 2.13 Hydraulic press forging

Open-die forging

- **Open-die forging** is carried out between flat dies or dies of very simple shape.
- The process is used for mostly **large objects** or when the number of parts produced is small.
- Open-die forging is often used to **preform** the workpiece for closed-die forging.



2.3 Selecting materials.

2.3.1. Forging Materials

Virtually all metals have alloys that are forgeable, giving the designer the full spectrum of mechanical and physical properties of ferrous and non-ferrous alloys.



Die materials

Required properties

- Thermal shock resistance
- Thermal fatigue resistance
- High temperature strength
- High wear resistance
- High toughness and ductility
- High hardenability
- High dimensional stability during hardening
- High machinability



Forging die

Die materials: alloyed steels (with **Cr, Mo, W, V**), tool steels, cast steels or cast iron. (Heat treatments such as nitriding or chromium plating are required to improve die life)

Note:

- 1) **Carbon steels** with 0.7-0.85% C are appropriate for small tools and flat impressions.
- 2) **Medium-alloyed tool steels** for hammer dies.
- 3) **Highly alloyed steels** for high temperature resistant dies used in presses and horizontal forging machines.

Die materials

Die life can be increased by

- 1) Improving die materials such as using composite die or
- 2) Using surface coating or self-lubricating coatings

Ultra hard surface coatings

Ultra hard surface coating on die surface is used to

- Improve die life.
- Reduce energy input.
- Reduce die-related uptime and downtime.
- Reduce particulate emission from lubricants.

Based on this other specification listed below are some of forgeable materials, in order of increasing forging difficulty:

- | | |
|--------------------------------|-------------------------------|
| ✓ Aluminum alloys | ✓ Magnesium alloys |
| ✓ Copper alloys | ✓ Carbon and low alloy steels |
| ✓ Martensitic stainless steels | ✓ Maraging steels |
| ✓ Austenitic stainless steels | ✓ Nickel alloys |
| ✓ Titanium alloys | ✓ Columbium alloys |
| ✓ Tantalum alloys | ✓ Molybdenum alloys |
| ✓ Tungsten alloys | ✓ Beryllium |

- **Carbon:** the greatest volume of forgings for a very wide range of applications.
- **Stainless steels:** widely used where resistance to heat and corrosion are required
- **Aluminum forgings:** used in applications where temperatures do not exceed 150oC.
- **Copper, brass and bronze:** offer excellent corrosion resistance with high thermal and electrical conductivity.
- **Iron, nickel and cobalt high temperature alloy:** for applications of cyclical and sustained loads at high temperatures.
- **Titanium:** are used where high strength, low weight and excellent corrosion resistance, combined with moderate heat resistance, are required.
- **Magnesium:** offer the lowest density of any commercial structural metal, at operating temperatures similar to aluminum. **Special emphasis will be given on types of steels on the following pages.**

2.3.1.1 Steels

Steel may be defined as iron in a modified form, artificially produced, containing a certain amount of carbon and other constituents and possessing a hardness, strength, elasticity, etc., which vary with chemical composition and thermal treatment.

- Steels can be classified by a variety of different systems such as: The composition, such as carbon, low-alloy or stainless steel,
- The manufacturing methods, such as open hearth, basic oxygen process, or electric furnace methods,
- The finishing method, such as hot rolling or cold rolling, The product form, such as bar plate, sheet, strip, tubing or structural shape,
- The de oxidation practice, such as killed, semi-killed, capped or rimmed steel,
- The microstructure, such as ferritic, pearlite and martensitic,
- The required strength level, as specified in ASTM standards,
- The heat treatment, such as annealing, quenching and tempering, and thermo-mechanical processing,
- Quality descriptors, such as forging or commercial quality.

There are hundreds of steels that range in carbon content from approximately 0.06% to 1.5%. Many contain metallic alloying elements, such as manganese, chromium and molybdenum, ranging from traces amounts to approximately 9%. Virtually all can be readily forged. There are two groups within the general classification of steels: carbon steels, and alloy steels.

2.3.1.2 Carbon Steels

As defined in ASTM standards, carbon steel is a steel that conforms to a specification that prescribes a maximum limit, in mass percent, of not more than: 2.00 for carbon and 1.65 for manganese, but does not prescribe a minimum limit for aluminum, boron, chromium, cobalt, columbium, molybdenum, nickel, tungsten, vanadium, or zirconium. Popular carbon grades include DIN C15, C45, and C60. Carbon grades are used extensively in applications which require machining, welding, forging or induction hardening.



2.3.1.3 Alloy Steels

In general, alloy steel is used when more strength, ductility or toughness is required than can be obtained in a carbon grade. In addition, alloy grades should be used where properties such as corrosion resistance, heat resistance and low-temperature impact values are required. Micro alloyed steels, which are carbon products with very low ranges of elements (such as vanadium, niobium and/or titanium), and stainless steels may be classified as alloy steels.

Alloyed steels (with Cr, Mo, W, V), tool steels, cast steels or cast irons. (Heat treatment such as Nitriding or chromium plating are required to improve die life's)

Carbon steels: with 0.7-0.85%C are appropriate for small tools and flat impressions.

Medium-alloyed tool steels: for hammer dies.

Highly alloyed steels: for high temperature resistant dies used in presses & horizontal.

2.4 OHS measures.

2.4.1 General Requirements

Occupational Health and Safety: Occupational health and safety (OHS) is a branch of public health aimed at improving workplace health and safety standards. It studies injury and illness trends in the worker population and offers suggestions for mitigating the risks and hazards they encounter on the job. Wear appropriate clothing and shoes for your job. · Know the location of fire extinguishers and first aid kits. So, Requirements of OHS:

- Sufficient room for handling the work, including material and scrap.
- Walkway shall be provided; of sufficient width to permit the free movement. A minimum Walkway width of 4 feet 6 " is recommended.

- Machinery and equipment should be so located with respect to sources of light that of sufficient intensity will fall on the work.
- All hammer treadles shall be substantially and effectively guarded to prevent accidental tripping.
- A proper timber or bar shall be provided at each hammer for blocking up the ram when changing or otherwise working on the dies or hammer,
- A scale guard of substantial construction shall be provided on the back of every hammer,
- Walkway and working spaces shall be kept in good order and free of obstructions at all times.
- Use tongs or steel fork for handling hot metal on the floor.
- Goggles should always be worn when operating a hammer or cold-trim press.
- Safe clothing. -For protection against flying scale wear asbestos or leather aprons; asbestos or leather gloves or canvas gloves with leather palm (the latter are cooler); Congress shoes, and leggings. For handling rough stock wear hand leathers.
- Always avoid the use of damaged hammers.
- Never strike a hardened surface with a hardened tool.
- No person should be allowed to stand in line with the flying objects.
- Always use the proper tongs according to the shape of the work.
- The anvil should always be free from moisture and grease while in use.
- The handle of the hammer should always be tightly fitted in the head of the hammer.
- Always put out the fire in the forge before leaving the forge shop.
- Always keep the working space clean.
- Head of the chisel should be free from burrs and should never be allowed to spread.

Self-check-2

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. choose the correct answer for given alternative (5 point each)

- Which one of the following is mostly used to drive nails, fit parts, or break up objects?
A) hammer die B) Swaging C) Hammer
- Which one of the following is used for finishing corners in shouldered work where the flatter would be inconvenient to use?
A) Set hammer B, Bending C, upsetting
- Which one of the following is provided with a pair of dies made of cast steel, one upper and one lower, having suitably shaped depression made in them for forming the forgings.
A) Drop hammer B) Upsetting C) Bending

II. Answer the following questions (3point each)

- List forgeable materials
- Define Occupational Health and Safety.
- Explain *Steels*

III. Say true or false (5 point each)

- Hammers are either gravity type or power assisted.
- A steam hammer is an industrial power hammer driven by steam that is used for tasks such as shaping forgings and driving piles
- Carbon is widely used where resistance to heat and corrosion are required
- Copper, brass and bronze are offer excellent corrosion resistance with high thermal and electrical conductivity.

Operation Sheet

Operation Title: -Upsetting or jumping up

Instructions: follow the following instruction to make upsetting the available material

Purpose: This process increasing the cross-section of a at the expense of its length

Required tools and equipment: - Tong, Forge, Round bar Charcoal, PPE

Precaution: Use PPE and Tongs

Procedure:

1. Heat the portion to be jumped up.
2. Bounce the metal on the lower die.
3. Hold the bar with tong and hammer the end.

Quality Criteria: Dimensional accuracy and Surface finish

LAP Test

Name: _____

Date: _____

Time started: _____

Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 6 hours.

Task: Check upsetting or jumping up based on the specification.

Unit Three: Hammer Forging Techniques

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Hammer forging technique.
- Annealing technique.
- Recognizing defects.
- Appropriate rectification action on defects
- Correct techniques to the handling of hot metal

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Selecting and applying hammer forging technique.
- Applying annealing technique.
- Recognizing defects.
- taking appropriate rectification action on defects
- Applying correct techniques to the handling of hot metal

3.1. Hammer Forging Technique

3.1.1 Purpose of Hammer Forging

Forging hammers are used in the drop forging to form the metal between two dies. The first half of the die is attached to the anvil and the second part to the hammer. The material is placed in the lower die and then hammered with the upper one until the hot metal flows in all directions, filling the die cavity.

Hammer forging is an equipment intensive but efficient method for making rifled gun barrels. Hammer-forged rifling starts with a reusable mandrel that carries the reverse image the entire length of the bore and uses it to produce the desired rifling profile. There are four types of forging manufacturing processes that are commonly used to shape metal parts. These processes include impression **die forging (closed die)**, **cold forging**, **open die forging**, and **seamless rolled ring forging**.

3.1.2. Four Types Of Forging Manufacturing Processes

- A. Die Forging (Closed Die)
- B. Seamless Rolled Ring Forging
- C. Open Die Forging
- D. Cold Forging,

A. Impression Die Forging (Closed Die)

Closed die forging (also known as impression die forging) is a metal forming process that compress a piece of metal under high pressure to fill an enclosed die impression. For some special shapes, second forging operation is required to reach final shapes and dimensions. The difference between open and impression-die forging is, with open die forging the work piece is basically compressed between two dies whereas with impression die forging it fills the cavities of the dies and produce a more complex shape.

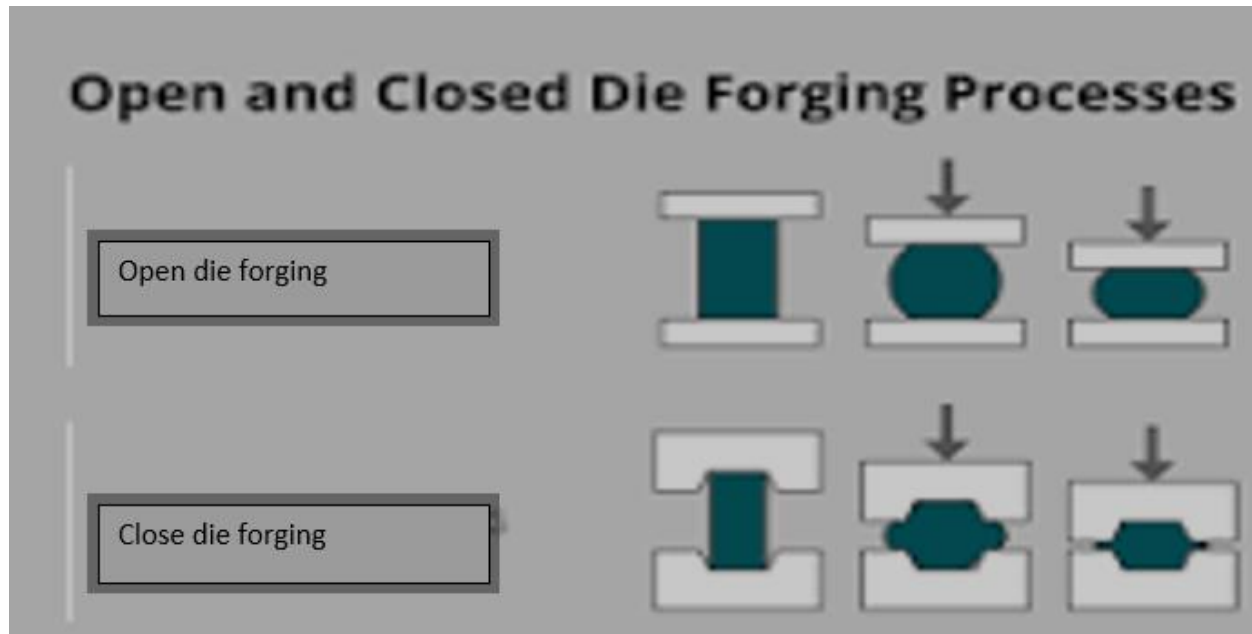


Figure 3.1 Impression Die Forging (Closed Die) and die forging

E. Seamless Rolled Ring Forging

Seamless rolled ring forging process begins by cutting a desired material's starting stock to size before rounding it on the open die presses. The rounded piece is then upset and then pierced to make a preform. The preform is a donut-shaped forging ready to be placed on a ring rolling mill. Seamless forged rings are created through a process called ring rolling, which uses a machine called a rolling mill. The rolling mill can generate rings of a range of diameters and weights. The process starts with a circular metal piece that is pierced to form a doughnut-shaped component. After this ring is formed, it's heated to recrystallization temperature. From there it's placed on an idler roll and moves towards a drive roll. This step causes the ring to rotate and increases their diameter and the wall thickness of the rolling rings. Seamless rings are produced using a range of configurations: tall cylinders, smaller parts resembling washers, etc., manufactured using a shaping tool.

Seamless rolled rings are used for:

- Bearings
- Clutches
- Couplings
- Drives
- Flanges
- Gears
- Glass-lined reactors
- Machines
- Robotics
- Valves

You'll find them being used in the mining, power generation, and oil industry, as well as by the military. They help power rock crushing equipment, jet engines, windmills and railways. If you're interested in learning more about seamless rolled ring forging, Specialty Ring Products can help. For more than a century, we've been a leader in the forging industry, a four-generation family-owned company committed to quality work and evolving our processes and standards. Contact us today to learn more, or to request a forging quote.

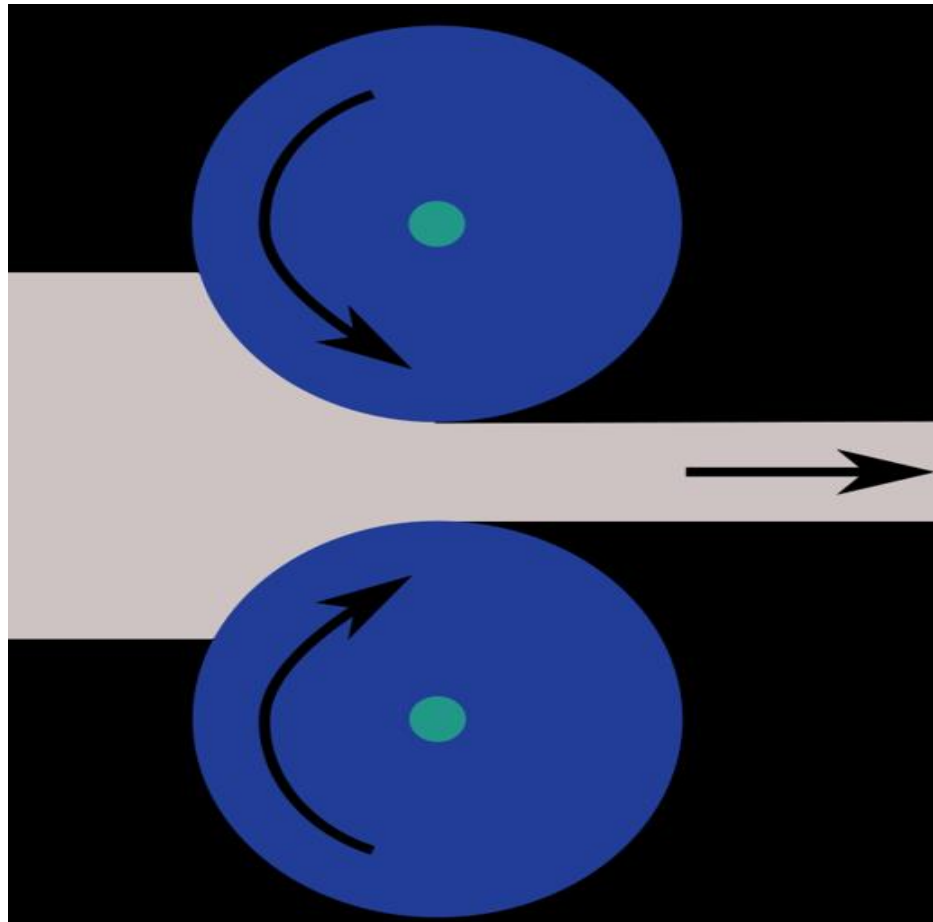


Figure 3.2 Seamless Rolled Ring Forging

A. Open Die Forging

Open-die forging, also known as free forging or smith forging, is the process of striking a hammer to deform a piece of metal, typically placed on a stationary anvil. Another approach is to use compression to press the metal between simple dies. These simple dies are typically flat, semi-round or V-shaped. Open die forging is a type of forging in which the metal pieces or workpiece are deformed to the desired shape with the help of dies that do not completely enclose the material. The material produced in the open die forging requires secondary machining operations to get the desired accuracy and tolerances. In this forging process the material is shaped by placing the workpiece on a stationary anvil and then hammering it with the help of a power hammer. Here the die is attached to the hammer or the hammer acts as die.

This forging technique is generally used to shape metal parts, steels, or alloy steels. The parts produced is not of greater accuracy and hence require machining operation on the lathes or milling machines, etc. to give it the desired accuracy.

The main parts of open die forging are:

1. **Hammer/Ram:** The hammer or ram is used to apply force on the workpiece.
2. **Die:** A die is attached to the hammer or ram that makes contact with the workpiece to give it a desired shape and size. The die used in open die forging may be of flat, concave, and convex surfaces or a tool to make holes or to cut off part. The most common flat surfaces die is used.
3. **Anvil:** It is a stationary part that supports the workpiece during the hammering.
4. **Workpiece:** It is the metal parts that will be used to deform and changes it to the final product. The metal workpieces are heated to red hot before hammering.

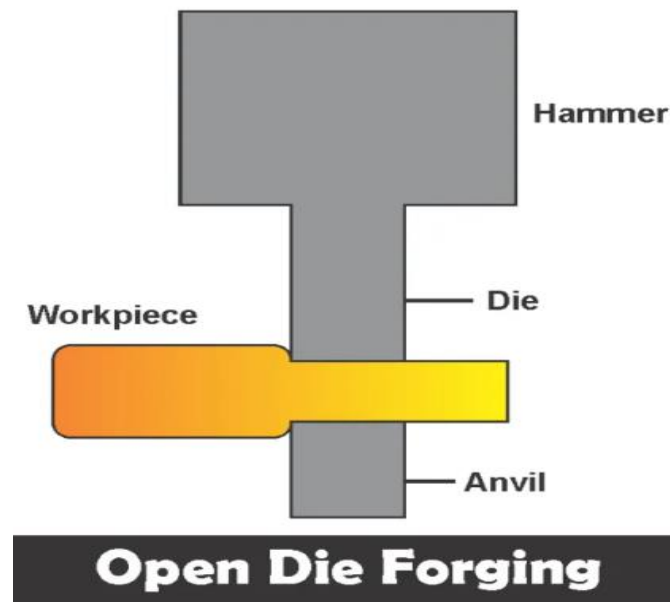
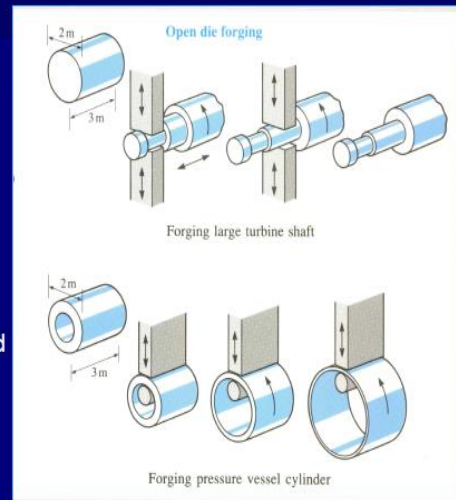


Figure 3.3 Open die forging

Open-die forging

- **Open-die forging** is carried out between flat dies or dies of very simple shape.
- The process is used for mostly **large objects** or when the number of parts produced is small.
- Open-die forging is often used to **preform** the workpiece for closed-die forging.



Working Principle

In open die forging, the workpiece is heated and placed on the anvil and then it is hammered with the ram or hammer. The force of the hammer that makes contact with the workpiece compresses it and allows it to expand in the direction that is not in contact with the hammer surface and anvil. The hammering process continues and a skilled worker changes the orientation of the workpiece to give it the required shape. When the workpiece gets cold during hammering, it is heated again and then the process continues until the final dimension is not obtained.

In this forging since the metal part is hammered continuously, the grains in the workpiece arranged themselves more uniformly and we get a finer grain size with the continuous flow that results in the greater strength of the final product. The parts produced in the open die forging has greater strength, fatigue resistance, wear resistance, fine microstructure, fewer voids as compared with similar machined or cast parts

Open Die Forging: Involves the shaping of heated metal parts between a top die attached to a ram and a bottom die attached to a hammer, anvil or bolster. Open die forging is another drop forging process that metal is getting deformed for desire shapes without any limitation between the top and bottom anvils in all directions utilizing power or pressure. So, it is also named as free forging.

Main feature of open die forging is that the production equipment is relatively simple, so the cost is low. Compared with the casting blank, open die forging eliminates the defects such as shrinkage, gas holes, porosity, etc. So, products after open die forging have higher mechanical properties. Unlike closed die forging, open die forging shape is simple and the operation is flexible, therefore, it always acts as important parts in heavy machinery equipment's. Another feature is that the shape and dimensions of open die forgings is mainly controlled by manual operation. So, the size accuracy of products is relatively low, and the machining allowance will be large with high working strength. That is why open die forging is mainly applied for single and low volume production.



Figure 3.4 Production of Open Die Forging

Open die forging is currently operated by labour and machines. With labour operation, the production efficiency is low, and working strength is large, so this kind of production way is only suitable for simple and single production. In modern production, machines have become the main way for open die forging production. The degree of operator's profession will also affect the dimensions and accuracy of products.

Main Equipments

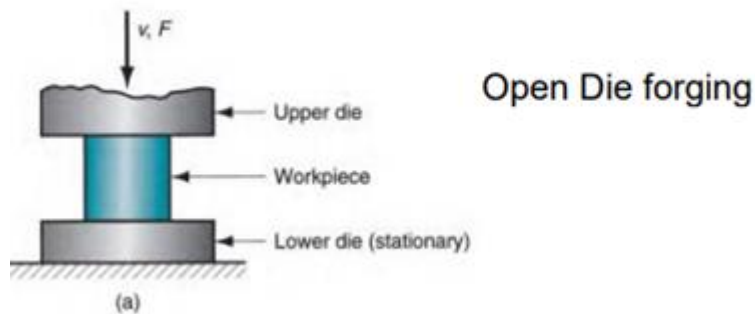


Figure 3.5 Open die forging equipment

Open die forging equipment's are mainly divided into forging hammer and hydraulic press. Main used forging hammers are air hammer and steam hammer. Hydraulic press is working and getting blanks deformed by using of static pressure that produced by liquid. This is the only method to produce large forgings

Common Open Die Forging Defects

1. Crack. It could be caused by bad billet quality, insufficient heating, low forging temperature or wrong cooling method. Besides, improper forging method may also cause the crack.
2. Depressed deformation on end and crack in axis.
3. Fold



Open-Die Forging with Friction

Actual deformation of a cylindrical workpart in open-die forging, showing pronounced *barreling*: (1) start of process, (2) partial deformation, and (3) final shape

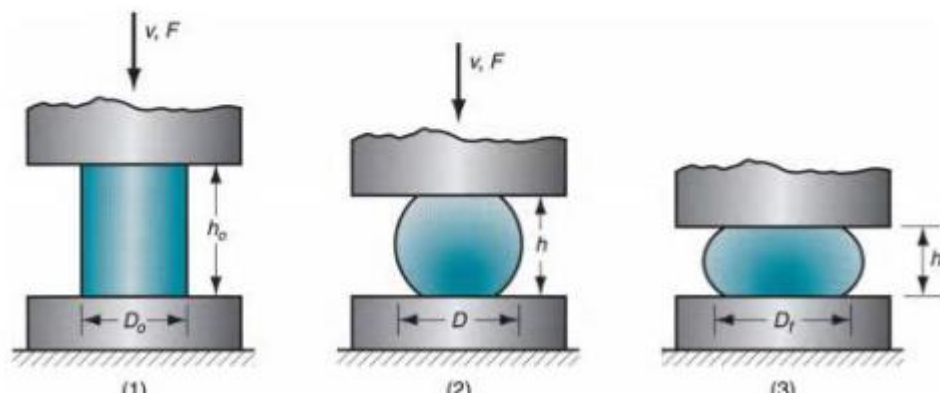


Figure 3.6 open die forging

D. Cold Forging:

Cold hammer forging produces accurate and durable barrels. During cold hammer forging, Tikka barrels are hammered from all sides against the mandrel inside the barrel, transferring the mirror image of the rifling machined on the surface of the mandrel. A cold hammer forged barrel has many advantages. A cold hammer forged barrel has smoother barrel surfaces compared to other barrel manufacturing methods such as button rifling and cut rifling. This guarantees consistent high quality and precision.

Cold forging: various forging processes conducted at or near ambient temperature to produce metal components to close tolerances and net-shape. These include bending, cold drawing, cold heading, coining, **extrusion (forward or backward), punching, thread rolling, and others.**

Cold heading: plastically deforming metal at ambient temperatures to increase the cross-sectional area of the stock (either solid bar or tubing) at one or more points along the longitudinal axis. See Figure 3.7. **Cold working:** imparting plastic deformation to a metal or alloy at a temperature below recrystallization to produce hardness and strength increases via strain hardening.

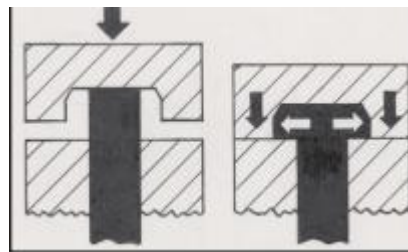


Figure 3.7. Cold heading or upsetting

Cold heading or upsetting is a cold forging process where steel is gathered in the head and in other locations along the length of the part, if required. Metal flows at right angles to the ram force, increasing diameter and reducing length.

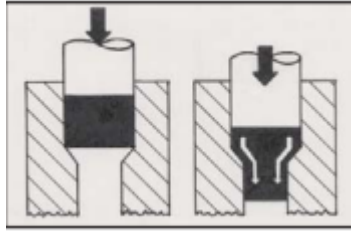


Figure 3.8. Forward extrusion

Forward extrusion, a basic cold forging process, reduces slug diameter while increasing length. Stepped shafts and cylinders are typical examples of this process.

Three Main Principle of Forging: There are many different kinds of forging processes available; however, they can be grouped into three main classes:

- **Drawn out:** length increases, cross-section decreases.
- **Upset:** length decreases, cross-section increases.
- **Squeezed in closed compression dies:** produces multidirectional flow.

Working Principle cold hammer forging: Cold forging uses a displacement process to shape the material into the desired shape. Compressive force squeezes the metal between a punch and die at room temperature until the material conforms to the die's contours. Cold forging techniques include rolling, pressing, drawing, spinning, heading, and extruding. Forging changes a metal workpiece through compression at either cold, warm, or hot temperatures. Cold forging improves the strength of the metal by hardening it at room temperature. Hot forging results in optimal yield strength, low hardness, and high ductility by hardening the metal at extremely high temperatures. Whether to use hot or cold forging depends on the finished component's function, industry, and production volume. While cold forging compresses metal at room temperature, hot forging requires high heat. A **primary differentiator of cold and hot forging** is that the high heat of hot forging allows the metal to take on more elaborate and complex forms than cold forging.

HOT FORGING: The hot forging temperature varies depending on the type of metal. Hot forging starts with heating the dies to prevent any loss of temperature during the process and ensure crystallization doesn't occur until forming is complete. Heating causes the metal to

become more ductile. When the pressure of the dies squeezes the hot metal, the structure transforms into a more refined grain that results in increased yield strength and ductility

Factors to consider when hot forging include:

- **Cooling.** If the metal cools to a temperature lower than the minimum threshold, it completes the forging. The metal must be reheated if this occurs before achieving the final shape.
- **Tolerances.** Dimensional tolerances with hot forging are less precise than cold forging.
- **Dies.** Hot forging dies are custom-made to the customer's part specifications

COLD FORGING: Cold forging uses a displacement process to shape the material into the desired shape. Compressive force squeezes the metal between a punch and die at room temperature until the material conforms to the die's contours. Cold forging techniques include rolling, pressing, drawing, spinning, heading, and extruding.

Factors to consider when cold forging include:

- **Material volume.** Careful control over the material volume prevents stress and damage, particularly in closed forging, as the excess has nowhere to escape.
- **Bowdlerizing.** This coating process improves material flow during the process to reduce force, stress, and friction while improving surface quality.
- **Annealing.** Annealing softens the metal, improving the material flow. It can be applied as an intermediate process when work hardening occurs before the forging process is completed.
- **Lubrication.** Lubrication is critical during cold forging. High-viscosity oil protects against metal-on-metal friction and applying thin oil dissipates heat

Advantages of hot and cold forging include:

- **Hot forging.** Increased ductility for more complex parts and allows for more options for customization
- **Cold forging.** Creates no waste, requires little to no finishing work, maintains dimensional accuracy, and results in high surface quality.

Disadvantages of hot and cold forging include:

- **Hot forging.** Additional cost for heat treatment, less precise dimensional tolerance, risk of warping
- **Cold forging.** Few options for customization, risk of residual stress, may require heat treatment

3.2 Annealing technique.

Heat treatment is carried out for releasing the internal stresses arising in the metal during forging and cooling of work piece. It is used for equalizing the granular structure of the forged metal and improving the various mechanical properties. Generally forged parts are forged metals, Full Annealing, spheroid zed annealing and Spheroid zed annealing to obtain the desired results.

3.2.1 Annealing of forged metals

The purpose of heat treatment processes of steel is employed for the following reason:

- To soften the steel so that it may be more easily machined or cold worked
- To refine the grain size & structure
- to improve mechanical properties like strength & ductility
- To relieve internal stress which may have been caused by hot or cold working or by unequal contraction in casting
- To alter electrical, magnetic or other physical properties
- To remove gases trapped in the metal during initial casting

3.2.2 Full Annealing

It consists of authentication of the steel followed by slow cooling. For hypo-eutectoid steel, it consists of austenitizing the steel at 10-30°C above the AC3 line and holding it at this temperature for a desired length of time, followed by slow furnace cooling. This leads to the formation of a fine ground austenite structure. The subsequent slow cooling enables the austenite to decompose at low degree of super cooling so as to form pearlite and ferrite. In case of hyper-eutectoid steel heated above AC1 to spheroidized the pro eutectoid cementite. Therefore, it is the general practice to use spheroidized annealing. In case of heating above ACM temperature and cooled slowly results in formation of pro eutectoid cementite at the grain boundaries. The retarded cooling facilities ferrite precipitation as a separate cluster. This might result in soft spots during hardening and render the steel brittle to forming and service stresses.

3.2.3 Spheroid zed Annealing

This is done by heating the steel just above or slightly below AC1 temperature for a prolonged time, followed by a slow cooling in order to soften the steel as much as possible. It is adopted to spheroidize the carbides of lamellar pearlite or secondary cementite. Commonly four methods are practiced for this treatment

First Method

The steel is heated nearer to AC1 temperature and held at that temperature for a long time for the formation of coarse globular cementite, the temperature should be as close to AC1 as possible.

Second Method

The steel is heated slightly above AC1 temperature and held for a prolonged time followed by slow cooling at a rate of 10 - 20°C per hour up to 550 - 600°C and then cool in still air.

Third Method

It is heating the steel slightly above AC1 and holding for a predetermined time and then cooling to just below AC1 temperature and holding for prolonged time and subsequently cooling to the room temperature.

Fourth Method

Spheroid zing is done by repeatedly heating and cooling just above and below AC1 temperature. During heating above AC1 temperature only the small sized grains of cementite will dissolve in the austenite, but there is insufficient time for the larger cementite grains to dissolve.

In the subsequent cooling cycle, the molecules of cementite are deposited mainly on the cementite grains that are not dissolved in the austenite. Hence, a coagulation process occurs. This Method has taken less time compared to previous methods but difficult to perform.

3.2.4 Isothermal Annealing

This is derived from the exact knowledge of temperature – time diagrams. This treatment consists of austenitizing the steel at the full annealing temperature and then cooling rapidly to appropriate temperature below Art by 50 60°C. After the transformation is complete, the steel is cooled in a furnace, or air cooled or rapidly cooled.

Properties after Annealing

Annealing results in the formation of ferrite, spheroidal cementite and coarse pearlite. All these phases and micro-constituents are relatively soft. Therefore, annealing is called as softening treatment, and produces relatively lower hardness values. After annealing hardness of steel can vary from 110 BHN (Brinell hardness number) to 230 BHN, depending upon the carbon content and the alloying elements. Hardness increases with increase in carbon content and the alloying elements.

Table 3.1 Variation of Annealing Temperature and The Resulting Hardness with Carbon Content in the Steel

Sl. No.	Carbon content in Steel Per cent	Annealing Temperature C	hardness BHN
1	0.18-0.22	860-900	110-149
2	0.23-0.28	850-890	130-180
3	0.29-0.38	840-880	140-206
4	0.39-0.55	820-870	150-217
5	0.56-0.80	790-840	160-230
6	0.81-0.99	790-830	170-230

3.3 Recognizing defects

3.3.1 Concept of Steel Defects

Steel forging defects are not widely discussed because of a natural reluctance by forging company to draw attention to them. There are many imperfections that can be considered as being defects, ranging from those traceable to the starting materials to those caused by closed die forging process or by post forging operations. Defects can be defined as imperfections that

exceed certain limits. In other words, there may be imperfections that are not classified as true “defects” because they are smaller than allowances in the applicable specifications.

The following listed information is about common and not so common defects of steel forgings that come from the actual closed die forging operations or from post forging operations typical of many forge plants. The goal here is to acquaint the reader with these various defects, with how they can affect forging performance, and how to eliminate them with future forging production.

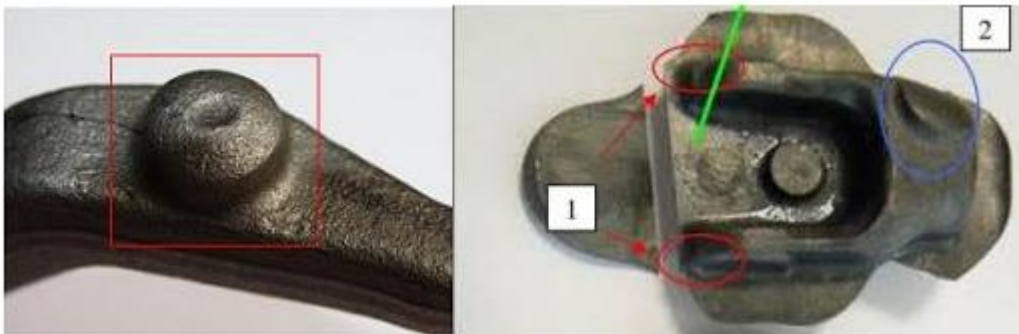


Figure 3.9 Steel Forgings defect

1) Unfilled Section

As the name implies in this type of defect some of the forging section remain unfilled. This is due to poor design of die or poor forging technic. This is also due to less raw material or poor heating. This defect can be removed by proper die design, proper availability of raw material and proper heating.

2) Cold Shut

Cold shut includes small cracks at corners. These defects occur due to improper design of forging die. It is also due to sharp corner, and excessive chilling in forging product. The fillet radius of the die should be increase to remove these defects.

3) Scale Pits

Scale pits are due to improper cleaning of forged surface. This defect generally associated with forging in open environment. It is irregular deputations on the surface of forging. It can be removed by proper cleaning of forged surface.

4) Die Shift

Die shift is caused by misalignment of upper die and lower die. When both these dies are not properly aligned the forged product does not get proper dimensions. This defect can be removed by proper alignment. It can be done by provide half notch on upper die and half on lower die so at the time of alignment, both these notches will match.

5) Flakes

These are internal cracks occur due to improper cooling of forge product. When the forge product cooled quickly, these cracks generally occur which can reduce the strength of forge product. This defect can be removed by proper cooling.

6) Improper Grain Growth

This defect occurs due to improper flow of metal in casting which changes predefine grain structure of product. It can be removed by proper die design

7) Incomplete Forging Penetration

This defect arises due to incomplete forging. It is due to light or rapid hammer blow. This defect can be removed by proper control on forging press.

8) Surface Cracking

Surface cracking occurs due to exercise working on surfaces at low temperature. In this defect, so many cracks arise on work piece. This defect can be removed by proper control on working temperature.

9) Residual Stresses in Forging

A defect commonly found in forged parts includes;

- Defects resulting from the melting practice such as dirt, slag and blow holes.
- Ingot defects such as pikes, cracks scabs, poor surface and segregation.
- Defect due to faulty forging design.
- Defects of mismatched forging because of improper placement of the metal.
- Defects due to faulty design drop forging die.
- Defects resulting from improper forging such as seams, cracks, laps. etc.

- Defects resulting from improper heating and cooling of the forging part such as burnt metal and decarburized steel.

Some common forging defects along with their reason are given below.

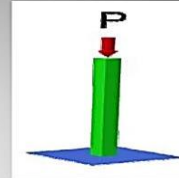
- Mismatched forging: due to non-alignment of proper die halves.
- Brunt and overheated metal: improper heating of metal at high temperature.
- Fibred flow lines discontinued: because of very rapid plastic flow of metal.
- Scale pits: by squeezing of scale into the metal surface during forging.
- Oversize components: worn out dies, incorrect dies, misalignment of die halves.

Other types of defects, occurring in the forging operations are the follows:

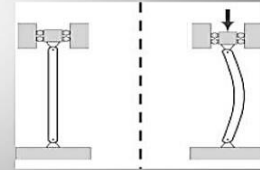
- Incomplete die filling.
- Die misalignment.
- Forging laps.
- Incomplete forging penetration- should forge on the press.
- Micro structural differences resulting in pronounced property variation.
- Hot shortness, due to high Sulphur concentration in steel and nickel.
- Pitted surface, due to oxide scales occurring at high temperature stick on the dies.
- Buckling, in upsetting forging, due to high compressive stress.
- Surface cracking, due to temperature differential between surface and center, or excessive working of the surface at too low temperature.
- Micro cracking, due to residual stress.

Typical forging defects

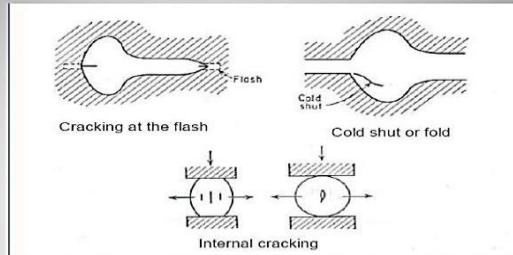
- Incomplete die filling.
- Die misalignment.
- Forging laps.
- Incomplete forging penetration- should forge on the press.
- Micro structural differences resulting in pronounced property variation.
- Hot shortness, due to high sulphur concentration in steel and nickel.



- Pitted surface, due to oxide scales occurring at high temperature stick on the dies.
- Buckling, in upsetting forging. Subject to high compressive stress.
- Surface cracking, due to temperature differential between surface and centre, or excessive working of the surface at too low temperature.
- Microcracking, due to residual stress.



Typical forging defects



- **Flash line crack**, after trimming-occurs more often in thin work-pieces. Therefore should increase the thickness of the flash.
- **Cold shut or fold**, due to flash or fin from prior forging steps is forced into the work-piece.
- **Internal cracking**, due to secondary tensile stress.

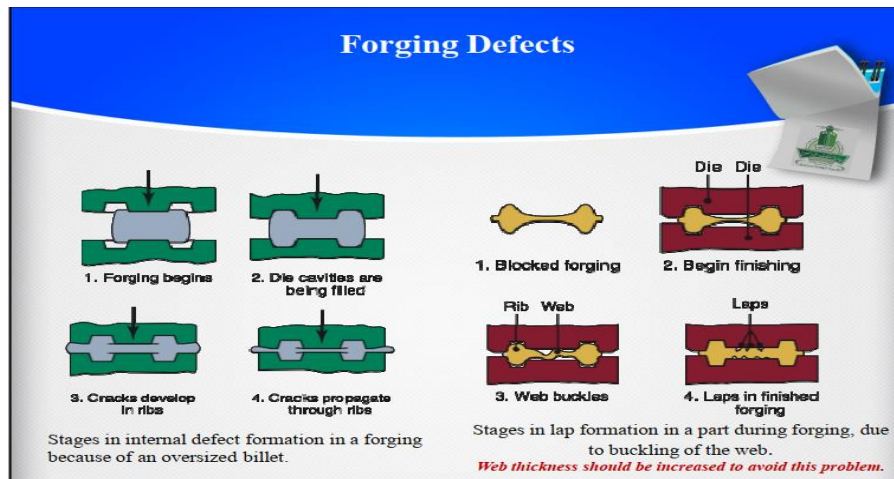


Fig 3.10 Typical forging defect

3.4 Appropriate Rectification Action on Defects

Defects Rectification Certificate means a certificate issued by the Contract Administrator signifying the completion to his satisfaction of rectification of all defects notified by him to be rectified in such works section of the Main Contract which includes a Sub-Contract Works Section. It may be called "Certificate of Completion of Making Good Defects" or "Maintenance

Certificate" depending on the term used in the Main Contract. In that case, the term "Defects Rectification Certificate" in this Sub-Contract shall be read as "Certificate of Completion of Making Good Defects" or "Maintenance Certificate", as the case may be.

3.4.1 Removal of Defects in Forging

Defects in forging can be removed as follow:

Surface cracks and decarburized areas are removed from forging parts by grinding on special machines.

- Care should also be taken to see that the job is not under heated, decarburized, overheated and burnt
- Shallow cracks and cavities can be removed by chipping out of the cold forging with pneumatic chisel or with hot sets.
- The parting line of a forging should lie in one plane to avoid mismatching.
- Destroyed forgings are straightened in presses, if possible.
- Die design should be properly made taking into consideration all relevant and important aspects that may impart forging defects and ultimate spoilage
- The mechanical properties of the metal can be improved by forging to correct fiber line.
- The internal stresses developed due to heating and cooling of the job can be removed by annealing or normalizing

3.5 Techniques to Handling the Hot Metal

May include, but not limited to: • Diesel, electric and gas furnaces; coke fires and gaseous • oxygen/fuel equipment.

3.5.1 Some common considerations

Sufficient draft on surfaces should be provided to facilitate easy removal of forgings from the dies. It depends mainly on the depth of the die cavity. The greater the depth, the larger draft will be the required. Generally, however, a 1 to 5 degrees draft is provided on press forgings and 3 to 10 degrees on drop forgings.

Sharp corners where ever occur should always be avoided as far as possible to prevent concentration of stresses leading to fatigue failures and to facilitate ease in forging. The usual practice is to provide fillets of more than 1.6 mm radius. The exact size of the fillet is

however decided according the size of the forging. If a perfectly sharp corner is required, the fillet can be removed at later stage.

- Forgings which are likely to carry flash, such as in drop and press forgings, should preferably have the parting line in such a position that the same will divide them in two equal halves.
- As far as possible the parting line of a forging should lie in one plane.
- The forged component should ultimately be able to achieve a radial flow of grains or fibers.
- Attention should be given to avoid the presence of pockets and recesses in forgings. If they cannot be avoided, their number should be reduced to a minimum as far as possible.
- High and thin ribs should not be designed. Also, cavities which are deeper than their diameters should be avoided.
- Metal shrinkage and forging method should be duly taken into account while deciding the forging and finishing temperatures.
- Although it is possible to achieve quite close tolerances of the order of 0.4 mm on either side through forging and therefore it is adequate to provide allowances to compensate for metal shrinkage, machining, die wear, trimming and miss-match of dies.

3.5.2 Protection from the Hazard Touching the Hot Surfaces

Heat reaches at 35000C-40000C at the electric arc welding. Since the metal materials transmit the heat well, this heat spreads to the welding part and to the metals touching it after a while. Metal materials also reach at the high temperatures at the operations of cutting and welding by oxi-gas welding. Touching the metals reached at the high temperatures by the naked skin will cause the serious burns. Therefore, hot surfaces mustn't be directly touched, leather gloves, leather apron and leather boot should be worn while working.

3.5.3 Considerations for Handling Tools and Materials in forging

- Use hook or hangers for all tools
- Use tongs that fit work
- Wear face shield or goggles
- Wear leather apron and gloves
- Be cautious of flying pieces of metal
- Avoid hard hammer blows on anvil face

- Label hot metal with chalk or soap stone
- Hot cut on ‘anvil chipping block only
- Grip tong handles on end
- Keep tong jaws parallel on work
- Clean up promptly

Self-check-3

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. choose the correct answer for given alternative (5 point each)

1. One of the following is true about forging
 - A. It is shaping of metal using localized compressive forces
 - B. Forging is often classified according to the temperature at which it is performed: "cold", "warm", or "hot" forging
 - C. Forged parts can range in weight from less than a kilogram to 580 metric tons
 - D. Forged parts usually require further processing to achieve a finished part
 - E. All of the above
2. During Up –setting is one is not occurred
 - A. cross-section decreases
 - B. length decreases
 - C. cross-section increases
 - D. All of the above
3. During Drawn out of forging is one is not occurred
 - A. length increases
 - B. cross-section decreases
 - C. cross-section increases
 - D. All of the above
4. Piercing and punching are used
 - A. To produce holes in metals
 - B. To produce center
 - C. To produce layout
 - D. All of the above
5. _____ is used to reduce the cross-sectional area of a portion of the stock in forging.
 - A. Hardy
 - B. Fullering
 - C. Swaging
 - D. Flattering

6. _____ is used as a supporting device during hammering operation
 - A. Hardy
 - B. Filleting
 - C. Swaging
 - D. Anvil
7. Which is true about setting hammer
 - A. It is used for finishing corners and shouldered work where the use of flatter is inconvenient.
 - B. It is made by high carbon steel
 - C. It also be used for drawing out purpose.
 - D. All of the above
8. Forging processes classification equipment as
 - A. Open - die forging
 - B. Closed - die forging
 - C. Forging hammer or drop hammer
 - D. Press forging
 - E. A & C F. A & B
9. Forging presses types is/are
 - A. Mechanical presses
 - B. Hydraulic presses
 - C. Crank press
 - D. A & B
10. One of the following is not type of heat treatment
 - A. Annealing
 - B. Normalizing
 - C. Protecting
 - D. Hardening
11. Properties of annealing
 - A. Heating the steel to austenite phase
 - B. Cooling slowly to through transformation range
 - C. Cooling is in closed furnace

- D. All of the above
12. Purpose of annealing is
- A. To reduce hardness
 - B. To remove internal stress
 - C. To improve machinability
 - D. All of the above
13. Types of annealing
- A. Full annealing
 - B. Box annealing
 - C. Process annealing
 - D. All of the above
14. Defect during forging
- A. Unfilled section
 - B. Scale pit
 - C. Quench crack
 - D. All of the above
15. ___ is done by heating the steel just above or slightly below AC1 temperature for a prolonged time, followed by a slow cooling in order to soften the steel
- a. Isothermal Annealing b. Spheroid zed Annealing
 - b. Full Annealing c. Annealing

II. Answer the following questions (3point each)

1. What is Defects Rectification Certificate?
2. Define Annealing of forged metals
3. Explain Isothermal Annealing

III. Say true or false (5 point each)

1. Full Annealing is consisting of authentication of the steel followed by slow cooling.
2. Full Annealing is done by heating the steel just above or slightly below AC1 temperature for a prolonged time, followed by a slow cooling in order to soften the steel as much as possible
3. Isothermal Annealing is derived from the exact knowledge of temperature – time diagrams.

Operation Sheet

Operation Title: -Drawing down

Instruction: Given necessary templates, tools and materials you are required to perform the following tasks with 6 hours.

Purpose: This process makes the metal thinner, by reducing its cross-section. Metal to be forged is first hammered on the back of a die. The process can produce tapers that arc, Hat, circular, or square. Figure 1.1 shows the steps to follow in drawing down a circular taper:

Required tools and equipment: - Tong, Hearth, and Round bar Charcoal, PPE, and drop Hammer

Procedure:

1. Hammer four sides to produce a short square (Figure 1.1a).
2. Lengthen the square taper (Figure 1.1b)).
3. Hammer the corners of the long square in step 2 to produce an octagonal shape (Figure 1.1(c))
4. Continue round all the corners in step 3 to obtain a circular end (Figure (d)). If the taper is fat or square go through either the first two or three stages above.

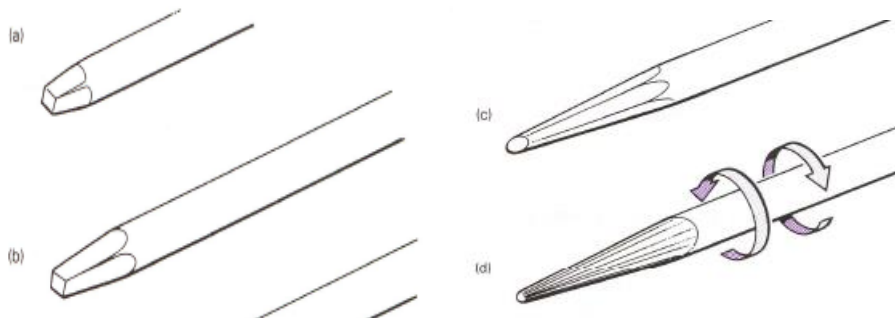


Figure 1.1 Stages in drawing down

A) First stage — Short Square; B) second stage — Long Square
(C) Third stage — octagonal shape; (d) final stage — round shape)

Precaution: Use PPE and Tongs

Quality Criteria: Dimensional accuracy and Surface finish. Roundness

LAP Test

Name: _____

Date: _____

Time started: _____

Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 10 hours.

Task : Drawing down

Unit Four: Assure Quality Work

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Equipment in a manner.
- Controlling Heating process
- Measuring form and shape
- OHS measures and procedures

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Operating equipment and minimizes oxidization with operational procedures.
- Controlling heating process to specified areas as per instruction
- Measuring form and shape on the standard devices
- OHS measures and procedures throughout the process

4.1 Use equipment in a manner with operational procedures

4.1.1 Definition Assure quality work

A Quality Assurance Specialist is a professional who is responsible for monitoring, inspecting and proposing measures to correct or improve an organization's final products in order to meet established quality standards. QA establishes and maintains set requirements for developing or manufacturing reliable products. A quality assurance system is meant to increase customer confidence and a company's credibility, while also improving work processes and efficiency, and it enables a company to better compete with others.

4.1.2. Purpose of Quality Assurance

QA establishes and maintains set requirements for developing or manufacturing reliable products. A quality assurance system is meant to increase customer confidence and a company's credibility, while also improving work processes and efficiency, and it enables a company to better compete with others. Quality assurance involves the systematic review of educational provision to maintain and improve its quality, equity and efficiency. It encompasses school self-evaluation, external evaluation (including inspection), the evaluation of teachers and school leaders, and student assessments. Not only does it help to prevent mistakes and defects to the software being developed, it also ensures that customers receive the highest quality products, services and solutions. In short, quality assurance ensures accuracy and is the deciding factor for your product launch

4.1.3 Safety Precautions

While working in forging shop;

- Always avoid the use of damaged hammers.
- Never strike a hardened surface with a hardened tool.
- No person should be allowed to stand in line with the flying objects.
- Always use the proper tongs according to the type of work.
- The anvil should always be free from moisture and grease while in use.

- Always wear proper clothes, foot-wears and goggles.
- Handle of the hammer should always be tightly fitted in the head of the hammer.
- Always put out the fire in the forge before leaving the forge shop.
- Always keep the working space clean.
- Proper safety guards should be provided on all revolving parts.
- Head of the chisel should be free from burrs and should never be allowed to spread.
- During machine forging, always observe the safety rules prescribed for each machine.
- One must have the thorough knowledge of the working of the before operating it.

4.2 Controlling Heating process

4.2.1 Control of Heat Exposure

Whenever there is exposure to excessive heat, suitable protective measures should be provided. Control of exposure of individuals to excessive heat may be provided by such methods as; PPE, Reflective shielding, Controlled openings, Evaporative cooling, Water jackets, Chain curtains; or Air curtains and Signage. In addition to this the following controlling system are considered:

A. Combustion Safeguards:

Protection against dangerous accumulations of unburned mixtures of fuel and air within the furnace, caused by accidental burner-flame extinguishment or lack of automatic pre-ventilation, should be provided.

B. Lighting Oil and Gas Furnaces:

A lighting torch should be provided to light oil-fired and gas-fired furnaces, unless automatic means are provided.

Note. Operators should stand clear of furnace openings to avoid being exposed to possible flashback. When lighting oil-fired or gas-fired furnaces, the torch should be placed near the burner opening before the burner valve is opened.

Electrical Heating: Manufacturer's recommendations should be followed in the operation and maintenance of all electrical heating equipment.

Control of heating devices: For good control of heating devices such as hearth or forging furnace, the following points should always be considered.

- The nozzle pointing into the center of the hearth is called the tuyre and is used to direct a stream of air into the burning coke. The air is supplied by centrifugal blower.
- As the hottest part of the fire is close to the tuyre opening, therefore, the tuyre is provided with a water jacket to prevent it from burning away.
- The hood provided at the top of hearth collects smoke, fumes etc., and directs them away from the workplace through the chimney in form of exhaust.
- The fuel for the fire may be either blacksmithing coal or coke. To light the fire, either use paper and sticks or preferably a gas poker.
- Impurities will collect as clinker and must be removed from the bottom of the fire when the fire cools.
- The blowers are used to control the air supply using forced draught. Regulators control the draught and the temperature of the fire.
- Blower delivers to forge adequate supply of air at proper pressure which is very necessary for the combustion of fuel.
- A centrifugal blower driven by an electric motor is an efficient means of air supply in forging hearth.
- Fire tools such as rake, poker and slice are generally used to control or manage the fire and theses tools are kept nearby the side of the hearth.
- The place of the metal to be heated should be placed just above the compact Centre of a sufficiently large fire with additional fuel above to reduce the heat loss and atmospheric oxidation.

4.3 Measuring form and shape

4.3.1 Forging Measurement and Quality Control

Modern measuring techniques, classic and coordinate measuring techniques in the forging industry (various stages of technological sequence), with the use of various measuring tools, instruments and machines applied in workshop metrology. The work points to different aspects of measuring techniques used mainly for two groups of objects, emphasizing their important role in the context of safety (achieved forgings—products) and the significant measurement problems

due to the extreme conditions in industrial hot forging processes. The first group comprises various measurements of forgings (control during and after forging and mechanical treatment). The second group includes measurements of the forging equipment involving a broadly understood quality control (geometrical characteristics, surface quality etc.), often combined with comprehensive control and durability analysis of forging tools. The work analyzes the possibility and validity of applying scanning techniques for direct control of the quality and change of the geometry of the tools in industrial forging processes, without the necessity of their disassembly, and also measurement systems of temperature, forces and displacement in forging processes.

The technological process of die forging consists of several stages, which include delivering the material from the plant, its cutting and heating, as well as a thermal treatment of the final product (4.1). At each of the mentioned stages, there is a potential risk of an error causing a forging flaw.

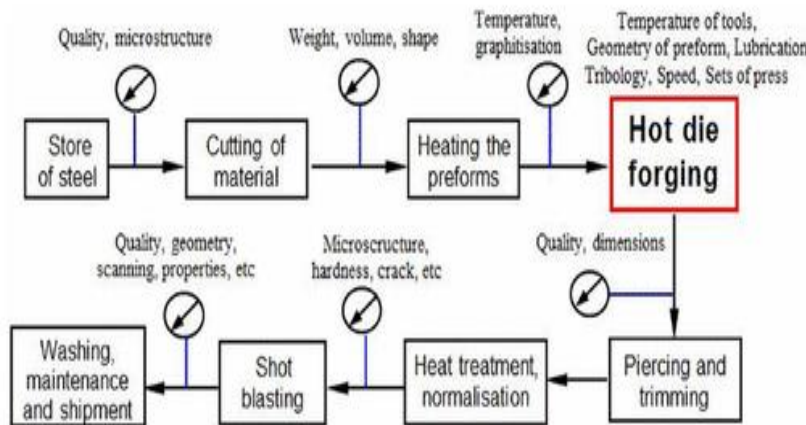


Fig.4.1. Flowchart of hot die forging technology

In the case of the measurement of the charge material, the control usually concerns its mass and geometry after cutting. There are two possible ways of rod cutting into **appropriate dimensions** of the charge material. The most frequently used one is cold or hot cutting with breaker knives (in the case of large diameters). A less frequently applied way is cutting with a saw, which, on one hand, is more precise and does not cause burrs or geometry changes, and on the other hand, it is less efficient (it lasts longer) and involves material losses in the form of chips. That is why the control of the charge material more often concerns the perform cuts with break knives.

In order to select the appropriate parameters of the cutting system (value of the gap and the system inclination), a series of numerical FEM simulations of the cutting process was performed. The fracture model according to the Cockcroft–Latham criterion was applied. The problem of fractures was solved by way of correcting the geometry of the blade’s edge so that it would be parallel to the axis of the cut bar and not cause a bending stress in the bar.

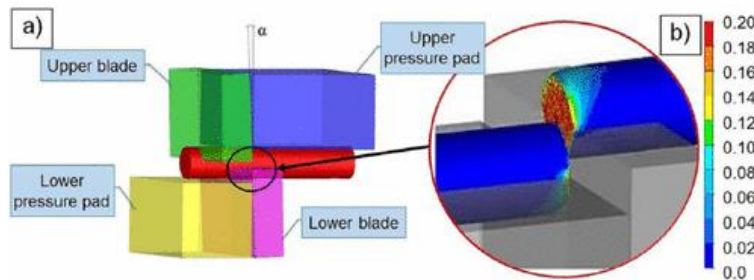


Figure 4.2 (a) numerical model and (b) FEM

(A and B), Schematic representation of the cutting method: (a) numerical model of the cutting process after changes—introduced blade inclination and (b) results of FEM using the Cockcroft–Latham fracture criterion

During the initiation of the forging process, forgings from the particular operations are sampled with the purpose to check the machine’s settings and the appropriateness of the assembly and production of the tools themselves. Directly in the production are controlled: the appropriate heat temperature of input material and the hot forging undergoes check-up, and its key geometrical characteristics are evaluated. Measuring the temperature of input material is carried out by a pyrometer, often connected to the sorter of improperly heated performs (Figure a)), and hot forging is done mostly with the use of calipers (Figure b)) or caliper altimeters (Figure c)). Temperature measurements of input material and forgings are important for the correctness of the process and assumed properties. Often, they pose quite a challenge and a major problem because they are difficult to execute. It is noteworthy that in the case of the classic measurement of hot forgings using measuring equipment, measurements are carried out at an ambient temperature, and nominal dimensions of the product are converted to the picture of hot forging. This is an exception to the requirements of the ISO norm, which is an international standard that specifies the standard reference temperature for geometrical product specification and verification (the temperature is fixed at 20 °C)

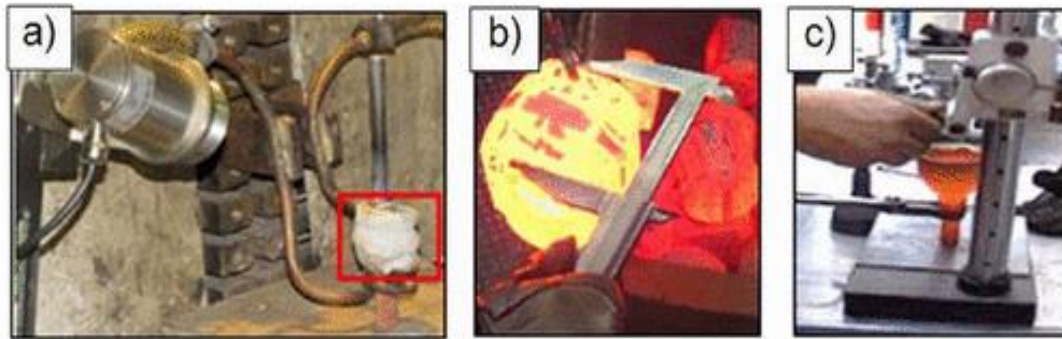


Figure 4.3 (a) hook perform, (b) flange forging and (c) height measurement

.Measurement of a hot forging: (a) hook perform and view of it after forging, (b) flange forging and (c) height measurement of the forging casing of a constant velocity joint body (CVJB). For example, designed for the automotive and the aircraft industry, when 100% control and high shape–size precision is required, for example, in the case of thin elements, specially constructed measuring instruments are applied, in order to check all the key geometrical characteristics of the given product. Gauges are used in the case of controlling the measuring characteristics of the shape of the determined contour and surface, for complicated shapes of the contours and surfaces of nominal elements, when the application of the universal metrological tools is difficult or even impossible due to the complexity of the measuring characteristics and the assumed reference bases. An example of such a measurement is shown in figure 3.2, where one can see application of inspection techniques for the key characteristics of the shape of the determined contour and surface of the forging with the use of virtual gauges with partial bases in the PolyWorks environment (reverse engineering and inspection software for 3D digitizers for rapid prototyping, 3D modeling, inspection etc.).

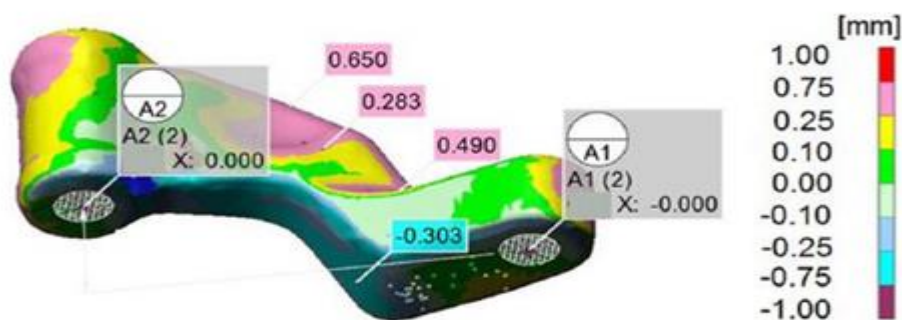


Figure 4.4. Virtual gauge

A view of virtual gauge with partial bases constructed in Poly Works environment for the key shape characteristic control of the determined contour and surface.

4.4 OHS measures and procedures

4.4.1 Care of Hammer forging

The field of occupational health and safety sets standards to mandate the elimination, mitigation, or substitution of jobsite hazards. Use the following guidelines when working with hammers. Always use appropriate (PPE), especially safety gloves and eye protection, focus on the work. Otherwise, you may accidentally strike yourself or damage the work.

Always use a hammer the right size and weight for the job.

Make sure the hammer is in good condition before you use it.

- ✓ Make sure there are no splinters in the handle of the hammer.
- ✓ Make sure the handle is set securely in the head of the hammer.
- ✓ Replace loose, cracked, or broken handles.
- ✓ Discard and replace hammers with cracked claws or eye sections.
- ✓ Discard and replace any hammer with a chipped, cracked, or mushroomed face.

Make sure the face of the hammer is clean.

- Hold the hammer properly.
- Grasp the handle firmly near the end and hit the nail squarely. Avoid glancing blows.
- Use hammers for the appropriate purpose and in the correct way.

Avoid the following actions:

- ✓ Hitting a hardened steel surface, concrete, or stone with a steel claw hammer. Metal chips from such use can cause injury.
- ✓ Hitting with the hammer handle or using the hammer as a pry bar. This type of use can split the handle and cause injury.

- ✓ Hitting a hammer with or against another hammer. This type of use can damage both hammers and cause injury.
- ✓ Hitting with the cheek or side of the hammer head.

4.4.2 Steps in occupational health and safety procedures

An occupational health and safety (OHS) policy is an employer's written commitment to the health and safety of both their employees and their workplace. Health and safety legislation requires all employers to implement workplace health and safety programs

The Six Steps

1. Develop an OHS Program. Your company's program should reflect a guiding principle that your organization seeks to uphold.
2. Obtain Feedback.
3. Implement a Training Strategy.
4. Identify and Assess Workplace Hazards.
5. Develop and Implement Risk Control Strategies.
6. Review, Promote, Maintain, and Improve Your OHS Strategy.

4.4.3 General safety precautions

Follow the following while working in forging shop;

- Always avoid the use of damaged hammers.
- Never strike a hardened surface with a hardened tool.
- No person should be allowed to stand in line with the flying objects.
- Always use the proper tongs according to the type of work.
- The anvil should always be free from moisture and grease while in use.
- Always wear proper clothes, foot-wears and goggles.
- The handle of the hammer should always be tightly fitted in the head of the hammer.
- Always put out the fire in the forge before leaving the forge shop.
- Always keep the working space clean.

- Proper safety guards should be provided on all revolving parts.
- Head of the chisel should be free from burrs and should never be allowed to spread.
- During machine forging, always observe the safety rules prescribed for each machine.
- One must have the thorough knowledge of the working of the before operating it.

Self-Check -4

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. choose the correct answer for given alternative (5 point each)

1. Which one of the following is not Control of Heat Exposure?
A) Lighting Oil and Gas Furnaces B) Combustion Safeguards: C) None
2. Which one of the following is sets standards to mandate the elimination, mitigation, or substitution of jobsite hazards
A, Occupational health and safety, B) Cut, C) OHS, D) A and C
3. The result of hitting a hardened steel surface, concrete, or stone with a steel claw hammer. Metal chips from such use can cause injury axis A) Avoidable actions B) The correct action C) No answer
4. What should be considered for good control of heating devices such as hearth or forging furnace?
 - a. nozzle pointing into the center of the hearth
 - b. As the hottest part of the fire is close to the tuyre opening
 - c. The hood provided at the top of hearth collects smoke
 - d. All

II. Answer the following questions (3point each)

1. List safety hammer to make sure the hammer is in good condition before you use it
2. Define OHS
3. List Considerations for Handling Tools and Materials in forging


III. Say true or false (5 point each)


1. . Always use the proper tongs according to the type of work.
2. The anvil should always be free from moisture and grease while in use.
3. Always wear proper clothes, foot-wears and goggles
4. Proper safety guards should be provided on all revolving parts.
5. Head of the chisel should be free from burrs and should never be allowed to spread

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Developers Profile

No	Name	Qualification (Level)	Field of Study	Organization/ Institution	Mobile number	E-mail
1	W/medhina Andualem	A	Manufacturing Technology	Debre Markos Poly Technic college	0913080488	Kenuandu1621@gmail.com
2	WALIYI BENA	A	Manufacturing Technology	AKPTC	0912305425	waliyibena2019@gmail.com
3	Biruk Dessie	B	Mechanical Engineering	A.A Tegbaried Poly Technic College	0913419004/ 0967733412	birukdesie27@gmail.com
4	Gossa Firiesenbt	A	Manufacturing Technology	DRIE DAWA POLYTECHNIC COLLEGE	0923179949	firesenbtgosa@gmail.com

