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Ministry of Labor and Skills

Basic welding Work Level I

Based on March, 2022, Curriculum Version 1

Module Title: - Performing Hand Forging
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Prepared by: Ministry of Labor and Skill

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Contents

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Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronym

PPE- Personal Protective Equipment
OHS- Occupational Health and Safety
LAP-Learning Activity Performance
RPE- respiratory protective equipment
ISO – International Organization for Standards

Introduction to the Module

Hand forging process is also known as black-smithy work which is commonly employed for production of small articles using hammers on heated jobs. Black-smithy is, therefore, a process by which metal may be heated and shaped to its requirements by the use of blacksmith tools. In smith forging or hand forging the desired shape is obtained by judgment.
Hand forging consists essentially of changing or altering the shape and section of metal by hammering at a temperature, at which the metal is entirely plastic and can be easily deformed or shaped under pressure. The shop in which the various forging operations are carried out is known as the smithy or smith's shop.
This module covers the units:

- Hand forging work
- Hand forging techniques
- Quality assure work

Learning Objective of the Module

- Analyze and plan hand forging work
- Perform hand forging techniques
- Assure quality work.

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit1: Analyze and Plan Work

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

- Interpret drawing for forging techniques
- hand forging Tools and formers
- Heat and temperatures applied in hand forging
- 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:

- Interpret drawing for forging techniques
- Apply hand forging Tools and formers
- Apply Heat and temperatures in hand forging
- Use Drafting Work plan

1.1. Interpret drawing for forging

1.1.1. Introduction

Forging is a type of metal Forming Processes by means of localized compressive forces exerted by manual or power hammers presses or especial forging machines. Forging is one of the oldest metal working operations known, dating back to 5000 (4000) B.C. and is used in making parts of widely varying sizes and shapes from a variety of metals. In forging, the shape of the raw material is changed by repositioning material rather than removing it.

Forging is the process of deforming the metal into different shapes by heating up to plastic state and by hammering or pressing at red hot condition. The process is usually carried out above re-crystallization temperature. Therefore this process is called hot working process. The term usually preferred to the production of heavy parts and in large scale. Forging is a process of shaping the metal components in cold or hot condition by the application of impact or pressure but the primary difference between various forging methods is the rate which the energy is applied

FORGING METHODS

(1) Hand forging

(2) Drop forging

(3) Press forging

(4) Roll forging

Hand forging: Hand forging is made by heating the metal until it is plastic state in an open-hearth furnace and there by hammering is done on anvil by smith/sledge hammer with use of open face dies to get the desired shape and size by judgment of an individual.

Drop forging: In this process of forming the desired shape by placing a heated bar or billet on the lower half of the forging die and hammering the top half of the die into the metal by means of a power hammer by repeated blows the impact of which compel the plastic metal to conform the shape of the die. This method is used to produce large number of small and medium sized forging of similar parts.

Press forging: In this process the heated billet is squeezed between die. The pressure is applied by the forging press which completes the operation in a single stroke. Large forging is generally shaped by thin method.

Roll forging: Rolling involves the passing of a heated bar between revolving rolls that contains an impression of the required shape. It is used to reduce short thick section to long slender pieces.

Advantages of forging

- Usually have better mechanical properties, especially if the fiber flow lines are directed.
- Can be held to within fairly close dimensional tolerances
- A wide range of forgeable metals is available.
- Forgings are readily welded & incorporated in welded structures.

Limitations of forging processes

- Many intricate and cored shapes possible by casting processes can’t be forged
- Usually, forgings cost more than castings

- Closed impression dies for forgings normally cost more than patterns.
- Permanent molds, or die equipment needed for casting processes
- High tool cost and high tool maintenance
- Limitations in size and shape
- High tool cost and high tool maintenance and Limitations in size and shape
- Limitations in size and shape
- High tool cost and high tool maintenance and Limitations in size and shape

Fig.1.1 .Hand forging tools

In hand forging and similar fields, engineering drawings need to communicate information that is legally binding by providing a specification. Engineering drawings utilized in any forging operation need to meet the following requirements:

The drawings should be unambiguous and clear. For any part of a component there must be only one interpretation. If there is more than one interpretation or indeed there is doubt or fuzziness within the one interpretation, the drawing is incomplete because it will not be a true specification.

The drawing must be suitable for duplication. A drawing is a specification which needs to be communicated. The information may be communicated electronically or in a hard copy format. The drawing needs to be of a suitable scale for duplicating and of a sufficient scale such that if is micro-copied it can be suitable magnified without loss of quality.

1.1. 2.Drawing

Drawing down

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

- Hammer four sides to produce a short square
- Lengthen the square taper
- Hammer the corners of the long square in step 2 to produce an octagonal shape

  Continue round all the corners in step 3 to obtain a circular end (Fig.1.2 (d)

  If the taper is fat or square go through either the first two or three stages above

Avoid piping (hollow ends) when drawing down a taper.

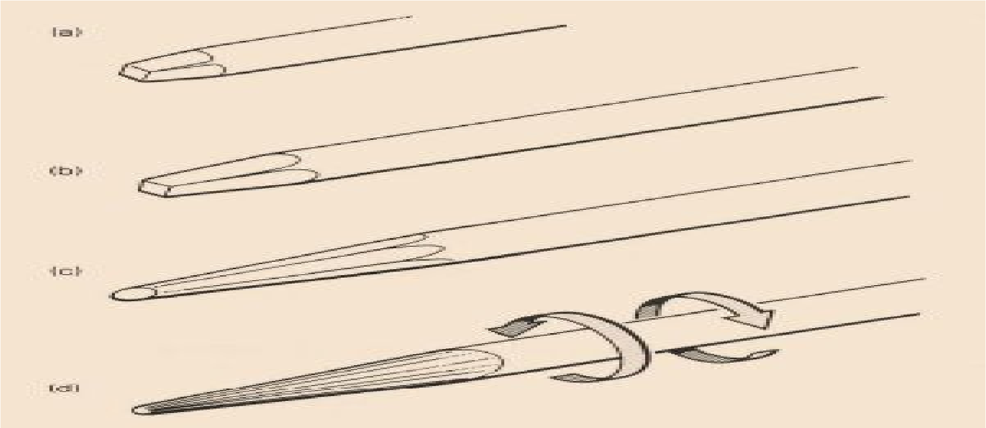


Fig. 1.2.Stages in drawing down: 4 a) first stage short- square; b) second stage-long square; (C) third stage- octagonal shape; (d) final stage- round shape.

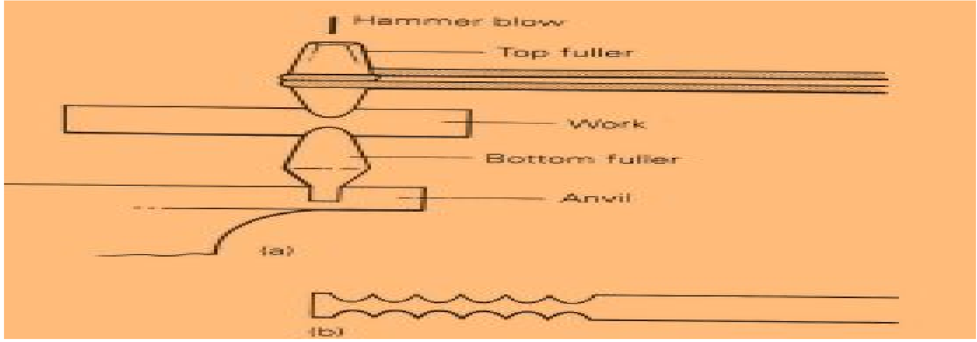


Fig: - 1.3.Drawing down

1.2. Tools and formers in hand forging

Basic tools and formers used in hand forging operations are:

1. Anvil

An anvil is a most commonly tool used in forging shop. It acts as a support for blacksmith's work during hammering. The body of the anvil is made of mild steel with a tool steel face welded on the body, but the beak or horn used for bending curves is not steel faced.. The square or hard hole is used for holding square shanks of various fittings. Anvils in forging shop may vary up to about 100kg to 150 kg and they should always stand with the top face about 0.75m from the floor. This height may be attained by resting the anvil on a wooden or cast iron base in the forging shop.

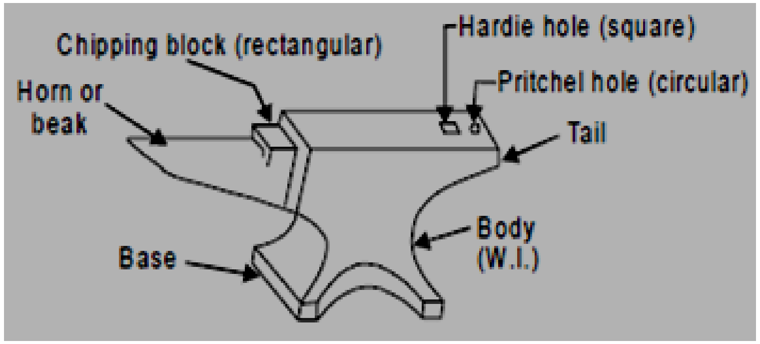


Fig. 1.4.Anvi

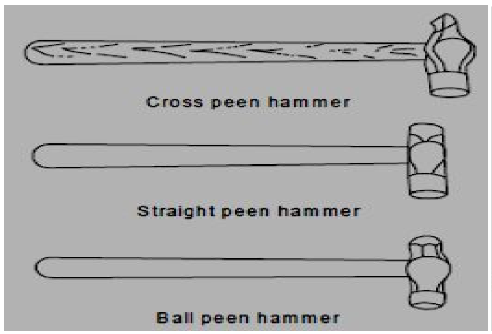
2. Hand forging hammers

There are two major kinds of hammers used in hand forging:

(1) The hand hammer used by the smith himself and

(2) The sledge hammer used by the striker.

Hand hammers may further be classified as (a) ball peen hammer, (b) straight peen hammer, and (c) cross peen hammer. Sledge hammers may further be classified as (a) Double face hammer, (b) straight peen hammer, and (c) cross peen hammer. Hammer heads are made of cast steel and, their ends are hardened and tempered. The striking face is made slightly convex. The weight of a hand hammer varies from about 0.5 to 2 kg where as the weight of a sledge hammer varies from 4 to 10 kg.



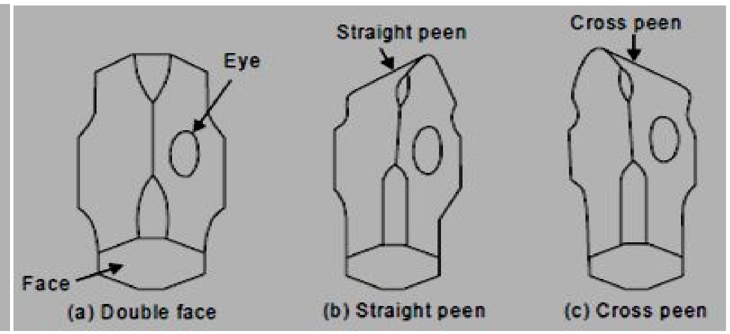


Fig.1.5. Hand hammers   Fig1.6 Sledge hammers

3. Set hammer

A set hammer is used for finishing corners in shouldered work where the flatter would be inconvenient. It is also used for drawing out the gorging job.

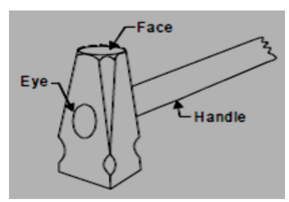


Fig 1.7. Set hammer

4. Flatter

Flatter is commonly used in forging shop to give smoothness and accuracy to articles which have already been shaped by fullers and swages.

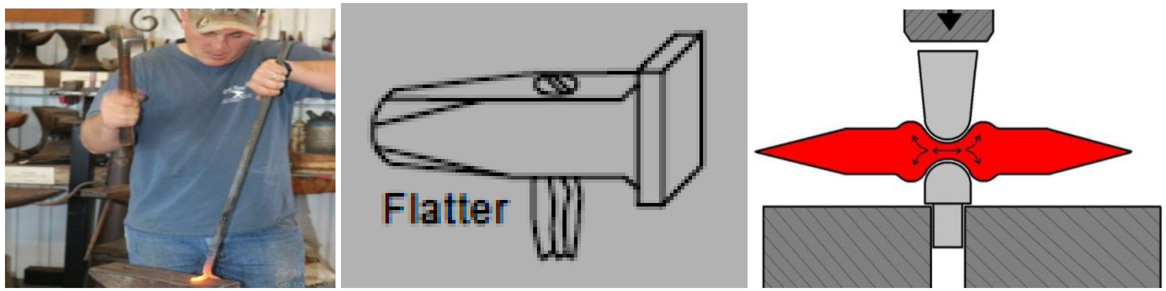


Fig1.8. Flatter

5. Swage

Swage is used for forging work which has to be reduced or finished to round, square or hexagonal form. It is made with half grooves of dimensions to suit the work being reduced. It consists of two parts, the top part having a handle and the bottom part having a square shank which fits in the hard hole on the anvil face.

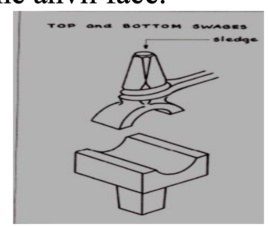


Fig. 1.9 Swage

6. Swage block

Swage block is mainly used for heading, bending, squaring, sizing, and forming operations on forging jobs. It is 0.25m or even more wide. It may be used either flat or edgewise in its stand.

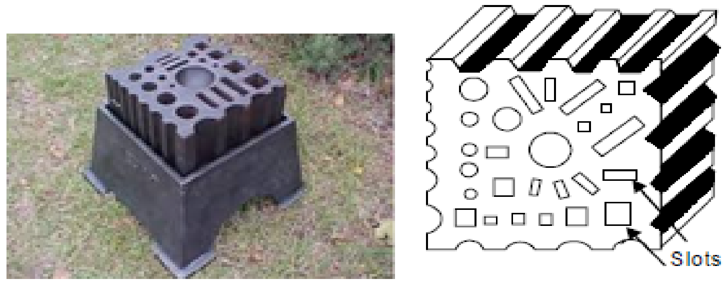


Fig. 1.10. Swage block

7. Fuller

Fuller is used for spreading a heated metal stock. It is also used for necking down a forgeable job. It is made in top and bottom tools as in the case of swages. Fuller is made in various shapes and sizes according to needs, the size denoting the width of the fuller edge

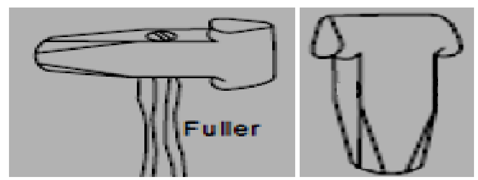


Fig1.11. Fuller

8. Punch

Punch is used in forging shop for making holes in metal part when it is at forging heat.

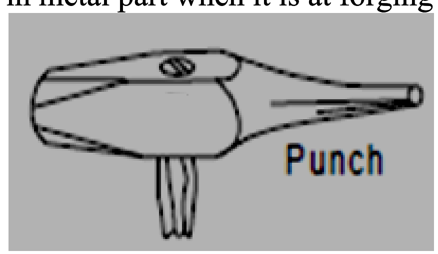


Fig.1.12. Punch

8. Drift

Drift is a tapered rod made of tool steel. Holes are opened out by driving through a larger tapered punch called a drift.

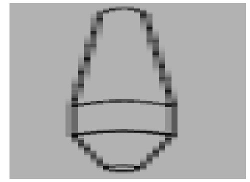


Fig. 1. 13. Drift

10. Rivet header

Rivet header is used in forging shop for producing rivets heads on parts.

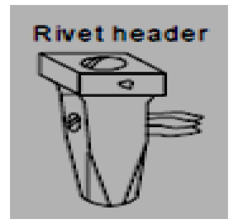


Fig1.14. Rivet header

11. Chisels

Chisels are used for cutting metals and for nicking prior to breaking. They may be hot or cold depending on whether the metal to be cut is hot or cold. The main difference between the two is in the edge. The edge of a cold chisel is hardened and tempered with an angle of about 60°, whilst the edge of a hot chisel is 30° and the hardening is not necessary. The edge is made slightly rounded for better cutting action.

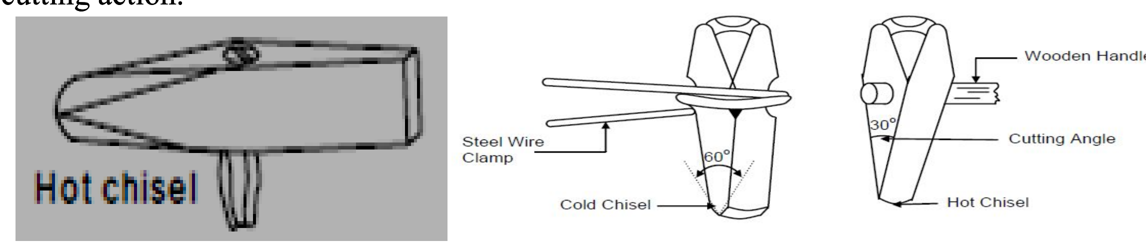


Fig 1.15.Chisels

12. Hardy

Hardier is a type of chisel used in forging shop. Its taper shank is fixed into the hardies hole of the anvil, the cutting edge being upward. The part to be cut is kept over the cutting edge of the fixed hardies on anvil and another chisel is placed over the job and the cutting is performed by hammering.

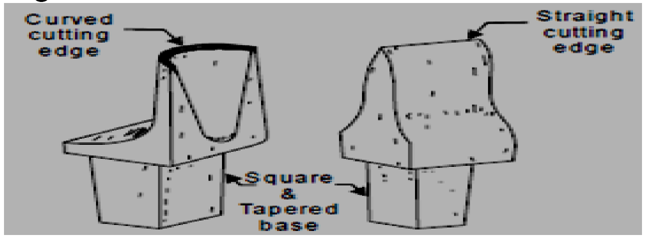


Fig1.16. Hardy

13. Tongs

Tongs are generally used for holding work while doing a forging operation. Various kinds of tongs are shown in the figure below.

1. Flat tongs are used for mainly for holding work of rectangular section.
2. Straight-lip fluted tongs are commonly used for holding square, circular and hexagonal bar stock.
3. Rivet or ring tongs are widely used for holding bolts, rivets and other work of circular section.
4. Gad tongs are used for holding general pick-up work, either straight or tapered.

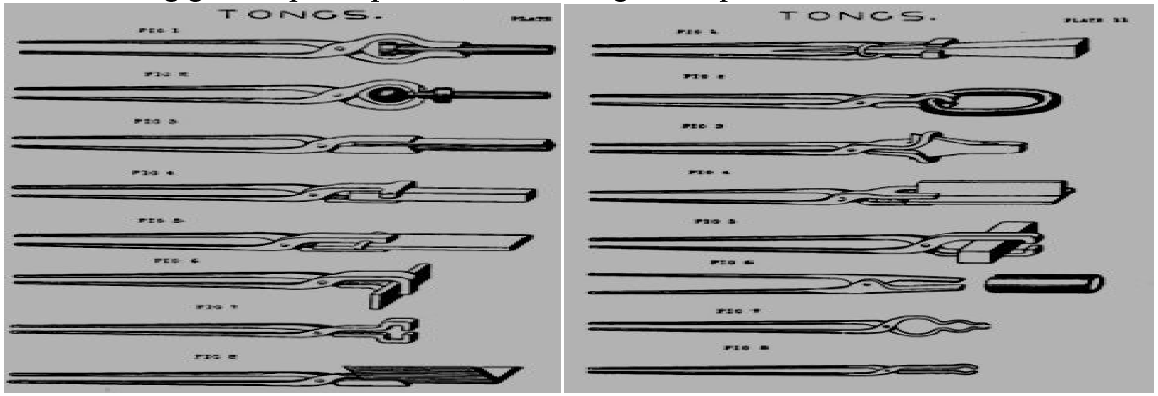


Fig1.17. Tongs

14. Shovel

Shovel is used to place coal or coke in the furnace. It is also used to set coal pieces in furnace and remove ash from furnace.

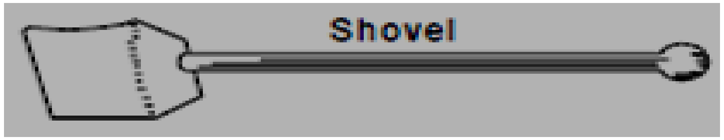


Fig.1.18. Shovel

15. Poker

Poker is a steel rod which is used to poke (stir) fire in the hearth. Poker is employed for removing clinker from the furnace and to loosen the compact coal pieces in the furnace.

Fig.1.19.Poker

16. Rake

Rake is used to take heated work piece out of the fire. Rake is also used to put coal pieces on tuyres.

Fig .1.20.Rake

1.3. Heat and temperatures applied in hand forging

A metal must be heated to a temperature at which it will possess high plastic properties to carry out the forging process. 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. Insufficient temperatures will not introduce sufficient plasticity in the metal to shape it properly by hammering etc. Moreover, under these conditions, cold working defects such as hardening and cracking may occur in the product.

The temperature of heating steel for hand forging can be estimated by the color of heat and which color of the light emitted by the heated steel. For accurate determinations of forging temperatures of the heated part, the optical pyrometers are generally used.

Table1.1. Forging temperatures for different metals

Type of metals	Forging Must	
	Start at	Finish at
Mild Steel	1300°C	800°C
Medium Carbon Steel	1250°C	750°C
High Carbon Steel	1150°C	800°C
Wrought Iron	1250°C	900°C
Aluminum and Magnesium Alloys	500°C	300°C
Copper, Brass and Bronze	950°C	6OO°C

Table1.2. the color and brightness of different forging processes

Heat color	Operation performed
Dull red	Hardening or annealing high carbon steels
Medium red	Hardening or annealing medium carbon steels; minor bends in mild steels
Bright red	Annealing mild steels
Orange	Forging of high carbon steels
Yellow	Forging of medium carbon steels
Bright yellow	Forging of mild steels
White (Metal which looks oily in the fire and throws off a few whitish sparks)	Forge welding

1.3.1. Forge ability

The ease with which forging is done is called forge ability. The forge ability of a material can also be defined as the capacity of a material to undergo deformation under compression without rupture. Forge ability increases with increase in temperature. The pure metals have good malleability and thus good forging properties. Malleability is the ability of the material to be flattened into thin sheets without cracking by hot or cold working. Ductility is the property of a material enabling it to be drawn into wire with the application of tensile force. The metals having high ductility at cold working temperature possesses good forgeability. Forgeable materials should possess the required ductility and proper strength. Some forgeable metals are given as under in order of increasing forging difficulty.

1. Aluminum alloys
2. Magnesium alloys

7. Nickel alloys
8. Titanium alloys

3. Copper alloys.
4. Carbon and low alloy steels
5. Martensitic stainless steels (harder, fine, BCC)
6. Austenitic stainless steels (hard, ductile, non magnetic,FCC)
9. Columbium alloys
10. Tantalum alloys
11. Molybdenum alloys
12. Tungsten alloys

1.4. Drafting Work plan

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.

4.2. Equipment & materials

- Forge hearth,
- tongs, anvil,
- sledge,
- flatter hammer,
- Steel rod.

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.

PART-I : Decide whether the following statements are "True" or "False" and write your answer on the space given.

_________1. The content of an engineering drawing must provide all the information for that stage of its manufacture.

_________2. Anvil acts as a support for blacksmith's work during hammering.

_________3. Holes are opened out by driving through a larger tapered tool steel rod called a drift.

_________4. Tongs are generally used for holding work while doing a forging operation.

PART-II: Select the best answer from the given alternatives and write its letter on the space provided

_____1. Which of the following is not type of hand hammers used in hand forging?

A. Straight peen B. Cross peen. C Ball peen. D. Sledge

_____2. Which of the following tool is used for making holes in metal part when it is at forging heat?

A. Drift B. Fuller C . Punch D. Swage

_____3. A type of tool used for forging work which has to be reduced or finished to round, square or hexagonal form is

A. Fuller B. Swage C. Flatter D. Punch

_____4. Is used to take heated work piece out of the fire

A. Shovel B. Poker C. Rake D. Drift

PART-III: Match the items listed under column "A" with those expressions listed under "B"

"A"	"B"
_____1. The round hole in the anvil called	A. Fuller
_____2. It is used for finishing corners in shouldered work	B. Pitched hole
_____3. It is used for spreading and necking down a heated metal	C. Shovel
_____4. It is used to place coal or coke in the furnace	D. Set hammer

Unit 2: Hand Forging Techniques

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

- Set up heat equipment Hand forging techniques
- Apply and carry out forging techniques
- Allowances for materials shrinkage and oxidization

This guide 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:

- Describe heating equipments
- Apply hand forging techniques
- Recognize allowances for materials shrinkage and oxidization.

2. Setting up heating equipment

- Heating Procedure of Metal Setting for fire
- Clean out the old fire from the forge hearth and remove the ash
- .Put some wood shaving over the tubers and light.
- Turn on a little air using litters by hand or power blower to get the fire started
- Keep a forging fire neutral throughout the heating of metal.

2.1. Operate Heating equipment

- Heating Devices (Hearths and Furnaces)
- .The heating of metal is done either in a smith's hearth or in a furnace.
- .The hearths (commonly known as forges) are used for heating metals for hand forging.
- .It is a very old method of heating still it is used.
- .The furnaces are used for heating metals for heavy forging

Hearths: - the hearths may be classified as open or closed hearths; the blacksmith forges may have one or two hearths which are called single hearth or double hearth respectively.

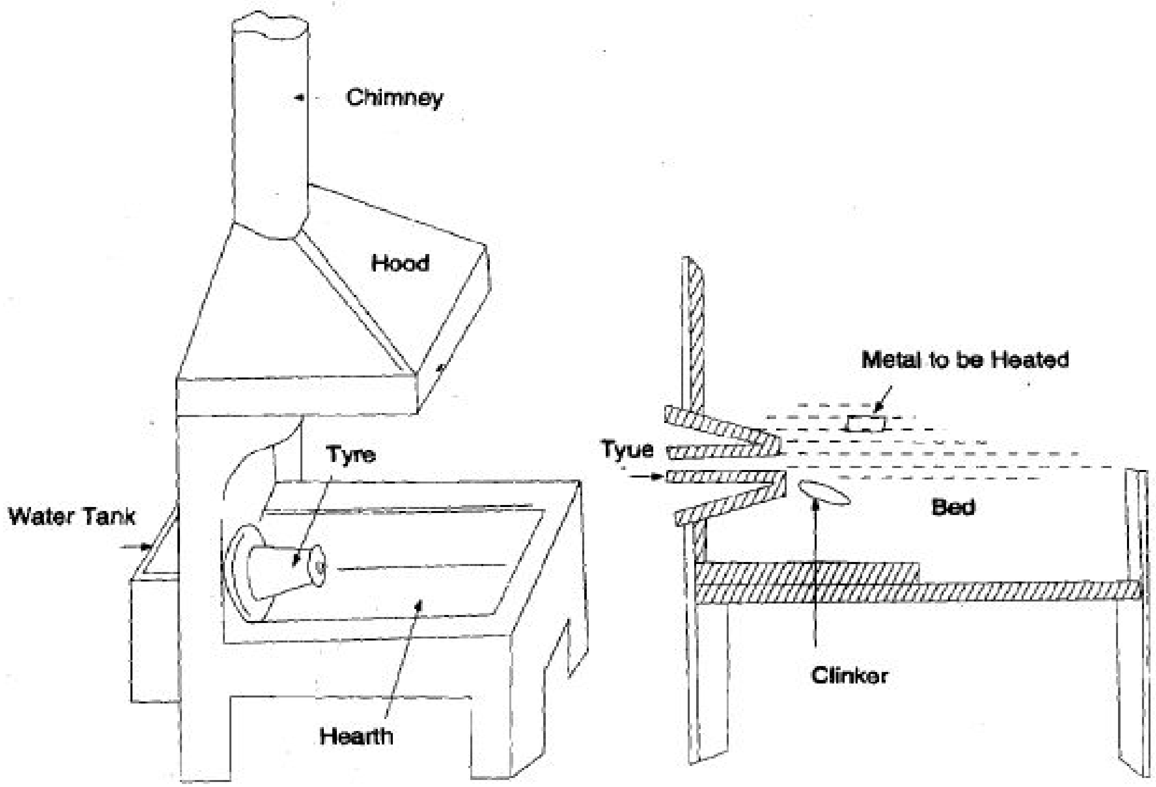


Fig.2.1. Blacksmith hearth

a) Fuels used in forging shop

The fuels used in forging shop are classified as solid, liquid and gaseous fuels which are discussed as under.

Solid fuels

- ✓ Wood, coal, anthracite, peat, charcoal, coke, pulverized fuel etc.
- ✓ Liquid fuels
- ✓ Crude oil, petroleum, kerosene, tar oil etc.
- ✓ Gaseous fuels

Natural gas and some artificially produced gases are used generate heat.

A good fuel should have always possesses the following essential characteristic which are given as under.

The fuel should be able to generate the required heat.

- ➢ It should have complete combustion.
- ➢ It should be highly efficient.
- ➢ It should not produce excess smoke and flying ash.
- ➢ It should be easy to fire, cheap and easily available.

b) Heating Procedure

- Clean out the old fire from the forge hearth and remove the ash
- Put some wood shaving over the tubers and light.
- Turn on a little air using litters by hand or power blower to get the fire started
- Keep a forging fire neutral throughout the heating of metal.

C) Control of heating devices

For good control of heating devices such as blacksmith hearth, the following points should always be considered:

The nozzle pointing into the centre 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 black-smith 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.

Furnaces

Furnaces are also commonly used for heating metals for heavy forging. Gas, oil or electric-resistance furnaces or induction heating classified as open or closed hearths can be used. Gas and oil are economical, easily controlled and mostly used as fuels. The formation of scale, due to the heating process especially on steel creates problems in forging. A non-oxidizing atmosphere should, therefore, be maintained for surface protection. Special gas-fired furnaces have been developed to reduce scaling to minimum. Electric heating is the most modern answer to tackle scaling and it heats the stock more uniformly also. In some cases, coal and anthracite, charcoal containing no Sulphur and practically no ash are the chief solid fuels used in forging furnaces.

Forge furnaces are built raise temperatures up to 1350°C in their working chambers. They should be sufficiently large to allow proper combustion of the fuel, and to obtain uniform heating of the forging jobs. Each heating furnace consists of parts including firebox, working chamber, chimney, flues, regenerator /recuperate or/ and various auxiliary arrangements.

Since the work, in the furnaces, is heated by the flames produced from the combustion of fuel, therefore these furnaces may be called as flame furnaces. The gas and oil mostly used as fuels as these are economical and easily controlled. The work does not come in direct contact with the fuel. The following are the various types of furnaces used for heating steel:

a) ***Box or box type furnaces***:- These are widely used in forging shops for heating small and medium size work; these furnaces are usually made of steel frame lined with insulating and refractory bricks.

b) ***Continuous type furnaces****:* - These furnaces are provided with mechanical pusher and are tad for mass production of articles. In these furnaces, the pieces of steel are charged at one end and pushed to the furnace for heating at correct temperature.

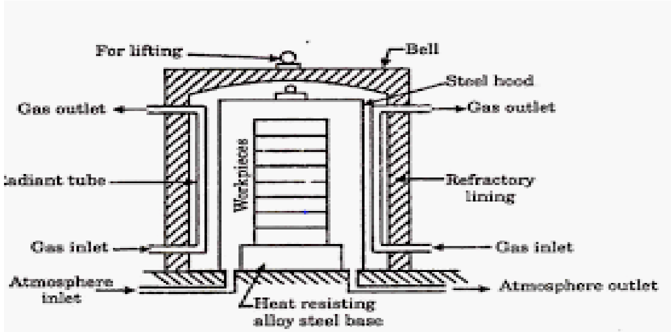
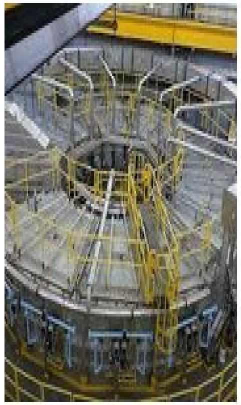
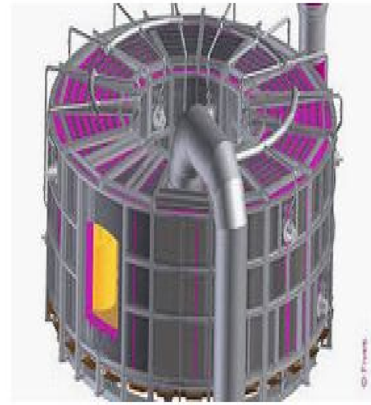
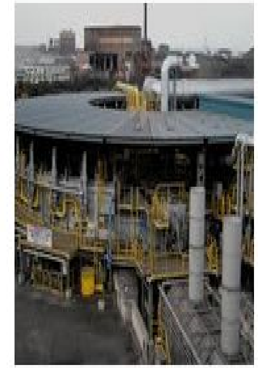


Fig. 5.31. Semi-continuous furnace.

c) ***Slot type furnaces:*** - These furnaces are commonly used for heating bars at one end for forging or other forging operation, in these furnaces, a slot is provided at the front through which the bar is inserted for heating

d) ***Rotary hearth furnaces:*** - These furnaces are sometimes used for heating large number of pieces steel for forging. In these furnaces, the speed of rotation is adjusted in such a way that the ink is heated to the required temperature after one or two revolutions.



*e) **High frequency induction furnaces**:*-these furnaces are quite popular with the availability (cheap electric power). The work produced by induction heating is free from oxide scale, have uniform temperature and takes less time,
f) Resistance *furnaces:*- These furnaces are faster than induction furnaces are often automated in these furnaces; the work is connected to the circuit of a step down transformer.

2.2. Hand forging techniques.

Blacksmiths had many years to develop forging techniques and tools. You may find that the same technique has many different names. As a beginner it is more important that you understand the steps and the outcome of using a technique;
There is usually more than one way to get the same end result. Blacksmiths have a variety of tools and techniques to choose from
It is important to remember that forging will change the size and shape of a piece of metal; however, unless you cut a piece off, the volume will stay the same.

1. Drawing out

Drawing out is used to reduce the thickness of a bar and to increase its length. It may be carried out by working the metal over the anvil as shown in the following figure. The rounded horn of the anvil acts as a blunt edge, which forces the metal to flow lengthwise when struck by the hammer. For drawing down very heavy work, fuller may be used for drawing down a bar over the horn of anvil.

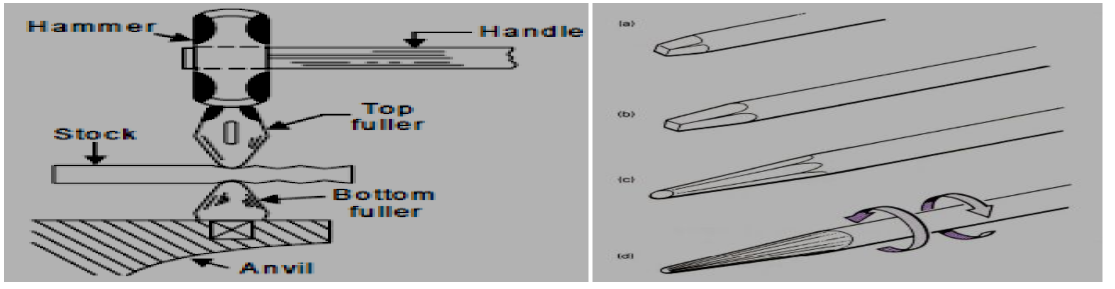


Fig. 2.1. Drawing out

2. Fullering and flattening

Fullering operation involves heating the stock in the black smith hearth. Then heated stock is placed on the fuller fixed on anvil. A fuller is put over the sock and hammering is done to reduce the cross section of job increasing its width thus having the work in corrugated shape. Those corrugations are latter flattened by using flatter tool and a set hammer can also be used for this purpose. Fullering is always followed by flattening operation.

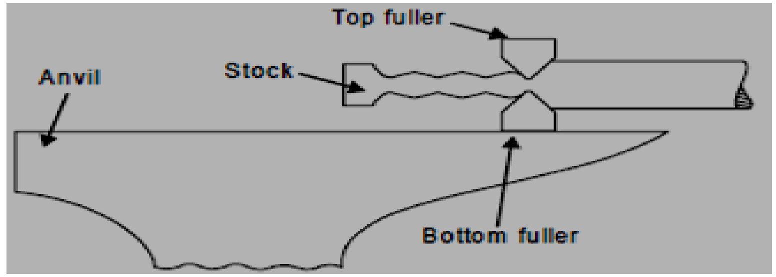


Fig. 2.2. Fullering

3. Upsetting

Upsetting is simply the reverse of drawing, or the process of making a piece shorter and thicker. Upsetting is also known as jumping operation which is carried out to increase the thickness (or diameter) of a bar and to reduce its length. It is done when more metal is needed to give extra strength, as when a hole is to be punched for an eye.

There are two main points to be observed in upsetting:

1. Heat the bar or rod to a high red or nearly white heat throughout the section to be upset.
2. Strike extremely heavy well-directed blows.

In one method of upsetting, the bar is held in the tong and supported vertically on the anvil. The top edge of the bar is then hammered to form the upset on the bottom hot end of the bar.

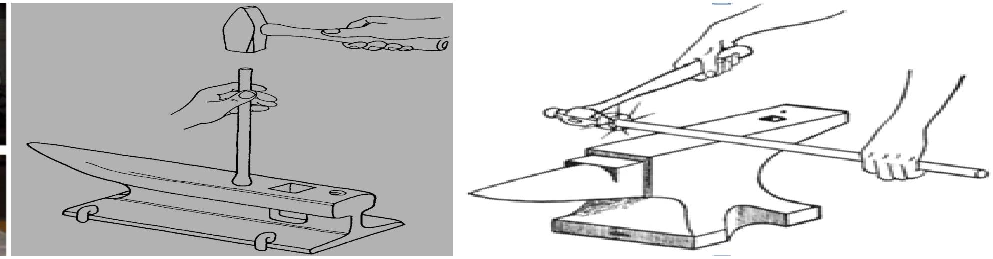
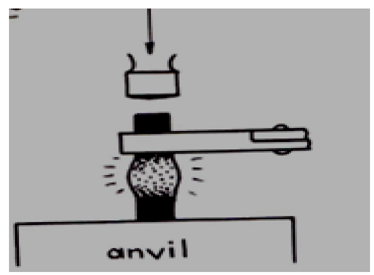


Fig.2, 3.Upsetting *Fig.2.4. Upsetting by Striking*

Upsetting may be required on any of the end portions, central portion or complete length. This is accomplished by heating the work in furnace. The portion of the work to be upset must remain hot and the rest may be cooled down by dipping it into the cold water.



4. Swaging

Swaging is the process of finishing a round or hexagonal section of bar. It is made possible by the use of a pair of swage. The process involves:

1. **Heating the metal**
    1. Placing the metal between the top and bottom swages;
    2. Striking the top swage while rotating the work

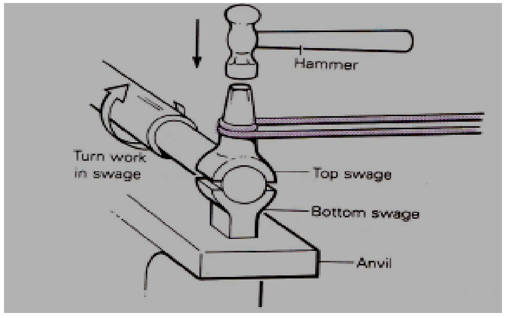


Fig 2.5. Swaging

5. Bending

It is also a very common operation and frequently used in work shop. Bending operation is carried out by keeping the work-piece on the edge of the anvil face, anvil horn or any other fixture support. A thin rod can be bent by inserting one end of the bar in the hole and bend it with the help of wrench or tong. While bending the bar, the metallic fibers on the inside portion of the bend-rod are shortened and those on outer periphery of the bar are extended. Slight thinning also takes place at the contact. So to avoid thinning, little upsetting can be done on that portion where operation is performed.

Secondary bends revealed after correction of the primary bend.

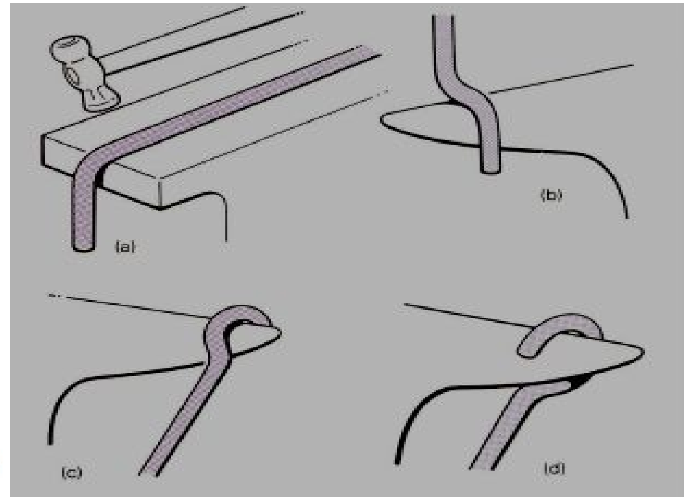


Fig 2.6. Bending forming an eye

When a strip of metal is bent to an angle, the material on the inside of the bent is compressed while that on the outside is stretched. To calculate the correct length of metal required to form an eye (loop), it is necessary to calculate the length of the middle layer or neutral axis.

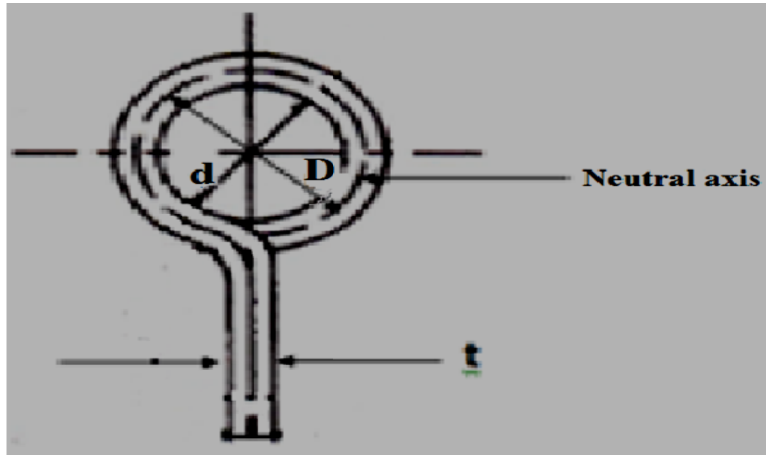


Fig 2.7.

Radius of neutral axis i.e. R. n.a. = d + t/2

To know the length of metal required to forge a loop or an eye on the end of piece of steel, we must know the inside diameter.

Example: Inside diameter, d= 30mm, thickness of the metal, t=6mm, Neutral axis, D=36mm i.e. D= d+t

The length of metal used= Π*D

The length of metal required to make the loop will be the length of the neutral axis which is equal to its circumference.

$$C = \Pi * D = 3.14 * 36\text{mm}$$
$$= 113.04\text{mm of a metal.}$$

To calculate the length of steel required to form a bracket, it is essential to know the thickness of the metal, the radius of the bend and the angle of the bend.

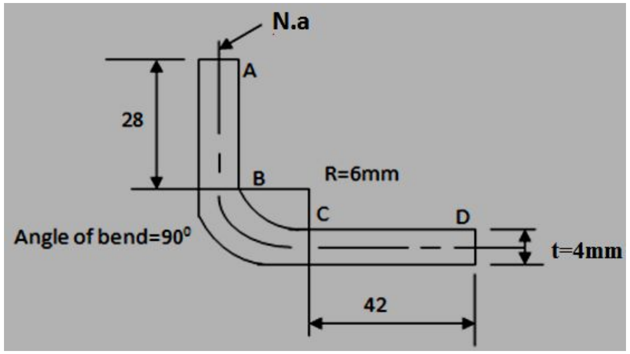


Fig 2.8

To find the length of metal required, we divide the drawing into straight lines and calculate the length of each part along the neutral axis. Therefore,

A-B= 28mm;   C-D= 42mm & B-C is quarter of a circle.

R.n.a= 6+2=8mm, so, diameter (ø) N.a. = 16mm

The circumference, C=ΠD= 16*3.14= 50.24mm

Then dividing by four= 50.24mm/4= 12.56mm

Therefore, the exact length of metal to make the bracket = 28mm+12.56mm+42mm= 82.56mm

When the bend is not at right angle, the length of the arc has to be calculated from the angle at which the metal is bent. For example, to make a 45^0, it has been bent through an angle of $180^0- 45^0$ which equals 135^0 which is 3/8 of a circle so that 3/8 of a circumference will give the length of the neutral axis i.e.

$C= \Pi D*3/8$

6. Twisting

Twisting is really a form of bending. Small pieces may be twisted by heating the section to be twisted to a uniform red heat, clamping a pair of tongs at each end of the section and applying a turning or twisting force. If the piece is too large to be twisted this way, it may be clamped in a vise and twisted with a pair of tongs or a monkey wrench, the jaws of the vise and the wrench being carefully placed at the ends of the section to be twisted. It is important that the work has to be done rapidly before the iron cools too much. For a uniform twist, the iron must be at a uniform temperature.

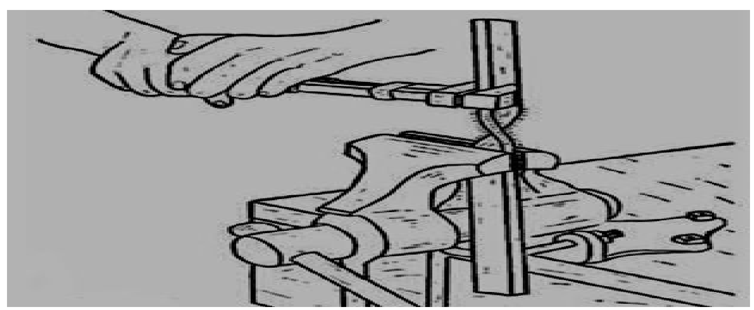


Fig 2.9 .Twisting

7. Punching Holes

It is sometimes easier to punch a hole in a piece of iron than to drill it; and for some purposes a punched hole is better. For instance, in forming an eye on the end of a bar in making a hook or a clevis, punching makes a stronger eye. A small or medium size hole is first punched and then expanded by driving the tapered punch on further through the hole, first from one side and then the other. Thus less material is wasted than if the hole were drilled, and a stronger eye results.

The steps in punching a hole in hot iron are as follows:

1. Heat the iron to a good working temperature, a high red or nearly white heat.
2. Place the hot iron quickly on the flat face of the anvil-not over the pritchel hole or hardy hole. Punching over a hole would stretch and bulge the iron.
3. Carefully place the punch where the hole is to be made and drive it straight down into the metal with heavy blows until it is about two-thirds of the way through.
4. Turn the iron over and drive the punch back through from the other side. Reheat the iron and cool the punch if needed. The punch should be carefully located so as to line up with the hole punched on the other side.

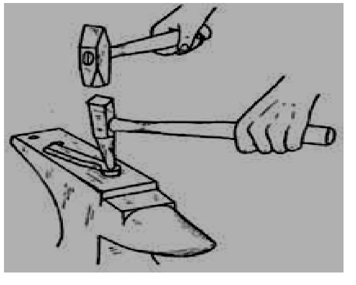
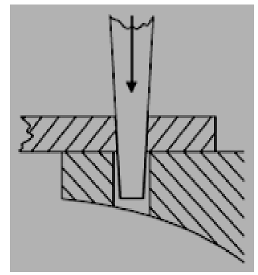


Fig .2.10 punching tool

8. Drifting

Sometimes a circular drift is also used to enlarge the hole to the required dimensions. Both the operations can be carried out at room as well as at high temperature.



9. Cutting with the Hardies

The blacksmith does most of his cutting of iron and steel on the hardies rather than with a hack saw. Although the hardie does not leave quite so smooth a cut as a saw, it is quite satisfactory for most work. It cuts faster and easier than a saw and is less expensive to use, as there are no blades to wear out or break. To use a hardies, the rod or bar to be cut is simply placed on it and hammered down against the sharp edge. Hardies may be used for either hot or cold cutting (chiseling). Some smiths prefer to keep two hardies, one that is thick and stocky and tempered for cutting cold iron and one that is thin for, cutting hot iron. The hardy, like any other Cutting tool, works much better if kept sharp. It may be ground like a cold chisel.

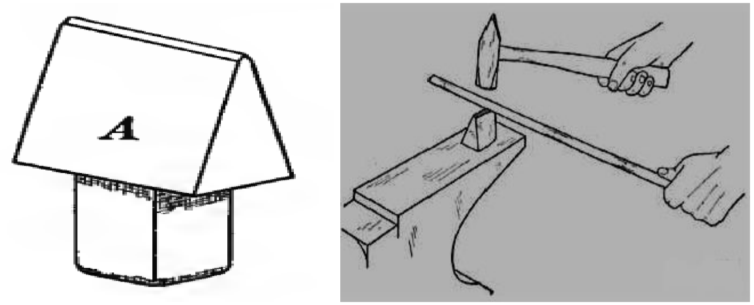


Fig.1.9 Hardies

10. Forge welding

It is one of the most important operations performed by blacksmiths. Wrought iron and low carbon steels including mild steel can be satisfactorily forge welded. The process of forge-welding is explained in the following steps:

(a) The ends of the two work pieces to be welded are a little bit upset and cleft shape or tapered shape is given. In case, the work pieces are greater than 30 mm, cleft shape is given and in other cases tapered shape is enough. This operation may need heating again and again.

(b) Both ends are heated to about 1000°C in case of mild steel which is essential for sound welding.

(c) The ends of both pieces after being heated must be mechanically cleaned so as to remove oxidized film, so that proper cohesion may take-place while both the pieces are in pasty state (white hot). At this stage a protection to the metal is provided to prevent the air oxidation of the white hot surfaces.

(d) After putting both ends together, hammer the joint slowly to avoid excessive metal spread. This enables the crystals of both ends anchor each other and during this period the temperature may also drop.

(e) Now firm hammering can be applied at the junction, thus both ends are forge welded, which has much strength as the parent metal.

Common forms of forge welded joints are:

(i) Lap or scarf weld

(ii) Butt weld

(iii) Tor jump weld

(iv) Split, fork, splice or V-weld

a

b

c

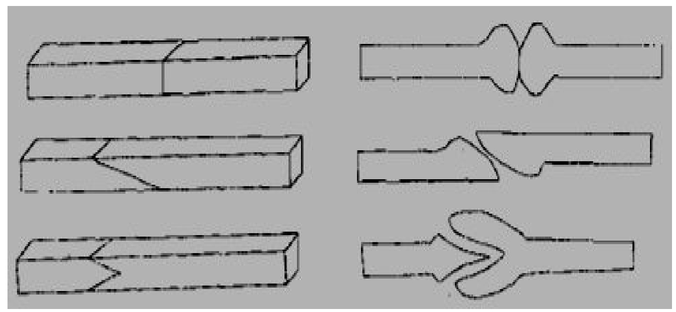


Figure: (a) Butt Weld, (b) Scarf Weld, and (c) 'V' weld or Splice Weld

2.2.1 Forging processes

Forging processes may be classified into hot forging and cold forgings and each of them possesses their specific characteristics, merits, demerits and applications.

a. Hot forging

Hot forging is defined as working a metal above its recrystallization temperature. The main advantage of hot forging is that as the metal is deformed the strain-hardening effects are negated by the recrystallization process. Other advantages include:

Decrease in yield strength, therefore it is easier to work and takes less energy (force)

Increase in ductility

Elevated temperatures increase diffusion which can remove or reduce chemical in homogeneities

Pores may reduce in size or close completely during deformation

In steel, the weak, ductile, FCC austenite is deformed instead of the strong BCC ferrite at lower temperatures

The disadvantages of hot working are:

- Undesirable reactions between the metal and the surrounding atmosphere
- Less precise tolerances due to thermal contraction and warping from uneven cooling
- Grain structure may vary throughout the metal due to many various reasons

b. Cold forging

Cold forging is defined as working a metal below its recrystallization temperature, but usually around room temperature.

Advantages:

- No heating required
- Better surface finish
- Superior dimensional control
- Better reproducibility and interchangeability
- Directional properties can be imparted into the metal
- Contamination problems are minimized

Disadvantages:

- ✓ Higher forces are required
- ✓ Heavier and more powerful equipment and stronger tooling are required
- ✓ Metal is less ductile
- ✓ Metal surfaces must be clean and scale-free
- ✓ Intermediate anneals may be required to compensate for loss of ductility that accompanies strain hardening
- ✓ The imparted directional properties may be detrimental
- ✓ Undesirable residual stress may be produced

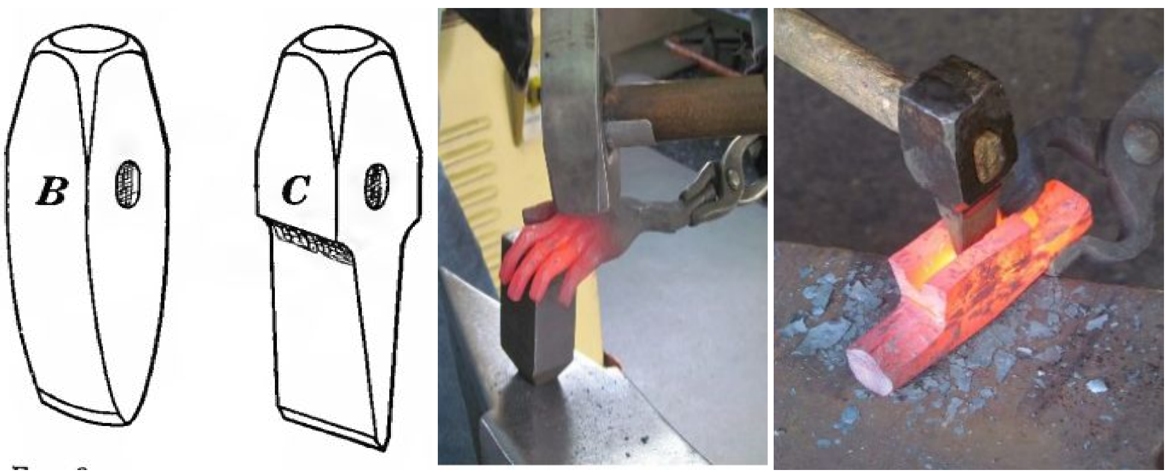


Fig.1.10 Cold and hot cutters

2.2.3. The cost of a forged component

Cost of Direct Material

- ✓ Calculate the Net weight = Volume of forging × 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 × Density of material)
- ✓ Direct material cost = Gross weight × Price per kg.

Cost of Direct Labor

- ✓ Direct labour cost is estimated as follows:
- ✓ Direct labour cost = t × 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 40Φ 30Φ 20Φ (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 =π/4[(5)2 ×3 + (4)2 × 3.5 + (3)2 × 3 + (2)2 × 5] =π/4(178) = 139.73 cc Net weight = 139.73 × 7.86 = 1098 gm= 1.098 kg

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

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

Tong loss = 2 × Area of cross-section of bar × 7.86 = 2 ×π/4× (2)2 × 7.86 = 197.44 gm =0.197 kg

Sprue loss = 7 % of net weight=7/100× 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÷π/4× (2)2 = **44.5 cm**

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

Direct labour cost = Rs. 50 per piece Overheads = 150 percent f labour cost = 1.5 × 50 = **Rs. 75**

Cost per piece = 25.14+50+75 = Rs. 150.14 =**Rs. 150**

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.

a. Advantages of forging

Some common advantages of forging are given as under.

- Forged parts possess high ductility and offers great resistance to impact and fatigue loads.
- Forging refines the structure of the metal.
- It results in considerable saving in time, labor and material as compared to the production of similar item by cutting from a solid stock and then shaping it.
- Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.
- Because of intense working, flaws are rarely found, so have good reliability.
- The reasonable degree of accuracy may be obtained in forging operation.

- The forged parts can be easily welded.

b. *Disadvantages of forging*

- Few disadvantages of forging are given as under.
- Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.
- The close tolerances in forging operations are difficult to maintain.
- Forging is limited to simple shapes and has limitation for parts having undercuts etc.
- Some materials are not readily worked by forging.
- The initial cost of forging dies and the cost of their maintenance is high.
- The metals gets cracked or distorted if worked below a specified temperature limit.

The maintenance cost of forging dies is also very high.

2.2.5. Allowances for materials shrinkage and oxidization.

Forging is a most popular production process because it lends itself to mass production as well as to the production of individual sample parts. Complex shapes can be hammered by skilled blacksmiths. A conical protrusion from the anvil, holes in the anvil, a variety of pegs with different cross sections, and auxiliary tools, including a large selection of shaped hand hammers, may assist the blacksmiths and their helpers.

Parts produced by hot forging require machining on surfaces that will locate with other parts in a final product. Thus the detailed shape features of a forging are developed from the required-machined part by adding various allowances to the machined surfaces, although some of these allowances also form part of the forging design for surfaces that will not be machined. The first allowance added to the machined surface is a finish or machining allowance. This amount is in addition to any dimensional tolerances and must be sufficient to result in a clean surface after finish machining. The allowance for machining is dependent on several factors, but particularly on the amount of oxidation that will result from heating the part up to the forging temperature. The level of oxidation will be dependent on the material type and on the overall size of the forgin

Allowance for Forged material

Table Machining allowances for forging (mm)

Shrinkage allowance		
Length or width, mm	*Commercial.* or - *mm*	*Close* + or - *mm*
Up to 25	008	0.05
26 to 50	0.15	0.06
51 to *75*	0.23	0.13
76 to 100	0.30	0.15
101 to 125	0.38	0.20
126 to 150	0.45	0.23
each additional 25	add 0.075	0.038
For example 400	1.200	0.830

Shrinkage allowance

The forgings arc generally made at a temperature of 1150 t0 1300 C. At this temperature, the material gets expanded and when it is cooled to the atmospheric temperature, its dimension would be reduced. it is very difficult to control the temperature at which forging process would be complete, therefore to precisely control the dimensions. Hence a shrinkage allowance is added on all the linear dimensions

Die wear allowance

The die wear allowance it added to account for the gradual wear of the die which takes place with the use of the die. The suggested values are presented in Table following table:

Finish allowance

Machining allowance is to be provided on the various forged surfaces which need to he further

Self Check – 2

PART-I: Select the best answer from the given alternatives and write its letter on the space provided

1. Which of the following fuels are used in forging shop?

A Solid fuels   B Liquid fuels   C Gaseous fuels   D. All

2. A forging operation used to reduce the cross section of job increasing its width thus having the work in corrugated shape is

A. Drawing out   B Upsetting   C. Fullering   D. Punching

3. Which of the following are advantages of cold working?

A. No heating required   C. Superior dimensional control

B. Better surface finish   D. Increase in ductility

4. The disadvantages of hand forging are

A. Rapid oxidation   C. Limited to simple shapes

B. Close tolerances are difficult   D. All

PART-II: Match the items listed under column "A" with those expressions listed under "B"

"A"	"B"
_______ 1. The nozzle pointing into the centre of the hearth	A. Upsetting
_______ 2. It is used to reduce the thickness of a bar and to increase its length	B. Drifting
_______3. The process of making a piece shorter and thicker	C. Tuyre
_______ 4. It is enlarging a hole punched by hot forging	D. Drawing out

PART-III: Give short and brief answers

1. Describe how swaging operation is performed in hand forging.
2. What is the difference between hot forging and cold forging?
3. Explain the purpose of adding

Operation sheet-2

Operation title:-Upsetting or jumping up

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

Equipment tools and materials: - Tong, Forge, Round bar Charcoal, PPE

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.

Precaution: use PPE and tongs

Quality criteria: Dimensional accuracy and Surface finish

Operation title:-Drawing down

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

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

Procedure:

I. Hammer four sides to produce a short square (Fig.a) 2. Lengthen the square taper (Fig.b)).

3. Hammer the corners of the long square in step 2 to produce an octagonal shape (Fig. (c)).

4. Continue round all the corners in step 3 to obtain a circular end (Fig. (d)). if the taper is fat or square go through either the first two or three stages above.

Avoid piping (hollow ends) when drawing down a taper

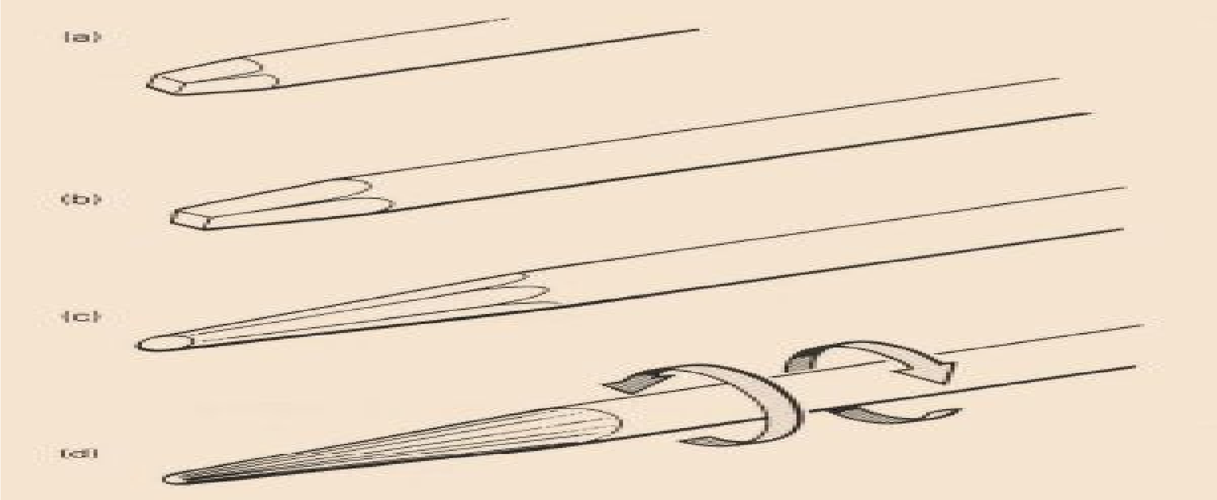


Fig.1.1. Stages in drawing down: a) first stage -short square; b) second stage- long square; (C) Third stage-octagonal shape; (dl final stage-round shape.

Precaution: use PPE and tongs

Quality criteria: Dimensional accuracy and Surface finish. Roundness.

Operation title: - Flattening

Equipment tools and materials: - Tong, Hearth, Round bar Charcoal, PPE, drop Hammer

Procedure: You use the flatter with the sledge hammer to flatten filtered piece Flattening enables you to finish off an undulating surface.

To flatten:

1. Hold the hot metal on lower die.
2. Strike the work piece with the drop hammer
3. Move work pieces them to all areas and repeat step 2.

Precaution: use PPE and tongs

Quality criteria: Dimensional accuracy and Surface finish. Roundness

Unit 3: Quality Assure Work

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

- minimize Equipment oxidization
- Control heat
- Measure form and shape
- (OHS) measures and procedure

This guide 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:

- Operate equipment that minimizes oxidization
- State how to minimize oxidation
- Recognize how to measure form and shape
- (OHS) measures and procedure

3.1. Minimizes Equipment oxidization

3.1.1. Minimizing oxidation

1. Oxidation Behavior

Depending on the carbon concentration in the steel, this alloying element has an influence on the formation of the scale layers and their structures. The rolled, partially annealed, and milled sheet samples, with l = 150 mm × w = 20 mm × t = 4 mm and an average roughness of Ra ≈ 0.5 µm , were inductive reheated with 20 K/s in the Biaxial Test Apparatus BTA 840 from Bähr (Bähr Thermo analyze GmbH now TA Instruments, Hull horst, Germany). A defined time–temperature regime was investigated. After reaching the oxidation temperature (900–1250 ◦C), a holding process of various durations (20–120 s) was set for oxidation. Oxygen was actively supplied via nozzles near the sample surface. After the oxidation time, the samples were cooled under vacuum as quickly as possible. To protect the scale layer from external influences and damage, all samples were covered with epoxy resin at room temperature. Light micro graph was used to measure the thickness, mean pore size, and total pore volume of the layers, so that the correlation between oxidation morphology, carbon content, oxidation temperature, and oxidation time could be determined [21].In general, it was identified that, with increasing temperature and/or time, the layers thickness increased as a result of the diffusion process. There were correlations between the carbon content and the resulting scale thickness.

. The heating of metal is done either in a smith's **hearth or in a furnace**. The hearths (commonly known as forges) are used for heating metals for hand forging. It is a very old method of heating still it is used. The furnaces are used for heating metals for heavy forging.

1. Hearths: - the hearths may be classified as open or closed hearths, the blacksmith forges may have one or two hearths which are called single hearth or double hearth respectively.

A common form of the hearth, as shown in Fig (a), is a single hearth open type forge. Its size varies from 1.5 m to 2.5m square and 0.8 m to 1.2 m deep. It is provided with a lining of fire clay or other refractory material to withstand the excessive heat produced due so the combustion of fuel.

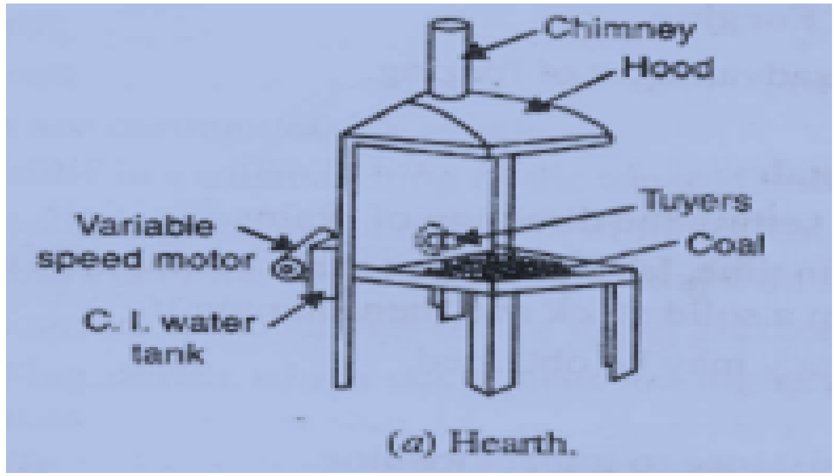


Fig 3.1. Heating Devices (hearth*)*

The fuel used in a hearth may he coke, coal or charcoal. For general work, low sulphur is used. There is an inlet for blowing air either through the back or bottom. The air is generally applied through a motorize fan blower. The motorized fan is generally fitted with a series-wound variable speed motor.

Heating controls allow you to easily regulate the temperature of your home. The **controls** automatically turn the **heating** on and off based on settings input by the user, to ensure maximum comfort. ... The latest technology allows you to automatically **control** your **heating** to work around your daily schedule.

Temperature is the **most important** one because it provides a critical condition for combustion, chemical reaction, fermentation, drying, calcinations, distillation, concentration, extrusion, crystallization, and air conditioning. Poor **temperature control** can cause major safety, quality, and productivity problems.

If your **temperature** is above 250°F, close down the vents to reduce the amount of oxygen in order to reduce the **temperature**. If your **temperature** dips below 225°F, open up the vents fully to allow more oxygen in to increase the **temperature**. Learn more about **temperature control**.

No-Cost Ways to Improve Air Conditioning Efficiency

1. Clean around outdoor condenser unit
2. Vacuum indoor vents and keep vents unblocked.
3. Increase your thermostat by a few degrees.
4. Keep lamps and other heat producing appliances away from your thermostat.
5. Keep curtains and blinds closed in the heat of the day.
6. Clear your drain line

3.1.2. Materials used in forging

Mostly in forging, Ferrous & Non-Ferrous metals are used in manufacturing purpose.

Ferrous metals: these contain iron as a main constituent, these are stronger.

Some of them are low and medium carbon steels, alloy steels, stainless steels, titanium, die-steels.

Ferrous metal forging temp.in ◦c

1. Low carbon steel 1250◦C
2. Medium carbon steel 850-1100◦C
3. Stainless steel 1200◦C

Non-ferrous metals:

Non-ferrous metals do not contain iron as the main constituent. Generally they are weaker than ferrous metals but have other important properties such as corrosion resistance, high electrical and thermal conductivity, good formability and special electrical & magnetic properties the chief non-ferrous metals used in the industrial purpose are copper, aluminum, zinc, lead, tin, magnesium and their alloys.

Non-ferrous metals forging temp in ◦c

1. Brass 650-800◦C
2. Bronze 825-900◦C
3. Aluminum alloys 350-450◦C
4. Copper 900◦

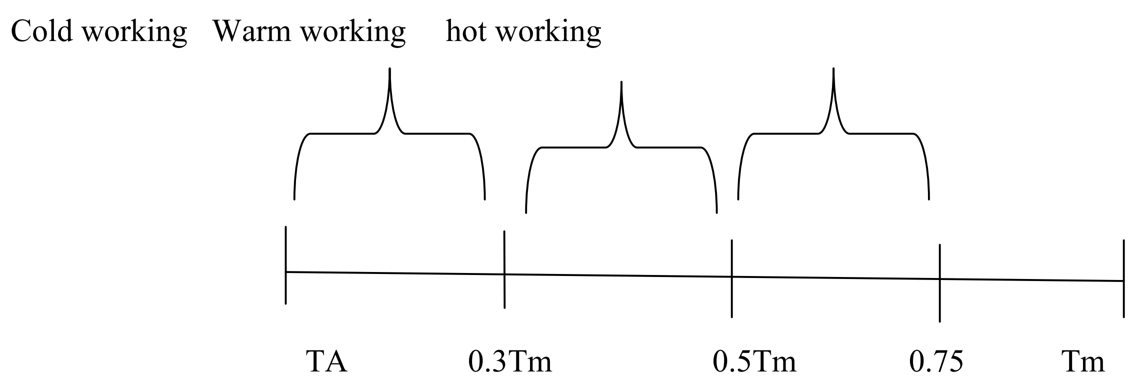
3.1.3. Forging temperatures

Forging temperature is a temperature at which a metal becomes soft like clay or its shape can be changed by applying a relatively small force without creating cracks in metal.

Note: - Temperatures for alloys (combination of metals) will lie between the temperatures specified for the metals utilized.

When heating a piece of steel on a forge the blacksmith must always watch the flame of the fuel. Metal is best heated a bright slightly smoking flame, because such a flame excludes all possibility of overheating the metal. The difference between the initial and final forging temperature is called the forging temperature interval.

There are three temperature ranges-cold, warm, and hot working:



TA is the ambient (room) temperature, and Tm is the work metal melting temperature

Cold working is metal forming performed at room temperature.

- ✓ **Advantages**: better accuracy, better surface finish, high strength and hardness of the part, no heating is required.

Disadvantages: higher forces and power, limitations to the amount of forming, additional annealing for some material is required, and some material are not capable of cold working.

Warm working is metal forming at temperatures above the room temperature but bellow the recrystallization one.

Advantages: lower forces and power, more complex part shapes, no annealing is required.

Disadvantages: some investment in furnaces is needed.

Hot working involves deformation of preheated material at temperatures above the re-crystallization temperature.

- ✓ Advantages: big amount of forming is possible, lower forces and power is required, forming of materials with low ductility, no work hardening and therefore, no additional annealing is required.
- ✓ Disadvantages: lower accuracy and surface finish, higher production cost, and shorter tool life.

3.1.5. Defects in forged parts

The following are some of the reasons for forging defects:

(I) .Faulty original metal,

(II). Incorrect die design.

(III). Improper heating, and

(IV) .improper forging operation

Forging Defects

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

- Defects commonly found in forged parts that have been subjected to plastic deformation are as follows.
- 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 in the die. Defects due to faulty design drop forging die. Defects resulting from improper forging such as seams, cracks, and laps. etc.
- Defects resulting from improper heating and cooling of the forging part such as burnt metal and decarburized steel.

3.1.4. Removal of Defects in Forging

Defects in forging can be removed as follows:

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

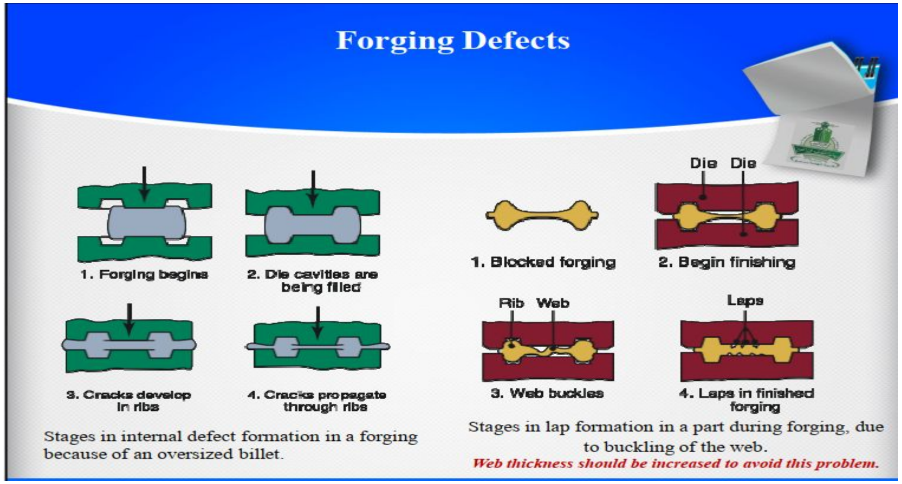
Care should also be taken to see that the job is not under heated, decarburized, overheated and burnt

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



Fig; 3.3. Forging defect

3.2. Control Heat

3.2.1. Heat treatment of forging

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 annealed, normalized and tempered to obtain the desired results.

Annealing

In general, annealing is the opposite of hardening. You anneal metals to relieve internal stresses, soften them, make them more ductile, and refine their grain structures. Annealing consists of heating a metal to a specific temperature, holding it at that temperature for a set length of time, and then cooling the metal to room temperature. The cooling method depends on the metal and the properties desired. Some metals are furnace-cooled, and others are cooled by burying them in ashes, lime, or other insulating materials.

Normalizing

Normalizing is a type of heat treatment applicable to ferrous metals only. It differs from annealing in that the metal is heated to a higher temperature and then removed from the furnace for air cooling. The purpose of normalizing is to remove the internal stresses induced by heat treating, welding, casting, forging, forming, or machining. Stress, if not controlled, leads to metal failure; therefore, before hardening steel, you should normalize it first to ensure the maximum desired results.

Hardening

The hardening treatment for most steels consists of heating the steel to a set temperature and then cooling it rapidly by plunging it into oil, water, or brine. Most steels require rapid cooling (quenching) for hardening but a few can be air-cooled with the same results. Hardening increases the hardness and strength of the steel, but makes it less ductile. Generally, the harder the steel, the more brittle it becomes. To remove some of the brittleness, you should temper the steel after hardening.

Tempering

After the hardening treatment is applied, steel is often harder than needed and is too brittle for most practical uses. Also, severe internal stresses are set up during the rapid cooling from the hardening temperature. To relieve the internal stresses and reduce brittleness, you should temper the steel after it is hardened. Tempering consists of heating the steel to a specific temperature (below its hardening temperature), holding it at that temperature for the required length of time, and then cooling it, usually instill air. The resultant strength, hardness, and ductility depend on the temperature to which the steel is heated during the tempering process.

3.2.2. Control of Heating Devices

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

1. The nozzle pointing into the center of the hearth is called the tuber and is used to direct a stream of air into the burning coke. The air is supplied by centrifugal blower.
2. As the hottest part of the fire is close to the tuber opening, therefore, the tuber is provided with a water jacket to prevent it from burning away.
3. 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.

4. The fuel for the fire may be either black-smiting coal or coke. To light the fire, either use paper and sticks or preferably a gas poker.

5. Impurities will collect as clinker and must be removed from the bottom of the fire when the fire cools.

6. The blowers are used to control the air supply using forced draught. Regulators control the draught and the temperature of the fire.

7. Blower delivers to forge adequate supply of air at proper pressure which is very necessary for the combustion of fuel.

8. A centrifugal blower driven by an electric motor is an efficient means of air supply
in forging hearth.

9. 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. Rake is used to take heated work piece out of the fire. Poker is a steel rod which is used to poke (stir) fire in the hearth.

10. The place of the metal to be heated should be placed just above the compact center of a sufficiently large fire with additional fuel above to reduce the heat loss and atmospheric oxidation

3.2.3. Making preventive maintenance

Maintenance is a broad definition concerned with controlling the condition of equipment.

The trainees should detect the overhaul preventive maintenance (PM) action of Forge hand tools & hammers, formers & heating equipment.

This moderate approach begins with an attempt to plan on preventive maintenance of a forge work.

Cleaning, repairing hand tools, formers, heating equipment

Select preventive maintenance task

Choose preventive maintenance interval with normal life span

Determine normal life span before defect

Prevent hand tools, formers, hammers & forging machines from deterioration

Lubricating forging machine

Checking daily surveillance of forging machine

3.3. Measure form and shape

Testing of metals

Metal testing is accomplished for the purpose of for estimating the behavior of metal under loading (tensile, compressive, shear, torsion and impact, cyclic loading etc.) of metal and for providing necessary data for the product designers, equipment designers, tool and die designers and system designers. The material behavior data under loading is used by designers for design calculations and determining whether a metal can meet the desired functional requirements of the designed product or part. Also, it is very important that the material shall be tested so that their mechanical properties especially their strength can be assessed and compared. There fore the test procedure for developing standard specification of materials has to be evolved. This necessitates both destructive and non-destructive testing of materials.

Destructive tests of metal include various mechanical tests such as tensile, compressive, hardness, impact, fatigue and creep testing. A standard test specimen for tensile test Non-destructive testing includes visual examination, radiographic tests, ultrasound test, liquid penetrating test and magnetic particle testing.

Tensile test

A tensile test is carried out on standard tensile test specimen in universal testing machine.

Fig. 7.3 shows a schematic set up of universal testing machine reflecting the test specimen griped between two cross heads. Fig. 7.4 shows the stress strain curve for ductile material. Fig. 7.5 shows the properties of a ductile material. Fig. 7.6 shows the stress strain curves for wrought iron and steels. Fig. 7.7 shows the stress strain curve for nonferrous material.

Compression Test

Compression test is reverse of tensile test. This test can also be performed on a universal testing machine. In case of compression test, the specimen is placed bottom crossheads. After that, compressive load is applied on to the test specimen. This test is generally performed for testing brittle material such as cast iron and ceramics etc. Fig. 7.8 shows the schematic compression test set up on a universal testing machine. The following terms have been deduced using figures pertaining to tensile and compressive tests of standard test specimen.

3.4. Occupational Health and Safety in Forging Work Shop

Introduction

Hand forging is an oldest shaping process used for producing small articles for which accuracy in size is not so important. The parts are shaped by heating them in an open fire or hearth by the blacksmith and shaping them through applying compressive forces using hammers. Thus hand forging is the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive forces exerted through some means of hand hammers.

Almost all metals and alloys can be forged. The low and medium carbon steels are readily hot forged without difficulty, but the high-carbon and alloy steels are more difficult to forge and require greater care. Forging is generally carried out on carbon steels, alloy steels, wrought iron, copper-base alloys, alumunium alloys, and magnesium alloys.

1. Personnel Protective Equipment (PPE)

All PPE clothing and equipment should be of safe design and construction, and should be maintained in a clean and reliable fashion. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment (RPE).

Employers should take the fit and comfort of PPE into consideration when selecting appropriate items for their workplace. PPE that fits well and is comfortable to wear will encourage employee use of PPE. Most protective devices are available in multiple sizes and care should be taken to select the proper size for each employee. If several different types of PPE are worn together, make sure they are compatible. If PPE does not fit properly, it can make the difference between being safely covered or dangerously exposed. It may not provide the level of protection desired and may discourage employee use.

To ensure the greatest possible protection for employees in the workplace, the cooperative efforts of both employers and employees will help in establishing and maintaining a safe and healthful work environment. In general, employers are responsible for:

- Performing a "hazard assessment" of the workplace to identify and control physical and health hazards.
- Identifying and providing appropriate PPE for employees.
- Training employees in the use and care of the PPE.
- Maintaining PPE, including replacing worn or damaged PPE.
- Periodically reviewing, updating and evaluating the effectiveness of the PPE program.

Employers are required to train each employee who must use PPE. Employees must be trained to know at least the following:

- When PPE is necessary.
- What PPE is necessary?
- How to properly put on, take off, adjust and wear the PPE.
- The limitations of the PPE.
- Proper care, maintenance, useful life and disposal of PPE.

In general, employees should:

- Properly wear PPE,
- Attend training sessions on PPE,

- Care for, clean and maintain PPE, and
- Inform a supervisor of the need to repair or replace PPE.

3.4.1. Preventative OHS procedures

Effective management of employee safety and health protection is a decisive factor in reducing the extent and severity of work-related injuries and illnesses and their related costs. In fact, an effective safety and health program forms the basis of good employee protection, can save time and money, increase productivity, and reduce employee injuries, illnesses and relate workers' compensation costs.

To assist employers and employees in developing effective safety and health procedures, these guidelines identify four general elements critical to the development of a successful safety and health management system:

- Management leadership and employee involvement,
- Worksite analysis,
- Hazard prevention and control, and
- Safety and health training.

3.4.2. Safety regulation in forging work shop

During forging operations, burning injury and damage of tools and equipment may occur due to lack of safe work habits. Therefore, you must follow commonly recognized safety rules and safety practices in order to avoid possible accidents or personal injury.

Some safety precautions generally followed while working in forging shop are given as under.

1. Always avoid the use of damaged hammers.

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

There are basic rules that apply to all hand tools and formers used in hand forging. These are:

- ✓ Keep all tools in good working order.
- ✓ Use the tool only for what it is designed to do.
- ✓ Examine the tool for damage before each use.
- ✓ Always follow the manufacturer’s instructions when operating any tool.
- ✓ Always wear the appropriate PPE when operating any tool.

Self check-3

<u>PART ONE</u>

Directions: **Answer all the questions listed below. Use the Answer sheet provided in the next pag**e:

1. Advantage of cold working is

(*a*) Better dimensional accuracy (*b*) better surface finish

(*c*) Higher strength (*d*) all of these.

2. Typical hot working temperature range for steel is

(*a*) 650–1050°C (*b*) 650–723°C

(*c*) 500–910°C (*d*) none of these.

3. The forging operation of "upsetting" is

(*a*) Reverse of drawing down process (*b*) it is a bending operation

(*c*) It is a drifting operation (*d*) none of these.

Directions: Answer all the questions listed below.

PART-II: Decide whether the following statements are "True" or "False" and write your answer on the space given. Use the Answer sheet provided in the next page

________1. Metal testing is accomplished for the purpose of estimating the behavior of metal under loading.

________2. Destructive testing /Mechanical testing/ requires destroying the specimen in order to measure the property.

________3. Hardness embraces many different properties such as resistance to wear, scratching, deformation and machinability.

________4. When metal is subjected to suddenly applied load or stress, it may fail.

PART-III: Match the items listed under column "A" with those expressions listed under "B"

"A"	"B"
_____1. Destructive testing	A. Sharply testing
_____2. Non-destructive testing	B. Ductility
_____3. Tensile property	C. Ultrasound testing
_____4. Impact strength	D. Hardness testing

Operation sheet-3: How to Perform a Tensile Test

Operation title: Performing tensile test

Purpose: To determine a metal's tensile strength, yield strength and ductility

Instruction: To begin the preparation, ready a sample for tensile testing. The standard appearance of a test specimen features a small cross-section or gage length with two large ends that are called shoulders. The entire tensile test will focus on the gage length, while the shoulders will be firmly gripped by the tensile tester machine. All tensile testing machines have main capabilities for test specimens, such as maximum force capacity, speed, precision and accuracy. Force capacity is the machine's capability to produce enough force to break the material. The machine should be able to control the speed at which it applies force. Most importantly, the machine should be able to measure the length and strain with precision and accuracy.

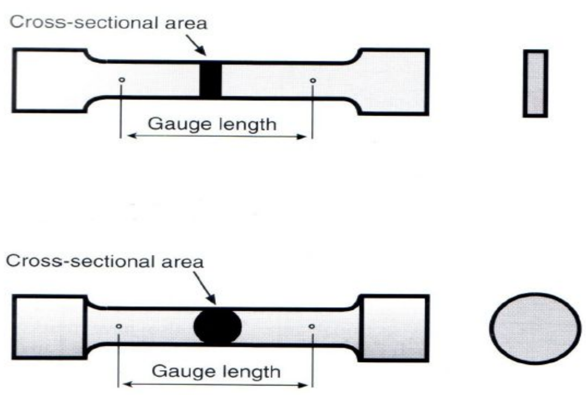


Fig. 4.16 Tensile test specimen

Tools and requirement:

- Universal test/tensile testing/ machine
- extensometer
- Proper grips and fixtures to hold your sample
- PPEs

Steps in doing the task:

1. Prepare a tensile test specimen.

2. Position the lower and upper clamps in their proper position to accommodate the length of the test sample.

3. Next, place the material between the tensile clamps. Vertically align the sample from the upper clamp (the fixed grip) to the lower clamp (the grip in charge of applying tension).

4. After securing the sample, attach the extensometer to its length. While it undergoes testing, the extensometer will be monitoring and measuring any changes in the material.

5. To begin the tensile stress test, slowly separate the tensile clamps at a constant speed. While the substance undergoes tension, the tester can observe how much elongation is occurring in the process.

6. Eventually, the specimen will begin to deform in the middle of its length. Changes in the stress-strain curve will begin to appear during this phase. Once the specimen breaks, the tensile testing has officially ended.

7. After the fracture, unlatch the specimen piece from the tensile clamps. The tensile testers or technicians will calculate the tensile strength, yield strength and ductility of the material. After taking the final measurements, the broken specimen will be compared to the undamaged copy made before the test.

Quality Criteria: The tester should familiarize himself with the tensile test machines and the data gathering techniques.

Precautions: Although the test for tensile strength is simple, many errors can occur if the tester becomes impatient with the process or if he or she rushes it altogether. In order to gain valid results and information from the test, patience and attention to detail is absolutely necessary, especially in the preparatory stage.

Lap Test-3

Task-1: Carry out hardness testing on a sample of carbon steels.

Task-2: Perform spark test on a variety of metals and identify their types.

Task-3: Inspect surface cracks of ferrous and non ferrous metal specimen using penetrates available in your work shop.

References

Introduction to Basic manufacturing processes and workshop technology, Rajender S., 2006 New Age International (P) Ltd., Publishers
Ferrous and Non-Ferrous Metals – Its Definition, List, Properties, 2018 © CivilSeek
Materials Science & Engineering: An Introduction, William D. Callister, Jr., John Wiley & Sons, Inc., 2007.
Metal properties, char, uses, and codes - od1643
© 2004 ASM International. All Rights Reserved. Tensile Testing, Second Edition (#05106G)
Mechanical Behaviour of Materials, William F. Hosford, Cambridge University Press, 2010.
Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 1988.
https://www.britannica.com/technology/materials-testing
https://www.asminternational.org/documents/10192/3465262/05105G_Chapter_1.pdf/e13396e8-a327-490a-a414-9bd1d2bc2bb8
https://www.ikbooks.com/home/samplechapter?filename=150_Sample-Chapter.pdf
Đttp://nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Machine%20design1/pdf/Module-1_Lesson-1.pdf

https://openoregon.pressbooks.pub/manufacturingprocesses45/chapter/unit-1-introduction-to-heat-treating-and-safety/

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