BASIC METAL WORKS

Level I

Learning Guide-08

Unit of Competence: - Identify Properties of Metals

Module Title: - Identifying Properties of Metals

LG Code: IND BMW1 M08 LO1- 4- LG8

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LO1: Classify common ferrous and non-ferrous metals

Instruction Sheet	Learning Guide 08

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

- Distinctions between ferrous and non-ferrous metals
- Identifying properties of Metal

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Classify distinctions between ferrous and non-ferrous metals and alloys in terms of colour codes, strength, density, corrosion resistance, electrical conductivity and magnetic properties.
- Identify metal properties like yield stress, proof stress, tensile stress, elongation, impact strength, toughness, fatigue strength, wear resistance, heat resistance, hardness, bending.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described in number 3 to 20.
3. Read the information written in the "Information Sheets 1". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-check 1" in page 5.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 1).

6. If you earned a satisfactory evaluation proceed to "Information Sheet 2". However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
7. Submit your accomplished Self-check. This will form part of your training portfolio

8. Read the information written in the "Information Sheet 2". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
9. Accomplish the "Self-check 2" .
10. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 2).
11. Read the information written in the "Information Sheets 3 . Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
12. Accomplish the "Self-check 3" .
13. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 3).
14. If you earned a satisfactory evaluation proceed to "Operation Sheet 1" . However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
15. Read the "Operation Sheet 1" and try to understand the procedures discussed.
16. If you earned a satisfactory evaluation proceed to "Operation Sheet 2" . However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.

17. Read the “Operation Sheet 2” and try to understand the procedures discussed.
18. If you earned a satisfactory evaluation proceed to “Operation Sheet 3” . However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
19. Read the “Operation Sheet 3” and try to understand the procedures discussed.
20. Do the “LAP test” (if you are ready). Request your teacher to evaluate your performance and outputs. Your teacher will give you feedback and the evaluation will be either satisfactory or unsatisfactory. If unsatisfactory, your teacher shall advice you on additional work.

Information Sheet 1	**classify common ferrous and non-ferrous metals**

1. Classify common ferrous and non-ferrous metals

1.1. Classify ferrous and non-ferrous metals

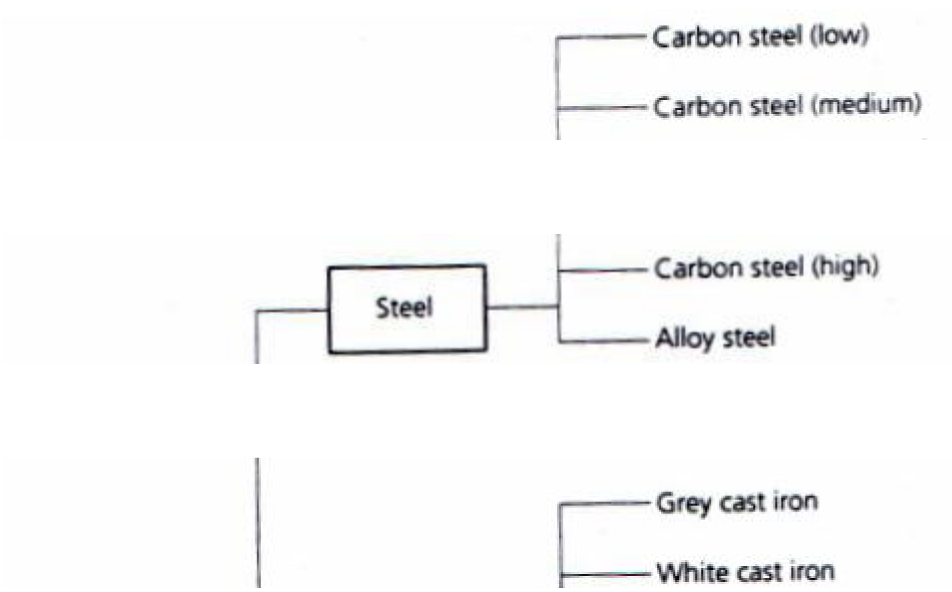
Introduction of common engineering materials

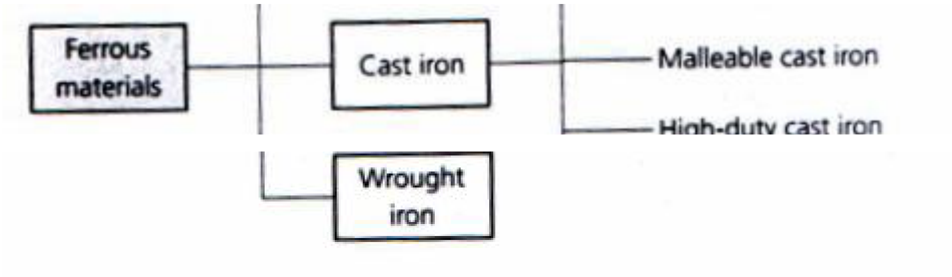
Common engineering materials are normally classified as metals and nonmetals. Metals and non-metals differ in their properties. The choice of materials for a given job depends very much on its properties, cost, availability and such other factors. Metals may conveniently be divided into ferrous and non-ferrous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

i. Ferrous metals

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 ferrous metals themselves can also be classified into "families', and these are shown in figure 2.





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> 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. Carbons in cast iron are present either in Free State like graphite or in combined state as commentate. 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 grayish 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 coddles 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 machinability 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

►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.

►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.

►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.

►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 aluminum. 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 steel

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.

Ii. Non-ferrous metals

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, aluminium, tin, lead, zinc, and nickel, etc., and their alloys.

♠ 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, melachite 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:

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.

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.

♠ **Aluminum**

Aluminum 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 Aluminium 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:

♦***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.

♦***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.

♦***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.

♠ 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.

×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.

× ***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.

× ***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.

× ***Nomonic alloy***

The composition of nomonic alloy is given as under. Cr = 15 to 18%, Co = 15 to 18%, Ti = l.2 to 4.0%, Al = l.5%, Ni = Remaining. Nomonic is widely used for making gas turbine engines

× ***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.

♠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

♠ **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.

♠ **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.

iii. Basic metal identification

When you are selecting a metal to use in fabrication, to perform a mechanical repair, or even to determine if the metal is weldable, you must be able to identify its basic type.

A number of field identification methods can be used to identify a piece of metal. Some common methods are surface appearance, spark test, chip test, magnet test, and occasionally a hardness test.

1.1.1. Color codes

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

CODE : A group of general rules or systematic procedures for Design, Fabrication, Installation and Inspection methods prepared in such a manner that it can be adopted by legal jurisdiction and made into a law.

1.1.2. ***Strength*** It is the ability of a material to resist the externally applied forces without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.

1.1. 3. Density Mass per unit volume is called as density

1.1.4. Corrosive Resistance: Corrosive resistance is the resistance to eating away or wearing by the atmosphere, moisture, or other agents, such as acid

1.1.5. 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 Surface Appearance

Sometimes you can identify a metal simply by its surface appearance. *Table 1-1* indicates the surface colours of some of the more common metals.

Table 1-1 — Surface Appearance of Some Common Metals

Metal	Color		Color and Structure
	Unfinished, unbroken surface	Freshly filed surface	Newly fractured surface
Aluminum	Light gray	White	White: finely crystalline
Brass and Bronze	Reddish-yellow, yellow-green, or brown	Reddish-yellow to yellowish-white	Red to yellow
Copper	Reddish-brown to green	Bright copper color	Bright red
Iron, Cast-gray	Dull gray	Light silvery gray	Dark gray: crystalline
Iron, Cast-white	Dull gray	Silvery white	Silvery white: crystalline
Iron, Malleable	Dull gray	Light silvery gray	Dark gray: finely crystalline
Iron, Wrought	Light gray	Light silvery gray	Bright gray
Lead	White to gray	White	Light gray: crystalline
Monel metals	Dark gray	Light gray	Light gray
Nickel	Dark gray	Bright silvery white	Off-white
Steel, Cast and Steel, Low-carbon	Dark gray	Bright silvery gray	Bright gray
Steel, High-carbon	Dark gray	Bright silvery gray	Light gray
Steel, Stainless	Dark gray	Bright silvery gray	Medium gray

As you can see by studying the table, a metal's surface appearance can help you identify it, and if you are unsure, you can obtain further information by studying a fresh filing or a fresh fracture. If a surface examination does not provide you with enough information for a positive identification, it should give you enough information to place the metal into a class.

In addition to the colour of the metal, distinctive marks left from manufacturing also help in determining the identity of the metal.

• Cast iron and malleable iron usually show evidence of the sand mold.

• Low-carbon steel often shows forging marks.

• High-carbon steel shows either forging or rolling marks.

Inspecting the surface texture by feel may also provide another clue to its identity.

- Stainless steel, in the unfinished state, is slightly rough.
- Wrought iron, copper, brass, bronze, nickel, and Monel are smooth.
- Lead is smooth but has a velvety appearance.

When visual clues from surface appearance; filings, fractures, manufacturing marks, or textural clues from the feel of the surfaces, do not give enough information to allow positive identification, other tests become necessary.

Some are complicated and require equipment Seabees do not usually have. However, the following are a few additional simple tests, which are reliable when done by a skilled person: spark test, chip test, magnetic tests, and hardness test.

Self-Check -1	Written Test

Directions 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 pt each)

________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.

***Note:* Satisfactory rating – 4 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Information Sheet 2	Identifying properties of Metal

2. Identifying properties of Metal

► Physical Properties

These properties are related to the atomic structure and density of the material.

(i) Coefficient of Linear Expansion: The coefficient of linear expansion is the increase in length of a body for a given rise in temperature. Metal expands when heated and contracts when cooled. It increases not only in length, but also in breath and thickness. The increase in unit length when a solid is heated one degree is called the coefficient of linear expansion.

(ii) Heat and Electrical Conductivity: Heat and electrical conductivity is the ability of a material to conduct or transfer heat or electricity.

(iii) Magnetic Susceptibility: Magnetic susceptibility is the ability of a material to hold a magnetic field when it is magnetized.

(iv) Reflectivity: Reflectivity is the ability of a material to reflect light or heat.

(v) Specific Gravity: Specific gravity is the ratio of weights between two objects of equal volume, one of which is water.

(vi) Melting Point: The melting point is the temperature at which a substance passes from a solid state to a liquid state.

► **Mechanical Properties**

1.2.1 Yield Stress: 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.

1.2.2 Proof stress: is the ability of material to return to its original size, shape, and dimensions after being deformed. proof 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.

1.2.3Tensile 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, harden ability, and resistance to heat.

1.2.4 Elongation 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 elongation 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 elongation; however, they lack the necessary tensile strength to be drawn into fine wire. Most metals have increased elongation and ductility at higher temperatures. For example, iron and nickel are very elongation when heated bright red.

1.2.5 Impact stress: 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

1.2.6 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., hard metals are brittle; however, the terms should not be confused or used synonymously.

1.2.7 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.

1.2.8 Wear Resistance: Abrasion resistance is the resistance to wearing by friction.

1.2.9 Heat Resistance It is generally termed as to specify the variation of resistivity with temperature

1.2.10 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.

➢ 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.

Some important properties are defined as under.

Melting Point

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 Aluminium is 650°C.

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

- ***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.

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.

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.

- **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.

Self-Check -2	Written Test

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

PART-I: 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

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

"A"	"B"
_____1. Elasticity	A. The property of breaking without warning
_____2. Ductility	B. A combination of high strength and medium ductility
_____3. Malleability	C. The capacity to be rolled or hammered into thin sheets
_____4. Toughness	D. The capacity to be drawn from a larger to a smaller diameter of wire
_____5. Brittleness	E. The ability of material to return to its original size, shape and dimension

Note: **Satisfactory rating - 4points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

LAP Test	Practical Demonstration

Name: _____________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 8-12 hours.

Task 1: Identify ferrous and non ferrous metals stating their characteristics briefly.

Task 2: List the common ferrous and non ferrous metals.

Task 3: Describe mechanical properties of metals.

Task 4: State briefly physical, electrical, magnetic and thermal properties of metals.

.

Information Sheet 1	Test basic application

2.1. Selecting cutting tools for the machinability

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. In present-day machine shop practice, the vast majority of tools come from two of these 'genera' - high speed steels and cemented carbides. The other main groups of cutting tool materials are carbon (and lower alloy) steels, cast cobalt-based alloys, ceramics and diamond.

Cutting tool materials should have the following properties in order to do justice to the stresses placed on them:

- **Hardness and pressure resistance,**
- **Bending strength and toughness,**
- **Edge strength,**
- **Inner bonding strength,**
- **High temperature strength,**
- **Oxidation resistance,**
- **Small propensity to diffusion and adhesion,**
- **Abrasion resistance,**
- **Reproducible wear behavior.**

Self-Check - 1	Written Test

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

1. **State at least five properties cutting tool materials. (5 points)**
2. **Write the process in which have proved fittest to satisfy the demands put upon them in terms of the life of the tool**

Note: **Satisfactory rating - 3points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ **Date:** ________________

Short Answer Questions

Information Sheet 2	Test basic applications and methods for manufacturing

2.2 Selecting correct cutting tools.

Proper manufacturing process selection is related to characteristics of materials , tolerances, surface finishes obtained and cost. Many traditional manufacturing processes have been now automated and are being computer controlled to optimize the processes. Some materials can be processed at room temperature ,but others require elevated temperatures, which means additional furnaces and appropriate tooling. Some materials are soft and ductile, whereas others are hard ,brittle and abrasive ,thus requiring special processing techniques and tool and die materials

Different materials have different manufacturing characteristics ,such as cast ability ,forge ability ,workability, machinability and weld ability. Few materials have the same favorable characteristics in all categories. For example ,a material that is castable or forgeable may later present problems in machining , grinding or finishing operations that may be required in order to produce a product with acceptable surface finish and dimensional accuracy.

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

2.2.2 Weld ability **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 weldable but some are more difficult than another.**

Steel is readily weldable (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

2.2.3 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 forgeability.

Corrosion is defined as the deterioration of a material, usually a metal, because of a reaction with its environment.

2.2.4 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.

Self-Check – 2	**Written Test**

Directions: Short Answer Questions

1. Briefly define the following property of metals in manufacturing process: (2 pts each)

- **a. Castability**
- **b. Weldability**
- **c. Forgeability**

Note: **Satisfactory rating - 3points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ **Date:** ________________

Information Sheet 3	**Carrying out Basic methods of processing engineering materials**

2.3 Introduction of Carrying out Basic methods of processing engineering materials

These processes involve large amount of plastic deformation. The cross-section of work piece changes without volume change.

Classification of Bulk Deformation Processes

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

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

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

2.2.4 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).

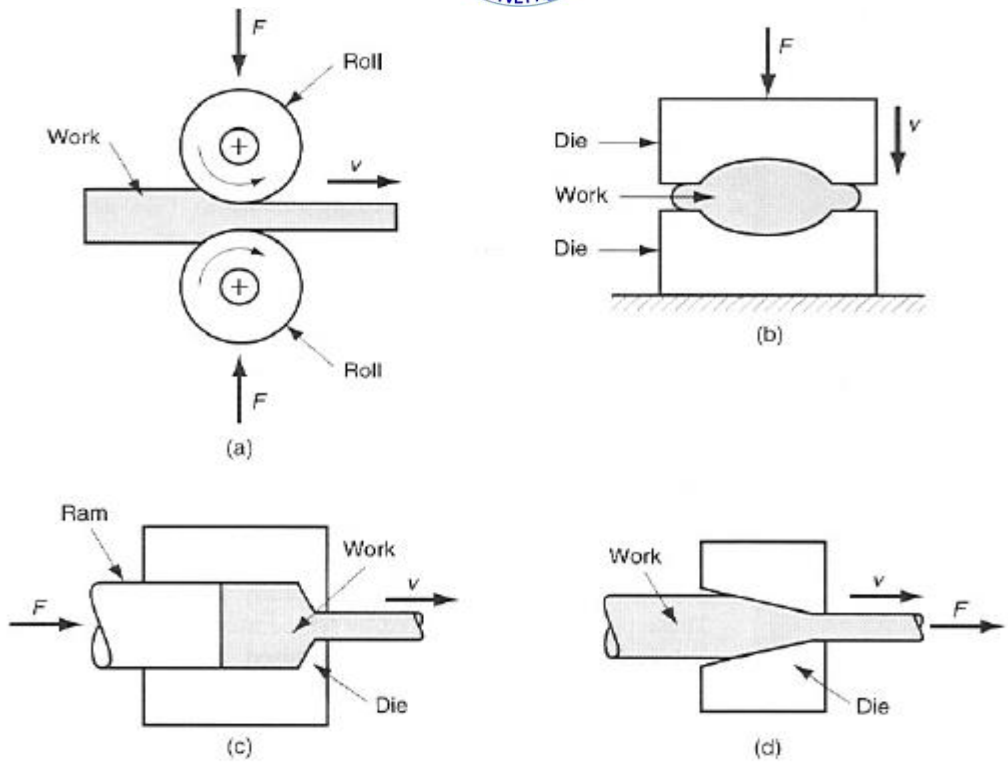


Fig 2.3.1- 2.3.4 (a) rolling, (b) forging, (c) extrusion, (d) drawing

2.3.5 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.

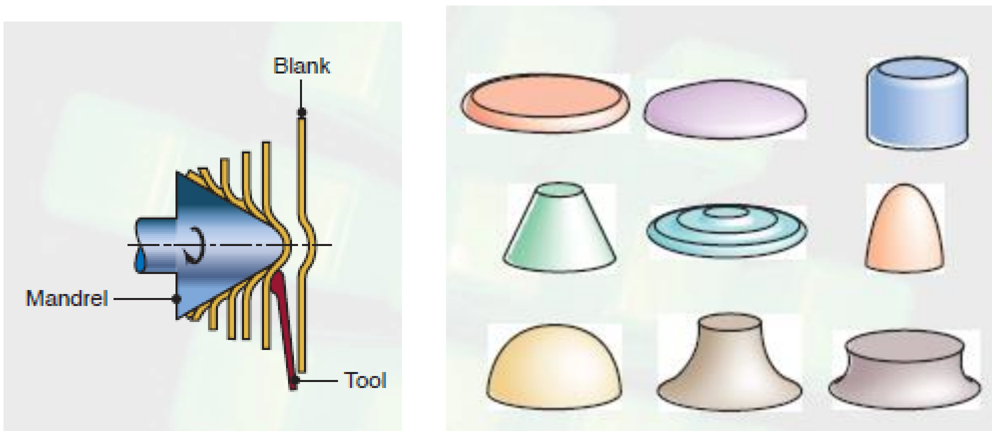


Fig 2.3.5 Typical shapes produced by the conventional spinning process. Circular marks on the external surfaces of components usually indicate that the parts have been made by spinning, such as aluminum kitchen utensils and light reflectors.

Self-Check – 3	Written Test

Directions: Short Answer Questions

1. Briefly define the following basic methods of engineering materials processing: (2 pts each)

- **a. Rolling**
- **b. Forging**
- **c. Extrusion**
- **d. Drawing**
- **e. Spinning**

Note: **Satisfactory rating - 3points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ **Date:** _______________

Information Sheet 4	Experiencing methods of manufacturing in

2.4.1Hot working: - homogenizes and refines the crystallographic structure of the material and thus ultimately improves its strength and toughness

2.4.2 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.

2.4.3 Thermal processes

Thermal processing of materials refers to manufacturing and material fabrication techniques that are strongly dependent on the thermal transport mechanisms. Materials processing is one of the most important and active areas of research in heat transfer today. 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 – 4	Written Test

Directions: Short Answer Questions

1. Briefly define the following methods of manufacturing: (2 pts each)

a. **Hot working**
b. **Cold working**
c. **Thermal processes**

Note: **Satisfactory rating - 2points** **Unsatisfactory - below 1 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ **Date: ________________**

LAP Test	Practical Demonstration

Name: _______________________________ **Date:** _________________

Time started: _________________________ **Time finished:** _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 4 hours.

Task 1: Briefly explain the common properties of cutting tool materials.

Task 2: Briefly describe the following property of metals in manufacturing process:

a. Castability
b. Weldability
c. Forgeability

.Task 3: Explain the following basic methods of engineering materials processing:

1. Rolling
2. Forging
3. Extrusion
4. Drawing
5. Spinning

Task 4: Explain clearly the purpose of hot working, cold working and thermal processes

Information Sheet-1	perform basic common ***metal tests***

3.1 preparing basic ***metal tests***

Metal testing is accomplished for the purpose of for estimating the behavior of metal under loading (tensile, compressive, shear, torsion and impact, cyclic loading etc.) of metal and for

Providing necessary data for the product designers, equipment designers, tool and die designers and system designers.

The material behavior data under loading is used by designers for design calculations and determining whether a metal can meet the desired functional requirements of the designed product or part. Also, it is very important that the material shall be tested so that their mechanical properties especially their strength can be assessed and compared. 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. A standard test specimen for tensile test is shown in Fig. 3

Non-destructive testing includes visual examination, radiographic tests, ultrasound test, liquid penetrating test and magnetic particle testing.

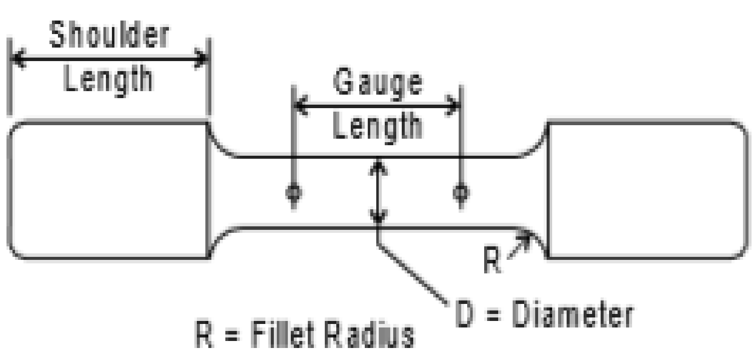


Fig 3 tensile test specimen

3.1.1 Test strength

A strength test is carried out on standard tensile test specimen in universal testing machine. Fig. 4 shows a schematic set up of universal testing machine reflecting the test specimen

Griped between two cross heads. Fig. 5 shows the stress strain curve for ductile material. Fig. 6 shows the properties of a ductile material. Fig. 7 shows the stress strain curves for wrought iron and steels. Fig. 8 shows the stress strain curve for non ferrous material.

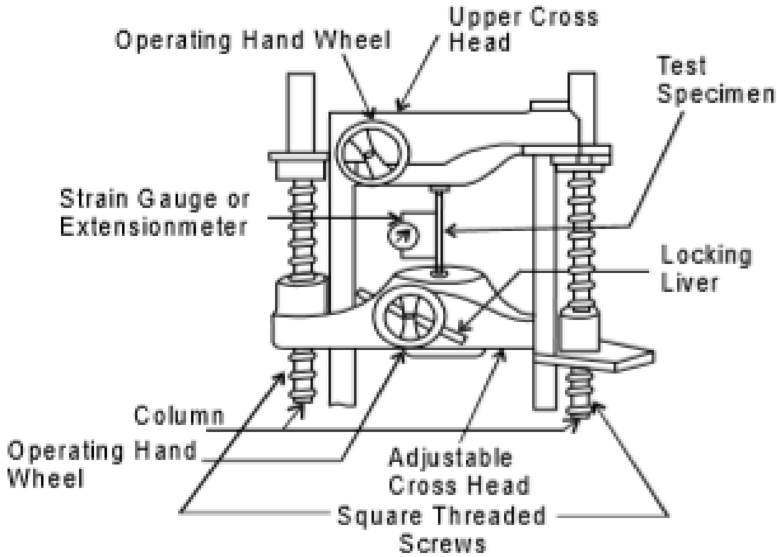


Fig 4 schematic universal testing machine

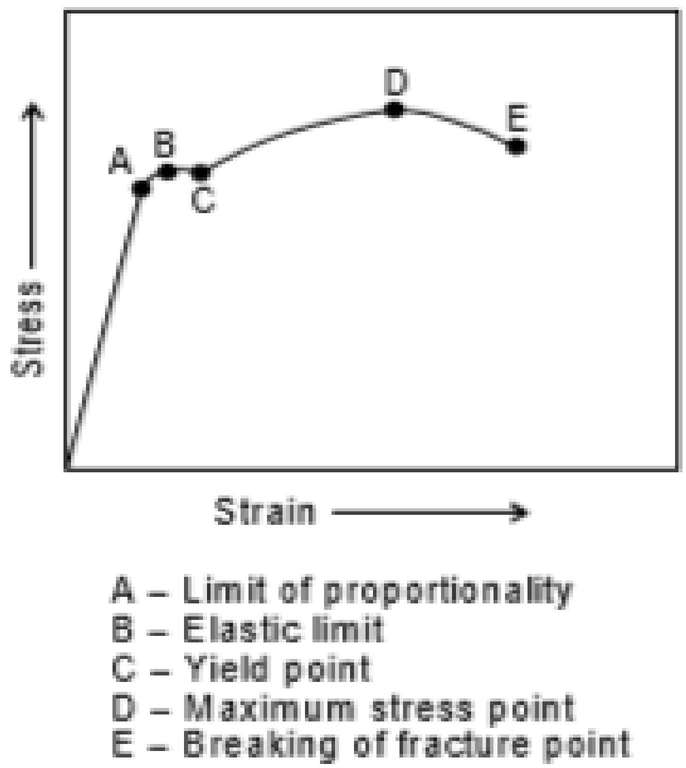


Fig 5 stress strain curve for ductile material

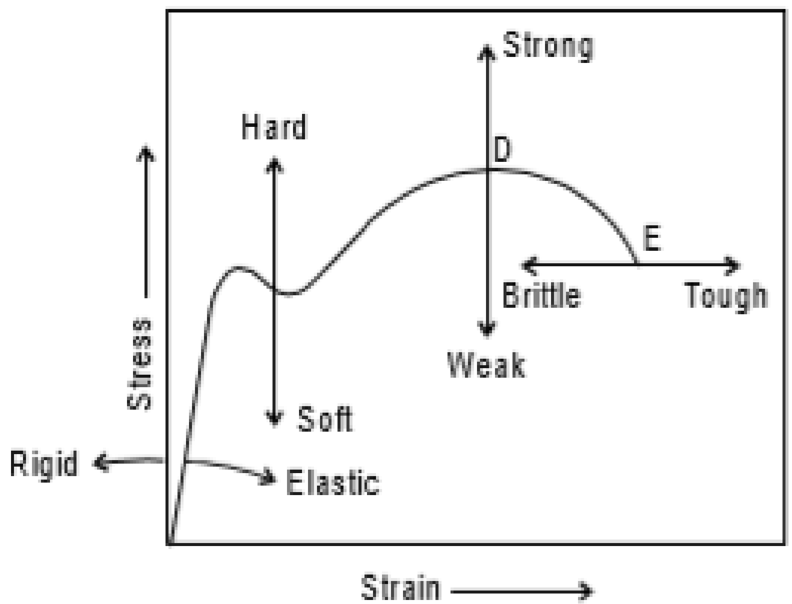


Fig 6 properties of ductile material

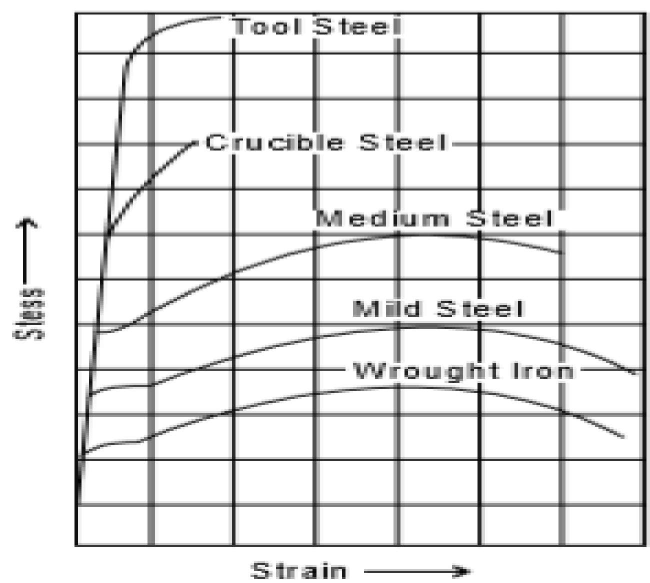


Fig 7 stress strain curve for wrought iron and steel

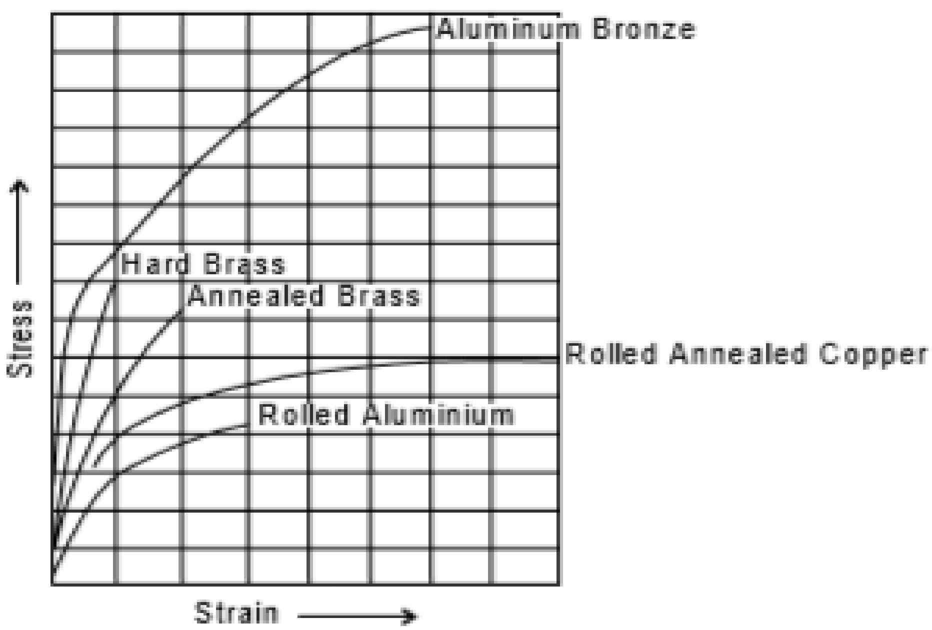


Fig 8 stress strain curve for non ferrous metal

3.1.2 Testing of Hardness

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

(d) Shore scleroscope

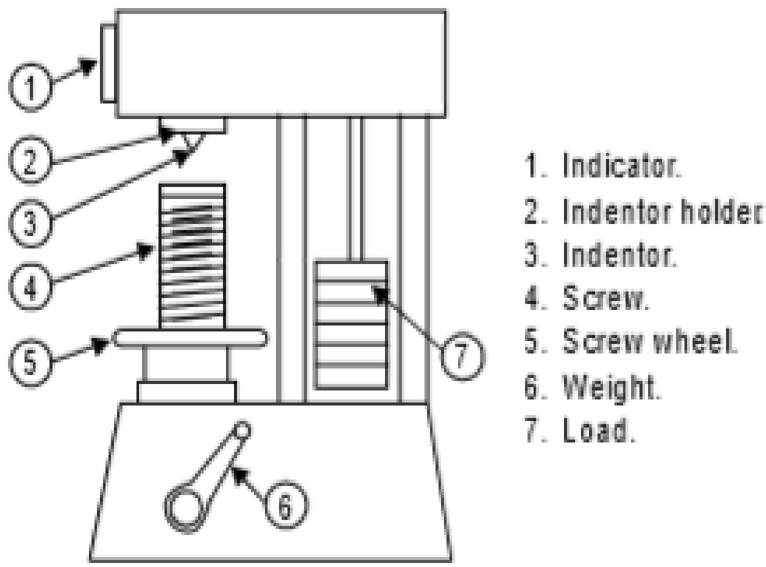


Fig 9 Rockwell hardness testing machine

3.1.3 Shear stress test

Because of the presence of submicroscopic cracks, brittle materials are often weak in tension, as tensile stress tends to propagate those cracks which are oriented perpendicular to the axis of tension. The tensile strengths they exhibit are low and usually vary from sample to sample. These same materials can nevertheless be quite strong in compression. Brittle materials are chiefly used in compression, where their strengths are much higher

3.1.4 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.

Fig. 10 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.

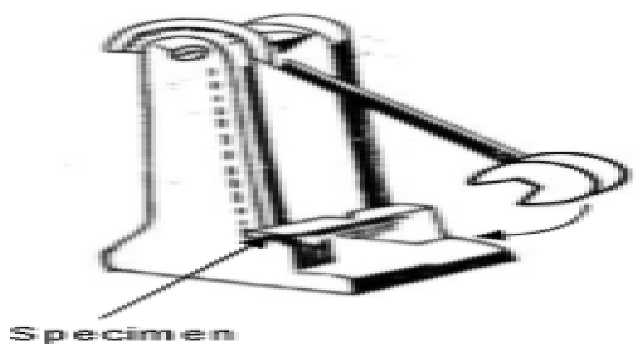


Fig 10 schematic impact testing machine setup

3.1.5 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

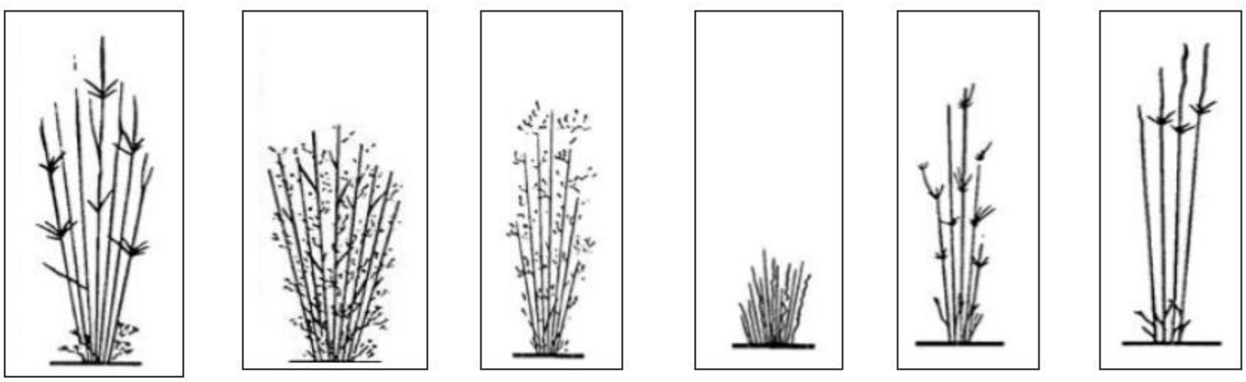
• Form of the sparks

• Colour of the sparks

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	

Table 2metal identification by spark test either a portable or stationary grinder



Low Carbon High Carbon Gray Cast Iron Nickel and Monel Stainless Steel Wrought Iron

Fig 11 metal identification by spark test either a portable or stationary grinder

Self-Check -1	Written Test

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 machine?
4. List at least three destructive and non-destructive testing machines?
5. Write the two common testing of impact strength machine?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1	Brinell hardness Test

MATERIAL: ASTM E10

PROCEDURE:

1) Using a large block of 1018 Cold Rolled Steel, perform five Brinell Hardness (5) tests and five (5) Rockwell Hardness tests.

2) When applying the load in the Brinell hardness test, ensure that the load is applied and released uniformly without bouncing the load and that the load is applied for fifteen (15) seconds.

To be included in the laboratory report:

1) Compute the Brinell hardness number (BHN):

2) Compare this value with the expected Brinell hardness number using the table on the next page and the Rockwell Hardness number.

METALS TEST DATA

Brinell hardness Test

(1) 1018 Cold Rolled Steel (large block)

Diameter of indented surface:

(1) ___________________

(2) ___________________

(3) ________________

(4) ________________

(5) ________________

Average: ________________

Information sheet 2	Comparing and recording basic material test results

3.2 Comparing and recording basic material test results.

A Material Safety Data Sheet (MSDS) is required under the U.S. OSHA Hazard Communication Standard. Most developed countries have similar regulations and requirements. The MSDS is a detailed informational document prepared by the manufacturer or importer of a hazardous chemical. It describes the physical and chemical properties of the product. MSDS's contain useful information such as flash point, toxicity, procedures for spills and leaks, and storage guidelines. Information included in a Material Safety Data Sheet aids in the selection of safe products, helps you understand the potential health and physical hazards of a chemical and describes how to respond effectively to exposure situations. Although there is an effort currently underway to standardizes MSDS's the quality of individual MSDS's vary. A MSDS may be useful but it can not substitute for prudent practices and comprehensive risk management.

MSDS Requirements are;

The requirements for MSDSs are found in paragraph (g) of 29 CFR 1910.1200 (See below for the full text of the regulation). MSDSs must be developed for hazardous chemicals used in the workplace, and must list the hazardous chemicals that are found in a product in quantities of 1% or greater, or 0.1% or greater if the chemical is a carcinogen. The MSDS does not have to list the amount that the hazardous chemical occurs in the product. Specifically.

In general, if your business uses hazardous chemicals (as opposed to manufacturing or importing them for sale to others) you should be able to obtain a MSDS from the manufacturer, so that you can post it in the workplace and keep it in your records.

If you are a manufacturer, who is looking for the MSDS form to create a sheet, OSHA's Hazard Communication Standard (HCS) specifies certain information that must be included on MSDSs, but does not require that any particular format be followed in presenting this information.

Observing OHS measures through the process in this unit.

Successfully managing health and safety in the workplace relies on commitment, consultation and co-operation. Everyone in the workplace needs to understand the need for health and safety, what their role is in making the workplace safer, and how they can fulfil their responsibilities and duties. Workers should be protected from occupational risks they could be exposed to. This could be achieved through a risk management process, which involves risk analysis, risk assessment and risk control practices. In order to carry out an effective risk management process, it is necessary to have a clear understanding of the legal context, concepts, risk analysis, assessment and control processes and the role played by all involved in the process. It is also desirable to base risk management on solid and tested methodologies.

Prevention of occupational risks

Within the context of their general obligations, employers have to take the necessary measures for the safety and health protection of workers, including prevention of occupational risks. This is a quite basic principle in the law of many countries. For instance, within the European Community, it was settled by the Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (Framework Directive 89/391/EEC), and then adopted by Member States' national laws. It should be noted that Member States can introduce more rigorous provisions to protect their workers.

For preventing occupational accidents and ill health, employers must perform risk assessment regarding safety and health at work, and decide on protective measures to take and, if necessary, on protective equipment to use. It is advisable that risk assessment should be done at least every year or every time a change is introduced in the workplace, for instance due to the introduction of new work equipment or procedure, or the use of a new chemical substance or preparation.

Preparation of the process

The preparation of the risk management process involves several activities, namely:

- Identification of exposed workers – particular attention should be given to:
- workers with special needs, such as pregnant women, young workers, aging workers and workers with disabilities;
- Maintenance workers, cleaners, contractors and visitors
- Characterization of tasks, work equipment, materials, and work procedures;
-
- Identification and characterization of safety measures in use;
- Identification of work accidents and occupational diseases related with the workplace in analysis; and
- Identification of legislation, standards or company regulations related to the workplace in analysis.

Several means can be used to support these activities. For instance:

- Direct observation while the job is being performed – walkthrough;
- Interviews with workers and managers;
- Check work accidents and occupational diseases records;
- Check equipment/machine technical data;
- Examine material safety data sheets regarding chemical substances used in workplace;

Self-Check -2	**Written Test**

Directions: **Answer all the questions listed below. (15 Points)**

I. <u>Give a short answer</u> (5 points for each)

1. What are the quantitative data in spread sheet to record?

2. Explain the severity level of problem report critical?

3. List reporting and recording material included?

Information Sheet-1	Define common heat treatment outcomes and applications.

LO.4. Define common heat treatment outcomes and applications

1. Identifying the most common *heat treatment* processes.

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 I- 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 workpiece.

The flowing of 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.

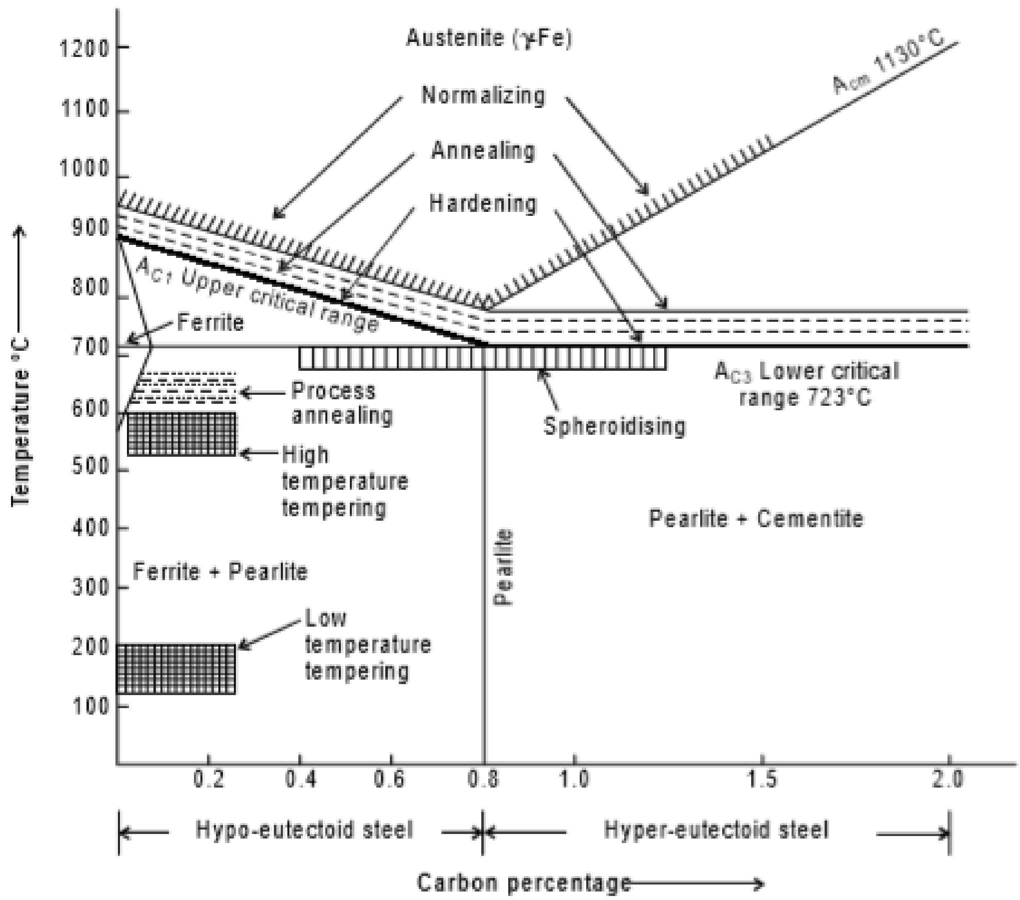


Fig. 12 shows the heating temperature ranges for various heat treatment processes

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.

Fig 12 shows the heating temperature ranges for normalizing process of both hypo and hyper carbon steel

Fig. 13 shows the structure obtained after normalizing of medium carbon steel.

Objectives

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

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.

Fig 12 shows the heating temperature ranges for annealing or softening process of both hypo and hyper carbon steel.

Fig. 14 shows the structure obtained after annealing of medium 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 recrystallisation or process annealing.

Objectives of 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.
5. Improve machinability.
6. 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 recrystallisation 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.

SPHEROIDIZATION

It is lowest temperature range of annealing process in which iron base alloys are heated 20 to 40°C below the lower critical temperature, held therefore a considerable period of time e.g. for 2.5 cm diameter piece the time recommended is four-hours. It is then allowed to cool very slowly at room temperature in the furnace itself. Fig 12 shows the heating temperature ranges for spheroidizing process of carbon steel. Fig. 14 shows the structure obtained after annealing of carbon steel. During this process, the cementite of steel which is in the combined form of carbon becomes globular or spheroidal leaving ferrite in matrix, thus imparting softness to steel. After normalizing of steels, the hardness of the order of 229 BHN and as such machining becomes difficult and hence to improve machining, these are spheroidised first and then machined. This treatment is carried out on steels having 0.6 to 1.4% carbon.

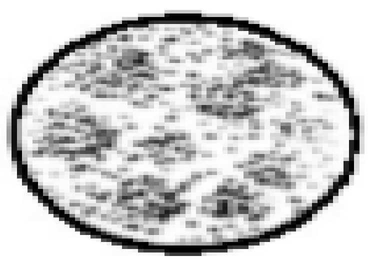


Fig 13 structure of normalized medium carbon steel

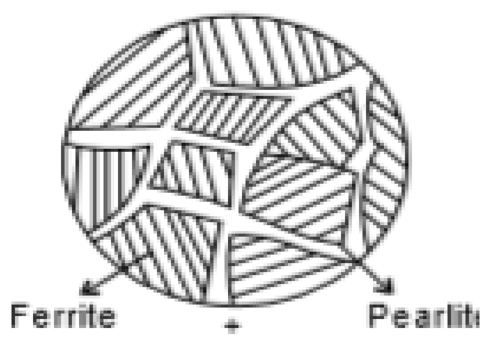


Fig 14 structure of annealed medium carbon steel

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

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.

Table-3The comparison between annealing and normalizing

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.

Fig 12 shows the heating temperature ranges for hardening process of both hypo and hyper carbon steel. Fig. 15 (a) shows the structure obtained on water quenching on hardening of medium carbon steel. Fig. 15 (b) shows the structure obtained on oil quenching on hardening of medium carbon steel. Fig15 (c) shows the structure obtained on water quenching on hardening of medium carbon steel and followed by tempering.

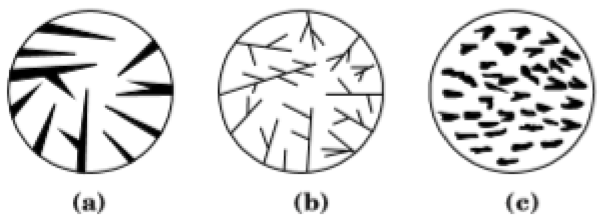


Fig 15 structure of hardened carbon steel

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 Fig. 16

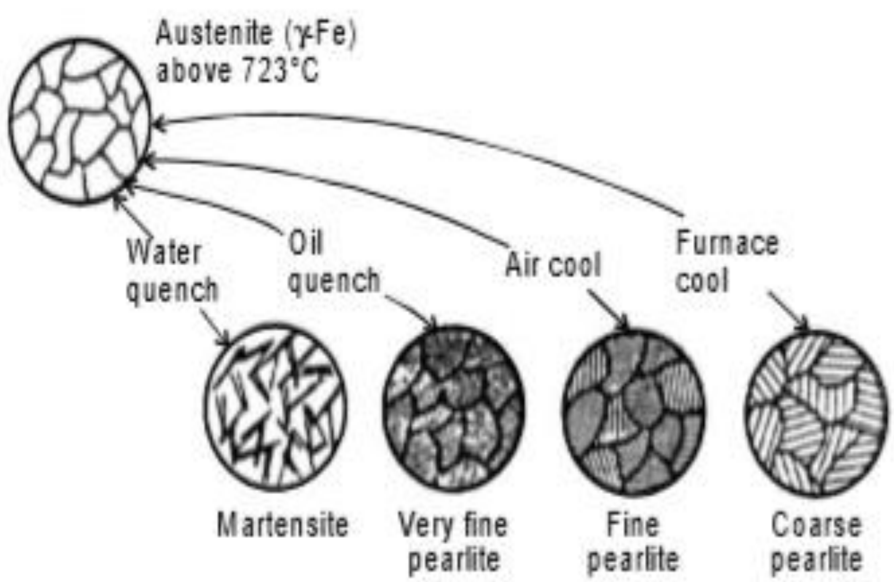


Fig 16 effect of cooling of austenitic transformation

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. After tempering structure is changed into secondary structure like martensite, troostite, sorbite and spheroidised. Fig. 17 shows different tempered states of martensite, troosite, sorbite and spherodite. Depending upon the temperature of reheat, the tempering process is generally classified in to three main categories.

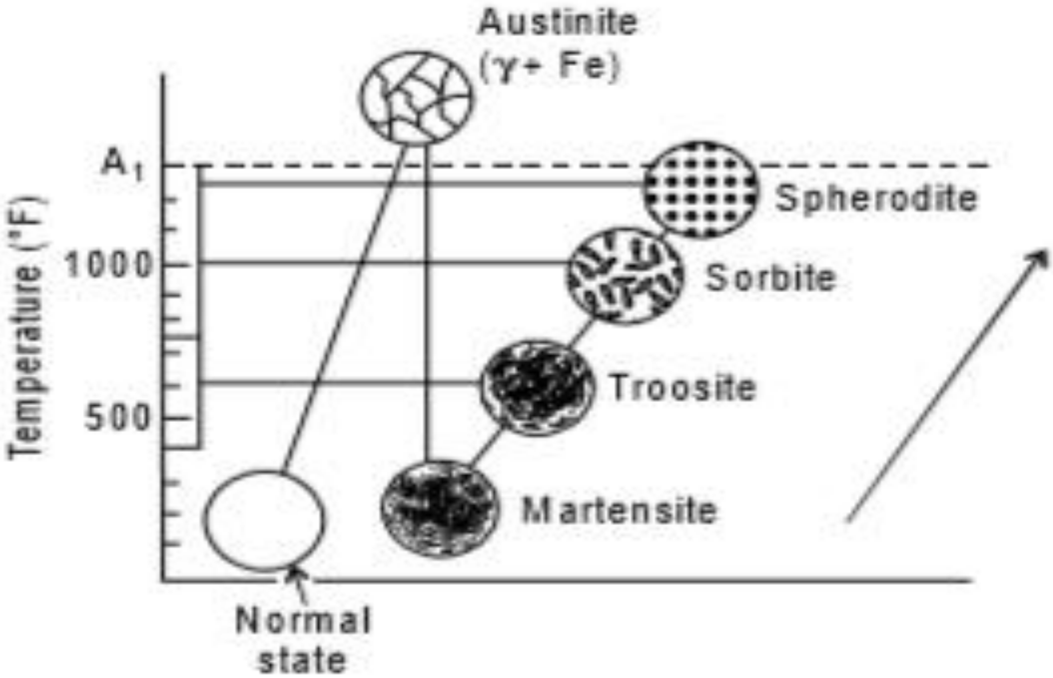


Fig 17 Structures of tempered states of martensite, troosite, sorbite and spherodite

. 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

(2) Nitriding.

(3) Cyaniding.

(4) Induction hardening.

(5) Flame hardening

Self-Check -1	Written Test

Directions: Short Answer Questions

1. Write the most common heat treatment process?
2. Mention at least four the purpose of annealing?
3. Write the different between hardening and annealing?
4. List at list four case hardening process?
5. Compare annealing and normalizing?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-2	• **Explaining the changes in metal properties caused by heating**

4.2 Explaining the changes in metal properties

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.

Successful heat treatment requires close control over all factors affecting the heating and cooling of a metal. This control is possible only when the proper equipment is available. The furnace must be of the proper size and type and controlled, so the temperatures are kept within the prescribed limits for each operation. Even the furnace atmosphere affects the condition of the metal being heat-treated.

The properties of metal caused by heating

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. To reduce tensile strength
7. To ease machining
8. To impart structure for subsequent hardening process
9. Relieve internal stresses
10. Reduce or eliminate structural in-homogeneity.
11. Refine grain size.
12. Increase or restore ductility and toughness

Self-Check -2	Written Test

Directions: Short Answer Questions

1. Discuss rapid cooling and slow cooling of metal that affects on the metal properties?
2. List down five the properties of metal caused by heating?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-3	Explaining the reasons for heat treatment use

4.3 Explaining the reasons for heat treatment use

The major objectives of heat treatment are given as

1. It relieves internal stresses induced during hot or cold working.
2. It changes or refines grain size.
3. It increases resistance to heat and corrosion.
4. It improves mechanical properties such as ductility, strength, hardness, toughness, etc.
5. It helps to improve machinability.
6. It increases wear resistance
7. It removes gases.
8. It improves electrical and magnetic properties.
9. It changes the chemical composition.
10. It helps to improve shock resistance.
11. It improves weldability.

Self-Check -3	Written Test

Directions: Short Answer Questions

1. Explain the reasons for heat treatment of metals? points 10

Note: **Satisfactory rating -5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

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4 MANUFACTURING PROCESSES R.C. Gupta

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This model TTLM was developed on September 04/01/2012 E.C at ADAMA