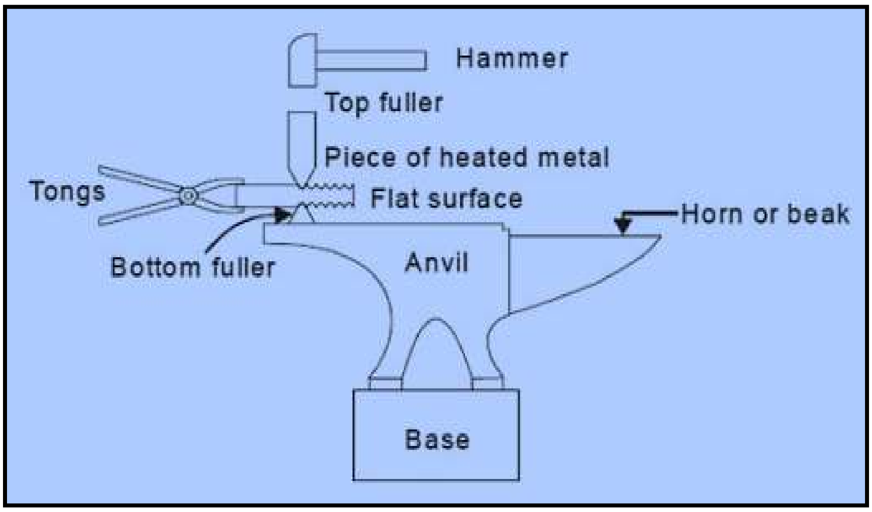
Mechanics

Level-I

Based on March, 2022, Curriculum Version-1



Module Title: - Performing Hand Forging

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Table of Content

Acknowledgment

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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 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.

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.

This module covers the units:

- Occupational health and safety in forging work shop
- Planning hand forging work
- Hand forging techniques
- Quality of hand forging

Learning Objective of the Module

- Recognize the use of occupational health and safety in forging work shop
- Plan hand forging work
- Describe hand forging techniques
- Clarify how to maintain quality of hand forging

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: Occupational Health and Safety in Forging Work Shop

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

- Personnel Protective Equipment (PPE)
- Preventative OHS procedures.
- Safety regulation in forging work shop

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:

- State the use of Personnel Protective Equipment (PPE)
- Describe preventative OHS procedures
- Identify safety regulation in forging work shop

1.1. 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.

1.2. 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.

1.3. 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.

1.4. 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-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. Hand forging is an oldest shaping process used for producing small articles.

_________2. Hand forging is the plastic deformation of metals at elevated temperatures.

_________3. All PPE clothing and equipment should be of safe design and construction.

_________4. Most protective devices are available in multiple sizes and care should be taken to select the proper size.

_________5. Training employees in the use and care of the PPE is not desirable.

_________6. An effective safety and health program forms the basis of good employee protection

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

"A"	"B"
______1. The shop in which the various forging operations are done	A. High carbon steel
______2. Helmets, gloves, eye protection, safety footwear	B. Hand forging
______3. Plastic deformation under pressure at high temperature	C. smithy

_____4. Difficult to forge and require greater care D. PPE

PART-III: Give short and brief answer

1. What is the purpose of training employee on the proper use of PPE?
2. State the four general elements critical to the development of a successful safety and health management system.
3. Mention at least five safety precautions generally followed while working in forging shop.

Unit 2. Planning Hand Forging Work

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

- Drawing interpretation for forging techniques
- Tools and formers in hand forging
- Heat and temperatures applied in hand forging

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:

- Interpret drawing for forging techniques
- Distinguish the use of tools and formers in hand forging
- Recognize heat and temperatures applied in hand forging

2.1 Drawing interpretation for forging techniques

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 complete. The content of an engineering drawing must provide all the information for that stage of its manufacture. There may be several drawings for several phases of manufacture, e.g. raw shape, bent shape and heat-treated. Although each drawing should be complete in its own right, it may rely on other drawings for complete specification, e.g. detailed drawings and assembly drawings.
- 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.
- Drawings must be language-independent. Engineering drawings should not be dependent on any language. Words on a drawing should only be used within the title block or where information of a non-graphical form needs to be given. Drawings need to conform to standards. The 'highest' standards are the ISO ones that are applicable worldwide. Alternatively standards applicable within countries may be used. Company standards are often produced for very specific industries.

2.2 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 round hole in the anvil called pritchel hole is generally used for bending rods of small diameter, and as a die for hot punching operations. The square or hardie 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.

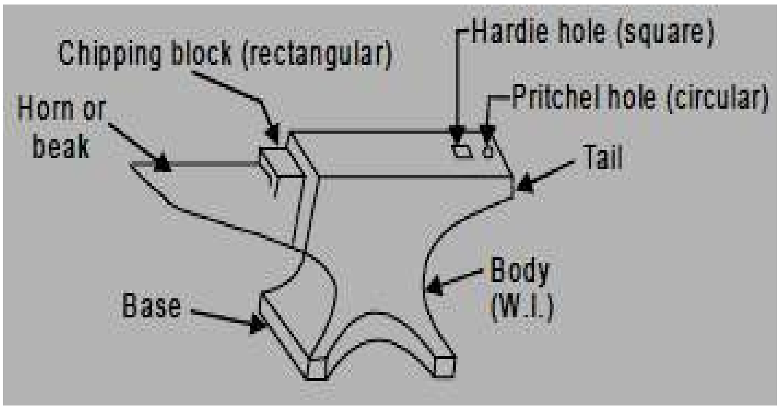


Figure 2.1. Anvil

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.

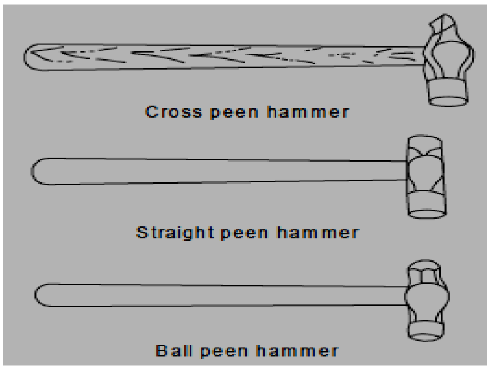


Figure 2.2 Hand hammers

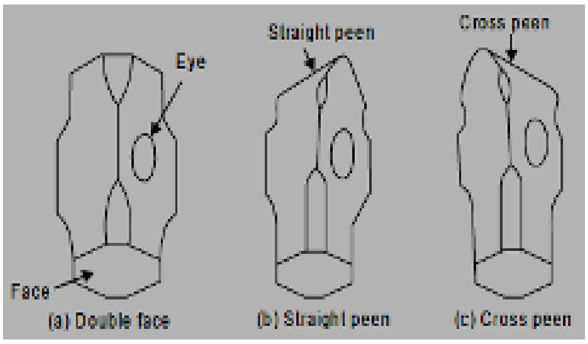


Figure 2.3 Sledge hammers

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.

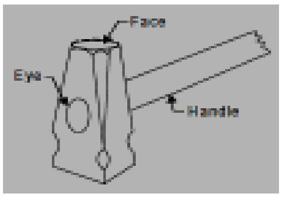


Figure 2.4 Set hammer

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.

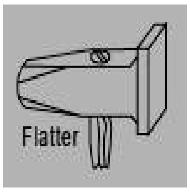


Figure 2.5 Flatter

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 hardie hole on the anvil face.

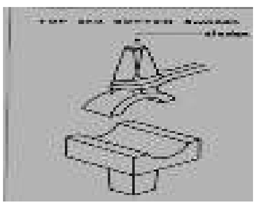


Figure 2.6 Swage

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.

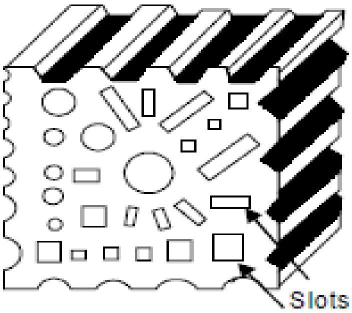


Figure 2.7 Swage block

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

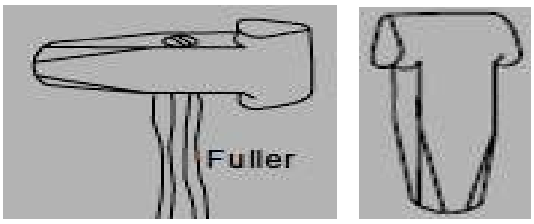


Figure 2.8 Top and bottom fuller

8. Punch

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

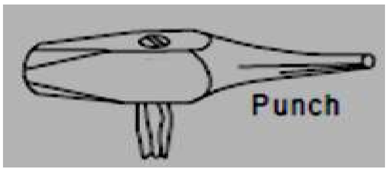


Figure 2.9 Punch

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.

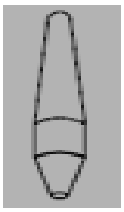


Figure 2.10 Drift

10. Rivet header

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

Figure 2.11 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.

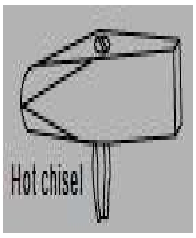


Figure Fig 2.12 Chisel

12. Hardie

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

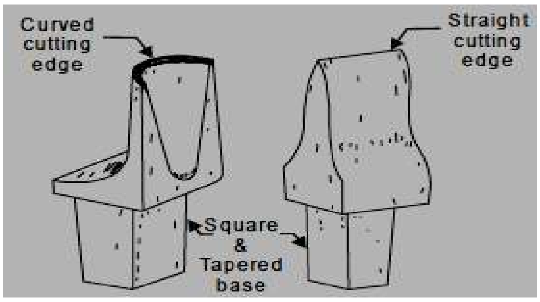


Figure 2.13 Hardie

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.

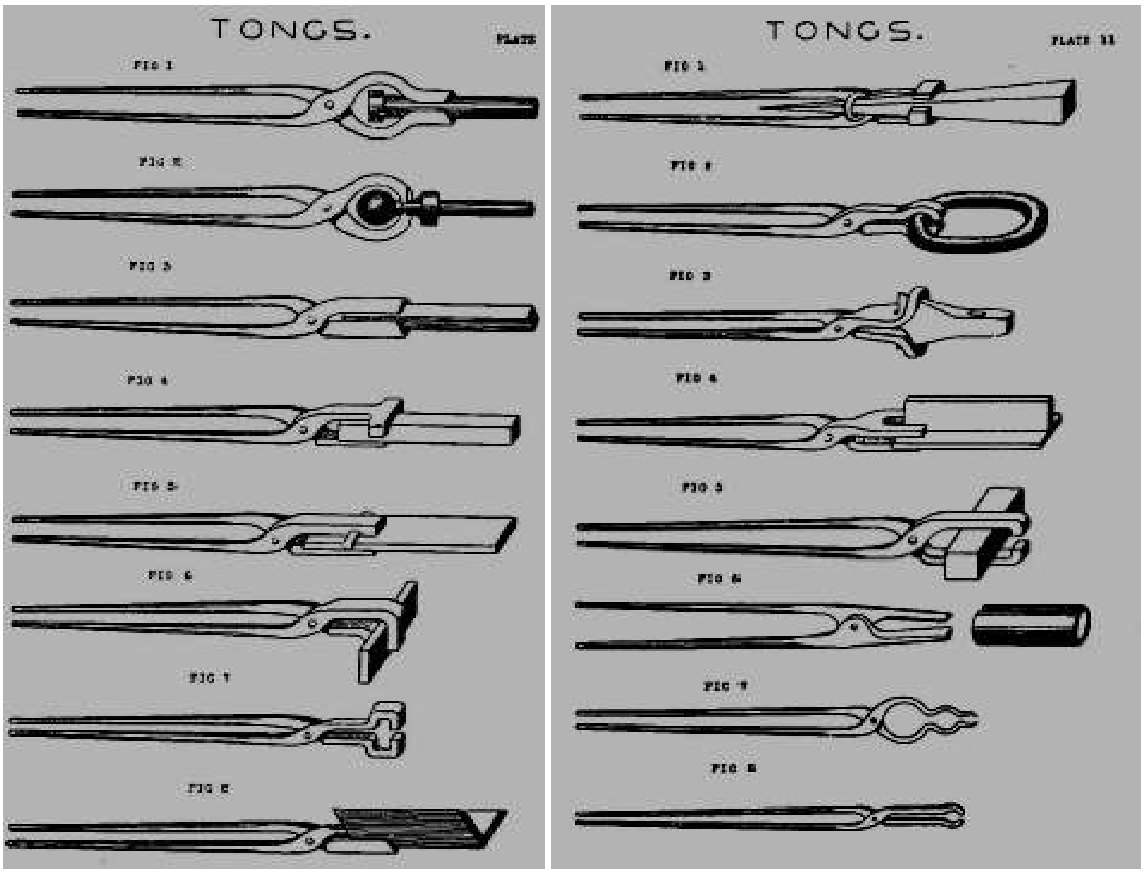


Figure 2.14 Tongs

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.

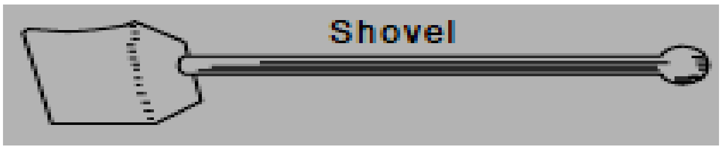


Figure 2.15 Shovel

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.

Figure 2.16 Poker

16. Rake

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

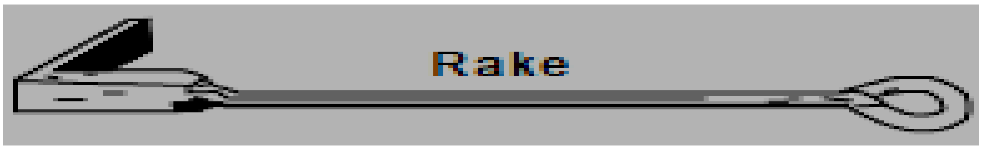


Figure 2.17 Rake

2.3 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.

Table 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
Aluminium and Magnesium Alloys	500°C	300°C
Copper, Brass and Bronze	950°C	6OO°C

Table 2 The colour and brightness of different forging processes

Heat colour	**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	Forge welding

(Metal which looks oily in the fire and throws off a few whitish sparks)	

2.3.1. Forgeability

The ease with which forging is done is called forgeability. The forgeability of a material can also be defined as the capacity of a material to undergo deformation under compression without rupture. Forgeability 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. Aluminium alloys
2. Magnesium 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)
7. Nickel alloys
8. Titanium alloys
9. Columbium alloys
10. Tantalum alloys
11. Molybdenum alloys
12. Tungsten alloys

Self check-2

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 "B" with those expressions listed under "A"

"A"	"B"
______1. The round hole in the anvil called	A. Fuller
______2. It is sed for finishing corners in shouldered work	B. Pritchel 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 3: Hand Forging Techniques

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

- Heating equipments
- Hand 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:

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

3.1. Heating equipments

Forgeable metals are heated either in a hearth or in a furnace.

1. Blacksmith hearth

Blacksmith hearths are widely used for heating the metals for carrying out hand forging operations.

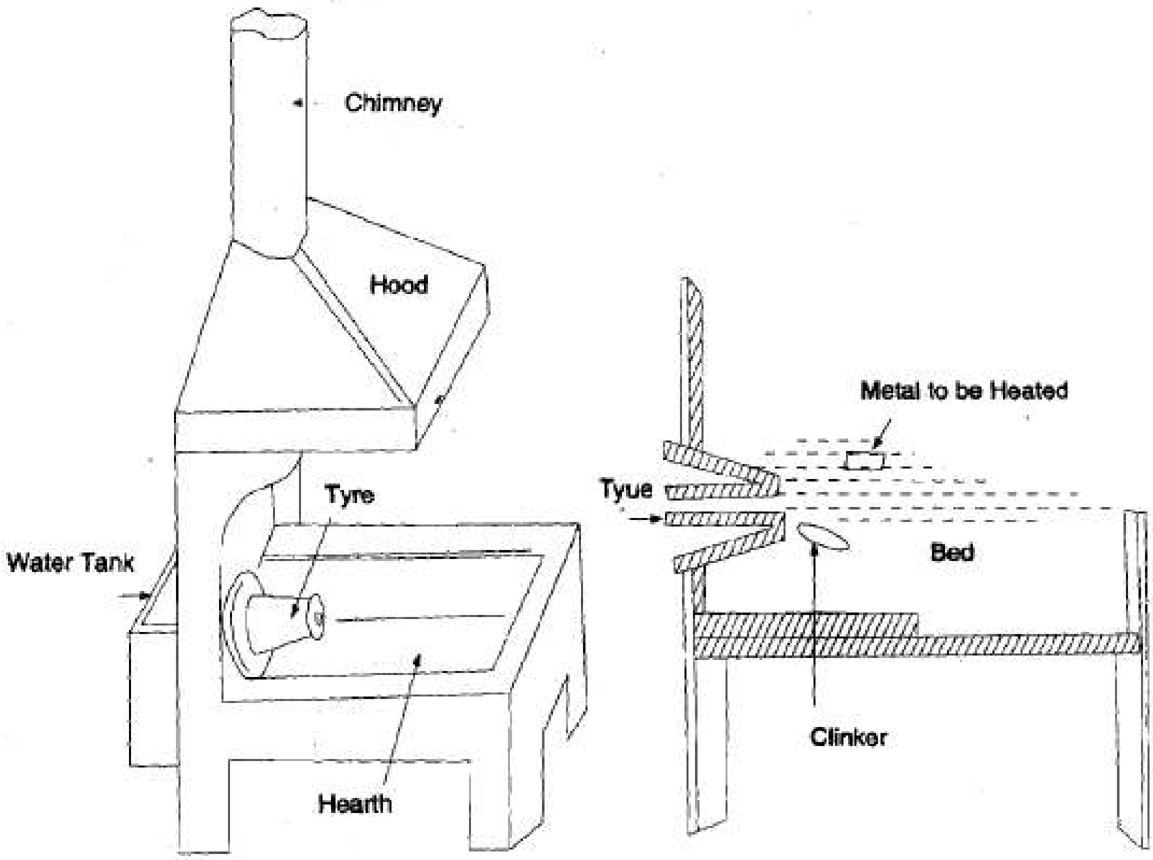


Figure 3.1 Blacksmith hearth

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.

a. The fuel should be able to generate the required heat.
b. It should have complete combustion.

c. It should be highly efficient.
d. It should not produce excess smoke and flying ash.
e. 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:

i. 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.
ii. As the hottest part of the fire is close to the tuyre opening, therefore, the tuyere (nozzle) is provided with a water jacket to prevent it from burning away.
iii. 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.
iv. 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.
v. Impurities will collect as clinker and must be removed from the bottom of the fire when the fire cools.
vi. The blowers are used to control the air supply using forced draught. Regulators control the draught and the temperature of the fire.
vii. Blower delivers to forge adequate supply of air at proper pressure which is very necessary for the combustion of fuel.
viii. A centrifugal blower driven by an electric motor is an efficient means of air supply in forging hearth.
ix. 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.

x. 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.

2. 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 /recuperator/ 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.

Figre 3.2 Box type furnace

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.

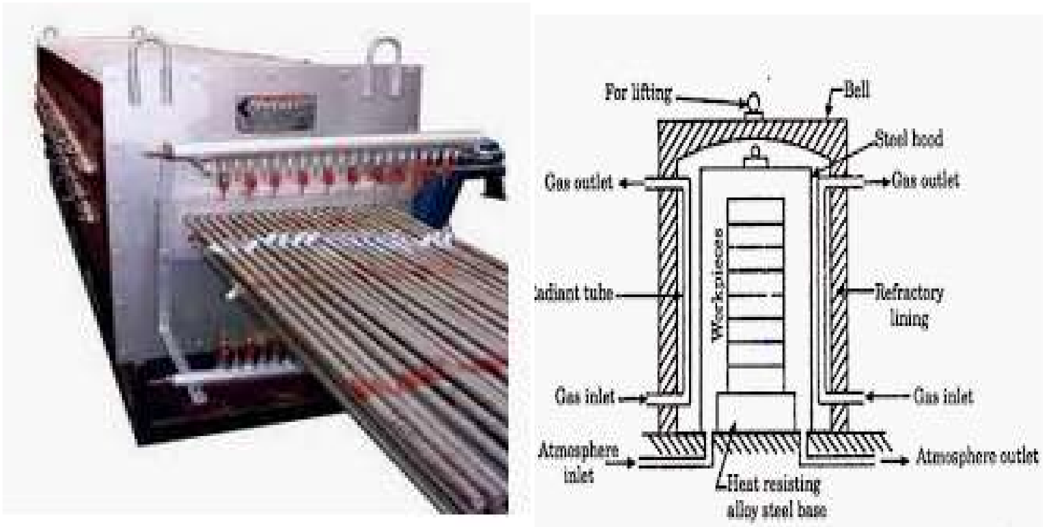


Figure 3.3 Continuous furnace

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.

Figure 3.4 Slot type furnace

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.

Figure 3.5 Rotary hearth furnace

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,

Figure 3.6 High frequency induction furnace

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.

Figure 3.7 Resistance furnace

3.2. Hand forging techniques

Some important hand forging operations are:

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.

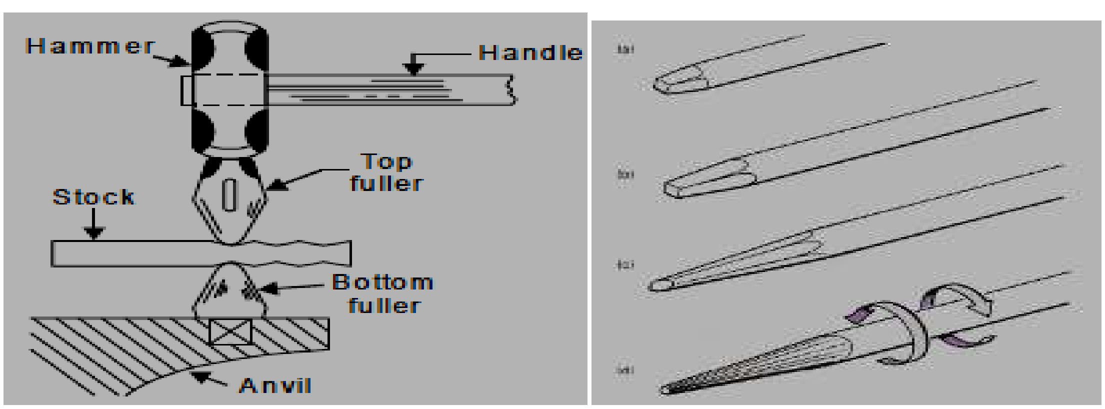


Figure 3.8 Drawing out

2. Fullering and flattening

Fullering (spreading) 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.

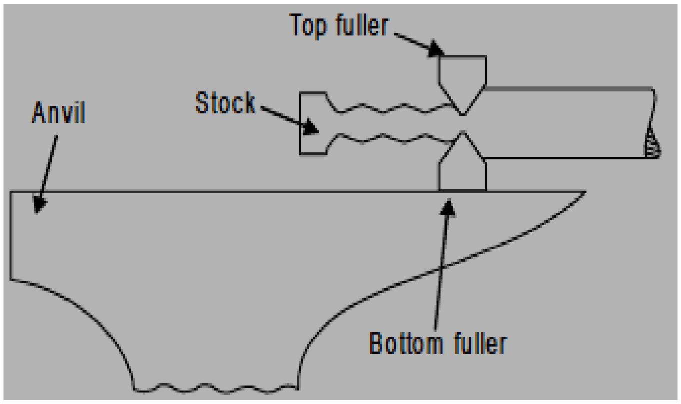


Figure 3.9 Fullering

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.

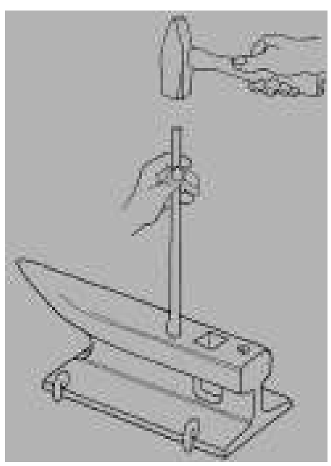


Figure 3.10 End upsetting

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.

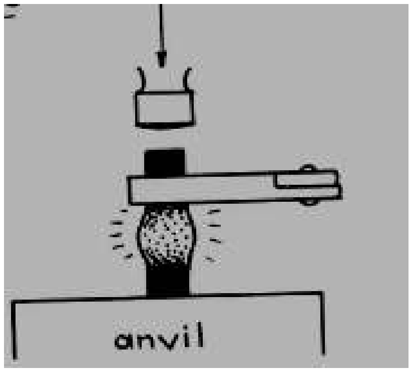


Figure 3.11 Center upsetting

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
2. Placing the metal between the top and bottom swages
3. Striking the top swage while rotating the work

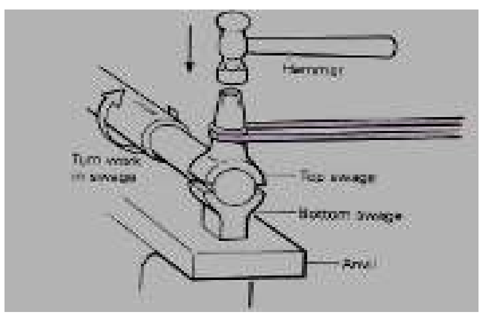


Figure 3.12 Swaging

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.

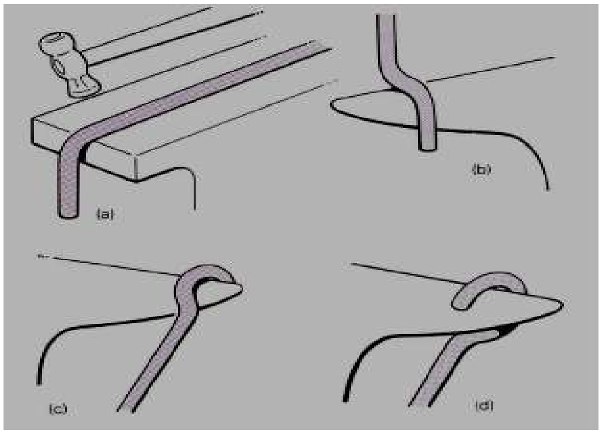


Figure 3.13 Bending/forming an eye

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.

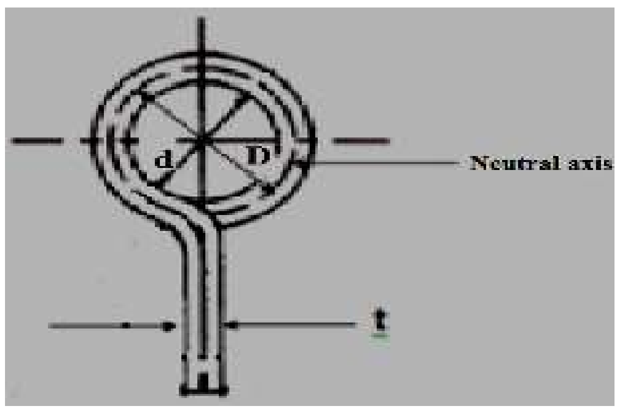


Figure 3.14 Radius of neutral axis i.e. R. n.a. = d + t/2

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.

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

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.

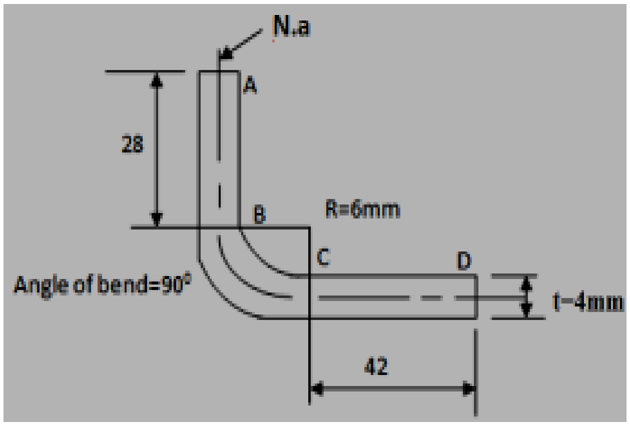


Figure3.15 Length of the bracket

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

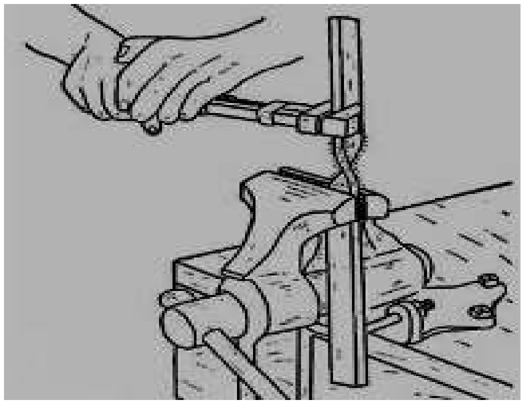
Then dividing by four= 50.24mm/4= 12.56mm

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= ΠD*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.



Figre 3.16 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.

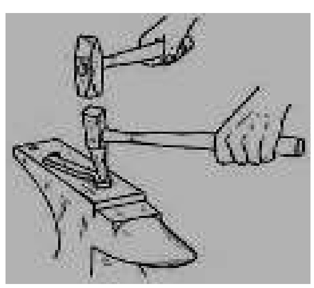


Figure 3.17 Punching

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.

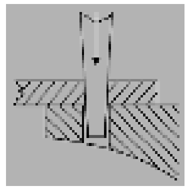


Figure 3.18 Drifting

9. Cutting with the Hardie

The blacksmith does most of his cutting of iron and steel on the hardie 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 hardie, 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 hardie, like any other Cutting tool, works much better if kept sharp. It may be ground like a cold chisel.

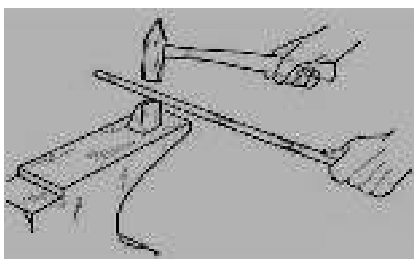


Figure 3.19 Cutting with hardie

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

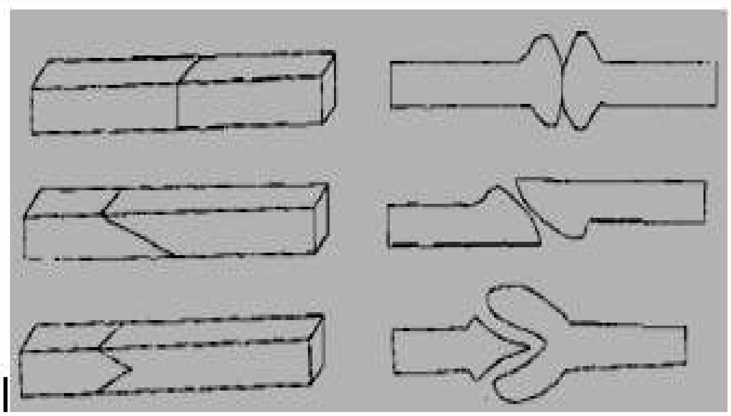


Figure: 3.20 (a) Butt Weld, (b) Scarf Weld, and (c) 'V' weld or Splice Weld

3.2.1 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 inhomogeneities

- 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

3.2.2. Advantages and disadvantages of forging

a. *Advantages of forging*

Some common advantages of forging are given as under.

1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads.
2. Forging refines the structure of the metal.
3. 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.

4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.
5. Because of intense working, flaws are rarely found, so have good reliability.
6. The reasonable degree of accuracy may be obtained in forging operation.
7. The forged parts can be easily welded.

b. ***Disadvantages of forging***

Few disadvantages of forging are given as under.

1. Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.
2. The close tolerances in forging operations are difficult to maintain.
3. Forging is limited to simple shapes and has limitation for parts having undercuts etc.
4. Some materials are not readily worked by forging.
5. The initial cost of forging dies and the cost of their maintenance is high.
6. The metals gets cracked or distorted if worked below a specified temperature limit.
7. The maintenance cost of forging dies is also very high.

3.3. 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 forging.

Table 1 Machining allowances for forgings

Greatest dimension, mm	Minimum allowance per surface, mm
Up to 200	1.5
201 to 400	2.5
401 to 600	3.0
601 to 900	4.0
Above 900	5.0

Greatest diameter, mm	Minimum allowance per surface, mm
Up to 50	1.5
51 to 200	2.5
Above 200	3.0

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.

Table 2 Shrinkage allowance for forgings

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

Self Check – 3

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 "B" with the expressions listed under "A"

"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. Tuyere (nozzle)
___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 allowances for shrinkage and oxidation.

Operation sheet-1

- **Operation title:** Drawing down
- **Purpose:** To make a center punch
- **Instruction:** By following the required steps produce a center punch using hand forging technique i.e. Drawing down

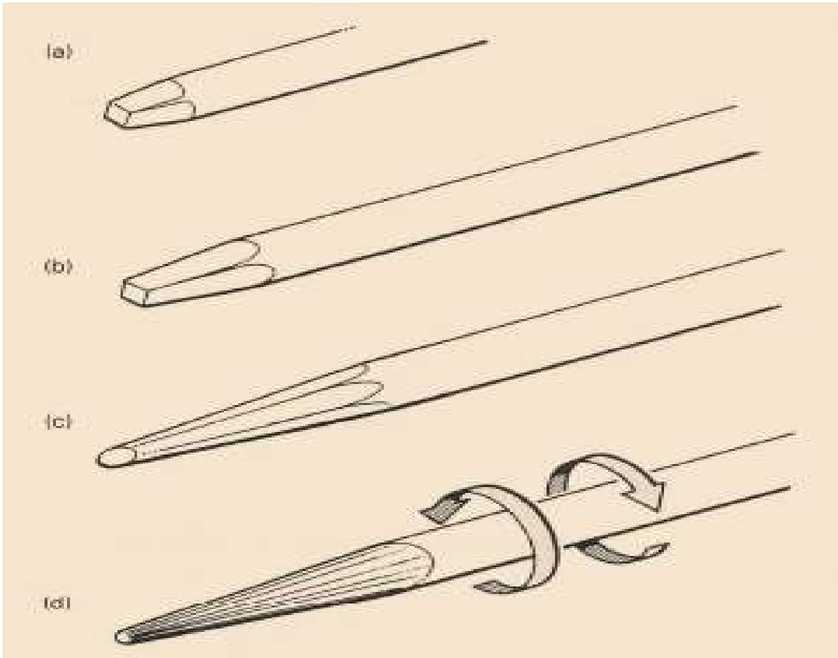


Figure 1.Steps in drawing down operation

Tools and requirement:

- Blacksmith hearth
- Anvil
- Hand hammer
- Proper tong
- Basic PPEs

Steps in doing the task:

1. Hammer four sides to produce a short square.

2. Lengthen the square taper.

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

4. Continue round all the corners in step 3 to obtain a circular end.

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

6. Always keep the metal at a good working temperature, reheating as may be necessary.

Quality Criteria: Heating temperature has to be appropriate and the work piece has to be hammered uniformly.

Precautions: PPE should be used all the time and hot metal has to be gripped firmly.

Operation sheet-2

- **Operation title:** Upsetting
- **Purpose:** To make a bolt head
- **Instruction:** By following the required steps produce a bolt head using hand forging technique i.e. upsetting

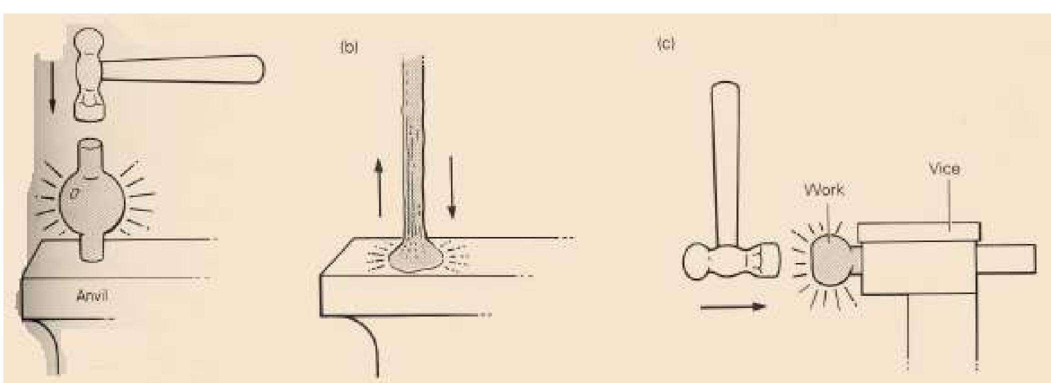


Figure 2 Steps in upsetting

Tools and requirement:

- Blacksmith hearth
- Anvil
- Hand hammer
- Proper tong
- Basic PPEs

Steps in doing the task:

I. Heat the portion to be jumped up.

2. Bounce the metal on the anvil face.

3. Hold the bar in the vice and hammer the end.

4. Always keep the metal at a good working temperature, reheating as may be necessary.

Quality Criteria: Hating temperature has to be appropriate and the work piece has to be hammered uniformly.

Precautions: PPEs should be used all the time and hot metal has to be gripped firmly.

Operation sheet-3

- **Operation title:** Bending/forming an eye
- **Purpose:** To make an eye
- **Instruction:** By following the required steps produce an eye using hand forging technique i.e. bending

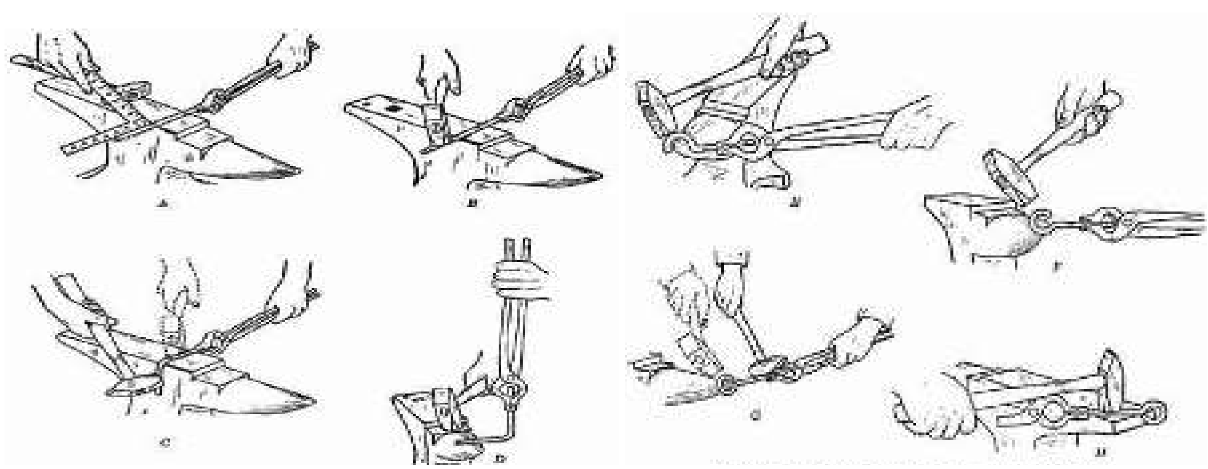


Figure 3 Steps in making an eye

Tools and requirement:

- Blacksmith hearth

- Anvil
- Hand hammer
- Proper tong
- Basic PPEs

Steps in doing the task:

1. Place a well-heated iron across the anvil with enough stock projecting over to form the eye.
2. Bend the projecting portion down, forming a right angle.
3. Finish the right angle bend by striking alternately on top and on the side, keeping the iron at a good working heat all times.
4. Start bending the tip end around the horn, being careful to strike "overhanging" or bending blows.
5. Gradually work back from the end to the square bend.
6. Turn the eye over and close it up. Exert considerable back pull on the tongs to keep the upper part of the eye up off the horn. In this position the hammer can strike bending blows instead of flattening or mashing blows.
7. Round the eye by driving it back over the point of the horn. Carefully note where the eye does not touch the horn, and strike down lightly in these places.
8. To straighten the stem of an eye, place it across the corner of the anvil face and strike the high points while the iron is at a good working heat. Always keep the metal at a good working temperature, reheating as may be necessary.

Quality Criteria: Heating temperature has to be appropriate and the work piece has to be hammered uniformly.

Precautions: PPEs should be used all the time and hot metal has to be gripped firmly.

Operation sheet-4

- **Operation title:** punching a hole
- **Purpose:** To make a hole through a hot metal.
- **Instruction:** By following the required steps produce a hole using hand forging technique i.e. punching

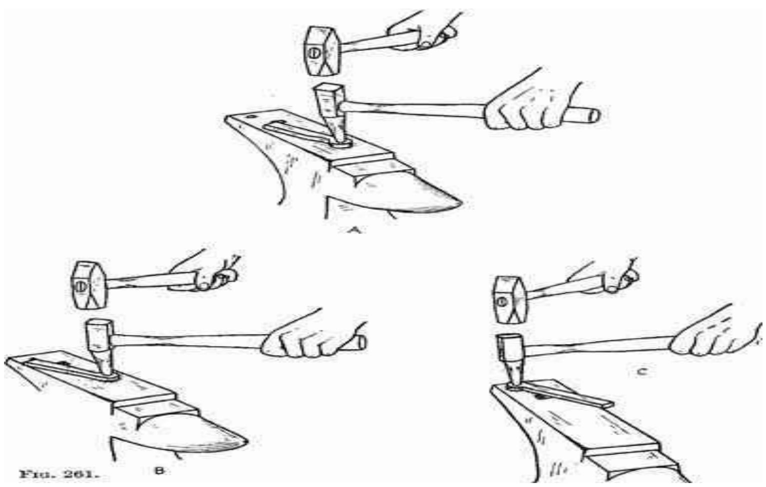


Figure 4 Steps in punching operation

Tools and requirement:

- Blacksmith hearth
- Anvil
- Hot punch
- Proper tong
- Basic PPEs

Steps in doing the task:

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 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.
5. Just as the punch is about to go through, move the piece over the pritchel hole or hardy hole to allow the small pellet or slug to be punched out.
6. Enlarge the hole to the desired size by driving the punch through the hole first from one side and then the other. Always keep the metal at a good working temperature, reheating as may be necessary.

Quality Criteria: Heating temperature has to be appropriate and the work piece has to be hammered uniformly.

Precautions: PPEs should be used all the time and hot metal has to be gripped firmly.

Lap Test-1

- Task-1: Carry out fullering (spreading) on a sample of carbon steels.
- Task-2: Perform forge welding of low carbon steel work pieces following the required procedures.

Unit 4: Quality Of Hand Forging
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Maintaining quality of forgings • Minimizing oxidation • Calculating and measuring form and shape 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: • Recognize how to maintain quality of forgings • State how to minimize oxidation • Clarify how to calculate and measure form and shape

4.1. Maintaining quality of forgings

In recent scenario every manufacturing organization is concerned with quality of the product in order to remain ahead of its competitors and be first preference of customers. It is important that finished product meet standard specification. Reduced testing is another important benefit derived directly from the integrity of forgings. The extreme strain rates generated during forging immediately identify the presence of defective raw material so that forgings are virtually "self-testing." Because of the part-to-part uniformity of forgings, manufacturers do not have to ascertain the quality of every incoming component before putting parts through further in-house processing. This benefit is especially important with outside purchased components that are subsequently machined. While forgings readily lend themselves to quality control sampling plans, many castings need to be 100% tested to ensure their integrity.

4.1.1. Defects in forged parts

Defects commonly found in forged parts that have been subjected to plastic deformation are as follows.

i. Defects resulting from the melting practice such as dirt, slag and blow holes.

ii. Ingot defects such as pikes, cracks scabs, poor surface and segregation.
iii. Defect due to faulty forging design.
iv. Defects resulting from improper heating and cooling of the forging part such as burnt metal and decarburized steel.

Forging is an experience oriented process. Throughout the years, a great deal of know-how and experience has been accumulated in this field, largely by trial-and-error methods. Forging process produces final products in very short time with little or no scrap. Thus there is saving in energy and material. Forgings sometimes cost more than parts produced by other processes like- casting or machining, but it gives more reliable parts with better mechanical and metallurgical properties. Since defects causes high rejection rates, it is important to move any process in the direction of eliminating all imperfections as part of an effective continuous improvement program. A good quality program begins with an attitude of making it right the first time. Forging processes are no exception to this. Economically, as well as from a quality perspective, it is better to understand and control the process so as to avoid defects rather than scrapping the defective parts during final inspection.

4.1.2. 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.

i. 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.

ii. 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.

iii. 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.

iv. 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.

4.2. Minimizing oxidation

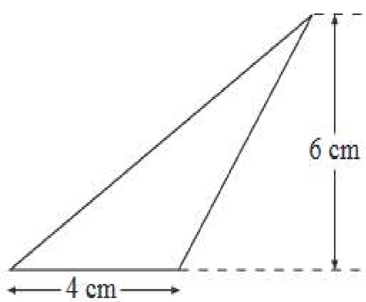
Depending on the carbon concentration in the steel, this alloying element has an influence on the formation of the scale layers and their structures. A defined time–temperature regime was investigated. To protect the scale layer from external influences and damage, all samples were covered with epoxy resin at room temperature. Light micrography 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. 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. In addition, it was determined that the oxidation rate decreased with increasing carbon content.

4.3. Calculating and measuring form and shape

Area, perimeter, and circumference are all measures of two-dimensional shapes. These are things you can think football field, a piece of paper, or a pizza.

- **Perimeter** or **Circumference:** this is the total length of a shape's outline.
- **Area:** this is the total amount of space inside a shape's outline.

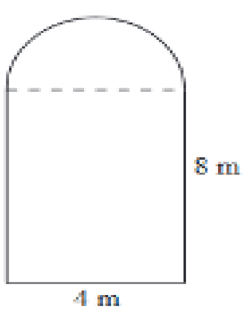
Example 1 Calculate the area of the triangle shown.



Solution Area = ½ *4* 6 = 12 cm^2

Example 2

Calculate the area of the shape shown:



Solution

Area of rectangle = $4 \times 8 = 32\ m^2$

Radius of semicircle = $4 \div 2 = 2m$

Area of semicircle = $½ *\pi*2^2$= 6.283185307 m^2

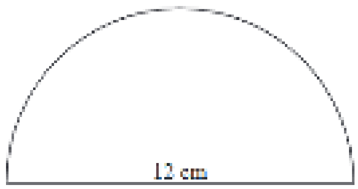
Total area = 32. m^2 + 6 .283185307 m^2

= 38 .283185307m^2

= 38.3 m^2 (to 3 significant figures)

Example 3.The diagram shows a semicircle of diameter 12 cm.

Calculate the perimeter of the semicircle.



Solution

Length of curve = $(\pi \times 12) \div 2$

= 18.84955592 cm

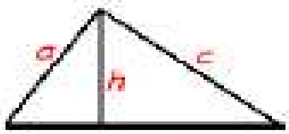
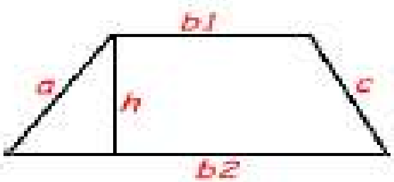
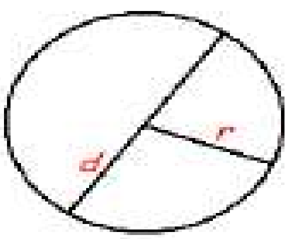
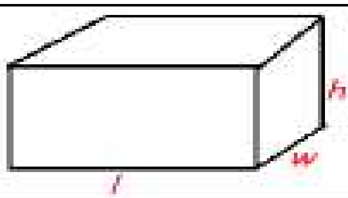
Straight edge = 12 cm

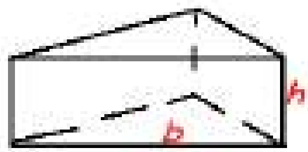
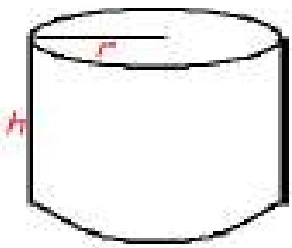
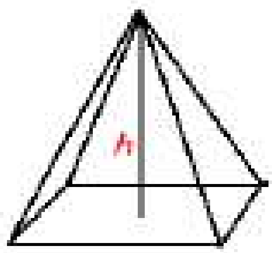
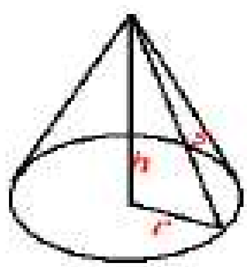
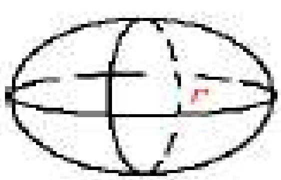
Total perimeter = 12 +18 84955592

= 30.84955592 cm

= 30.8 cm (to 3 significant figures.)

Table 1 Formulas for measuring perimeter, Area, Surface and Volume

Shapes	Formulas
	**Rectangle** **Area** = Length X Width $A = lw$ **Perimeter** = 2 X Lengths + 2 X Widths $P = 2l + 2w$
	**Parallelogram** **Area** = Base X Height $A = bh$ **Perimeter** = add the length of all sides $P = 2a + 2b$
	**Triangle** **Area** = 1/2 of the base X the height $A = \frac{1}{2} bh$ **Perimeter** = $a + b + c$ (add the length of the three sides)
	**Trapezoid** **Area** = 1/2 of the base X the height $A = (\frac{b1+b2}{2})h$ **Perimeter** = add lengths of all sides $P = a + b1 + b2 + c$
	**Circle** **Radius** = the distance from the center to a point on the circle (r). **Diameter** = the distance between two points on the circle through the center ($d = 2r$). **Circumference** = the distance around the circle ($C = \pi d = 2\pi r$). (Assume $\pi \approx 3.14$) **Area** = πr^2
	**Rectangular Solid** **Volume** = Length X Width X Height $V = lwh$ **Surface** = $2lw + 2lh + 2wh$

	**Prisms** **Volume** = Base X Height $V = bh$ **Surface** = $2b + Ph$ *(b is the area of the base P is the perimeter of the base)*
	**Cylinder** **Volume** = πr^2 X height $V = \pi r^2 h$ **Surface** = 2π radius X height $S = 2\pi rh + 2\pi r^2$
	**Pyramid** **Volume** = 1/3 area of the base X height $V = \frac{1}{3} bh$ b is the area of the base **Surface Area:** Add the area of the base to the sum of the areas of all of the triangular faces. The areas of the triangular faces will have different formulas for different shaped bases.
	**Cones** **Volume** = 1/3 area of the base x height $V = \frac{1}{3} \pi r^2 h$ **Surface** $S = \pi r^2 + \pi rs$ $= \pi r^2 + \pi r\sqrt{r^2 + h^2}$
	**Sphere** **Volume** $V = \frac{4}{3} \pi r^3$ **Surface** $S = 4\pi r^2$

Self check-4

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 extreme strain rates generated during forging immediately identify the presence of defective raw material.

________2. Heat treatment is carried out for releasing the internal stresses arising in the metal during forging

________3. Annealing is the opposite of hardening.

________4. The harder the steel, the more brittle it becomes.

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

"A"	"B"
_____1. Used to make metal more ductile	A. Hardening
_____2. Used to remove the internal stresses	B. Temering
_____3. Cooling steel rapidly by plunging it into oil, water, or brine.	C. Annealing
_____4. Used to reduce brittleness	D. Normalizing

Directions: Short Answer Questions

1. Describe common defects found in forged parts.
2. What type of heat treatment process is utilized to reduce extreme hardness and brittleness of forged steel?
3. State how oxidation is minimized in hand forging operations.

Operation sheet-1

- **Operation title:** Performing annealing heat treatment.
- **Purpose:** To increase the ductility of a carbon steel.

Instruction: In order to anneal steel, you're going to need a way of heating up the metal until it's bright red, hold it at that temperature for a while, and then very slowly allow it to cool. There are two main approaches to this: using a torch, forging furnace, or other non-regulated source of heat, or using a programmable heat treating oven.

Tools and requirement:

- Heat treatment furnace
- Temperature measuring apparatus (an optical pyrometer)
- Proper grips and fixtures to hold your sample
- PPEs

Steps in doing the task:

- To anneal steel, heat it up about 100 degrees F above its critical temperature.
- Soak it at that temp for 1 hour per inch of thickness.
- Let it cool at a maximum rate of 70 F per hour.

Quality Criteria: The person should familiarize himself with the heat treatment furnace, appropriate heating temmperature and the data gathering techniques.

Precautions: The person has to use PPEs and follow the operation carefully

Lap Test-1

- Task-1: Following the appropriate procedures carry out hardening heat treatment on a sample of carbon steel.
- Task-2: Following the appropriate procedures carry out tempering heat treatment and on a sample of carbon steel.