Mechanics Level I

Based on March, 2022, Curriculum Version 1

Module Title: - Identifying Properties of Metals

Module code: IND MCS1 M03 0322

TTLM Code: IND MCS1 TTLM 0822-V1

Nominal duration: 40Hour

Prepared by: Ministry of Labor and Skill

August, 2022

Addis Ababa, Ethiopia

Table of Contents

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

NDT- Non-Destructive Testing

OHS- Occupational Health and Safety

LAP-Learning Activity Performance

RPE-Respiratory Protective Equipment

HSS -High Speed Steels

Introduction to the Module

The knowledge of metals and their properties is of great significance for a design engineer. The machine elements should be made of such metals which have properties suitable for the condition of operation. In addition to this, a design engineer must be familiar with the effects which the manufacturing processes and heat treatment have on the properties of the metals.

The important properties of an engineering material determine the utility of the material which influences quantitatively or qualitatively the response of a given material to imposed stimuli and constraints.

This module covers the units:

- Ferrous and non-ferrous metals
- Management of OHS in the workplace
- Basic properties and processes in manufacturing
- Common metal tests
- Heat treatment of metals
- Quality and documentation of metal tests

Learning Objective of the Module

- Distinguish between ferrous and non-ferrous metals
- State OHS required in the work place
- Define common metal properties and processes
- Identify common metal tests its quality and documentation
- Describe common heat treatment methods.

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

Unit 1: Ferrous and non-ferrous metals

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

- Introduction
- Classification of Metals
- Metal properties

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:

- Identify ferrous, non-ferrous and their alloys
- Describe the different types of metal properties

1.1. Introduction

Common engineering materials are normally classified as metals and non-metals. Metals and non-metals differ in their properties. The choice of materials for a given job depends very much on its properties, cost, availability and such other factors. Metals may conveniently be divided into ferrous and non-ferrous metals.

1.2. Classification of Metals

1.2.1. Ferrous metals and their alloys

Ferrous metals may be defined as those metals whose main constituent is iron such as pig iron, wrought iron, cast iron, steel and their alloys. They are usually stronger and harder and are used in daily life products. They possess a special property that their characteristics can be altered by heat treatment processes or by addition of small quantity of alloying elements. Ferrous metals possess different physical properties according to their carbon content.

The most Ferrous metals are:

i. Cast iron

It is primarily an alloy of iron and carbon. The carbon content in cast iron varies from 1.5 to 4 per cent. Small amounts of silicon, manganese, sulphur and phosphorus are also present in it. Carbon in cast iron is present either in Free State like graphite or in combined state as cementite. Cast iron contains so much carbon or its equivalent that it is not malleable. One characteristic (except white cast iron) is that much of carbon content is present in free form as graphite. Largely the properties of cast iron are determined by this fact. Melting point of cast iron is much lower than that of steel. The characteristics of cast iron which make it a valuable material for engineering applications are:

(1) Very good casting characteristics.
(2) Low cost
(3) High compressive strength
(4) Good wear resistance
(5) Excellent machinability

The main limitation of this metal is brittleness and low tensile strength and thus cannot be used in those components subjected to shocks.

The varieties of cast iron in common uses are:

(1) Grey cast iron

(2) White cast iron

(3) Malleable cast iron

(4) Nodular cast iron

(5) Chilled cast iron

(6) Alloy cast iron

1. Grey Cast Iron

It is the iron which is most commonly used in foundry work. If this iron is machined or broken, its fractured section shows the greyish colour, hence the name "grey" cast iron. The grey colour is due to the fact that carbon is present in the form of free graphite. A very good characteristic of grey cast iron is that the free graphite in its structure acts as a lubricant. This is suitable for those components/products where sliding action is desired. The other properties are good machinability, high compressive strength, low tensile strength and no ductility. In view of its low cost, it is preferred in all fields where ductility and high strength are not required. The grey cast iron castings are widely utilized in machine tool bodies, automobile cylinder blocks and flywheels, etc.

2. White Cast Iron

It is so called due to the whitish colour shown by its fracture. White cast iron contains carbon exclusively in the form of iron carbide Fe_3C (cementite). From engineering point of view, white cast iron has limited applications. This is because of poor machinability and possessing, in general, relatively poor mechanical properties. It is used for inferior castings and places where hard coating is required as in outer surface of car wheels. Only crushing rolls are made of white cast iron. But it is used as raw material for production of malleable cast iron.

3. Malleable Cast Iron

Malleable cast iron is produced from white cast iron. The white cast iron is brittle and hard. It is, therefore, unsuitable for articles which are thin, light and subjected to shock and vibrations or for small castings used in various machine components. The malleable cast iron is produced from white cast iron by suitable heat treatment, i.e., annealing. This process separates the combined carbon of the white cast iron into noddles of free graphite. The malleable cast iron is ductile and may be bent without rupture or breaking the section. Its tensile strength is usually higher than that of grey cast iron and has excellent machining qualities. Malleable cast iron components are mainly utilized in place of forged steel or parts where intricate shape of these parts creates forging problem. This material is principally employed in rail, road automotive and pipe fittings, etc.

4. Nodular Cast Iron

It is also known as "spheroidal graphite iron" or ductile iron or "High strength Cast iron". This nodular cast iron is obtained by adding magnesium to the molten cast iron.

The magnesium converts the graphite of cast iron from flake to spheroidal or nodular form. In this manner, the mechanical properties are considerably improved. The strength increases, yield point improves and brittleness is reduced. Such castings can even replace steel components. Outstanding characteristics of nodular cast iron are high fluidity which allows the castings of intricate shape. This cast iron is widely used in castings where density as well as pressure tightness is a highly desirable quality. The applications include hydraulic cylinders, valves, pipes and pipe fittings, cylinder head for compressors, diesel engines, etc.

5. Chilled Cast Iron

Quick cooling is generally known as chilling and the iron so produced is “chilled iron”. The outer surface of all castings always gets chilled to a limited depth about (1 to 2 mm) during pouring and solidification of molten metal after coming in contact with cool sand of mould. Sometimes the casting is chilled intentionally and some becomes chilled accidentally to a small depth.

Chills are employed on any faces of castings which are required to be hard to withstand wear and friction. Chilled castings are used in producing stamping dies and crushing rolls railway, wheels cam followers, and so on.

6. Alloy cast iron

The cast irons as discussed above contain small percentages of other constituents like silicon, manganese, sulphur and phosphorus. These cast irons may be called as plain cast irons. The alloy cast iron is produced by adding alloying elements like nickel, chromium, molybdenum, copper and manganese in sufficient quantities in the molten metal collected in ladles from cupola furnace. These alloying elements give more strength and result in improvement of properties. The alloy cast iron has special properties like increased strength, high wear resistance, corrosion resistance or heat resistance. The alloy cast irons are extensively used for automobile parts like cylinders, pistons, piston rings, crank cases, brake drums, parts of .crushing and grinding machinery etc.

ii. Wrought iron

The meaning of "wrought" is that metal which possesses sufficient ductility in order to permit hot and/or cold deformation. Wrought iron is the purest iron with a small amount of slag forged out into fibres. The typical composition indicates 99 per cent of iron and traces of carbon, phosphorus, manganese, silicon, sulphur and slag.

iii. Steels

Steel is an alloy of iron and carbon with carbon content maximum up to 1.7%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel. Other elements e.g. silicon, sulphur, phosphorus and manganese are also present to greater or lesser amount to import certain desired properties to it. Most of the steel produced now-a-days is plain carbon steel.

A. Plain carbon steel

Plain carbon steel is an alloy of iron and carbon. It has good machineability and malleability. It is different from cast iron as regards the percentage of carbon. It contains carbon from 0.06 to 1.5% whereas cast iron possesses carbon from 1.8 to 4.2%. Depending upon the carbon content, a plain carbon steels can divided to the following types:

1. Dead carbon steel — up to 0.15% carbon
2. Low carbon or mild steel — 0.15% to 0.45% carbon
3. Medium carbon steel — 0.45% to 0.8% carbon
4. High carbon steel — 0.8% to 1.5% carbon

1. Dead carbon steel

It possesses very low percentage of carbon varying from 0.05 to 0.15%. It has a tensile strength of 390 N/mm2 and a hardness of about 115 BHN. Steel wire, sheets, rivets, screws, pipe, nail and chain are made from this steel.

2. Low carbon or mild steel

Low carbon steel is sometimes known as mild steel also. It contains 0.20 to 0.30% C which has tensile strength of 555 N/mm2 and hardness of 140 BHN. It possesses bright fibrous structure. It is tough, malleable, ductile and more elastic than wrought iron. It can be easily forged and welded. It can absorb shocks. It rusts easily. Its melting point is about 1410°C. It is used for making angle, channels, case hardening steel, rods, tubes, valves, gears, crankshafts, connecting rods, railway axles, fish plates, small forgings, free cutting steel shaft and forged components etc.

3. Medium carbon steels

Medium carbon steel contains carbon from 0.30 to 0.8%. It possesses having bright fibrous structure when fractured. It is tough and more elastic in comparison to wrought iron. It can be easily forged, welded, elongated due to ductility and beaten into sheets due to its good malleability. It can easily absorb sudden shocks. It is hardenable by treatment. It rusts readily. Its melting point is 1400°C. It can be easily hardened and it possesses good balance of strength and ductility.

It is generally used for making railway coach axles, bolts, connecting rods, key stock, wires and rods, shift and break levers, spring clips, gear shafts, small and medium forgings, railway coach axles, crank pins on heavy machines, spline shafts, crankshafts, forging dies, set screws, die blocks, self tapping screws, clutch discs, valve springs, plate punches, thrust washers etc.

4. High carbon steels

High carbon steels (HCS) contain carbon from 0.8 to 1.5%. Because of their high hardness, these are suitable for wear resistant parts. Spring steel is also high carbon steel. It is available in annealed and pre-tempered strips and wires. High carbon steel loses their hardness at temperature from 200°C to 250°C. They may only be used in the manufacture of cutting tools operating at low cutting speeds. These steels are easy to forge and simple to harden.

B. Alloy steel

For improving the properties of ordinary steel, certain alloying elements are added in it in sufficient amounts. The most common alloying elements added to steel are chromium, nickel, manganese, silicon, vanadium, molybdenum, tungsten, phosphorus, copper, titanium, zirconium, cobalt, columbium, and aluminium. Each of these elements induces certain qualities in steels to which it is added. They may be used separately or in combination to produce desired characteristics in the steel. The main purpose of alloying element in steel is to improve machinability, elasticity, hardness, case hardening, cutting ability, toughness, wear resistance, tensile strength, corrosion resistance, and ability to retain shape at high temperature, ability to resist distortion at elevated temperature and to impart a fine grain size to steel.

C. Free cutting steel

The important features of free cutting steels are their high machinability and high quality surface finish after finishing. These properties are due to higher sulphur and phosphorus. Sulphur exists in the form of manganese sulphide (MnS) which forms inclusions in steel. These inclusions promote the formation of discontinuous chips and also reduce friction on the surface being machined so produces good surface finish easily.

D. Nickel steel

The percentage of Nickel varies from 2 to 45 in steel. Steel having 2% Ni makes steel more suitable for rivets, boiler plates, bolts and gears etc. Steel having Ni from 0.3 to 5% raises elastic limit and improves toughness. Steel containing Nickel has very high tensile strength. Steel having 25% Ni makes it stainless and might be used for I.C. engine turbine blade etc. If Ni is present up to 27%, it makes the steel non-magnetic and non-corrodible.

Invar (Ni 36%) and super-invar (Ni 31%) are the popular materials for least coefficient of expansion and are used for measuring instruments, surveyor tapes and clock pendulums. Steel having 45% Ni steel possesses extension equal to that of glass, a property very import making links between the two materials i.e. in electronic valves and bulbs.

E. Vanadium steel

Vanadium when added even in small proportion to an ordinary low carbon increases significantly its elastic limit and fatigue resistance property. Vanadium makes steel strong and tough. When vanadium is added up to 0.25%, the elastic limit of the steel is raised by 50% can resist high alternating stresses and severe shocks.

F. Manganese steel

Manganese when added in steel between 1.0 to 1.5% makes it stronger and tougher. Manganese between 1.5 to 5% in steel makes it harder and more brittle. 11 to 14% manganese in steel with carbon 0.8 to 1.5% makes it very hard, tough, non-magnetic and possesses considerably high tensile strength. Manganese steel may be forged easily but it is difficult to machine and hence it is usually ground. It is weldable and for welding it, a nickel manganese welding rod is used.

G. Tungsten Steel

Tungsten when added to steel improves its magnetic properties and hardenability. When tungsten is added to an extent of 6% to high carbon steel, it retains the magnetic properties to high degree and produce field more intense than ordinary steel. Steel having 8% tungsten gives sufficient hardness to it to scratch even glass. It is used for making permanent magnets and high speed cutting tools.

H. Silicon steel

Silicon addition improves the electrical properties of steel. It also increases fatigue strength and ductility.

I. Magnetic steels

Steels having 15 to 40% Co, 0.4 to 1 % C, 1.5 to 9% Cr, 0-10% W and remaining Fe possesses very good magnetic properties. High Cobalt steels, when correctly heat treated, are frequently used in the making of permanent magnets for magnetos, loud speakers and other electrical machines. An important permanent magnet alloy called Alnico contains approximately 60% Iron, 20% Nickel, 8% Cobalt and 12% Aluminum. This alloy cannot be forged and is used as a casting hardened by precipitation heat treatment.

J. Spring steels

Spring steels are used for the making springs. Various types of these steel along with their composition and uses are discussed as under.

***(i) Carbon-manganese spring steels*:** This type of steel contains C = 0.45 to 0.6, Si = 0.1 to 0.35% and Mn = 0.5 to 1.0%.. They are widely used for laminated springs for railway and general purposes.

(ii) Hyper-eutectoid spring steels: This type of steel contains C = 0.9 to 1.2%, 0.3% (max) and Mn = 0.45 to 0.70%.. This type of steel is used for volute and helical springs.

(iii) Silicon-manganese spring steels: This type of steel contains C = 0.3 to 0.62%, Si = 1.5 to 2% and Mn = 0.6 to 1 %. This type of steel is used for the manufacturing of railway and road springs generally.

K. Stainless steel

Stainless steel contains chromium together with nickel as alloy and rest is iron. It has been defined as that steel which when correctly heat treated and finished, resists oxidation and corrosive attack from most corrosive media. Stainless steel surface is responsible for corrosion resistance. Minimum chromium content of 12% is required for the film's formation, and 18% is sufficient to resist the most severe atmospheric corrosive conditions. Their principal alloying element is chromium while some other elements like nickel, manganese etc. can also be present in small amounts. Addition of nickel improves ductility and imparts strength.

A steel containing 18% chromium and 8% nickel is widely used and is commonly referred to as 18/8 steel. Stainless steel is highly resistance to corrosion and oxidation.

L. High speed steels

High Speed Steels (HSS) have been given this name due to the fact that these steels may be operated as cutting tools at much higher speeds that are possible with plain carbon tool steel. High speed steels cutting tools operate at cutting speed 2 to 3 times higher than for High carbon steels. At higher cutting speeds, sufficient heat may be developed during the cutting process. This heat causes the cutting edge of the tool to reach a high heat (red heat). This heat softens the carbon tool steel and thus the tool will not work efficiently for a longer period. These steels have the property of retaining their hardness even when heated to red heat. High hardness at elevated temperatures is developed by addition of elements such as tungsten, chromium vanadium to high carbon steels. These steel are generally used for making lathe cutting tools, planner cutting tools, shaper cutting tools, slotting cutting tools, drills, reamers, broaches, milling cutter and punches

1.2.2. Non-ferrous metals and their alloys

Non-ferrous metals are those which do not contain significant quantity of iron or iron as base metal. These metals possess low strength at high temperatures, generally suffer from hot shortness and have more shrinkage than ferrous metals. They are utilized in industry due to following advantages:

1. High corrosion resistance
2. Easy to fabricate, i.e., machining, casting, welding, forging and rolling
3. Possess very good thermal and electrical conductivity
4. Attractive colour and low density

The various non-metals used in industry are: copper, aluminum, tin, lead, zinc, and nickel, etc., and their alloys.

1. Copper

Copper is one of the most widely used non-ferrous metals in industry. It is extracted from ores of copper such as copper glance, copper pyrites, malachite and azurite. Copper is a corrosion resistant metal of an attractive reddish brown colour.

Common Properties of copper are**:**

(1) High Thermal Conductivity**:** Used in heat exchangers, heating vessels and appliances, etc.

(2) High Electrical Conductivity**:** Used as electrical conductor in various shapes and forms for various applications.

(3) Good Corrosion Resistance**:** Used for providing coating on steel prior to nickel and chromium plating

(4) High Ductility**:** Can be easily cold worked, folded and spun. Requires annealing after cold working as it loses its ductility.

The following two important copper alloys are widely used in practice:

1. **Brass (Cu-Zn alloy)-** It is fundamentally a binary alloy with Zn upto 50% . As Zn percentage increases, ductility increases upto ~37% of Zn beyond which the ductility falls. Small amount of other elements viz. lead or tin imparts other properties to brass. Lead gives good machining quality and tin imparts strength. Brass is highly corrosion resistant, easily machinable and therefore a good bearing material.

2. **Bronze (Cu-Sn alloy)-**This is mainly a copper-tin alloy where tin percentage may vary between 5 to 25. It provides hardness but tin content also oxidizes resulting in brittleness. Deoxidizers such as Zn may be added. *Gun metal* is one such alloy where 2% Zn is added as deoxidizing agent and typical compositions are 88% Cu, 10% Sn, 2% Zn. This is suitable for working in cold state. It was originally made for casting guns but used now for boiler fittings, bushes, glands and other such uses.

2. Aluminum

Aluminium is a white metal which is produced by electrical processes from clayey mineral known as bauxite. In its pure state, it is weak and soft but addition of small amounts of Cu, Mn, Si and Mg makes it hard and strong. It is also corrosion resistant, low weight and non-toxic.

Common Properties of Aluminum are**:**

(1) Like copper it is also corrosion resistant.

(2) It is very good conductor of heat and electricity although not as good as copper.

(3) Possesses high ductility and light weight so widely utilized in aircraft industry.

(4) Needs frequent annealing if cold worked since it becomes hard after cold working.

(5) In view of its ductility and malleability it has replaced copper in electrical transmission and appliances to some extent.

(6) It is used in manufacturing of household utensils including pressure cookers.

The following important Aluminum alloys are widely used in practice:

1. ***Duralumin***- This is an alloy of 4% Cu, 0.5% Mn, 0.5% Mg and aluminium. It is widely used in automobile and aircraft components.
2. ***Y-alloy-*** This is an alloy of 4% Cu, 1.5% Mn, 2% Ni, 6% Si, Mg, Fe and the rest is Al. It gives large strength at high temperature. It is used for aircraft engine parts such as cylinder heads, piston etc.
3. ***Magnalium***- This is an aluminium alloy with 2 to 10 % magnesium. It also contains 1.75% Cu. Due to its light weight and good strength it is used for aircraft and automobile components.

3. Nickel

Nickel is a silvery shining white metal having extremely good response to polish. The most important nickel's ore is iron sulphides which contain about 3% of nickel. About 90% of the total production of nickel is obtained by this source. Nickel is as hard as steel. It possesses good heat resistance. It is tough and having good corrosion resistance. Its melting point is 1452°C and specific gravity is 0.85. At normal temperature, nickel is paramagnetic. When it contains small amount of carbon, it is quite malleable. It is somewhat less ductile than soft steel, but small amount of magnesium improves ductility considerably.

The important nickel alloys are haste alloy, Monel metal, inconel, nomonic and ni-chrome.

i. Haste Alloy or high Temperature Alloy

Haste alloy or high temperature alloy is mainly a nickel base alloy. It contains Ni = 45%, Cr = 22%, Mo = 9%, Co = 1.5%, W = 0.5%, C = 0.15% and Fe = Remaining. The high temperature alloys are those alloys which can withstand high temperatures about 1100°C. These alloys are used in components of nuclear plants, jet and rocket engines etc.

ii. Monel Metal

Monel metal is an important alloy of nickel and copper. It contains 68% Ni, 30% Cu, 1% Fe and small amount of other constituents like manganese, silicon and carbon.

Monel metal is also used for pump fittings, condenser tubes, sea water exposed parts etc. It is widely used for making turbine blades, containers, parts for chemical plants, food handling machinery parts, marine parts, pump impellers, propellers, evaporators and heat exchangers in chemical works.

iii. Inconel

Inconel contains Ni = 80% Cr = 14% Fe = 6% Inconel is used for making springs, exhaust manifold of aircraft engines, machinery for food processing industries, especially milk and milk products. It is widely used for processing uranium and for sheathing for high temperature heating elements.

iv. Nomonic alloy

The composition of nomonic alloy is given as under. Cr = 15 to 18%, Co = 15 to 18%, Ti = 1.2 to 4.0%, Al = 1.5%, Ni = Remaining. Nomonic is widely used for making gas turbine engines

v. Ni-Chrome

Ni-chrome contains Ni = 60%, Cr = 15%, Fe = 20%. Ni-chrome is non-corrosive. It can easily withstand high temperatures without oxidation. Ni-chrome is commonly used for making electrical resistance wire for electric furnaces and heating elements.

4. Lead

Lead is a bluish grey metal with a high metallic lusture when freshly cut. It is the softest and heaviest of all the common metals. It is very malleable and may be readily formed into foil. It can readily be scratched with fingernail when pure. Lead has properties of high density and easy workability. It has very good resistance to corrosion and many acids have no chemical action on it. Its melting point is 327°C and specific gravity is 11.35. Lead and its alloys as engineering material have limited but important uses. Lead alloys are used for soldering (Pb–Sn, Pb–Sn–Sb) and bearings (Pb–Sn–Sb, Cu–Pb, Cu–Sn–Pb).

Lead is used in safety plug in boilers, fire door releases and fuses. It is also used in various alloys such as brass and bronze. It finds extensive applications as sheaths for electric cables, both overhead and underground. Its sheets are used for making roofs, gutters etc. It is employed for chemical laboratory and plant drains. In the soldering process, an alloy of lead and tin is most widely utilized as a solder material for joining metals in joining processes

5. ZINC

Zinc is bluish grey in color and is obtained from common ores of zinc are zinc blende (ZnS), zincite (ZnO), calamine (ZnCO3). The oxide is heated in an electric furnace where the zinc is liberated as vapor. The vapors are then cooled in condensers to get metallic zinc. Zinc possesses specific gravity is 6.2 and low melting point of 480°C. Its tensile strength is 19 to 25 MPa. It becomes brittle at 200°C and can be powdered at this temperature. It possesses high resistance to corrosion. It can be readily worked and rolled into thin sheets or drawn into wires by heating it to 100-150°C.

With regards to industrial applications, zinc is the fourth most utilized metal after iron, aluminium, and copper. Zinc is commonly used as a protective coating on iron and steel in the form of a galvanized or sprayed surface. It is used for generating electric cells and making brass and other alloys. The oxide of zinc is used as pigment in paints. Parts manufactured by zinc alloys include carburetors, fuel pumps, automobile parts, and so on.

6. TIN

Tin is recognized as brightly shining white metal. Tin is considered as a soft and ductile material. It possesses very good malleability. Its melting point is 232°C and specific gravity is 7.3. It is malleable and hence can be hammered into thin foils. It does not corrode in wet and dry conditions.

Therefore, it is commonly used as a protective coating material for iron and steel. The main source of tin is tinstone. To obtain crude tin, the ores of tins are crushed, calcined, washed and then smelted in a furnace using anthracite coal and sand.

Tin-base white metals are commonly used to make bearings that are subjected to high pressure and load. Tin is used as coating on other metals and alloys owing to its resistance to corrosion. It is employed in low melting point alloys as a substitute for Bismuth. It is generally preferred as moisture proof packing material. Because of its high malleability, it finds application in tin cans for storing food and food items.

7. Titanium and Titanium Alloys

In process industry unalloyed titanium is commonly used. Titanium is selected for its excellent corrosion resistance properties in large varieties of environments, especially in applications where high strength is not required. However, because of high cost its use is limited to exchanger tubes using sea water as coolant and for some specific corrosive chemicals. Titanium is light compared to iron (about 50%) and therefore it has the advantages of having lower weight to strength ratio. Ti6 Al–4V alloy is widely used titanium alloy where strength and toughness are required.

1.1. Metal properties

The various engineering metals properties are given as under.

1. Physical properties
2. Chemical properties
3. Thermal properties
4. Electrical properties
5. Magnetic properties
6. Optical properties, and
7. Mechanical properties

1 Physical Properties

The important physical properties of the metals are density, color, size and shape (dimensions), specific gravity, porosity, luster etc. Some of them are defined as under.

i. Density

Mass per unit volume is called as density. In metric system its unit is kg/mm3. Because of very low density, aluminum and magnesium are preferred in aeronautic and transportation applications.

ii. Color

It deals the quality of light reflected from the surface of metal.

iii. Size and shape

Dimensions of any metal reflect the size and shape of the material. Length, width, height, depth, curvature diameter etc. determines the size. Shape specifies the rectangular, square, circular or any other section.

iv. Specific Gravity

Specific gravity of any metal is the ratio of the mass of a given volume of the metal to the mass of the same volume of water at a specified temperature.

v. Porosity

A material is called as porous or permeable if it has pores within it.

2. Chemical Properties

The study of chemical properties of materials is necessary because most of the engineering materials, when they come in contact with other substances with which they can react, suffer from chemical deterioration of the surface of the metal. Some of the chemical properties of the metals are corrosion resistance, chemical composition and acidity or alkalinity. Corrosion is the gradual deterioration of material by chemical reaction with its environment.

3. Thermal Properties

The study of thermal properties is essential in order to know the response of metal to thermal changes i.e. lowering or raising of temperature. Different thermal properties are thermal conductivity, thermal expansion, specific heat, melting point, thermal diffusivity. Melting point is the temperature at which a pure metal or compound changes its shape from solid to liquid. It is called as the temperature at which the liquid and solid are in equilibrium. It can also be said as the transition point between solid and liquid phases. Melting temperature depends on the nature of inter-atomic and intermolecular bonds. Therefore higher melting point is exhibited by those materials possessing stronger bonds. Covalent, ionic, metallic and molecular types of solids have decreasing order of bonding strength and melting point. Melting point of mild steel is 1500°C, of copper is 1080°C and of Aluminum is 650°C.

4. Electrical Properties

The various electrical properties of materials are conductivity, temperature coefficient of resistance, dielectric strength, and resistivity. These properties are defined as under.

i. Conductivity

Conductivity is defined as the ability of the material to pass electric current through it easily i.e. the material which is conductive will provide an easy path for the flow of electricity through it.

ii. Temperature Coefficient of Resistance

It is generally termed as to specify the variation of resistivity with temperature.

iii. Dielectric Strength

It means insulating capacity of material at high voltage. A material having high dielectric strength can withstand for longer time for high voltage across it before it conducts the current through it.

iv. Resistivity

It is the property of a material by which it resists the flow of electricity through it.

5. Magnetic Properties

Magnetic properties of materials arise from the spin of the electrons and the orbital motion of electrons around the atomic nuclei. In certain atoms, the opposite spins neutralize one another, but when there is an excess of electrons spinning in one direction, magnetic field is produced. Many materials except ferromagnetic material, which can form permanent magnet, exhibit magnetic effects only when subjected to an external electro-magnetic field. Magnetic properties of materials specify many aspects of the structure and behaviour of the matter.

Various magnetic properties of the materials are magnetic hysteresis, coercive force and absolute permeability which are defined as under.

i. Magnetic Hysteresis is defined as the lagging of magnetization or induction flux density behind the magnetizing force or it is that quality of a magnetic substance due to energy is dissipated in it on reversal of its magnetism. Below Curie temperature, magnetic hysteresis is the rising temperature at which the given material ceases to be ferromagnetic, or the falling temperature at which it becomes magnetic. Almost all magnetic materials exhibit the phenomenon called hysteresis.

ii. *Coercive Force* is defined as the magnetizing force which is essential to neutralize completely the magnetism in an electromagnet after the value of magnetizing force becomes zero.

iii. Absolute Permeability is defined as the ratio of the flux density in a material to the magnetizing force producing that flux density. Paramagnetic materials possess permeability greater than one whereas di-magnetic materials have permeability less than one.

6. Optical Properties

The main optical properties of engineering materials are refractive index, absorptivity, absorption co-efficient, reflectivity and transmissivity. Refractive index is an important optical property of metal which is defined as under.

Refractive Index

It is defined as the ratio of velocity of light in vacuum to the velocity of a material. It can also be termed as the ratio of sine of angle of incidence to the sine of refraction.

7. Mechanical Properties

(i) Strength: The strength of a material is the property of resistance to external loads or stresses while not causing structural damage. The strongest substance known is tungsten molybdenum; titanium and nickel follow in order of strength of commercially pure metals. Pure iron is much weaker, but, when alloyed with the chemical element known as “carbon" to make steel, it may then become stronger than any of the pure metals except tungsten.

(a) Tensile Strength: Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line. Pure molybdenum has a high tensile strength and is very resistant to heat. It is used principally as an alloying agent in steel to increase strength, hardenability, and resistance to heat.

(b) Shear Strength: Shear strength is the ability of a material to resist being fractured by opposing forces acting in a straight line but not in the same plane.

(c) Compressive Strength: Compressive strength is the ability of a material to withstand pressures acting on a given plane.

(ii) Elasticity: Elasticity is the ability of material to return to its original size, shape, and dimensions after being deformed. Elastically stressed materials return to their original dimensions when the load is released, provided that the load is not too great. Distortion or deformation is in proportion to the amount of the load, up to a certain point. If the load is too great, the material is permanently deformed, and, when the load is further increased, the material will break.

(iii) Ductility: Ductility is the capacity of a material, such as copper, to be drawn or stretched under tension loading and permanently deformed without rupture or fracture. Specifically, the term denotes the capacity to be drawn from a larger to a smaller diameter of wire. This operation involves both elongation and reduction of area.

(iv) Malleability: Malleability is the property of a metal to be deformed or compressed permanently without rupture or fracture. Specifically, it means the capacity to be rolled or hammered into thin sheets. The property of malleability is similar to but not the same as that of ductility, and different metals do not possess the two properties in the same degree. Lead and tin are relatively high in order of malleability; however, they lack the necessary tensile strength to be drawn into fine wire. Most metals have increased malleability and ductility at higher temperatures. For example, iron and nickel are very malleable when heated bright red.

(v Plasticity: Plasticity is the ability of a metal, such as gold, silver, or lead, to be deformed extensively without rupture. This property, together with strength, is considered to be the two most important properties that a metal can possess.

(vi) Toughness: Toughness is a combination of high strength and medium ductility. Toughness is the ability of a material or metal to resist fracture, plus the ability to resist failure after the damage has begun. In short, a tough metal, such as a cold chisel, is one that can withstand considerable stress, slowly or suddenly applied, and that will deform before failure. Toughness has been defined by some metallurgists as having the property of absorbing considerable energy before fracture and, therefore, involves both ductility and strength.

(vii) Brittleness: The term "brittleness" implies sudden failure. It is the property of breaking without warning; that is, without visible permanent deformation. It is the reverse of toughness in the sense that a brittle piece of metal has little resistance to rupture after it reaches its elastic limit. Brittleness can also be said to be the opposite of ductility, in the sense that it involves rupture with very little deformation. In many cases, hard metals are brittle; however, the terms should not be confused or used synonymously.

(viii) Abrasion Resistance: Abrasion resistance is the resistance to wearing by friction.

(ix) Fatigue: When metal is subject to frequent repetitions of a stress, it will ultimately rupture and fail, even though the stress may not be sufficient to produce permanent deformation if continuously applied for a relatively brief time. Such a repetition of stress may occur, for example, in the shank of a rock drill. The definition of fatigue is the failure of metals and alloys that have been subjected to repeated or alternating stresses too small to produce a permanent deformation when applied statically.

(x) Machinability: Machinability is the ease or difficulty with which a material lends itself to being machined.

(xi) Hardness: Hardness is the ability of a material to resist penetration and wear by another material. It takes a combination of hardness and toughness to withstand heavy pounding. The hardness of a metal is directly related to its machinability, since toughness decreases as hardness increases. Steel can be hardened by heat treating it.

(xii) Castability

Castability is defined as the property of metal, which indicates the ease with it can be casted into different shapes and sizes. Cast iron, aluminium and brass are possessing good castability.

(xiii) Weldability

Weldability is defined as the property of a metal which indicates the two similar or dissimilar metals are joined by fusion with or without the application of pressure and with or without the use of filler metal (welding) efficiently. Metals having weldability in the descending order are iron, steel, cast steels and stainless steels.

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. Use the Answer sheet provided in the next page**

________1. Ferrous metals may be defined as those metals whose main constituent is iron.

________2. Cast iron is primarily an alloy of iron and carbon.

________3. Wrought iron is the purest iron which is tough, malleable and ductile.

________4. Tungsten steels are categorized as plain carbon steels.

________5. Non-ferrous metals possess high strength at high temperatures.

________6. An alloy of lead and tin is most widely utilized as a solder material for joining metals.

________7. Tin is commonly used as a protective coating material for iron and steel.

PART-II: Select the best answer from the given alternatives and write its letter on the space provided (1 pt each)

____1. The ability of a metal to resist being pulled apart by opposing forces acting in a straight line is

A. Shear strength C. shear stress
B. Tensile strength D. Compressive strength

____2. The ability of a material to resist penetration and wear by another material is named

A. Hardness C. Fatigue
B. Brittleness D. Toughness

_____3. The property of a metal which indicates the two similar or dissimilar metals are joined by fusion with or without the application of pressure and with or without the use of filler metal is

A. Castability C. Weldability
B. Machinability D. Formability

_____4. Which of the following is not nickel alloy?

A. Monel C. Nichrome
B. Inconel D. Duralumin

PART-III: Match the items listed under column "A" with those expressions listed under "B" (1 pt each)

"A"	"B"
___1. The property of breaking without warning	A. Elasticity
___2. A combination of high strength and medium ductility	B. Ductility
__3. The capacity to be rolled or hammered into thin sheets	C. Malleability
__4. The capacity to be drawn from a larger to a smaller diameter of wire	D. Toughness
__5. The ability of material to return to its original size, shape and dimension	E. Brittleness

Unit 2. Management of OHS in the workplace

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

- Personnel protective equipment (PPE)
- Preventative OHS procedures

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:

- Use Personnel protective equipment (PPE)
- Follow Preventative OHS procedures

2.1. Personal Protective Equipment (PPE)

Employers have duties concerning the provision and use of personal protective equipment (PPE) at work. PPE is equipment that will protect the user against health or safety risks at work. 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).

Making the workplace safe includes providing instructions, procedures, training and supervision to encourage people to work safely and responsibly. Even where engineering controls and safe systems of work have been applied, some hazards might remain.

These include injuries to:

- ✓ the lungs, e.g. from breathing in contaminated air
- ✓ the head and feet, e.g. from falling materials
- ✓ the eyes, e.g. from flying particles or splashes of corrosive liquids
- ✓ the skin, e.g. from contact with corrosive materials
- ✓ the body, e.g. from extremes of heat or cold

PPE is needed in these cases to reduce the risk.

2.1.1. Common Personal Protective Equipments

A. Aprons;
B. Gloves;
C. Protective equipment for adverse weather conditions;
D. Safety footwear;
E. Hard hats;
F. High visibility waistcoats;
G. Eye and face protection;
H. Laboratory coats;
I. Face masks; and
J. Ear defenders

2.1.2. Hazards and PPEs employed

a. Eyes Hazards

- Chemical or metal splash, dust, projectiles, gas and vapor, radiation.
- Safety spectacles, goggles, face screens, face shields, visors are used to protect them.
- Make sure the eye protection chosen has the right combination of impact/dust/splash/molten metal eye protection for the task and fits the user properly

b. Head and neck Hazards

- Impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery, chemical drips or splash, climate or temperature
- Industrial safety helmets, bump caps, hairnets and firefighters' helmets are used to protect them.

Some safety helmets incorporate or can be fitted with specially-designed eye or hearing protection

- Don't forget neck protection, e.g. scarves for use during welding
- Replace head protection if it is damaged

c. Ears Hazards

- Noise – a combination of sound level and duration of exposure, very high-level sounds are a hazard even with short duration.
- Earplugs, earmuffs, semi-insert/canal caps are used to protect them.
- Provide the right hearing protectors for the type of work, and make sure workers know how to fit them
- Choose protectors that reduce noise to an acceptable level, while allowing for safety and communication.

d. Hands and arms Hazards

- ✓ Abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, radiation, vibration, biological agents and prolonged immersion in water
- ✓ Gloves, gloves with a cuff, gauntlets and sleeping that covers part or all of the arm are used to protect them.
- ✓ Avoid gloves when operating machines such as bench drills where the gloves might get caught .
- ✓ Some materials are quickly penetrated by chemicals – take care in selection,
- ✓ Barrier creams are unreliable and are no substitute for proper PPE

- ✓ Wearing gloves for long periods can make the skin hot and sweaty, leading to skin problems. Using separate cotton inner gloves can help prevent this

e. Feet and legs Hazards

- Wet, hot and cold conditions, electrostatic build-up, slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash, vehicles.
- Safety boots and shoes with protective toecaps and penetration-resistant, mid-sole wellington boots and specific footwear, eg foundry boots and chainsaw boots are used to protect them.
- Footwear can have a variety of sole patterns and materials to help prevent slips in different conditions, including oil - or chemical-resistant soles. It can also be anti-static, electrically conductive or thermally insulating
- Appropriate footwear should be selected for the risks identified

f. Lungs Hazards

- Oxygen-deficient atmospheres, dusts, gases and vapours.
- Respiratory protective equipment (RPE) are used to protect them.
- Some respirators rely on filtering contaminants from workplace air. These include simple filtering face pieces and respirators and power-assisted respirators
- Make sure it fits properly, e.g. for tight-fitting respirators (filtering face pieces, half and full masks)
- There are also types of breathing apparatus which give an independent supply of breathable air, e.g. fresh-air hose, compressed airline and self-contained breathing apparatus

g. Whole body Hazards

- Heat, chemical or metal splash, spray from pressure leaks or spray guns, contaminated dust, impact or penetration, excessive wear or entanglement of own clothing
- Conventional or disposable overalls, boiler suits, aprons, chemical suits are used to protect them

2.2. Preventative OHS procedures

Health and safety policies and procedures are part of a framework for effective health and safety management. A general health and safety policy states management's intention to provide a safe and healthy workplace, and states the health and safety goals of a workplace.

An objective of the *Occupational Health and Safety* is the elimination, at the source, of risks to the health, safety and welfare of persons at work.

2.2.1. Implementing and Operating a Health and Safety Management System

- ✓ Implement a reporting system.
- ✓ Train workers how to identify and control hazards.
- ✓ Conduct inspections.
- ✓ Collect hazard control ideas.
- ✓ Implement hazard control ideas.
- ✓ Address/anticipate workplace emergencies.
- ✓ Seek input on workplace changes.

2.2.2. Implement OHS in your organization

- Establish occupational health and safety policies and an OHS program.
- Provide general direction to management, supervisors, and workers about their responsibilities and roles in providing a safe and healthy workplace.
- Provide specific direction and delegate authority to those responsible for health and safety.

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. Use the Answer sheet provided in the next page

________1. PPE is equipment that will protect the user against health or safety risks at work.

________2. Wet, hot and cold conditions, electrostatic build-up and slipping are not hazards for feet and legs.

________3. Health and safety policies and procedures are part of a framework for effective health and safety management.

________4. Making the workplace safe includes providing instructions, procedures, training and supervision

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 included in PPE?

A. Eye protection B. Helmets C. Safety footwear D. None

____2. An objective of the Occupational Health and Safety is the elimination risks at;

A. At the beginning of work B. At the end of work

C. At the middle of work D. At any stage of work

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

"A"	**"B"**
_____1. PPE for hands	A. Ear muff
_____2. RPE	B. Safety spectacles
_____3. PPE for eyes	C. Glove

Unit 3: Basic Properties and Processes In Manufacturing

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

- Basic metal properties in manufacturing
- Common metal manufacturing processes

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 machine-ability, cast-ability, weld-ability, forge-ability and corrosion resistance
- Distinguish rolling, forging, extrusion, drawing and spinning

3.1. Basic metal properties in manufacturing

3.1.1. Machineability

Machinability is the ease or difficulty with which a metal is being machined. The development of tool materials for cutting applications has been accomplished very largely by practical craftspeople. The tool materials which have survived and are commercially available today, are those which have proved fittest to satisfy the demands put upon them in terms of the life of the tool, the rate of metal removal, the surface finish produced, the ability to give satisfactory performance in a variety of applications, and the cost of tools made from them. Small propensity to diffusion and adhesion,

3.1.2. Castability is defined as the property of metal, which indicates the ease with it can be casted into different shapes and sizes. Cast iron, aluminium and brass are possessing good cast-ability**.** Casting is an operation of shaping metal by pouring it in the liquid state into a mold followed by solidification. Casting is also a metal detail, produced as a result of pouring a metal into a mold. In some cases casting is the only method of shaping a metal or alloy: when the alloy is not malleable and therefore it's plastic deformation is not possible or when a large detail of complex shape is to be produced.

3.1.3. Weldability is the capability of a material to be welded under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service. Weld-ability depends on various factors such as, nature of metals, weld designs, welding techniques, skills, etc .It has been stated that all metals are weld-able but some are more difficult than another.

Steel is readily weld-able (in many ways) than aluminium and copper. Copper is not easily welded due to its high thermal conductivity which makes it difficult to raise the parent metal to its melting point. It requires preheating ~300- 400oC.

3.1.4. 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 temperature. The pure metals have good malleability and thus good forging properties. The metals having high ductility at cold working temperature possesses good forge-ability.

3.1.5. Corrosion Resistance

Corrosion resistance is the resistance to eating away or wearing by the atmosphere, moisture, or other agents, such as acid. Corrosion is defined as the deterioration of a material, usually a metal, because of a reaction with its environment.

Corrosion is:

- A natural phenomenon that occurs over time.
- An electrochemical reaction (on metals)
- Happens at different rates with different metals and in different environments

With other metals such as copper, brass, zinc, aluminum, and stainless steel we can expect corrosion to take place, but it might take longer to develop. Unfortunately ordinary iron or steel does not form this protective layer, so must be separated from the environment by some other means. Generally protective coatings are utilized to protect metals from corrosion

3.2. Common Metal Manufacturing Processes

These processes involve large amount of plastic deformation. The cross-section of workpiece changes without volume change. Common bulk deformation Processes are:

a. Rolling: Compressive deformation process in which the thickness of a plate is reduced by squeezing it through two rotating cylindrical rolls.

b. Forging: The work piece is compressed between two opposing dies so that the die shapes are imparted to the work.

c. Extrusion: The work material is forced to flow through a die opening taking its shape

d. Drawing: The diameter of a wire or bar is reduced by pulling it through a die opening (bar drawing) or a series of die openings (wire drawing).

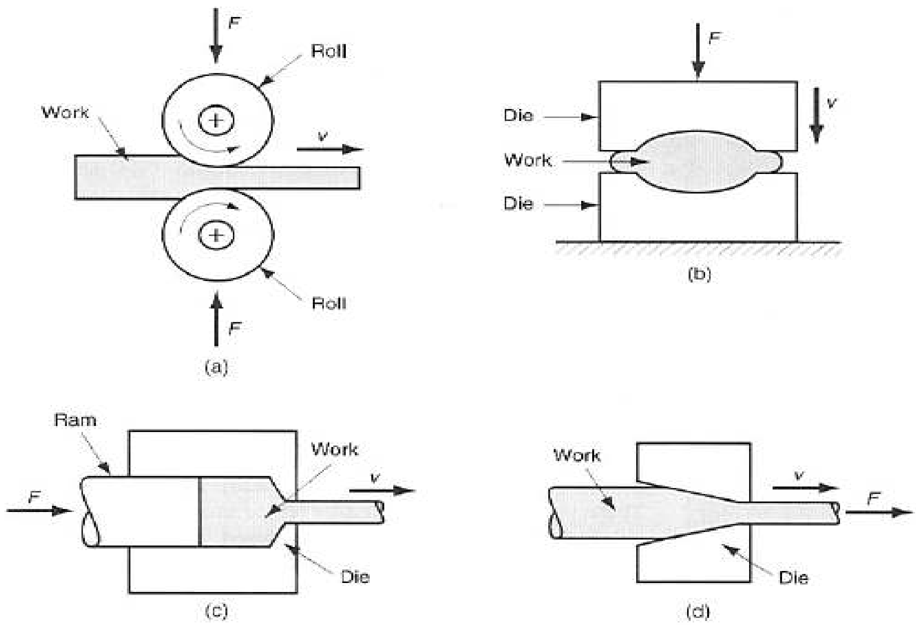

Fig. 3.1. (a) Rolling, (b) forging, (c) extrusion, (d) drawing

e. Metal spinning: Spinning is used to make tubular (axis-symmetric) parts by fixing a piece of sheet stock to a rotating form (mandrel). Rollers or rigid tools press the stock against the form, stretching it until the stock takes the shape of the form. Spinning is used to make rocket motor casings, missile nose cones, satellite dishes and metal kitchen funnels.

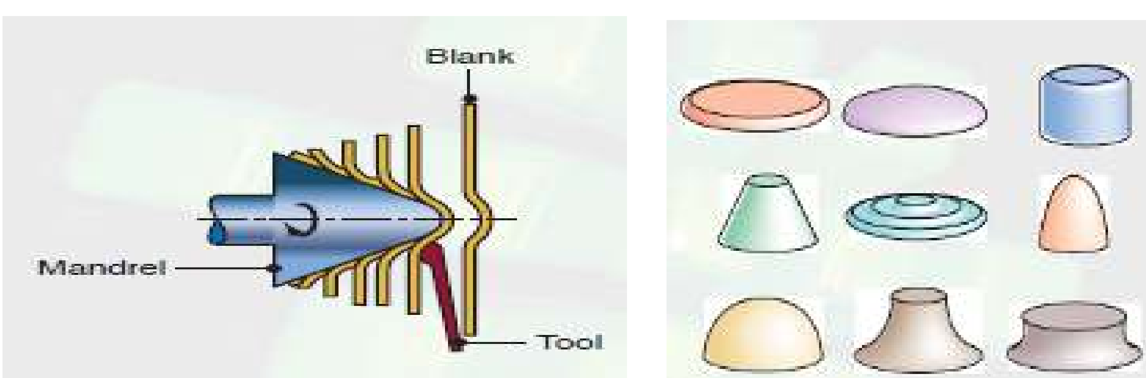

Fig. 3.2. Typical shapes produced by the conventional spinning process.

Circular marks on the external surfaces of components usually indicate that the parts have been made by spinning, such as aluminum kitchen utensils and light reflectors.

f. Methods of manufacturing in hot working, cold working and thermal processes

i. Hot working homogenizes and refines the crystallographic structure of the material and thus ultimately improves its strength and toughness

ii. Cold working increases its strength and hardness, dimensional tolerances and improves surface finish.

Hot operations are carried out at elevated temperatures and, consequently yield a hot-finished product showing a relatively low level of stress. While cold forming operations are confined to ambient temperature and are characterized by a high energy requirement.

iii. Thermal processes

Materials processing is one of the most important and active areas of research in heat transfer today. Thermal processing of materials refers to manufacturing and material fabrication techniques that are strongly dependent on the thermal transport mechanisms. Heat transfer is extremely important in a wide range of materials processing techniques such as crystal growing, casting, glass fiber drawing, chemical vapor deposition, spray coating, soldering, welding, polymer extrusion, injection molding, and composite materials fabrication.

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 methods of engineering materials processing is used to make tubular (axis-symmetric) parts by fixing a piece of sheet stock to a rotating form (mandrel)?

   A. Forging B. Rolling C .Spinning D. Drawing E Extrusion

2. Method of engineering materials processing in which compressive deformation process in the thickness of a plate is reduced by squeezing it through two rotating cylindrical rolls is

   A. Rolling B. Forging C. Extrusion D. Drawing E Spinning

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

"A"	"B"
___ 1. Hot working	A. Heat transfer is extremely important
____ 2. Cold working	B. Homogenizes and refines the crystallographic structure
____ 3. Thermal processes	C. Increases its strength and hardness

PART-III: Give short and brief answers

1. Briefly define the following property of metals in manufacturing process.

a. Castability
b. Weldability
c. Forgeability

Unit 4 : Common Metal Tests

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

- Basic metal tests and recording their results

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:

- State basic metal tests
- Distinguish between destructive and non-destructive testing

4.1 Basic metal tests

Metal testing is accomplished for the purpose of estimating the behaviour 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 behaviour 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. Therefore 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. Non-destructive testing includes visual examination, radiographic tests, ultrasound test, liquid penetrating test and magnetic particle testing.

4.1.1. Destructive testing

Destructive testing /Mechanical testing/ requires destroying the specimen in order to measure the property. Often it requires a specially prepared specimen.

i. Tensile test

Tensile tests are performed for several reasons. The results of tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared.

Finally, tensile properties often are used to predict the behavior of a material under forms of loading other than uniaxial tension. A tensile test is carried out on standard tensile test specimen in universal testing machine. Fig. 7.2 shows a schematic set up of universal testing machine reflecting the test specimen griped between two cross heads. Fig. 7.3 shows the stress strain curve for ductile material. Fig. 7.4 shows the properties of a ductile material.

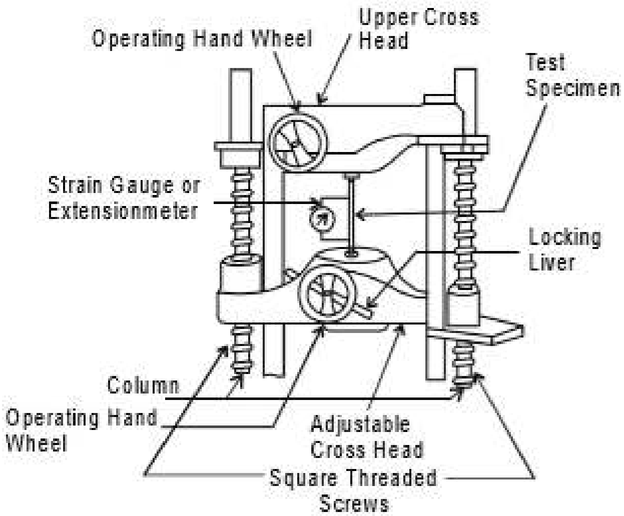

Fig.4.1. Schematic universal testing machine

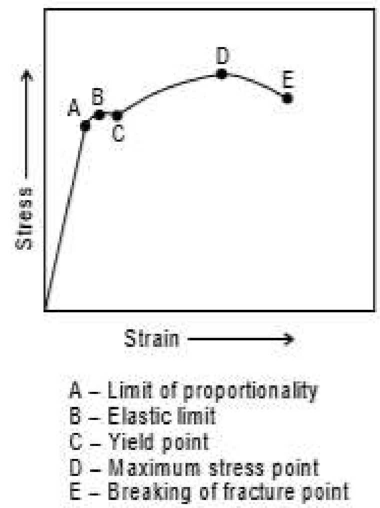

Fig.4.2. Stress strain curve for ductile material

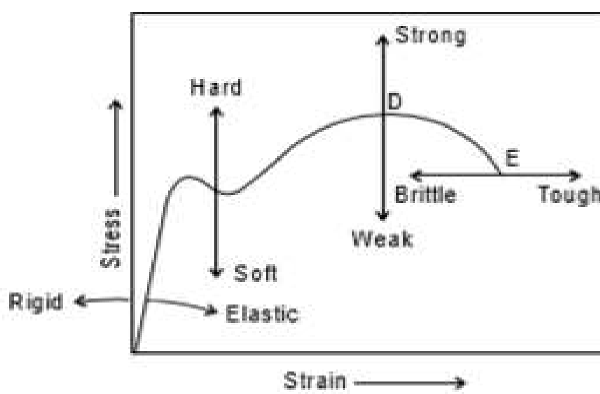

Fig. 4.3. Properties of ductile metal

ii. Hardness Testing

It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation and machinability etc. It also means the ability of a metal to cut another metal.

The hardness of a metal may be determined by the following tests.

(a) Brinell hardness test

(b) Rockwell hardness test

(c) Vickers hardness (also called Diamond Pyramid) test

a) Brinell hardness test

- Uses ball shaped indentor.
- Cannot be used for thin materials.
- Ball may deform on very hard materials
- Surface area of indentation is measured.

Fig. 4.4. Brinell hardness test

b) Rockwell hardness tests

- Gives direct reading.
- Rockwell B (ball) used for soft materials.
- Rockwell C (cone) uses diamond cone for hard materials.
- Flexible, quick and easy to use.

Fig. 4.5. Rockwell hardness test

C) Vickers hardness test

- Uses square shaped pyramid indentor.
- Accurate results.

- Measures length of diagonal on indentation.
- Usually used on very hard materials

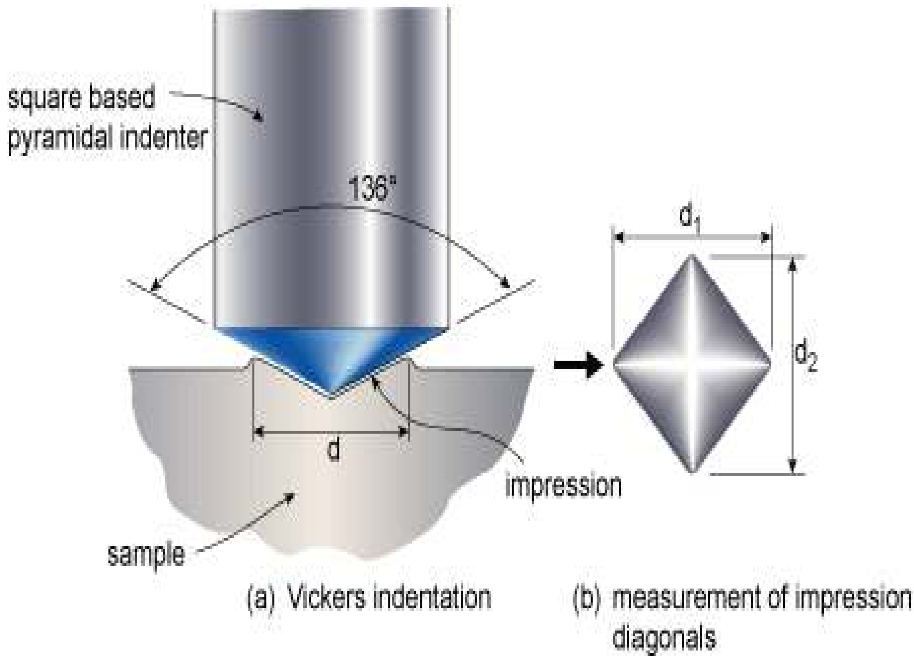

Fig.4.6. Vickers hardness test

iii. Testing of Impact Strength

When metal is subjected to suddenly applied load or stress, it may fail. In order to assess the capacity of metal to stand sudden impacts, the impact test is employed. The impact test measures the energy necessary to fracture a standard notched bar by an impulse load and as such is an indication of the notch toughness of the material under shock loading.

Izod test and the Charpy test are commonly performed for determining impact strength of materials. These methods employ same machine and yield a quantitative value of the energy required to fracture a special V notch shape metal. The most common kinds of impact test use notched specimens loaded as beams. V notch is generally used and it is get machined to standard specifications with a special milling cutter on milling machine in machine shop. The beams may be simply loaded (Charpy test) or loaded as cantilevers (Izod test). The function of the V notch in metal is to ensure that the specimen will break as a result of the impact load to which it is subjected. Without the notch, many alloys would simply bend without breaking, and it would therefore be impossible to determine their ability to absorb energy. It is therefore important to observe that the blow in Charpy test is delivered at a point directly behind the notch and in the Izod test the blow is struck on the same side of the notch towards the end of the cantilever.

The following figure shows the impact testing set up arrangement for charpy test. The specimen is held in a rigid vice or support and is struck a blow by a traveling pendulum that fractures or severely deforms the notched specimen. The energy input in this case is a function of the height of fall and the weight of the pendulum used in the test setup. The energy remaining after fracture is determined from the height of rise of the pendulum due to inertia and its weight. The difference between the energy input and the energy remaining represents the energy absorbed by the standard metal specimen. Advance testing setups of carrying out such experiments are generally equipped with scales and pointers, which provide direct readings of energy absorption.

a. Charpy Testing

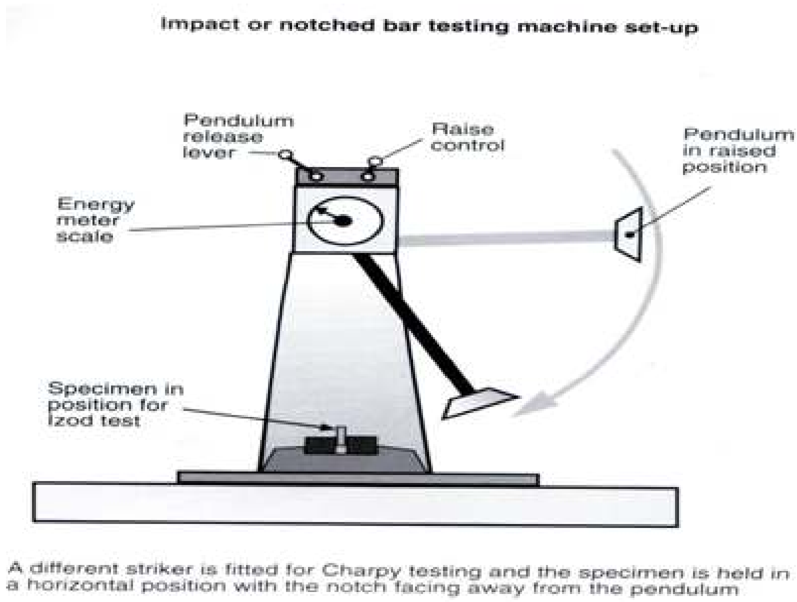

Fig. **4.7.** Charpy Testing

b. Izod test

- Strikes at 167 Joules.
- Test specimen is held vertically.
- Notch faces striker.

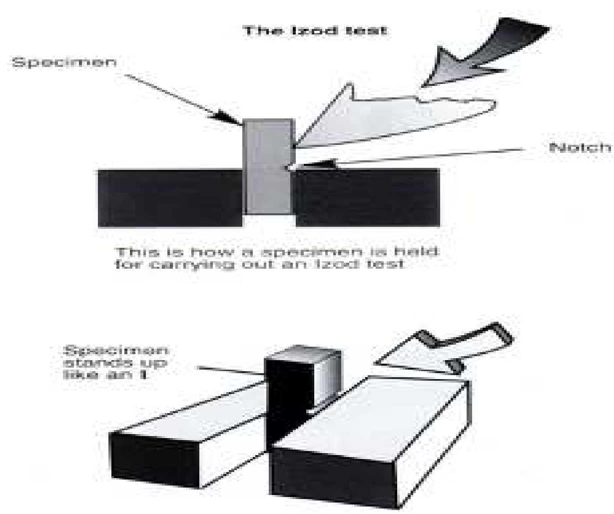

Fig.4.8. Izod test

iv. Spark Test

You perform the spark test by holding a sample of the unidentified material against an abrasive wheel and visually inspecting the spark stream. This test is fast, economical, convenient, easily accomplished, and requires no special equipment. As you become a more experienced Steelworker, you will be able to identify the sample metals with considerable accuracy. You can use this test to identify scrap-salvaged metal, which is particularly important when you are selecting material for cast iron or cast steel heat treatment.

When you hold a piece of iron or steel (ferrous metals) in contact with a high-speed abrasive wheel, small particles of the metal are torn loose so rapidly that they become red-hot. These small particles of metal fly away from the wheel, and glow as they follow a trajectory path called the carrier line, which is easily followed with the eye, especially when observed against a dark background.

The sparks (or lack of sparks) given off can help you identify the metal. Features you should look for include:

- Length of the spark stream
- Form of the sparks
- Colour of the sparks

Table 4.1.Metal identification by spark test with either a portable or stationary grinder

METAL	COLOR of Stream		Stream		Spurts	
	NEAR WHEEL	NEAR END	Volume	Length in/mm	Quantity of	Nature of
Wrought Iron	Straw	White	Large	65/1651	Very Few	Forked
1020 steel	White	White	Large	70/1778	Few	Forked
Carbon Tool Steel	White	White	(M)Large	55/1397	Very Many	Fine repeating
Gray Cast Iron	Red	Straw	Small	25/635	Many	Fine repeating
White Cast Iron	Red	Straw	Very small	20/508	Few	Fine repeating
Annealed Malleable cast	Red	Straw	Moderate (M)	30/762	Many	Fine repeating
High Speed steel	Red	Straw	Small	60/1524	Very Few	Forked
Manganese steel	White	White	(M)Large	45/1143	Many	Fine repeating
Stainless	Straw	White	Moderate (M)	50/1270	Many	Fine repeating
Tungsten Cr Die steel	Red	Straw	Small	35/889	Many	Fine repeating
Nitrided nitralloy	White	White	Large curved	55/1397	Moderate	Forked
Stellite	Orange	Orange	Very small	10/254	none	
Cemented tungsten carbide	Light Orange	Light Orange	Extra small	2/50.8	none	
Nickel	Orange	Orange	Very small	10/254	none	
Copper, brass, Aluminum			none		none	

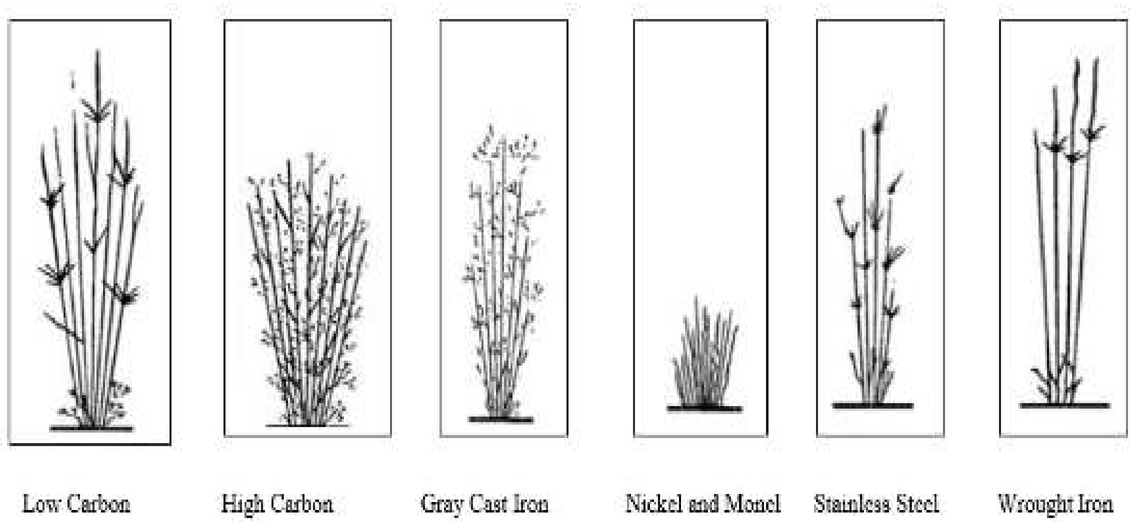

Fig. 4.9. Spark Test

v. Bending and straightening test

This test is specifically for round steel bars for concrete, the aim is to verify that their ductility is sufficient for cold forming operations. The test involves bending the sample to a pre-specified angle and partly straightening it to see if any fractures or cracks are formed. The bending and re-straightening angles, the radius of the tools and the distances between the supports is all dependant on the diameter of the sample, the type of surface and the quality of the steel.

Fig. 4.10. Bending and straightening testing machine

4.1.2. Non Destructive (NDT) testing

- measures attributes of the specimen without damaging it
- Does not normally need a prepared specimen.
- Typically used to find flaws inside a part.
- Useful for valuable components
- Can test components that are in use

Commonly used methods of NDT methods are:

1. **Visual testing (VT)**
   - ❖ The human eye is the most frequently used
   - ❖ It can be aided by lenses and magnifiers.
   - ❖ Can be applied to all sorts of materials for the detection of surface cracks, voids, pores, inclusions and for the assessment of surface roughness
2. **Liquid penetrant testing (PT)**
   - Used for surface flaws.
   - The *oil and chalk* test is a traditional version of this type of testing. Coloured dyes are now used.
   - Penetrants can be used for the inspection of all types of materials such as ferrous and non-ferrous, conductors and non-conductors, magnetic and non-magnetic and all sorts of alloys and plastics.
   - Most common applications are in castings, forgings and welding.

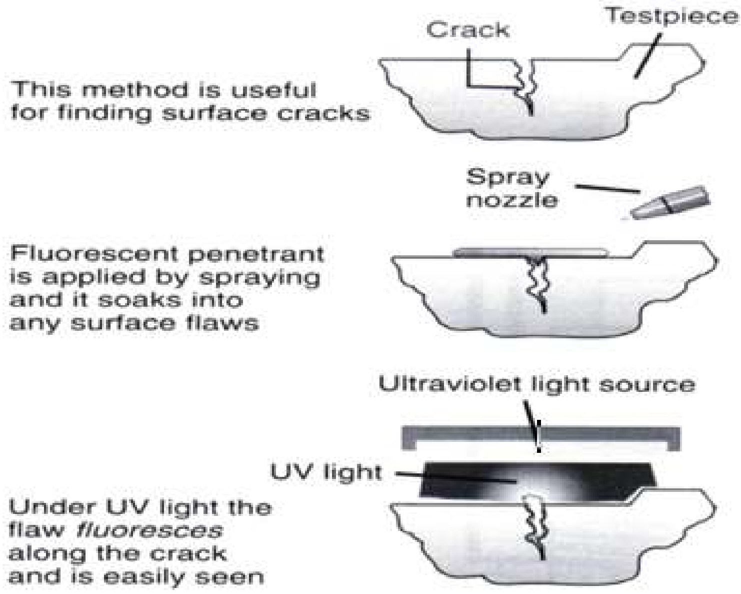

Fig. 4.11. Penetrant testing for flows

3. Magnetic particle testing(MT)

- Magnetic particle testing is a method of finding surface and near surface defects in any steel or iron sample capable of being magnetized.
- Used for ferrous metals.
- Detects flaws close to the surface of the material.
- The component to be tested must first be magnetized.
- Magnetic particles which can be dry or in solution are sprinkled onto the test piece.
- The particles stick to the magnetic field and flaws can be inspected visually by examining the pattern to see if it has been distorted.
- The component must be demagnetized after testing.

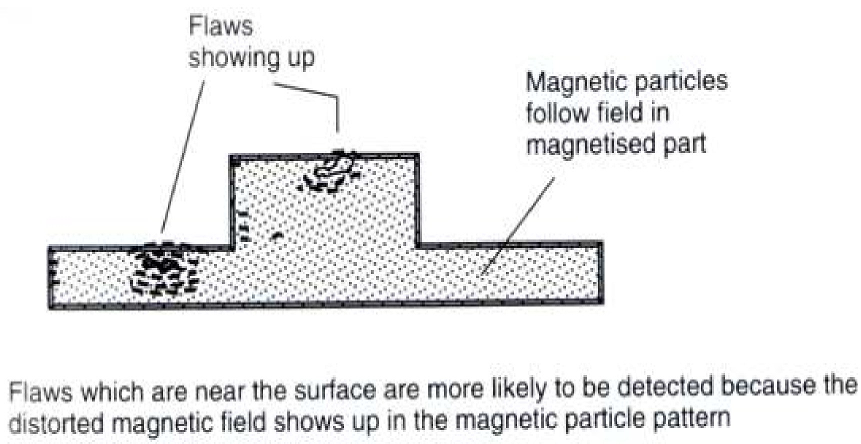

Fig.4.12. Detection of flows by magnetic particles

4. Eddy current testing (ET)

- Used for non-ferrous metals
- A.C. current is passed through the coil.
- The test piece is passed under the coil causing secondary currents called eddy currents to flow through the test piece.
- This causes a magnetic field to flow in the test piece.
- The flaws are detected on an oscilloscope by measuring a change in the magnetic field.

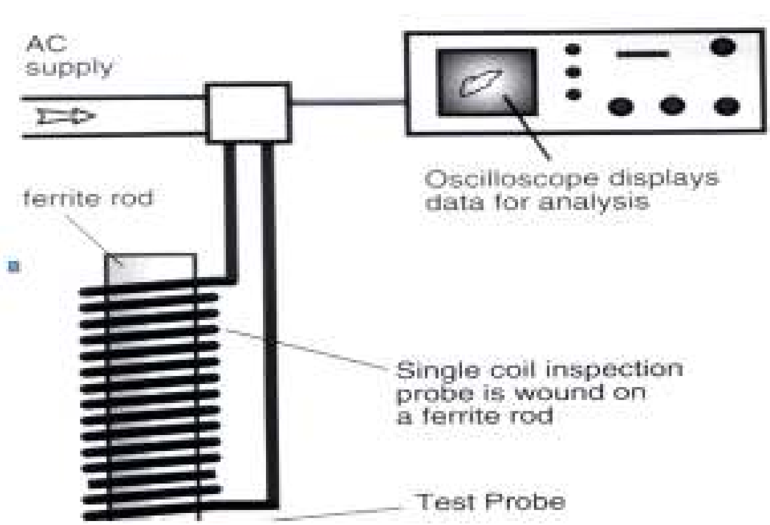

Fig. 4.13 Eddy current testing

5. Radiographic testing (RT)

This is a test generally used to find internal flaws in materials. It is used to check the quality of welds, for example, to find voids or cracks.

1. The x-ray are released by heating the cathode.
2. They are then accelerated by the D.C. current and directed onto the piece by the tungsten anode.
3. The x-rays then pass through the test piece onto an x-ray film which displays the results.
4. The x-rays cannot pass through the faults as easily making them visible on the x-ray film.

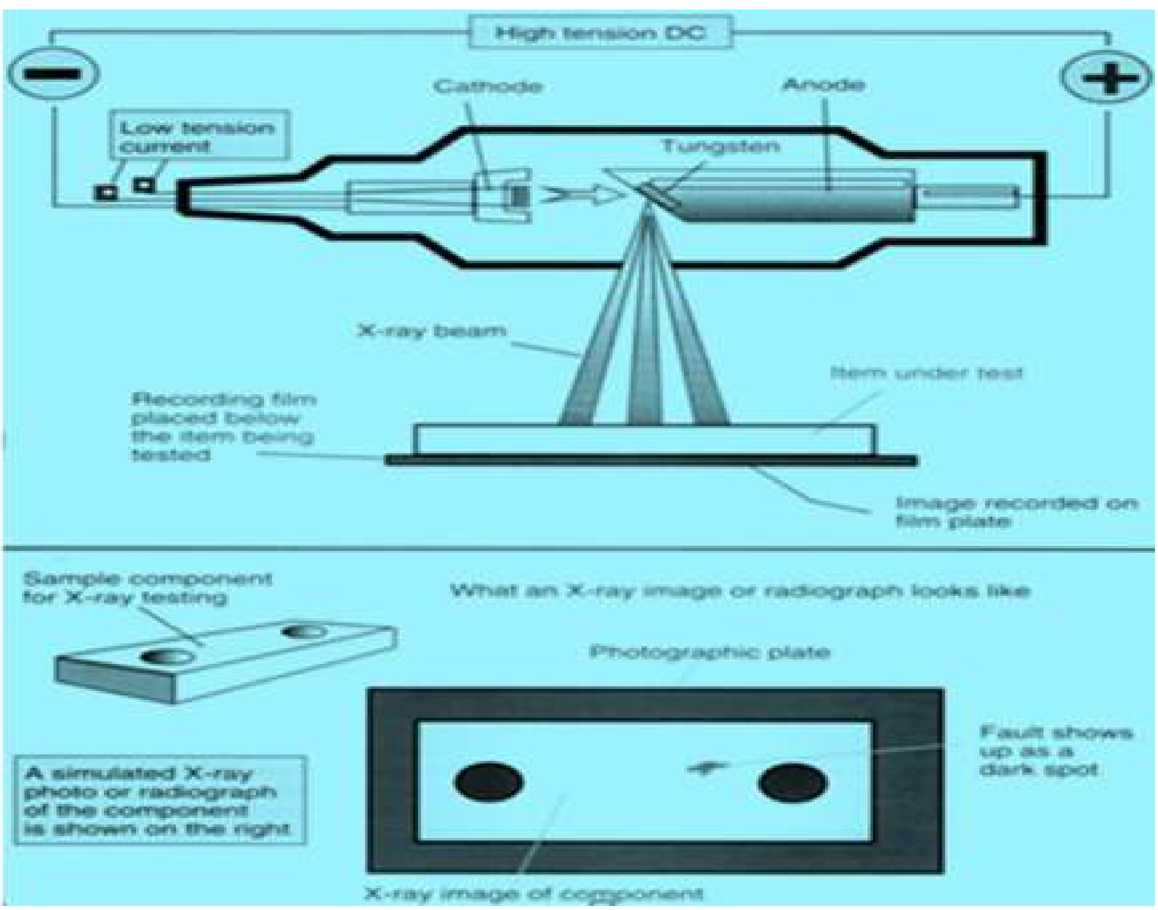

Fig. 4.14 Radiographic testin

6. Ultrasonic testing(UT)

Ultrasonic Sound waves are bounced off the component and back to a receiver. If there is a change in the time taken for the wave to return, this will show a flaw. This is generally used to find internal flaws in large forgings, castings and in weld inspections.

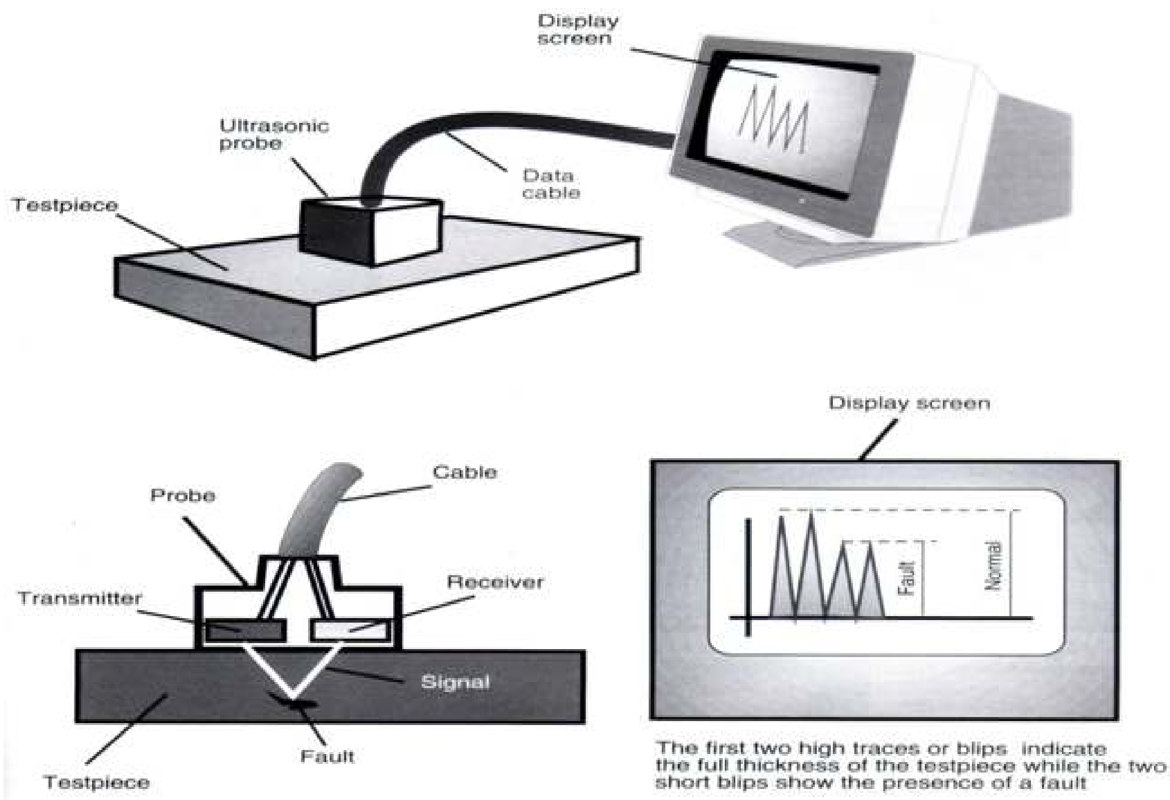

Fig. 4.15 Ultrasonic testing

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. Use the Answer sheet provided in the next page**

________1. Metal testing is accomplished for the purpose of estimating the behaviour 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-II: Match the items listed under column "A" with those expressions listed under "B"

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

Directions: Short Answer Questions

1. Write the purpose of metal testing?
2. What is the difference between destructive testing and non-destructive testing?
3. Mention at least three metal hardness testing machines.

Operation sheet-4: 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.

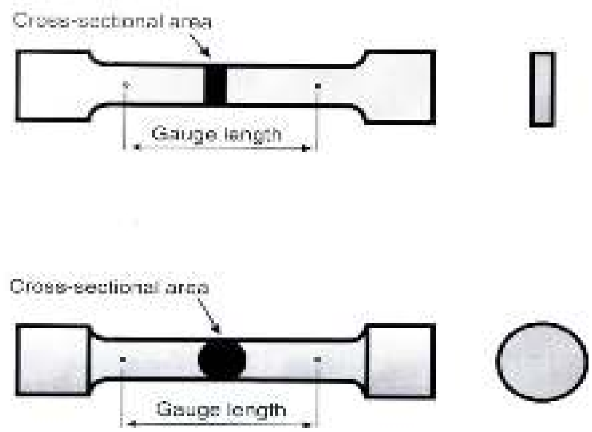

Fig. 4.16 Tensile test specimen

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-4

- 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 penetrants available in your work shop.

Unit 5: Heat Treatment of Metals
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Introduction • Common heat treatment methods and their effects 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: • Clarify purpose of heat treatment basic • Describe common metal heat treatment methods

5.1. Introduction

Heat treatment is a heating and cooling process of a metal or an alloy in the solid state with the purpose of changing their properties. It can also be said as a process of heating and cooling of ferrous metals especially various kinds of steels in which some special properties like softness, hardness, tensile-strength, toughness etc, are induced in these metals for achieving the special function objective.

It consists of three main phases namely

(i) Stage l- heating of the metal slowly to ensure a uniform temperature

(ii) Stage-2 Soaking (holding) the metal at a given temperature for a given time and cooling the metal to room temperature

(iii) Stage-3 Cooling of the metal to room temperature

The theory of heat treatment is based on the fact that a change takes place in the internal structure of metal by heating and cooling which induces desired properties in it. The rate of cooling is the major controlling factor. Rapid cooling the metal from above the critical range, results in hard structure. Whereas very slow cooling produces the opposite affect i.e. soft structure. In any heat treatment operation, the rate of heating and cooling is important. A hard material is difficult to shape by cutting, forming, etc. During machining in machine shop, one requires machineable properties in job piece hence the properties of the job piece may requires heat treatment such as annealing for inducing softness and machineability property in work piece.

5.2. Common heat treatment methods and their effects

The followings are the most common heat treatment processes:

1. Normalizing

2. Annealing.
3. Hardening.
4. Tempering
5. Case hardening (a) Carburizing (b) Cyaniding (c) Nitriding
6. Surface hardening (a) Induction hardening, (b) Flame hardening

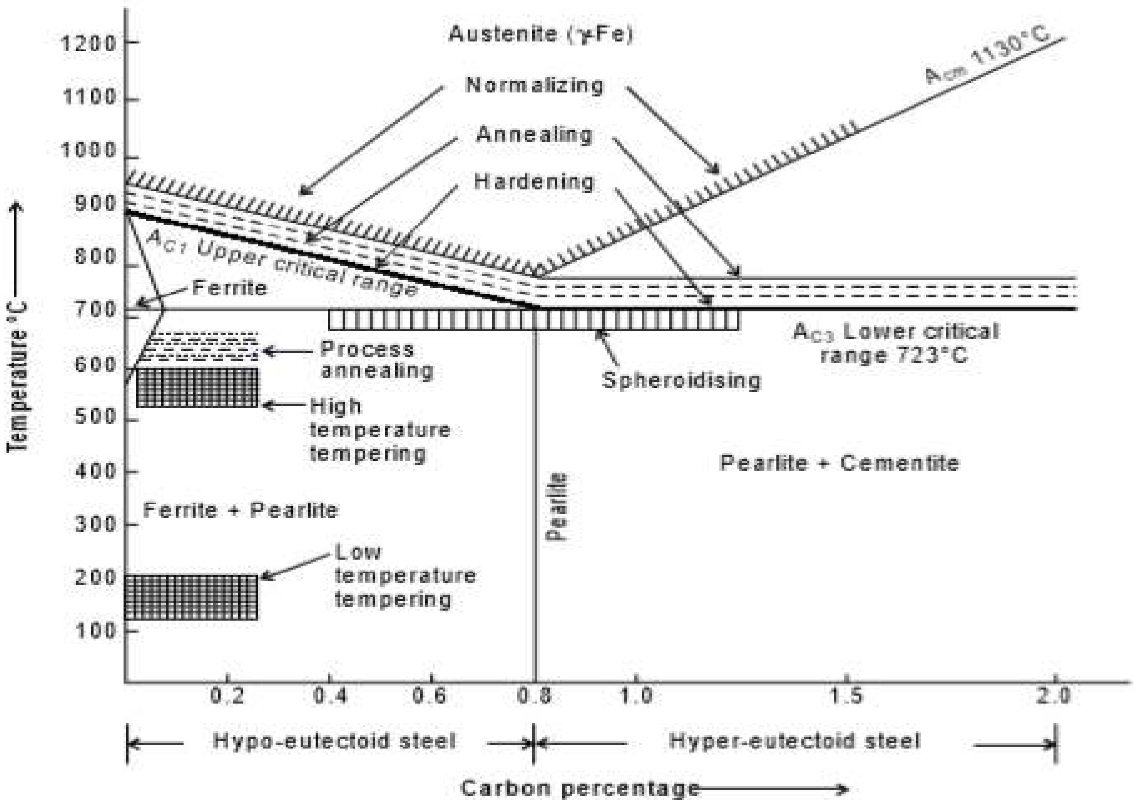

Fig. 5.1. The heating temperature ranges for various heat treatment processes

5.2.1. Normalizing

Normalizing is a defined as softening process in which iron base alloys are heated 40 to 50°C above the upper-critical limit for both hypo and hyper eutectoid steels and held there for a specified period and followed by cooling in still air up to room temperature. The above Figure shows the heating temperature ranges for normalizing process of both hypo and hyper carbon steel

Objectives of normalizing:

1. To soften metals
2. Refine grain structure
3. Improve machinability after forging and rolling

4. Improve grain size
5. Improve structure of weld
6. Prepare steel for sub heat treatment

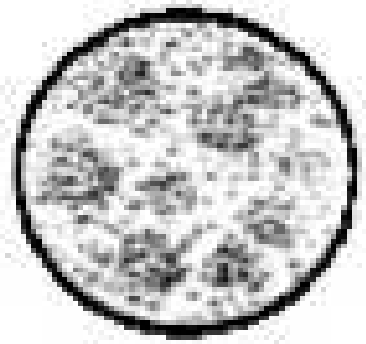

Fig.5.2. Structure of normalized medium carbon steel

5.2.2. Annealing

It is a softening process in which iron base alloys are heated above the transformation range held there for proper time and then cool slowly (at the of rate of 30 to 150°C per hour) below the transformation range in the furnace itself. Heating is carried out 20°C above upper critical temperature point of steel in case of hypo eutectoid steel and the same degree above the lower critical temperature point in case of type eutectoid steel. The above figure shows the heating temperature ranges for annealing or softening process of both hypo and hyper carbon steel.

The structure of steel on slow cooling changes into ferrite and pearlite for hypo eutectoid steel, pearlite for eutectoid steel and pearlite and cementite for hyper eutectoid steel. The time for holding the article in furnace is ½ to 1 hour. As ferrous metals are heated above the transformation range, austenite structure will be attained at this temperature. For a particular type of structure specific cooling rate is required to have good annealing properties for free machining. As metal is slowly cooled after heating and holding in and with the furnace and buried in non conducting media such sand, lime or ashes, carbon steels are cooled down at particular rate normally 150-200°C per hour while alloy steel in which austenite is very stable and should be cooled much lower (30°C to 100°C per hour).

Very slow cooling is required in annealing to enable austenite to decompose at two degrees of super cooling so as to form a pearlite and ferrite structure in hypo-eutectoid steel, a pearlite structure in eutectoid steel and pearlite and cementite structure in hyper eutectoid steel. In successfully annealed steel, the grains of ferrite are large and regular while pearlite consists of cementite and ferrite. Hypo-eutectoid hot worked steel may undergo full annealing to obtain coarse grain structure for free machining. When steel is cold worked the hardness (Brinell hard) considerably increases and ductility decreases slightly. The ductility of steel may be then restored by so called re-crystallization or process annealing.

The purpose of annealing is to achieve the following:

1. Soften the steel.
2. Relieve internal stresses
3. Reduce or eliminate structural in-homogeneity.
4. Refine grain size.
2. Improve machinability.
3. Increase or restore ductility and toughness.

Annealing is of two types (a) Process annealing (b) Full annealing. In process annealing, ductility is increased with somewhat decrease in internal stresses. In this, metal is heated to temperature some below or close to the lower critical temperature generally it is heated 550°C to 650°C holding at this temperature and it is slowly cooled. This causes completely re-crystallization in steel.

The main purpose of full annealing of steel is to soften it and to refine its grain structure. In this, the hypo-eutectoid steel is heated to a temperature approximately 20° to 30°C above the higher critical temperature and for hypereutectoid steel and tool steel is heated to a temperature 20 to 30°C above the lower critical temperature and this temperature is maintained for a definite time and then slowly cooed very slowly in the furnace itself.

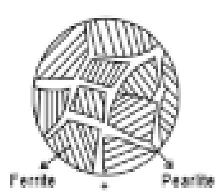

Fig.5.3. Structure of annealed medium carbon steel

The objectives of spheroidising are given as

1. To reduce tensile strength
2. To increase ductility
3. To ease machining
4. To impart structure for subsequent hardening process

Table 5.1. Comparison between annealing and normalising

S.No.	Annealing	Normalising
1	In this hypo-eutectoid steel is heated to a temperature approximately 20 to 30°C above temperature the higher critical temperature and for hypereutectoid steel is heated 20 to 30°C above the lower critical temperature.	In this metal is heated 30 to 50°C above higher critical temperature.
2	It gives good results for low and medium carbon steel	It also gives very good results for low and medium carbon steel
3	It gives high ductility	It induces gives higher ultimate strength, yield point and impact strength in ferrous material.
4	It is basically required to soften the metal, to improve machinability, to increase ductility, improve, to refine grain size.	It is basically required to refine grain size, improve structure of weld, to relieve internal stresses.

5.2.3. Hardening

Hardening is a hardness inducing kind of heat treatment process in which steel is heated to a temperature above the critical point and held at that temperature for a definite time and then quenched rapidly in water, oil or molten salt bath. It is some time said as rapid quenching also. Steel is hardened by heating 20-30°C above the upper critical point for hypo eutectoid steel and 20-30°C above the lower critical point for hyper eutectoid steel and held at this temperature for some time and then quenched in water or oil or molten salt bath.

Figure above shows the heating temperature ranges for hardening process of both hypo and hyper carbon steel.

Fig. 5.4. Structure of hardened carbon steel

Metal is heated up to austenite formation and is followed by fast and continuous cooling of austenite to temperature 205° to 315°C or even lower than that. Due to such rapid cooling, austenitic structure changes to new structure known as martensite. It is evident that faster the rate of cooling harder will be the metal due to formation of more martensitic structure. Martensite has a tetragonal crystal structure. Hardness of martensite varies from 500 to 1000 BHN depending upon the carbon content and fineness of the structure.

Martensite is a body centered phase produced by entrapping carbon on decomposition of austenite when cooled rapidly. It is the main constituent of hardened steel. It is magnetic and is made of a needle like fibrous mass. It has carbon content up to 2%. It is extremely hard and brittle. The decomposition of austenite below 320°C starts the formation of martensite.

Sudden cooling of tool steel provides thermal stresses due to uneven cooling. It provides unequal specific volume of austenite and its decomposition product. The structural transformations are progressing at different rates in outer layers and central portion of the article. When martensitic transformation takes place in the central portion of the article, due to tension stress produces cracks. The harness depends upon essentially on the cooling rate. The effect of cooling on austenite transformation is given in Figure below.

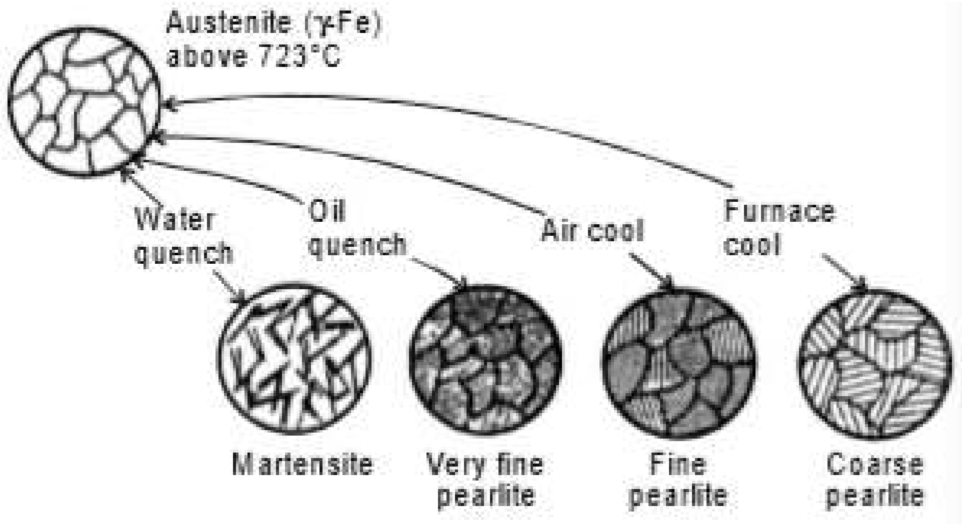

Fig. 5.5. Effects of cooling of austenite transformation

5.2.4. Tempering

If high carbon steel is quenched for hardening in a bath, it becomes extra hard, extra brittle and has unequal distribution internal stresses and strain and hence unequal harness and toughness in structure. These extra hardness, brittleness and unwanted induced stress and strain in hardened metal reduce the usability the metal. Therefore, these undesired needs must be reduced for by reheating and cooling at constant bath temperature. In tempering, steel after hardening, is reheated to a temperature below the lower critical temperature and then followed by a desired rate of cooling. Reheating the of hardened steel is done above critical temperature when the structure is purely of austenite and then quenching it in a molten salt path having temperature in the range of 150-500°C. This is done to avoid transformation to ferrite and pearlite and is held quenching temperature for a time sufficient to give complete formation to an intermediate structure referred to as bainite then cooled to room temperature. The temperature should not be held less than 4 to 5 minutes for each millimeters of the section.

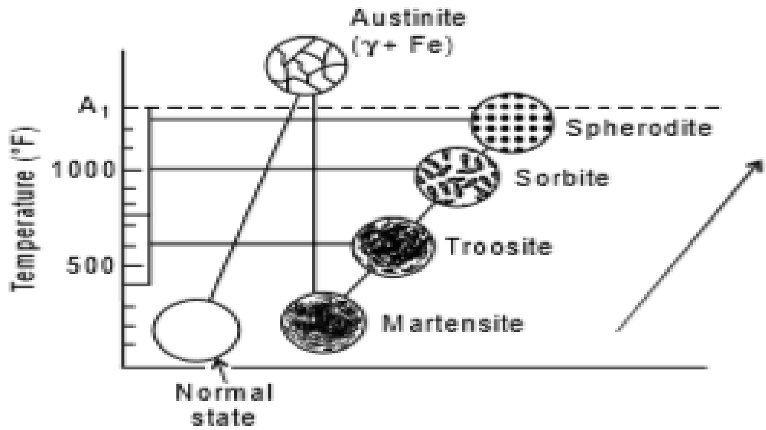

Fig. 5.6. Structure of tempered states of martensite, troosite, sorbite and spherodite

5.2.5. Case hardening

Sometimes special characteristic are required in metal such as hard outer surface and soft, tough and more strength oriented core or inner structure of metal. This can be obtained by casehardening process.

It is the process of carburization i.e. saturating the surface layer of steel with carbon or some other substance by which outer case of the object is hardened where as the core remains soft. It is applied to very low carbon steel. It is performed for obtaining hard and wear resistance on surface of metal and higher mechanical properties with higher fatigue, strength and toughness in the core.

The following are the case hardening process.

1. **Carburizing** : Carburizing is a process that introduces carbon in to a solid ferrous alloy by heating the metal in contact with a carbonaceous material
2. **Nitriding**: consists in subjecting machined and heat-treated steel, free from surface decarburization, to the action of a nitrogenous medium, usually ammonia gas.
3. **Cyaniding**: involves the introduction of both carbon and nitrogen into the surface layers of the steel

5.2.6. Surface Hardening

It is frequently desirable to harden only the surface of steels without altering the chemical composition of the surface layers. If steel contains sufficient carbon to respond to hardening, it is possible to harden the surface layers only by very rapid heating for a short period, thus conditioning the surface for hardening by quenching.

1. **Induction hardening**: In induction hardening, a high-frequency current is passed through a coil surrounding the steel, the surface layers of which are heated by electro-magnetic induction.
2. **Flame hardening:** is a process of heating the surface layers of steel above the transformation temperature by means of a high-temperature flame and then quenching.

Self check-5

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. Heat treatment is a heating and cooling process of a metal or an alloy in the solid state.

________2. Rapid cooling the metal from above the critical range, results in hard structure.

________3. Extra hardness, brittleness and induced stress and strain in hardened metal reduce the usability the metal.

________4. Case hardening is used to obtain hard and wear resistance on surface of metal.

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

"A"	"B"
_____1. Annealing	A. Carburizing
_____2. Hardening	B. Softening
_____3. Case hardening	C. Rapid quenching

Directions: Short Answer Questions

1. Write the most common heat treatment processes.
2. Mention at least four purposes of annealing.
3. Write the different between hardening and tempering.
4. List at list four case hardening processes.

Operation sheet-5: How to Harden Steel

- **Operation title:** Hardening steel
- **Purpose:** To make the steel tough, wear and tear resistant
- **Instruction:** The first important thing to know when heat treating a steel is its hardening temperature. Many steels, especially the common tool steels, have a well established temperature range for hardening. Steel is hardened by heating 20-30°C above the upper critical point for hypo eutectoid steel and 20-30°C above the lower critical point for hyper eutectoid steel and held at this temperature for some time and then quenched in water or oil or molten salt bath. Heat treating temperatures are very hot, so dress properly for the

job and keep the area around the furnace clean so that there is no risk of slipping or stumbling. Also, preheat the tongs before grasping the heated sample part.

Tools and requirement:

- Heating furnace
- Metal tongs
- Digital surface temperature meter
- PPEs

Steps in doing the task:

1. Preheat the furnace to 1200 degrees Fahrenheit.
2. When the furnace has reached 1200 degrees Fahrenheit, place the sample part into the furnace. Place the sample part into the center of the oven to help ensure even heating. Close and wait.
3. Once the sample part is placed in the furnace, heat it to 1500 degrees Fahrenheit. Upon reaching this temperature, immediately begin timing the soak for 15 minutes to an hour (soak times will vary depending on steel thickness).

Table 5.1. Approximate Soaking Time for Hardening, Annealing and Normalizing Steel

Thickness Of Metal (inches)	Time of heating to required Temperature (hr)	Soaking time (hr)
up to 1/8	0.06 to .12	0.12 to 0.25
1/8 to 1/4	0.12 to .25	0.12 to 0.25
1/4 to 1/2	0.25 to .50	0.25 to 0.50
1/2 to 3/4	0.50 to .75	0.25 to0 .50
3/4 to 1	0.75 to 1.25	0.50 to0 .75
1 to 2	1.25 to 1.75	0.50 to0 .75
2 to 3	1.75 to 2.25	0.75to 1.0
3 to 4	2.25to 2.75	1 to 1.25
4 to 5	2.75 to 3.50	1 to 1.25
5 to 8	3.50 to 3.75	1 to 1.50

Soak time is the amount of time the steel is held at the desired temperature, which is in this case 1500 degrees Fahrenheit.

4. When the soak time is complete, very quickly but carefully take the sample out with tongs. Place the sample part into a tank of oil for quenching. Move the sample part around as much as possible while it is quenching.
5. Once the sample part has been quenched down to around 125 degrees Fahrenheit, begin the tempering process. To temper the sample part it must be placed into the furnace at 375 degrees Fahrenheit. Allow it to soak for 2 hours, then remove the sample part and allow it to cool to room temperature. The sample part should now be approximately at a hardness of 60 RC.

Quality Criteria: In order to maintain the quality of the steel heating temperature and soaking time has to be set correctly.

Precautions: Always wear goggles and gloves when operating a heating furnace.

Before operating heating furnaces, **read all instructions** so that you know well how to handle it safely

Lap Test-5

- Task-1: Carry out annealing on a sample of carbon steel.
- Task-2: Perform tempering of a hardened carbon steel specimen.
- Task-3: Carry out carburizing carbon steel using carburizing fame in your work shop.

Unit 6: Quality and Documentation of Metal Tests
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Quality of metal tests • Faults and their corrective actions. • Data recording and reporting 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: • Clarify quality of metal tests • State faults and their corrective actions • Record and report data in metal testing

6.1 Quality of metal tests

The quality of the metals can be tested using highly standardized and high-quality testing machines to determine its properties. To determine the quality of the metals, several tests are conducted such as hardness test, tensile test, corrosion test, and many more.

Various procedures and approaches are utilized to determine if a given material is suitable for a certain application or if a certain product has been manufactured per the required specifications. The material may be tested for its ability to deform satisfactorily during a forming operation, or perhaps for its ability to operate under a certain stress level at high temperatures. For technological purposes, economy and ease of testing are important factors.

The accuracy of results is dependent on various parameters which may be separated into two categories:

- Metrological parameters such as class of machine and the accuracy of specimen dimensional measurements;
- Material and testing parameters such as nature of material, test piece geometry and preparation, testing rate, temperature, data acquisition and analysis technique.

In the absence of sufficient data on all types of materials it is not possible, at present, to fix values of accuracy for the different properties measured by the tensile test.

6.2 Faults and their corrective actions

Part failure is an undesirable aspect of in-service parts that is difficult to predict. A number of mostly qualitative tests have been devised to determine a part’s or material’s resistance to failure under cyclical stress or impacts. These include impact tests and cyclical stress tests, which are often made on specimens that include pre-made cracks. These types of tests are also useful for materials that don’t strain well and rupture quickly under applied stress, thus making them problematic for deformation testing. Failure property tests, which include fatigue, fracture toughness, and crack growth tests, provide the measured material properties.

6.3. Data recording and reporting

6.3.1. Data Recording: test records may be needed by many departments within an organization, including metallurgy, engineering, commercial, and legal departments. Engineering and metallurgy departments typically are most interested in material properties, but may use raw data for error checking or additional analyses. The metallurgy department wants to know how variations in raw materials or processing change the properties of the product being produced and tested, and the engineering department wants to know the properties of the material for design purposes.

Shipping, receiving, and accounting departments need to know whether or not the material meets the specifications for shipping, acceptance, and payment. The sales department needs information for advertising and for advising prospective customers. If a product incorporating the tested material later fails—particularly if persons are injured— the legal department may need test data as evidence in legal proceedings. In this case, a record of the raw data will be important for support of the original analysis and test report.

Upon completion of the group of tests performed on the sample, a statistical analysis may be made. The statistical analysis produces average (mean or median) values for representation of the sample in the subsequent database and also provides information about the uniformity of the material and the repeatability of the test.

The results of tests on each sample of material may be stored in a database for future use. The database allows a wide range of analyses to be performed using statistical methods to correlate the mechanical-properties data with other information about the material. For example, it may allow determination of whether or not there is a significant difference between the material tested and similar material obtained from a different supplier or through a different production path.

6.3.2. Data reporting: the test report usually contains the results of tests performed on one sample composed of several specimens. The information contained in the test report generally should include identification of the testing equipment, the material tested, and the test procedure; the raw and calculated data for each specimen; and a brief statistical summary for the sample. Each piece of test equipment used for the test should be identified, including serial numbers, capacity or range used, and date of certification or date due for certification.

Identification of the material tested should include the type of material (alloy, part number, etc.); the specific batch, lot, order, heat, or coil from which the sample was taken; the point in the processing sequence (condition, temper, etc.) at which the sample was taken; and any test or pretest conditions (test temperature, aging, etc.). The raw data for each specimen are recorded, or a reference to the raw data is included so that the data can be obtained from a file if and when they are needed.

Self check-6

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. Part failure is an undesirable aspect of in-service parts that is difficult to predict.

________2. Engineering and metallurgy departments typically are most interested in material properties.

________3. Each piece of test equipment used for the test should be identified

PART-II: Select the best answer and write its answer on the space provided.

_______1. Which body of an organization needs data records of material testing?

A. Metallurgy B. Engineering C. Commercial D. All

______2. The information contained in the test report should include

A. Identification of the testing equipment B. The material tested

C. Test procedure D. All

PART-III: **Give short and brief answers**

1. Describe how part failure is corrected.
2. What is the purpose of data recording in material testing?
3. Briefly state how the quality metal is tested.