BASIC WELDING WORK
Level-I

Based on March 2022, Curriculum Version 1

Module Title: - Identifying Properties of Metals

Module code: IND BWW1 M020322

Nominal duration: 80Hour

Prepared by: Ministry of Labour and Skill

August, 2022

Addis Ababa, Ethiopia

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Acknowledgment

Ministry of Labor and Skills and Ministry of Health 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).

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Acronym

AISI- American Iron and Steel Institute and the

SAE- Society of Automotive Engineering's

BHN-Brinell Hardness Number

DPH-diamond-pyramid hardness number

VHN - Vickers hardness number

Kg- kilogram

HRC- Hardness Rockwell scale

P - Lode

mm- milometer

Nm- Newton Meter

Fig- Figure

Introduction to the Module

In Welding Work filed; the Testing and Identifying Properties of Metals project helps to know the classification common ferrous and non-ferrous metals; to Test basic applications and methods for manufacturing; to perform basic common metal tests; to define common heat treatment outcomes and applications

This module is designed to meet the industry requirement under the welding occupational standard, particularly for the unit of competency: Identifying Properties of Metals.

This module covers the units :

- Classification and properties of metal
- Test application and methods
- Basic Metal test
- Heat treatment and application

Learning Objective of the Module

- Identify Classification of metal
- Identify properties of metal
- applications and methods for manufacturing of metal property
- Perform metal testing
- Identify Heat treatment and application

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 one: Classification of ferrous and non-ferrous metals

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

- Classification Ferrous and non-ferrous metals and alloys
- Types of 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 types of metals and their application
- Identify their natural property of physical and mechanical, thermal and chemical property of metals

1. Classification of ferrous and non-ferrous metals

Introduction of 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. The most convenient way to study the properties and uses of engineering materials is to classify them into 'families' as shown in figure below:

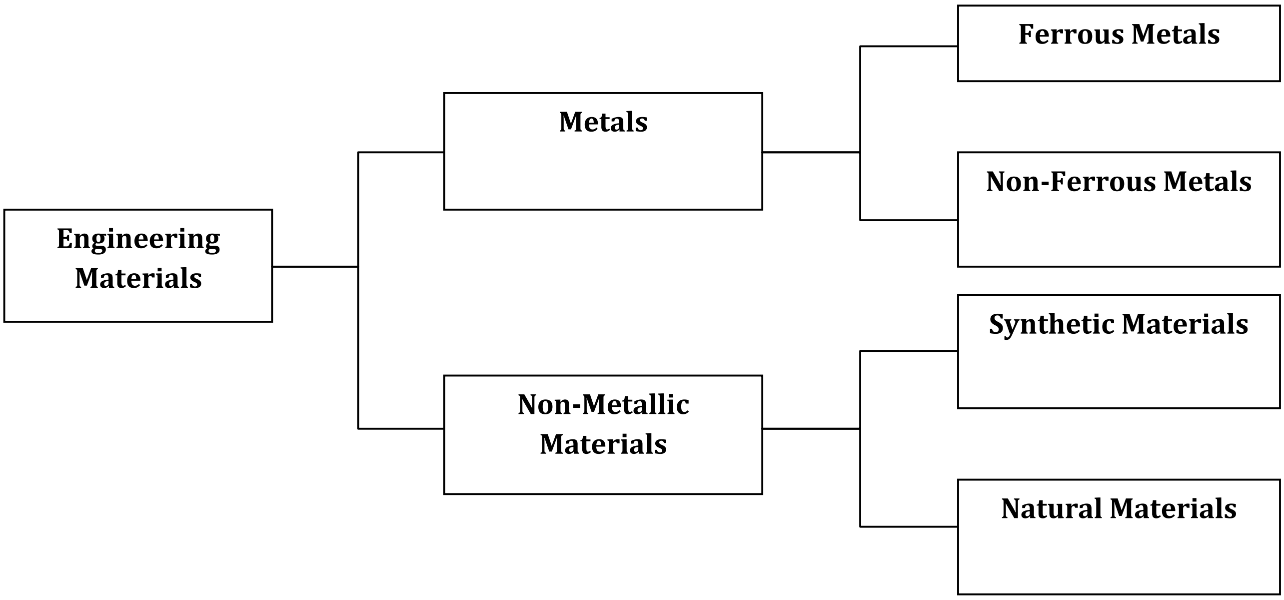


Figure 1Classifications of engineering materials

Metal

Metal is an element. There are over 118 known elements, and about 75 percent of them are classified as metals.

Alloy

An alloy is a mixture of two or more metals or of metals and one or more non-metals. The elements added to a metal to form an alloy may be either metal or non-metal. In most cases alloys have more desirable properties and are less expensive than pure metals.

Classification of metal

These metals can be broken down into four groups and classified as follows:

- Ferrous Metals
- Non-ferrous metals
- Ferrous Alloys
- Non-ferrous Alloys

1.1 Ferrous metals

These are metals and alloys containing a high proportion of the element iron. They are the strongest materials available and are used for applications where high strength is required at relatively low cost and where weight is not of primary importance. As an example of ferrous metals such as: bridge building, the structure of large buildings, railway lines, locomotives and rolling stock and the bodies and highly stressed engine parts of road vehicles. The ferrous metals themselves can also be classified into “families”, and these are shown in figure 2.

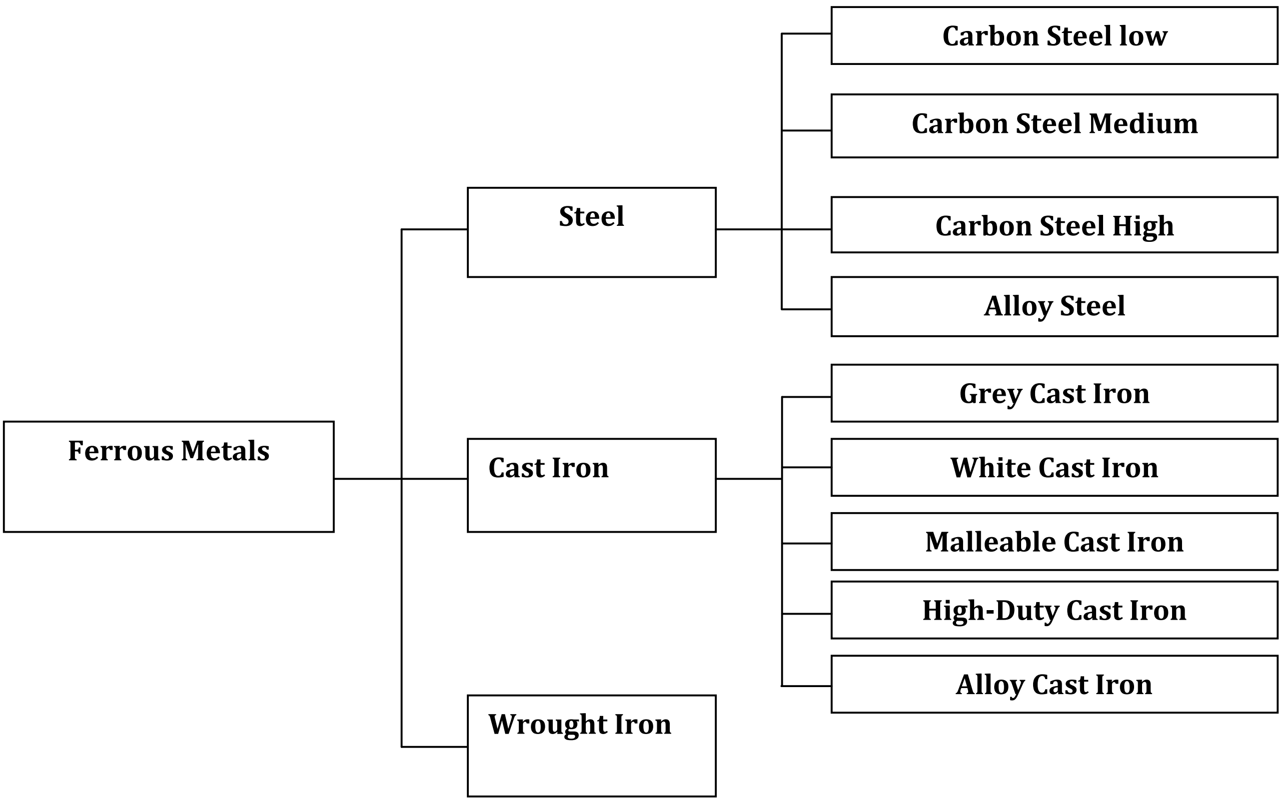


Figure 2 Classifications of Ferrous Materials

I. 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.

a) Low carbon steel, often called mild or soft steel, it contain 0.1 up to 0.3 per cent carbon. Low carbon steels are

- Have a lower tensile strength and hardness.
- Easy to welded, machined, and formed.
- Used for most bench metal

b) Medium carbon steel

It contains 0.3 up to 0.6 percent carbon. Medium carbon steels are used where strength and ductility are required. It is used for many standard machine parts & for projects like hammer heads and clamp parts.

c) High carbon

It contains 0.3 up to 0.6 percent carbon. High carbon steels have a higher tensile strength, hardness, and wear resistance but are low in ductility and have poor machinability.

II. Cast iron:-

It is a product of pig iron and contains a considerable amount of carbon and some impurities.

Cast iron is basically an alloy of iron and carbon and is obtained by re-melting pig iron with coke, limestone and steel scrap in a furnace known as cupola. The carbon content in cast iron varies from 1.7% to 6.67%. It also contains small amounts of silicon, manganese, phosphorus and sulphur in form of impurities elements.

General properties of cast iron

- Cast irons are difficult to weld.
- Cast iron is very brittle and weak in tension and therefore it cannot be used for making bolts and machine parts which are liable to tension.

- It has low cost, good casting characteristics, high compressive strength, high wear resistance and excellent machinability.
- The compressive strength of cast iron is much greater than the tensile strength.

There are four kinds of cast iron

a) Grey cast iron

b) White cast iron

c) Malleable cast iron

d) Ductile cast iron

e) Chilled cast iron

a) Gray cast iron

Gray cast iron is grey in color which is due to the carbon being principally in the form of graphite (C in free form in iron).

It contains:-

C = 2.5 to 3.8%. Mn = 0.4 to 1.0%

Si = 1.1 to 2.8 % P = less than 0.15% S = less than 0.1%

It is produced in cupola furnace by refining or pig iron.

Properties of gray cast iron

- When fractured it gives gray color.
- It can be easily cast.
- Low melting point
- Can be easily machined and possesses mach inability better than steel.
- Possesses lowest melting of ferrous alloys
- High resistance to wear
- Possesses high compressive strength

- Low tensile strength
- It has very low ductility and low impact strength as compared with steel.

Applications of gray cast iron

The grey iron castings are mainly used for machine tool bodies, automotive cylinder blocks, pipes and pipe fittings and agricultural implements. The other applications involved are

- Machine tool structures such as bed, frames, column etc.
- Household appliances etc…
- Gas or water pipes for underground purposes.
- Piston rings
- Rolling mill and general machinery parts
- Blocks and heads for engines.
- Frames of electric motor

b) White cast iron

It has a white appearance due to the form in which the carbon is present in the iron. White iron is usually cast in metal moulds which permit a rapid cooling rate so that the carbon remains in solution with the iron.

White iron is used for such purposes as chilled iron castings of rollers for rolling mills used in the production of steel plate.

It is extremely difficult to machine and the main purpose of white cast iron is to produce malleable iron.

C = 3.2 to 3.6%. Mg = 0.1 to 0.4%

Si = 0.4 to 1.1 % P = less than 0.3% S = less than 0.2%

Properties of White cast iron

- Its name is due to the fact that its freshly broken surface shows a bright white fracture.
- It is very hard due to carbon chemically bonded with iron as iron carbide (Fe_3C), which is brittle also.

- It possesses excellent abrasive wear resistance.
- Since it is extremely hard, therefore it is very difficult to machine.
- Its solidification range is 2650-2065°F.
- The white cast iron has a high tensile strength and a low compressive strength.

Applications of White cast iron

- For producing malleable iron castings.
- Railway brake blocks
- Heavy fabrication pipe joints

Figure 3, *White* cast iron product.

c) Malleable cast iron

Malleable iron is produced by placing white iron castings in an annealing furnace and subjecting them to temperatures above 870°c. The ordinary cast iron is very hard and brittle. Malleable cast iron is unsuitable for articles which are thin, light and subjected to shock. It can be flattened under pressure by forging and rolling .Typical uses for malleable iron are for pipe fittings & plumbing fixtures.

Properties of malleable cast iron

- Good corrosive resistance.

Applications of malleable iron

Malleable cast iron are generally used to form automobile parts, agriculture implementation, hinges, door keys, spanners mountings of all sorts, seat wheels, cranks, levers thin, waned components of sewing machines and textiles machine parts.

Figure 4, malleable cast iron product

d)* Ductile cast iron (Nodular*)

Ductile cast iron is also called as spheroid graphite iron. Its manufacturing process is very easy compared to other types. Its manufacturing process consists of manganese treatment which helps to increase the carbon content and opposes the formation of graphite in flaky form. It has very good engineering properties than malleable cast iron. Ductile cast iron has very good corrosion resistance, high strength and durability. So, usage of ductile iron dominates the other types. It is used for making sewer pipes, water conveying pipes etc.

Figure 5 ductile cast product

III. Wrought iron

Wrought iron is mechanical mixture of very pure iron and a silicate slag. It can also be said as a ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which a uniformly distributed quantity of slag is incorporated without subsequent fusion. This iron is produced from pig iron by re-melting it in the pudding furnace. Wrought iron is very ductile; forges well, can easily bend hot or cold, and can be welded.

Properties of Wrought iron

- excellent weldability
- good ductility and malleability
- Did not affect heat treatment. That is, cannot be hardened by heating and quenching.
- high tensile strength and compressive strength
- can be forged easily, and finally,
- Cannot take sudden loads.

Application of Wrought iron

It is used for making chains, crane hooks, railway couplings, and water and steam pipes.

It has application in the form of plates, sheets, bars, structural works, rivets, and a wide range of tubular products including pipe, tubing and casing, electrical conduit, cold drawn tubing, welding fittings, bridge railings.

Advantages and disadvantages of wrought iron

Advantages

Below are the benefits of wrought iron in its various applications.

- Toughness
- Excellent weldability
- High tensile strength
- High compressive strength

- Forged items are easily created.

Disadvantage

Despite the good advantages of wrought iron, some limitations still occur. Below are the disadvantages of wrought iron in its various applications:

- It cannot be hardened by heating and quenching
- It cannot take sudden loads

1.2 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. 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. Some widely used non-ferrous metals and alloys are classified as shown in figure 3.

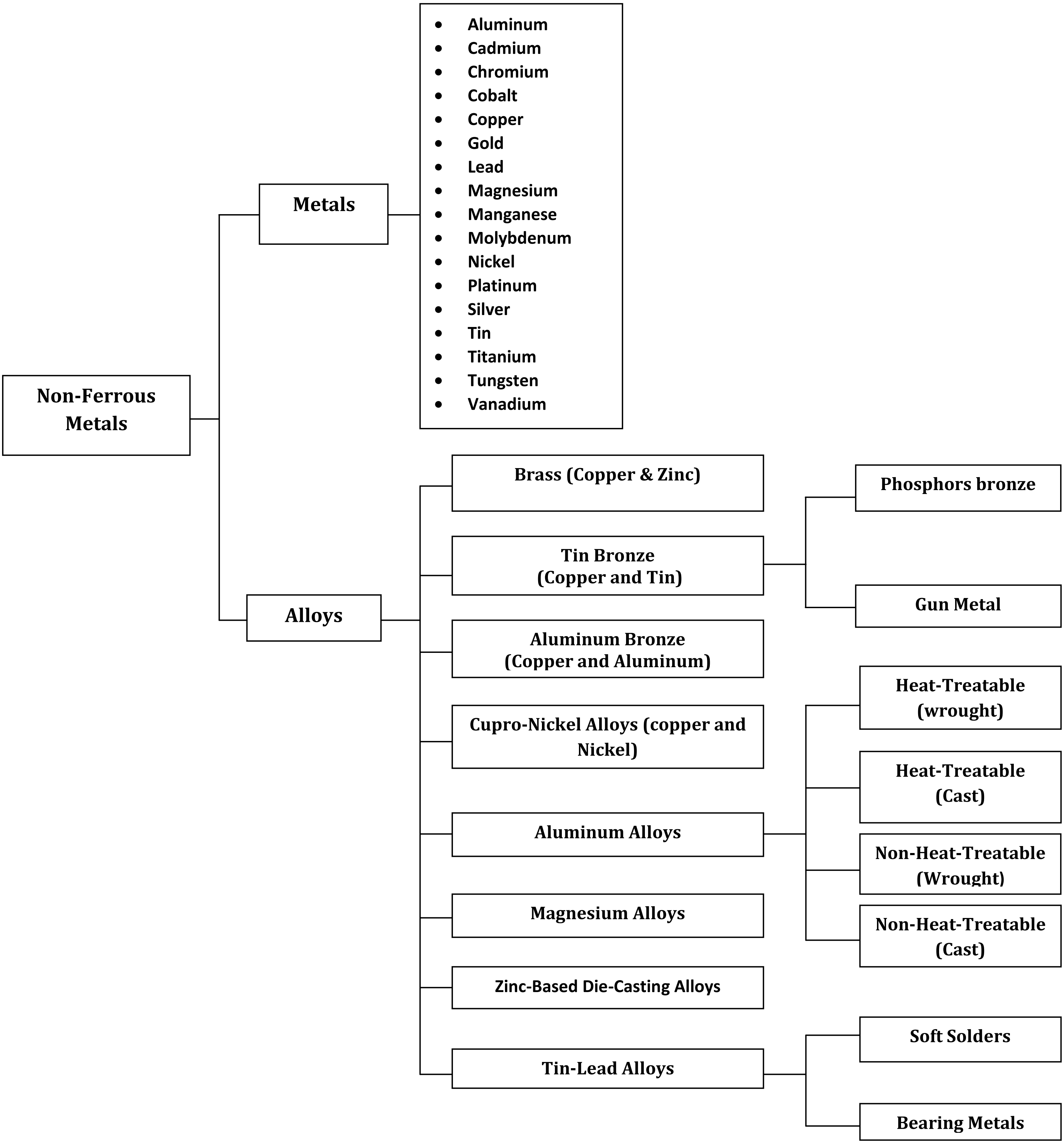


Figure 6 Classifications of Non-Ferrous Materials

I. 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 color.

Common Properties of copper are:

- high thermal conductivity:
- high electrical conductivity:
- good corrosion resistance:
- high 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 5to 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.

II. 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.

Properties of Aluminum are:

- Like a copper it is also corrosion resistant.
- It is very good conductor of heat and electricity although not as good as copper.
- Possesses high ductility and light weight so widely utilized in aircraft industry.
- Needs frequent annealing if cold worked since it becomes hard after cold working.
- 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 aluminum. 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.
- ***Magnesium***- This is an aluminum 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.

III. 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 following important nickel alloys are widely used in practice:

Types of some nickel alloys are

- Haste alloy,
- Monel metal,
- inconel,

- ni-chrome
- Nomonic etc……

• ***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.

IV. 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 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

V.ZINC

Zinc is bluish grey in color and is obtained from common ores of zinc are zinc blended (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, aluminum, 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.

VI. 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.

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.

1.3 Types of Metal properties

Metals in general have high electrical conductivity, thermal conductivity, luster and density, and the ability to be deformed under stress without cleaving. Chemical elements lacking these properties are classed as nonmetals.

A few elements, known as metalloids, sometimes behave like a metal and at other times like a nonmetal. Some examples of metalloids are as follows: boron, arsenic, and silicon.

As you have already studied, metals are divided into two classes, ferrous and nonferrous. Ferrous metals are those in the iron class and are magnetic in nature. These metals consist of iron, steel, and alloys related to them. Nonferrous metals are those that contain either no, or very small amounts of, ferrous metals.

Iron alloyed with various proportions of carbon gives low-, mid- and high-carbon steels, and as the carbon levels increase, ductility and toughness decrease. The addition of silicon will produce cast irons, while the addition of chromium, nickel, and molybdenum to carbon steels (more than 10%) results in stainless steels.

Since you will work mostly with alloys, you need to understand their characteristics. The characteristics of elements and alloys are explained in terms of physical, chemical, electrical, and mechanical properties.

Some basic properties of metals are:-

- Physical properties
- Chemical properties
- Mechanical properties
- Thermal properties
- Electrical properties
- Magnetic properties

1.3.1Physical 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.

a. Density

Mass per unit volume is called as density. In metric system its unit is kg/mm3.

b. Color

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

c. 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.

d. 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.

e. Porosity

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

1.3.2 Mechanical Properties

Under the action of various kinds of external forces, the behavior of the material is studied that measures the strength and lasting characteristic of a material in service. The mechanical properties of materials are of great industrial importance in the design of tools, machines and structures.

The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. The main mechanical properties of the metal are strength, stiffness, elasticity, plasticity, ductility, malleability, toughness, brittleness, hardness, formability, cast ability and weld ability.

a. Elasticity

It is defined as the property of a material to regain its original shape after deformation when the external forces are removed. It can also be referred as the power of material to come back to its original position after deformation when the stress or load is removed. It is also called as the tensile property of the material.

b. Plasticity

Plasticity is defined the mechanical property of a material which keep the deformation produced under load permanently. This property of the material is required in forging, in stamping images on coins and in ornamental work. It is the ability or tendency of material to undergo some degree of permanent deformation without its rupture or its failure. Plastic deformation takes place only after the elastic range of material has been exceeded. Such property of material is important in forming, shaping, extruding and many other hot or cold working processes. Materials such as clay, lead, etc. are plastic at room temperature and steel is plastic at forging temperature. This property generally increases with increase in temperature of materials.

c. Strength

Strength is defined as the ability of a material to sustain loads without undue distortion or failure. The internal resistance offered by a material to an externally applied force is called stress.

The capacity of bearing load by metal and to withstand destruction under the action of external loads is known as strength. The stronger the material the greater the load it can withstand.

This property of material therefore determines the ability to withstand stress without failure. Strength varies according to the type of loading. It is always possible to assess tensile, compressive, shearing and tensional strengths. The maximum stress that any material can withstand before destruction is called its ultimate strength..

d. Toughness

In materials science and metallurgy, toughness is the ability of a material to absorb energy and plastically deform without fracturing. Toughness is the strength with which the material opposes rupture. Strong materials are generally tough although ductility has a more pronounced effect in determining toughness.

e. Stiffness

It is defined as the ability of a material to resist deformation under stress. The resistance of a material to elastic deformation or deflection is called stiffness or rigidity. A material that suffers slight or very less deformation under load has a high degree of stiffness or rigidity. That means, the steel beam is stiffer or more rigid than aluminum beam.

A material which deforms less under a given load is stiffer than one which deforms more.

e. Ductility

Ductility is the capacity of a material to undergo deformation under tension without rupture as in a wire drawing operation.

A ductile material must be strong and plastic. The ductility is usually measured by the terms, percentage elongation and percent reduction in area which is often used as empirical measures of ductility. The materials those possess more than 5% elongation are called as ductile materials.

The ductile material commonly used in engineering practice are mild steel, copper, aluminum, nickel, zinc, tin and lead.

f. Malleability

Malleability is the ability of the material to be flattened into thin sheets under applications of heavy compressive forces without cracking by hot or cold working means.

It is capacity of a material to withstand deformation under compression without rupture.

A malleable material should be plastic but it is not essential to be so strong.

g. Hardness

Hardness is defined as the ability of a metal to cut another metal. A harder metal can always cut or put impression to the softer metals by good quality of its hardness. It holds many different properties such as resistance to wear, scratching, deformation and mach inability etc.

h. Brittleness

Brittleness is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. The materials having less than 5% elongation under loading behavior are said to be brittle materials.

Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Glass, cast iron, brass and ceramics are considered as brittle material.

i. 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.

l. Creep

When a metal part is subjected to a high constant stress at high temperature for a longer period of time, it will undergo a slow and permanent deformation (in form of a crack which may further circulate further towards creep failure) called creep

1.3.3 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

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.Hence matting point of metals is said to be the temperature at which metal starts to change from solid to liquid.

Table 1 melting points of some common metal

Elements	Melting points,^{0}c
Al	660
Ti	1660
Ni	1455
Fe	1539
CU	1083
Zn	419
Ag	232
Au	1063
Pb	327
W	3416

1.3.4 Electrical Properties

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

a. 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.

b. Temperature Coefficient of Resistance

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

c. 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.

d. Resistivity

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

e. Thermoelectricity

If two dissimilar metals are joined and then this junction is heated, a small voltage (in the mill-volt range) is produced, and this is known as thermoelectric effect.

1.3.5 Magnetic Properties

The magnetic properties of a substance can be determined by examining its electron configuration: If it has unpaired electrons, then the substance is paramagnetic and if all electrons are paired, the substance is then diamagnetic. The most common metals used for permanent magnets are iron, nickel, cobalt and some alloys of rare earth metals. There are two types of permanent magnets: those from “hard” magnetic materials and those from “soft” magnetic materials. “Hard” magnetic metals tend to stay magnetized over a long period.

Some important properties of a magnet are:

- It attracts magnetic substances.
- It points North-South direction when suspended freely.
- Poles of magnet are always in pair.
- Similar poles of magnet repel each other.
- Magnetic force can easily pass through non-magnetic substances

1.3.6 Chemical Properties

A chemical property is a characteristic of a particular substance that can be observed in a chemical reaction. Some major chemical properties include flammability, toxicity, heat of combustion, acidity, reactivity (many types), and chemical stability.

Corrosion

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

- 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 -1	Written Test

PART-I: Write "TRUE" if the statement is correct and "FALSE" if it is wrong statement. (----%)

1. High carbon steel provides high hardness and strength.
2. A ferrous and non-ferrous metal contains iron in their chemical compounds.
3. The copper is one of the most common non-ferrous metals.
4. Nickel is an example of non-ferrous metal.

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

Choose the correct answer for the following questions.

1. It contains 0.3 up to 0.6 percent carbon

A. Medium carbon steel
B. Plain carbon steels
C. High carbon steels
D. None

2. The basic principle raw material for all ferrous metal is
   A. Pig iron
   B. Cast iron
   C. Malleable
   D. iron All
3. Grey pig iron contains about _______% carbon in free form
   A. 4 %
   B. 3%
   C. 1%
   D. 2%
4. Which one of the following is correct about grey cast iron and white iron?
   A. Low in cost
   B. Very brittle
   C. cannot hammer
   D. All
5. Which one of the following is not correct about low carbon steel is
   A. Have a lower tensile strength and hardness
   B. It is easy welded machined, and formed
   C. It is used for most bench metal

D. None

6. Which one the following is not true about the properties of aluminum
   A. Good electrical conductivity
   B. Malleable and ductile
   C. Low thermal conductivity
   D. Resistance to corrosion
7. Copper is mainly used in
   A. Making electric cables and wires for electric machinery
   B. Motor Winding
   C. Electroplating
   D. All
8. Bronze is commonly an alloy of
   A. Copper and Aluminum B. copper and Tin C. Copper and Zinc D. Tin and Zinc
9. Which one of the following is not correct about mechanical properties of materials?
   A. Elasticity B. plasticity C. Density D. Strength
10. Which one of the following is true about metal identification?
   A. Magnetic test B. Visual test C. Spark test D. all

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

"Column A"	"Column B"
_____1. The property of breaking without warning	A. Elasticity
_____2. Combination of high strength and medium ductility	B Ductility
_____3.The capacity to be rolled or hammered into thin sheets	C Malleability
_____4The capacity to be drawn from a larger to a smaller diameter of wire.	D Toughness
	E. steel
_____5 Non-ferrous metal	F Brittleness
_____6. an alloy of CU and Zn	
_____7 an alloy of lead and tin	G Bronze
_____8.an alloy of CU and Sn	H Solder
_____9. Ferrous metal	I. Aluminum
_____10 The ability of material to return to its original size,	J. Brass

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.

.

Unit Two: Test basic applications and methods

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

- cutting tools for machine ability
- Test properties of manufacturability
- basic methods of process engineering materials
- Methods of manufacturing process

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:

- Select correct cutting tools for the machinability
- Test basics properties of manufacturability
- processing Carry out basic methods of engineering materials
- determine manufacturing methods

2. Test basic applications and methods

2.1. Cutting tools for the machine ability

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.

Selection of cutting tool

Proper manufacturing process selections are 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 mean 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.

2.1 Test properties of manufacturability

In order to test the material first we should have understand materials manufacturability, such as castability, 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.

2.1.1 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 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.

2.1.2 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 wieldable but some are more difficult than another. Steel is readily wieldable (in many ways) than aluminum 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

2.1.3 Forge ability

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.

2.3 Basic methods of processing engineering materials

Material deformation 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.

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

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

2.3.4 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).

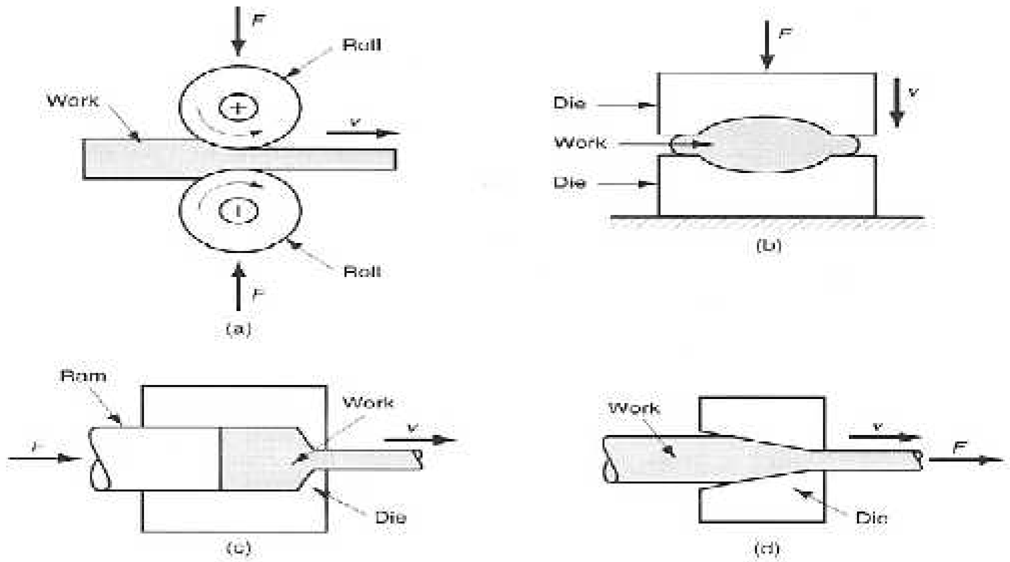
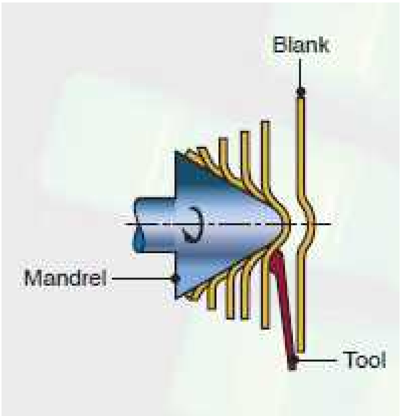


Figure 7(a) rolling, (b) forging, (c) extrusion, (d) drawing

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.



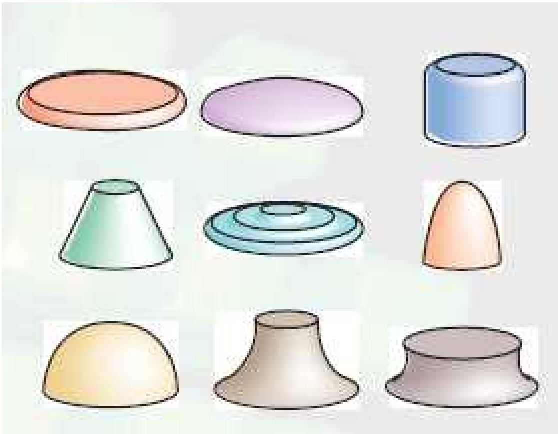


Figure 8 Typical shapes produced by the conventional spinning process

2.4 Methods of manufacturing processes

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 cheek-2	Written test

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

1. Cutting tool materials should have _______________properties.

   A. hardness and pressure resistance B. high temperature strength
   C. Reproducible wear behavior D. None of the above

2. Weld ability depends on

   A. nature of metals B. weld designs, C. welding techniques D skills

3. Deformation process in which the thickness of a plate is reduced by squeezing it through two rotating cylindrical rolls.

   A rolling B. Extrusion: C. drawing D Forging

4. A type of deformation process work material is forced to flow through a die opening taking its shape

   A. Forging B. Extrusion C Rolling: D. Drawing

5. The diameter of a wire or bar is reduced by pulling it through a die opening

   A. Drawing B. Forging C. Extrusion: D. Drawing

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

"Column A"	"Column B"
_____1, it is the ability to join easily	A. Cast ability
_____2, the ability to melt easily	B. Weld ability
_____3 makes tubular (axis-symmetric) parts	C. Forgeability
_____4, it is the ability compression without rupture	D. Metal spinning
_____5, the ability to remove material easily during the processes	E. Machine ability

PART-III- Short Answer Questions

1. Explain the difference between hot working and cold working (5 point)
2. What is a thermal process? (3 point)

LAP Test 2	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.

Unit Three: Basic metal tests

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

- Basic metal tests
- Record material test 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:

- perform basic metal tests
- Determine material properties
- Record and compare basic material test results

.

3. 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.

Testing of materials are generally classified in two categories.

1. **Destructive testing** (tensile test, hardness test, fatigue test, creep test and impact test)
2. **Non-destructive testing** (dye penetrate test, magnetic test, ultrasonic test, radiography, eddy current test etc.)

3.1.1 Testing of Hardness

Hardness usually implies resistance to deformation, resistance to permanent or plastic deformation or resistance to indentation.

There are three general types of hardness measurements depending upon the manner in which the test is conducted. These are

I. Scratch hardness
II. Indentation hardness
III. Rebound, or dynamic, hardness.

I. Scratch Hardness

Scratch hardness is the ability of a material to resist plastic deformation, usually by scratches and abrasion. one type of hardness test is the scratch hardness test, which measures the hardness of a material with the aid of a sharp object. This test measures how resistant a sample is to fracture or permanent plastic deformation due to friction.

Hardness is measured according to the Mohs scale. The Mohs scale is used to measure scratch hardness

- This consists of 10 standard minerals arranged in the order of their ability to be scratched.
- The softest mineral in this scale is talc (scratch hardness 1), while diamond has a hardness of 10. A fingernail has a value of about 2, annealed copper has a value of 3, and martensite a hardness of 7.
- A different type of scratch-hardness test measures the depth or width of a scratch made by drawing a diamond stylus across the surface under a definite load.

II. Indentation Hardness

There are different hardness tests are there for measuring hardness by in this category which are discussed one by one.

A. Brinell Hardness

Brinell hardness indicates the ability of a metal to resist permanent indentation deformation. The hardness shows the material's resistance to penetration by a spherical indenter under standardized conditions. Since Brinell hardness is a mechanical property, it also relates to the material's resistance to wear as well as plastic or permanent deformation, and the material's ability to indent or abrade another material.

The Brinell hardness test is used to determine hardness and is done by forcing a hard steel or carbide ball indenter of a specified diameter onto the test metal surface under a specified load. This is followed by measuring the diameter of the impression made on the metal surface. The hardness is expressed as Brinell hardness number, and is obtained by dividing the load in kilograms, by the surface area of the indention in square millimetres. Brinell numbers for commonly used metals range from HB 15 to 750. Typical values include:

- Pure aluminum = 15
- Mild steel = 120
- Hardened tool steel = 650–700
- Hard chromium plate = 1000
- Diamond = 8000

Brinell hardness is more important in materials with heterogeneous structures, and in particular those used in heavy trucks and bulldozers, forgings and castings, engine blocks and heads, rear-end housings, springs as well as various large and coarse surface parts.

- ❖ 10-mm-diameter steel ball at a load of 3,000 kg.
- ❖ For soft metals the load is reduced to 500 kg to avoid too deep an impression, and for very hard metals a tungsten carbide ball is used to minimize distortion of the indenter.
- ❖ The load is applied for a standard time, usually 30 sec.
- ❖ The diameter of the indentation is measured with a low-power microscope after removal of the load.
- ❖ The average of two readings of the diameter of the impression at right angles should be made.
- ❖ The surface on which the indentation is made should be relatively smooth and free from dirt or scale.
- ❖ The Brinell hardness number (BHN) is expressed as the load P divided by the surface area of the indentation.

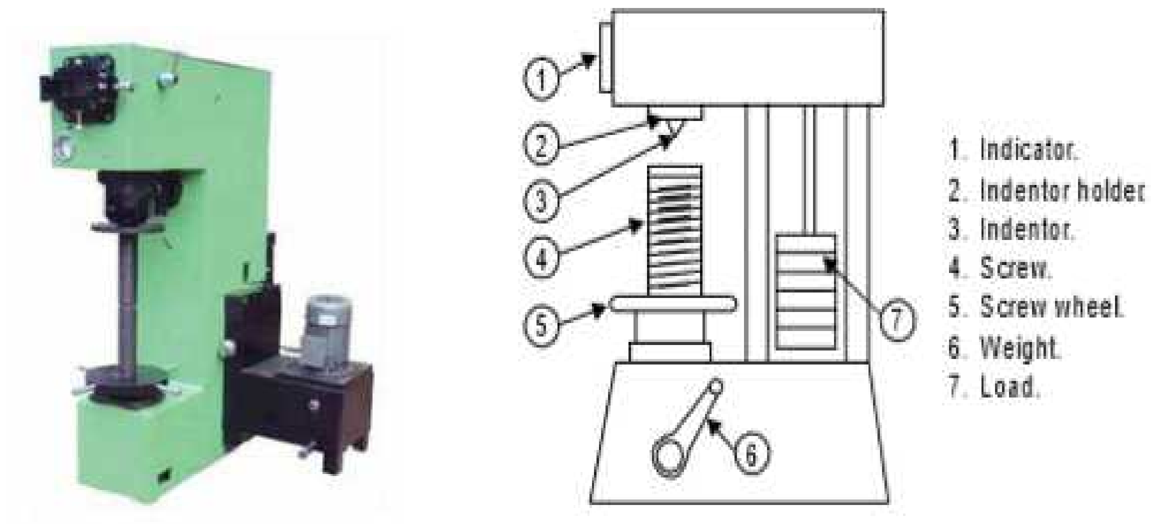
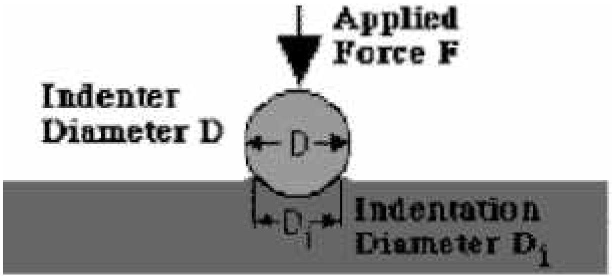


Figure 9 Brinell hardness machine



$$BHN = \frac{F}{\frac{\pi}{2} D \cdot (D - \sqrt{D^2 - D_i^2})}$$

Where F= applied load, kg D = diameter of ball, mm d = diameter of indentation, mm. Units of BHN are kilograms per square millimetre.

B. Vickers Hardness

- The Vickers hardness test uses a square-base diamond pyramid as the indenter. The included angle between opposite faces of the pyramid is 136°.
- This angle was chosen because it approximates the most desirable ratio of indentation diameter to ball diameter in the Brinell hardness test.
- Because of the shape of the indenter this is frequently called the diamond pyramid hardness test.
- The diamond-pyramid hardness number (DPH), or Vickers hardness number (VHN, or VPH), is defined as the load divided by the surface area of the indentation.

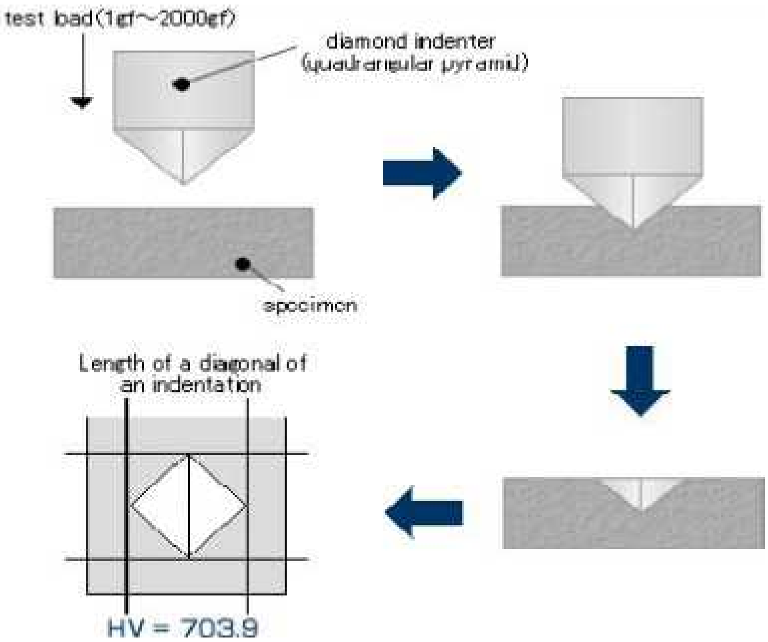
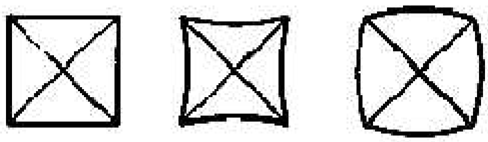


Figure 10 diamond-pyramid hardness

- The DPH may be determined from the following equation,
  - DPH = 2P sin ( ) / L2 = 1.854P/L2 θ

Where P = applied load, kg L = average length of diagonals, mm θ = angle between opposite faces of diamond = 136º

- A perfect indentation made with a perfect diamond pyramid indenter would be a square. (a)
- Pincushion indentation is due to sinking in of the metal around the fiat faces of the pyramid. This condition is observed with annealed metals and results in an overestimate of the diagonal length.
- The barrel-shaped indentation is found in cold worked metals. It results from ridging or piling up of the metal around the faces of the indenter. Underestimation diagonal length.



(a) (b) (c)

Figure 11 Rockwell hardness testing machine

C. Rockwell Hardness

- Its general acceptance is due to its speed, freedom from personal error, ability to distinguish small hardness differences in hardened steel, and the small size of the indentation, so that finished heat-treated parts can be tested without damage.This test utilizes the depth of indentation, under constant load, as a measure of hardness.
- A minor load of 10 kg is first applied to seat the specimen. This minimizes the amount of surface preparation needed and reduces the tendency for ridging or sinking in by the indenter. The major load is then applied, and the depth of indentation is automatically recorded on a dial gage in terms of arbitrary hardness numbers. The dial contains 100 divisions, each division representing a penetration of 0.00008 in. The dial is reversed so that a high hardness, which corresponds to a small penetration, results in a high hardness number.
- Unit less.

- A 120° diamond cone with a slightly rounded point, called a Brale indenter, and 1/16" diameter steel balls are generally used as indenters. Major loads of 60, 100, and 150 kg are used.

scale	Type of indenter	Major load(kgf)
A	Brale indenter	60
B	B 1/16" diameter steel ball	100
C	Brale indenter	150

Table 2 Type of indenter and loads

3.1.2 Spark Testing -grinder

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.

During this type of testing you should observe:-

a) Spark Color
b) Length of spark lines
c) Number of explosions
d) Explosion shape

It is an accurate method of identification

a) Sparks occur relative to oxidation of the heated metal particles
b) Iron does not oxidize rapidly therefore the spark lines are long and fade out with cooling

Figure 12spark test

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 3 metal identification by spark test either a portable or stationary grinder

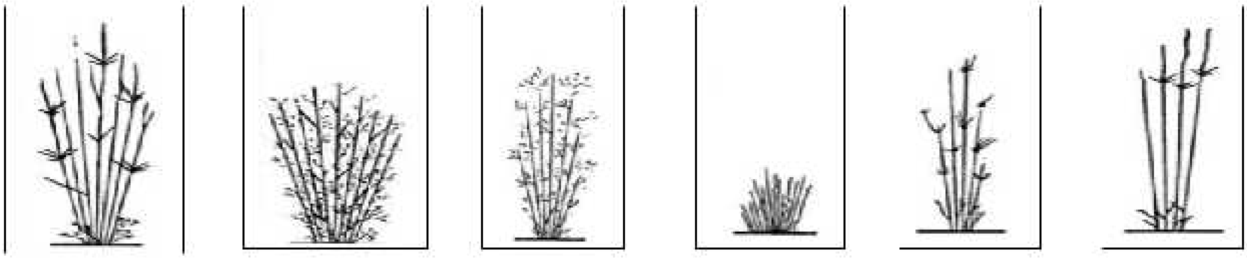


Figure 13 metal identification by spark test either a portable or stationary grinder

3.1.3 Tensile tester

Tensile testing is a destructive test process that provides information about the tensile strength, yield strength, and ductility of the metallic material. It measures the force required to break a composite or plastic specimen and the extent to which the specimen stretches or elongates to that breaking point.

The basic idea of a tensile test is to place a sample of a material between two fixtures called "grips" which clamp the material. The material has known dimensions, like length and cross-sectional area. We then begin to apply weight to the material gripped at one end while the other end is fixed.

Tensile testing provides data on the integrity and safety of materials, components and products, helping manufacturers ensure that their finished products are fit-for-purpose and manufactured to the highest quality. The data produced in a tensile test can be used in many ways including: To determine batch quality.

Measurement of tensile strength

Tensile strength is often referred to as ultimate tensile strength and is calculated by dividing the peak tension force the sample withstands by its cross sectional area. A tensile tester is used to measure tensile strength. A load cell is fitted to the tensile tester to measure tensile force. tensile strength is usually measured as the amount of force in pounds per square inch (psi) ormegapascals (MPa) required to pull a specimen to the point of material failure. This test is accomplished by placing a dumbbell shaped specimen into the grips, or jaws, of a tensometer.

The tensile strength is an intensive property, meaning that its value does not depend on the size of the test specimen. However, it is dependent on other factors such as (1) the preparation of the specimen, (2) temperature, and (3) the presence of surface defects.

Maximum and Minimum tensile strength

Tensile strength specifies the point at which a material goes from elastic to plastic deformation. It is expressed as the minimum tensile stress (force per unit area) needed to split the material apart.

The maximum stress, tensile or compressive, that can be applied to a metal without producing permanent deformation. When external forces act upon a material they produce internal stresses within it which cause deformation.

A strength test is carried out on standard tensile test specimen in universal testing machine. Fig.14 shows a schematic set up of universal testing machine reflecting the test specimen Griped between two cross heads. Fig.14 shows the stress strain curve for ductile material. Fig.15 shows the properties of a ductile material. Fig.16 shows the stress strain curves for wrought iron and steels. Fig. 17 shows the stress strain curve for non ferrous material.

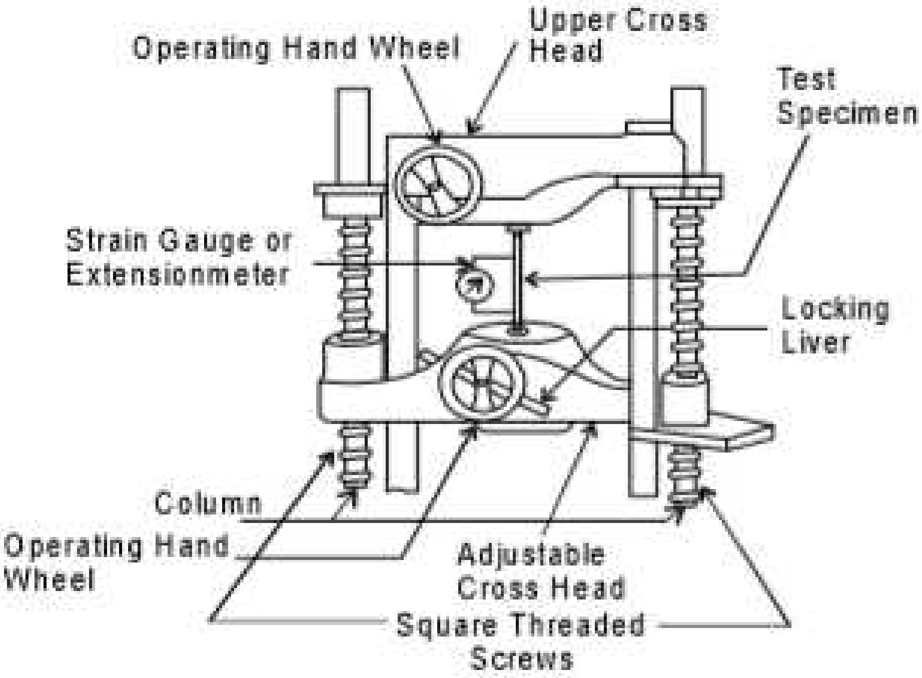


Figure 14 schematic universal testing machine

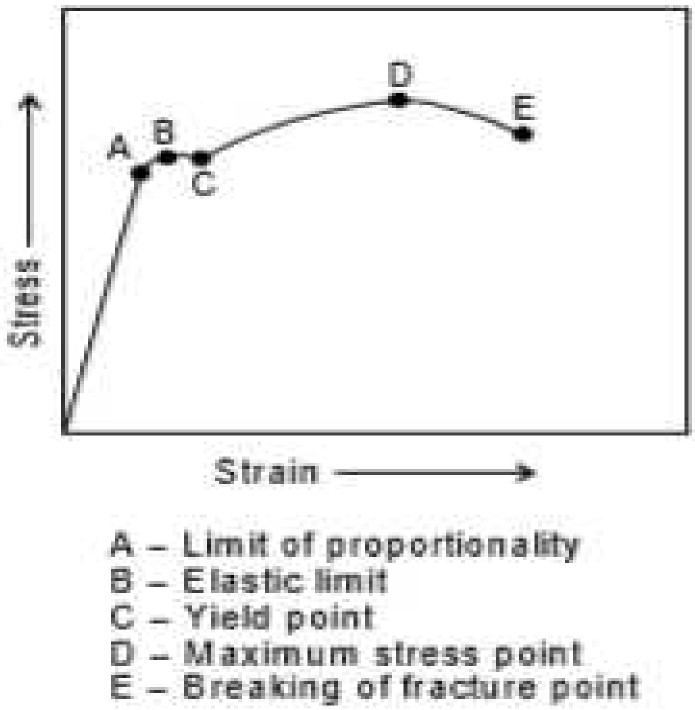


Figure 15 properties of ductile material

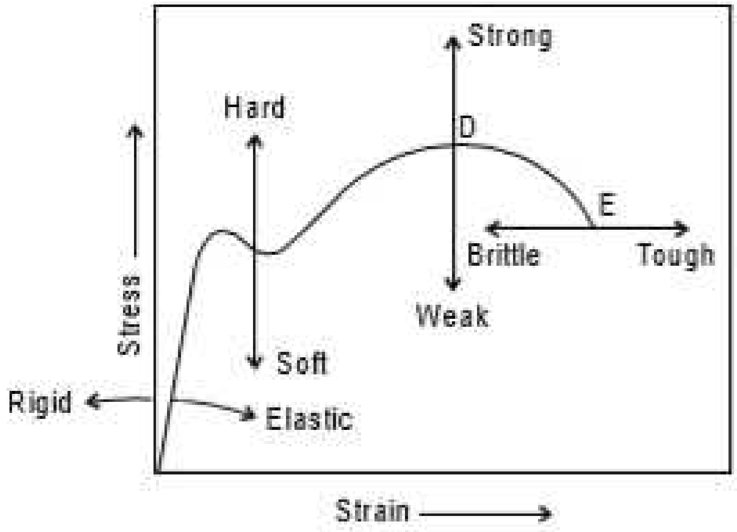


Figure 16 stress strain curve for ductile material

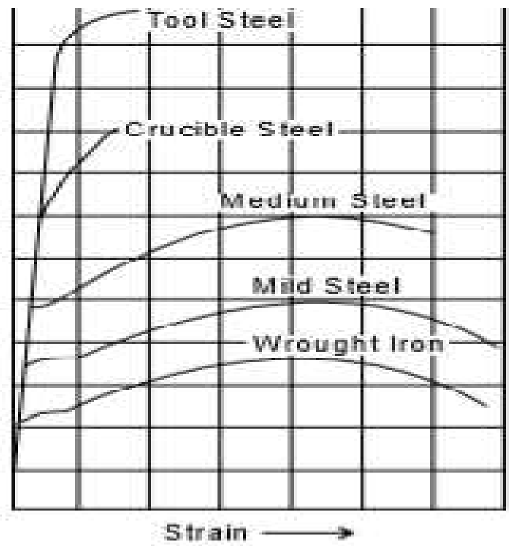


Figure 17 stress strain curve for wrought iron and steel

Error of tensile test

Travel measurements, required in stress-strain curves, elongation, and most other tensile tests, are subject to errors due to **system deflection**. These offsets originate from both the load cell and the test frame. Strain gage-based load cells, by their nature, deflect slightly as a load is applied.

3.1.4 Bending Testing

A bending test (bending tensile test) is a method of testing materials for their bending strength and other important properties. A destructive material testing is used for plastics fiber-reinforced plastics (FRP), metals and ceramic materials.

Bending is a manufacturing **process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most commonly sheet metal**. Commonly used equipment includes box and pan brakes, brake presses, and other specialized machine presses.

Bending tests are conducted by placing a length of material across a span and pushing down along the span to bend the material until failure. Bending tests reveal the elastic modulus of bending, flexural stress, and flexural strain of a material. the purpose of Bend testing a material allows for the determination of that materials ductility, bend strength, fracture strength and resistance to fracture.

3.1.5 Impact Testing

Shear tests are generally carried out **to measure the ability of an adhesive tape to resist creep under a constant load, applied parallel to the surface of the tape and substrate**. The purpose of this test is to compare the performance of an adhesive in a joint and to determine its mechanical response.

Shear testing is **performed to determine the shear strength of a material**. It measures the maximum shear stress that may be sustained before a material will rupture. Shear testing is commonly used with adhesives and can be used in either a tensile or comprehensive method.

The procedure in a direct shear test consists of;

1. placing a soil specimen in the direct shear device (shear box apparatus)
2. applying a predetermined normal stress,
3. providing the necessary conditions for wetting and/or draining of the specimen,
4. consolidating the specimen under the normal stress,

Types of Shear Tests and Drainage Conditions

- Direct shear test.
- Triaxial compression test.
- Unconfined compression test.
- Vane shear test

3.1.6 Impact Testing

Test of the ability of a material to withstand impact, used by engineers to predict its behavior under actual conditions. Many materials fail suddenly under impact, at flaws, cracks, or notches. The most common impact tests use a swinging pendulum to strike a notched bar; heights before and after impact are used to compute the energy required to fracture the bar.

Impact test **determines the amount of energy absorbed by a material during fracture**. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

There are two main forms of impact test, the **Izod** and the **Charpy** test. Both involve striking a standard specimen with a controlled weight pendulum travelling at a set speed. The amount of energy absorbed in fracturing the test piece is measured and this gives an indication of the notch toughness of the test material.

Both Charpy and Izod impact testing are **popular methods of determining impact strength, or toughness, of a material**. In other words, these tests measure the total amount of energy that a material is able to absorb. This energy absorption is directly related to the brittleness of the material.

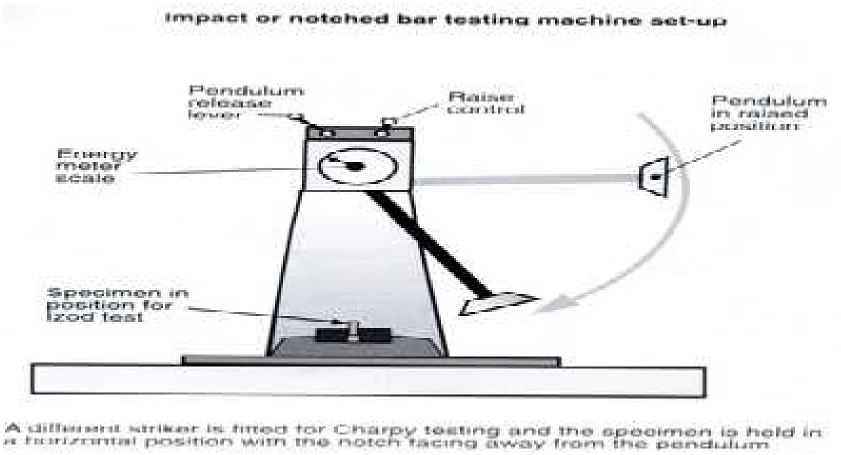


Figure 18 Charpy Testing

Measurement of impact strength

Impact strength is calculated by dividing impact energy in J (or ft-lb) by the thickness of the specimen. The test result is typically the average of 5 specimens. ISO impact strength is expressed in kJ/m2. Impact strength is calculated by dividing impact energy in J by the area under the notch.

Charpy test

The Charpy impact test is performed to evaluate the resistance of plastics to breakage by flexural shock according to standard test method ASTM. It indicates the amount of energy needed to break standard test specimens under specific conditions of specimen, mounting, notching and pendulum velocity at impact.

Factors Affecting Charpy Impact Energy

- Yield strength and ductility.
- Notches.
- Temperature and strain rate.
- Fracture mechanism

Izod test: - The Izod test is most commonly used ***to evaluate the relative toughness or impact toughness of materials*** and as such is often used in quality control applications where it is a fast and economical test.

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

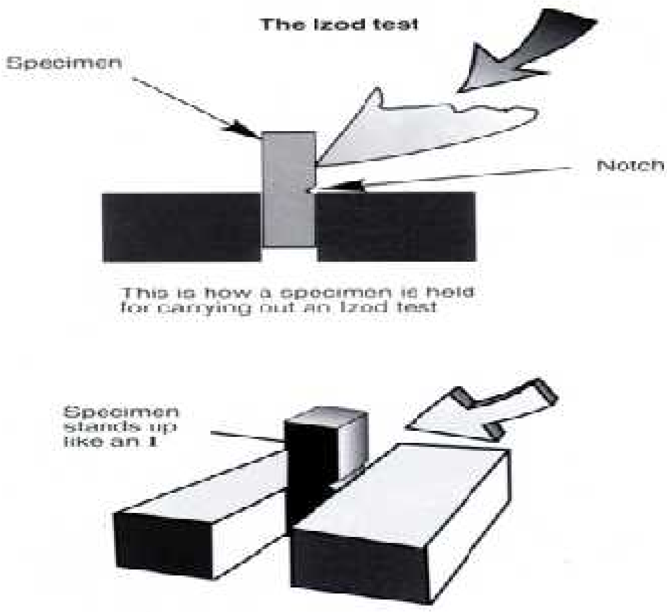


Figure 19 schematic Izod impact testing machine setup

3.2 Recording material test results.

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.

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 -3	Written Test

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

1. _______ test is fast, economical, convenient, easily accomplished, and requires no special equipment.

A. Impact Testing B. Brinell Hardness
C. Rockwell Hardness D Spark

2._____________is a type of hardness test uses a square-base diamond pyramid as the indenter

A. Vickers hardness B. Brinell Hardness. C. Rockwell Hardness D all

3. a type of material testing which resistance to permanent or plastic deformation.

A. Impact Testing B. tensile test C. hardness test D. spark test

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

A. Metallurgy. B. Engineering. C. Commercial. D. Legal departments. E. All

5. The information contained in the test report should include

A. Identification of the testing equipment B. The raw and calculated data for each specimen

C.Test procedure D. The material tested E. All

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

"Column A"	**"Column B"**
_____1.cannot used for thin materials.	A Destructive testing
_____2.used for soft materials	B Non-destructive testing
_____3.tensile test and hardness test	C Impact Testing
_____4.dye penetrate test and magnetic test	D Rockwell hardness tests
_____5.metal is subjected to suddenly applied load or stress, it may fail	E. Brinell hardness test

PART-III- Short Answer Questions

1. Explain the difference between Izod test and Charpy test
2. What is a thermal process?
3. Write the purpose of metal testing?
4. Mention at least three metal hardness testing machine?

Lap test 3.1

Name: ________________________ Date: _______________

ROCKWELL HARDNESS TESTS

Objective: To determine the Rockwell hardness number on B and C scales for a given metallic specimen.

Test Setup:

- ❖ Rockwell Hardness Testing Machine.
- ❖ Indenters:

  I. For Rockwell – B Test: Steel ball indenter of diameter $(1/16)^{th}$ inch.
  II. For Rockwell – C Test: Rockwell diamond cone of vertex angle 120^0 and tip radius 0.2 mm.

Standard Loads

Table 4 List of Material and load

SI NO	MATERIAL	For Rockwell –B test load kgf	For Rockwell – C test load kgf
1	Cast iron	-----	150
2	Mild steel	------	150
3	Brass	100	----
4	Gun metal	100	------
5	Aluminum	100	-------

Procedure:

1. Smoothen the surface of the specimen to be tested, and clean it to remove dirt and oil, if any.
2. Fix the appropriate indenter to the thrust member or penetrator.
3. Depending upon the material of the specimen and type of the indenter, select and set the required load stage, and see that the load lever is in position “A”.
4. Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction to have contact between specimen and the penetrator. Continue turning until the small pointer of the dial gauge reaches the red spot and the long pointer

comes to “0” mark on the dial gauge. This also indicates the application of a preload of 10 kg.

5. Turn the load lever from position “A” to position “B” to apply the main load on the specimen.
6. Wait for the long needle of the dial gauge to reach a steady position.
7. Release the main load by bringing back the load lever from position “B” to position “A” slowly.
8. Record the reading shown by the long pointer
   - on red scale for Rockwell – B Test
   - on black scale for Rockwell – C Test.
9. Turn the main nut in the counter clock wise direction and remove the specimen.

Note:

A. One division of Rockwell B or C scale is equal to a depth of indentation of 2 micron.
B. Rockwell hardness should be designated by HR, preceded by the hardness value and supplemented by a letter indicating the scale.

Ex: 60 HRC indicates Rockwell hardness of 60 on C scale.

Observations and Calculations:

I. Rockwell – B Test

Type of indenter Steel ball of diameter (1/16)th inch.

MATERIAL (Specimen)	**Load P,kg**	**Load P, N**	**Red scale reading ‘n’**	**Hardness value, n**	**Depth of indentation =(130-n) x 2 microns**
Brass					
Gun metal					
Aluminum					

II. Rockwell – C Test

Type of indenter Rockwall diamond cone of vertex angle 120^o

MATERIAL (Specimen)	Load P, kg	Load P, N	Red scale reading 'n'	Hardness value, n	Depth of indentation =(100-n) x 2 microns
Cast iron					
Mild steel					

Results and Conclusion:

____

____

____

Lap test 3.2

Name: ________________________ Date: ______________

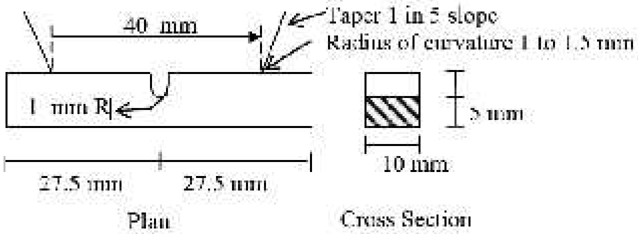
IMPACT TEST

Objective: - To determine the impact energy/Impact strength of a given test specimen by (a) Izod test (b) Charpy test

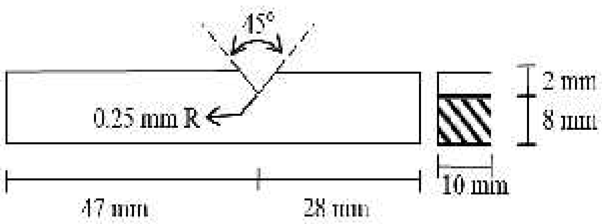
Theory: Definitions: Impact load, Impact energy, Impact strength, Toughness.

Test Set Up:

- Pendulum type impact testing machine. The machine consists of:
  - A pendulum of mass 18.748 kg, length = 825 mm with an angle of swing of 160o.
  - Specimen holder (different for Izod and Charpy tests)
  - Striking edge (different for Izod and Charpy tests)
  - Lock lever and pendulum releaser.
  - Pendulum brake.
  - A calibrated dial to measure the Impact energy, with red and black indicators.
  - Slide Calipers and Scale
- Standard Specimen for Charpy test:



- Standard Specimen for IZOD test:



Procedure:

1. Check the specimen for the its standard dimensions.
2. Depending upon the type of test, fix the corresponding striking edge to the hammer.
3. To find the frictional loss:

- Raise the pendulum to its highest position where it gets locked. At this position, the potential energy stored in the pendulum is 30 Nm.
- Set the dial to read 30 Nm with the indicator showing black colour.
- Press the lock lever first and then the pendulum releaser to release the pendulum.
- Stop the oscillations of the pendulum using the damper plate / brake.
- Record the reading on the dial which indicates the frictional loss directly.

Note: Read the black or red scale according as the indicator is black or red respectively.

i) Fix the specimen in its holder.

a) For Izod Test: The specimen should be placed vertically as a cantilever with the shorter end of the specimen projecting above the holder and V-Notch on the tension side.
b) For Charpy Test: The specimen should be placed horizontally as a simple beam and the U-notch on the tension side.

Note: Use the appropriate centraliser to keep the specimen in its proper position.

i. Raise the pendulum to its highest position where it gets locked. Set the dial to read 30 Nm with the indicator showing black colour.
ii. Release the pendulum by pressing down the lock lever first and then the pendulum releaser to strike the specimen.
iii. Use the damper plate / brake to stop the oscillations of the pendulum.
iv. Record the dial reading on the red or black scale depending upon whether the indicator is red or black respectively.
v. Observe whether the specimen has broken completely or not.

Note:

1. Utmost care must be taken to see that no person is present in the line of oscillation of the pendulum.
2. During the test, if the test piece is not completely broken, the impact value obtained is indefinite. Then the test report should state that the test piece was unbroken by joules, in case of Izod test, and the test report should state that the test piece was not broken by the striking energy of the testing machine, in case of Charpy test.

Observations and Calculations:

1. Material of the specimen : _____________
2. Mass of the pendulum : - 18.748 kg
3. Length of the pendulum :- 825 mm
4. Angle of swing : 160o
5. Frictional loss = Uf=_____________

I. Izod Impact Test:

Specimen no	Specimen dimensions	Observation reading u_o Nm	Impact energy or Impact valueU_I =U_O-U_f		Remarks
			Nm	Joules	

Table 5 Izod Impact Test result

I. Charpy Impact Test

Specimen No.	Specimen dimensions	Cross sectional dimensions of the specimen n below	Area of cross-section below the notch A	Observed reading U_0 Nm	Impact energy U_I=U_o-U_f Nm	Impact strength KU=U_I/A kg m mm	Remark

Table 6 charpy Impact Test result

Unit Four: Metal heat treatment and applications

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

- heat treatment processes and application
- Metal properties caused by heating
- Reasons for heat treatment

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:

- Identify the heat treatment processes and uses.
- Identify changes in metal properties caused by heating
- reasons for heat treatment

4.1 Heat treatment processes and application

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

- Stage l- heating of the metal slowly to ensure a uniform temperature
- Stage-2 Soaking (holding) the metal at a given temperature for a given time and cooling the metal to room temperature
- 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 machinable properties in job piece hence the properties of the job piece may requires heat treatment such as annealing for inducing softness and machinability property in work piece. **The flowing are 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.

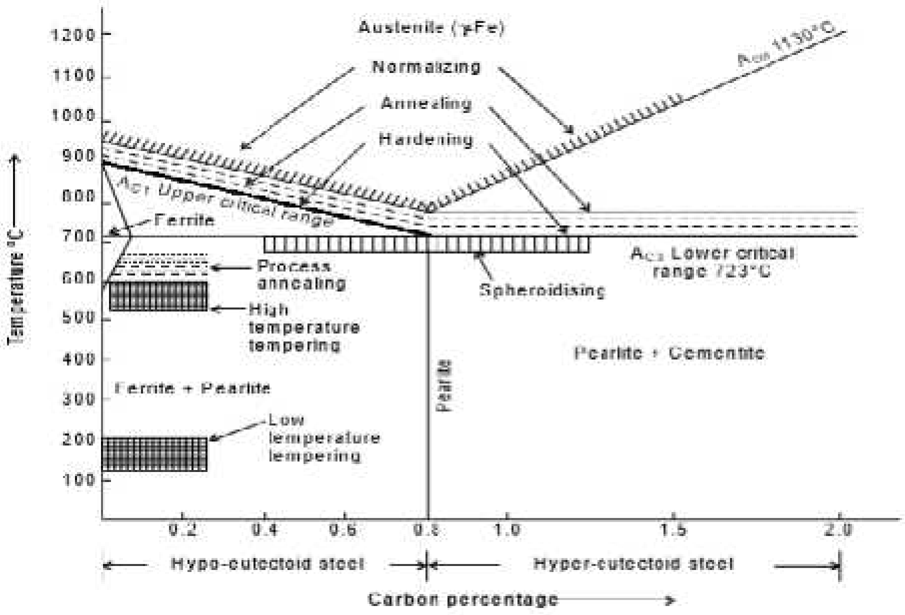


Figure 20 shows the heating temperature ranges for various heat treatment processes

4.1.1. 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.

It improves mechanical and electrical properties, machinability & tensile strength. Normalizing is the process of heat treatment carried out to restore the structure of normal condition.

Objectives

- To soften metals
- Refine grain structure
- Improve machinability after forging and rolling
- Improve grain size
- Improve structure of weld
- Prepare steel for sub heat treatment

Procedure for Normalizing:-The steel is heated to a temperature of about 40° to 50°C above its upper critical temperature. It is held at this temperature for a short duration. The steel is then allowed cool in still air at room temperature, which is known as air quenching.

Application of Normalizing

- It is applied castings and forgings to refine grain structure and to relieve stresses.
- It is applied after cold working such as rolling, stamping and hammering.

4.1.2 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 main aim of annealing is to make steel more ductile and malleable and to remove internal stresses. This process makes the steel soft so that it can be easily machined.

The purpose of annealing is to achieve the following

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

Annealing is of two types

1. Process annealing
2. Full annealing.

1. 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.

2. full annealing

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.

Procedure for Annealing

Depending on the carbon content, the steel is heated to a temperature of about 50° to 55°C above its critical temperature range. It is held at this temperature for a definite period of time depending on the type of furnace and nature of work. The steel is then allowed to cool inside the furnace constantly.

Application of annealing

It is applied to castings and forgings

4.1.3 Hardening

Hardening: The main aim of the hardening process is to make steel hard tough. In this process, steel is heated 30° – 40°C above the upper critical temperature and then followed by continues cooling to room temperature by quenching in water or oil. It is the opposite process of annealing**.**

Fig 18 shows the heating temperature ranges for hardening process of both hypo and hyper carbon steel. Fig. 18 (a) shows the structure obtained on water quenching on hardening of medium carbon steel. Fig. 18 (b) shows the structure obtained on oil quenching on hardening of medium carbon steel. Fig18 (c) shows the structure obtained on water quenching on hardening of medium carbon steel and followed by tempering.

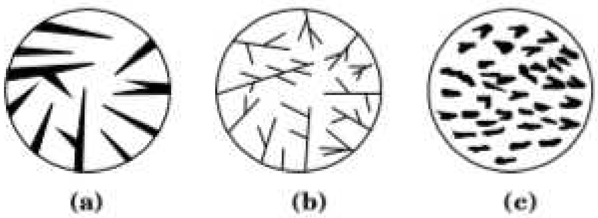


Figure 21 structure of hardened carbon steel

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. 19

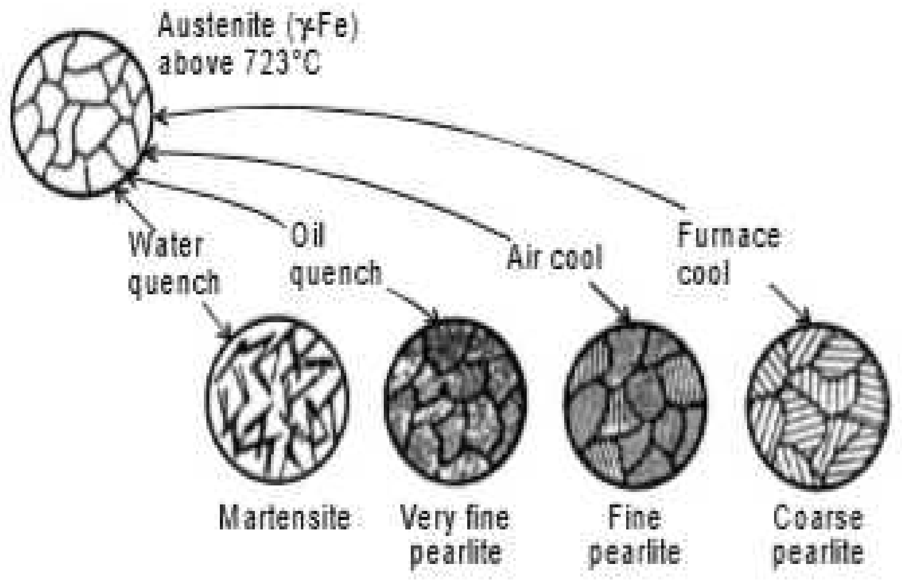


Figure 22 effect of cooling of austenitic transformation

Purpose of Hardening

- By hardening, it increases the hardness of steel.
- To resist to wear
- Allows the steel to cut other metals

Procedure for Hardening

The steel is heated above its critical temperature range. It is held at that temperature for a definite period of time. The steel is then rapidly cooled in a medium of quenching.

The quenching medium is selected according to the degree of hardness desired. The air, water, bring, oils and molten salts are used as quenching mediums. A thin section such knife blades are cooled in air. Water is widely used medium but it results in the formation of bubbles on the surface of the metal.

Hence brine solution is used to prevent this. Oil is used when there is a risk of distortion on cracks and is suitable for alloy steels. The molten salts are used to cool thin section to obtain crack-free and impact-resistant products.

Application of Hardening

It is applied for chisels, sledgehammer, hand hammer, centre punches, taps, dies, milling cutters, knife blades and gears.

4.1.4 Tempering

Tempering: When the hardening process hardens a steel specimen, it becomes brittle and has high residual stress. It is an operation used to modify the properties of steel hardened by quenching for the purpose of increasing its usefulness.

The tempering is divided into three categories according to the usefulness of steel required.

- Low-temperature tempering.
- Medium temperature tempering.
- High-temperature tempering.

Purpose of Tempering

- To relieve internally stressed caused by hardening.
- To reduce brittleness.
- Improve ductility, strength and toughness.
- To increase wear resistance.
- To obtain desired mechanical properties.

Procedure for Tempering

The steel after being quenched in the hardening process is reheated to a temperature slightly above the temperature range at which it is to be used, but below the lower critical temperature. The temperature here varies from 100°C to 700°C.

The reheating is done in a bath of oil or molten lead or molten salt. The specimen is held in the bath for a period of time till attains the temperature evenly, the time depends on the composition and desired quality of steel. Now the specimens is removed from the bath and allow to cool slowly in still air.

Application of Tempering

It is applied to **cutting tools, tools, and gears,** which are hardened by the hardening process.

4.1.5 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.

- ❖ Carburizing
- ❖ Nitriding.
- ❖ Cyaniding.
- ❖ Induction hardening.
- ❖ Flame hardening

❖ **Carburising**

In carburization, the hardness of the metal piece is increased by increasing the carbon content. The metal piece is heated below the melting point with high carbon materials such as charcoal. The heated metal piece then absorbs carbons to make it more hard and brittle.

❖ **Nitriding**

Nitriding is the process of the case or surface hardening in which nitrogen gas is employed to obtain hard skin of the metal. In this process, steel is heated in the presence of ammonia environment.

Due to this, a nitrogen atom is deposited and makes material hard. Induction hardening and Flame hardening objects are heated by an oxy-acetylene flame.

Purpose of Nitriding

- To harden the surface of the steel to a certain depth.
- Increase resistance to wear and fatigue.
- To increase corrosion resistance.

Procedure for Nitriding

It is done in the electric furnace where temperature varying between 450° and 510°C is maintained. The part is well machined and finished and placed in an airtight container provided with outlet and inlet tubes through which ammonia gas is circulated.

The container with the part is placed in the furnace and ammonia gas is passed through it while the furnace is heated.

During the process of heating nitrogen gas is released from ammonia in the form of atomic nitrogen, which reacts with the surface of the part, and forms iron nitrate. The depth of entrance depends upon the length of time spent at the nitriding temperature. The part is taken out and it does not require any quenching or further heat treatment.

Application of Nitriding

It is applied for hardening the surface of medium carbon alloy steels.

❖ **Cyaniding**

Cyaniding: In this process, steel is heated in the presence of sodium cyanide environment. Due to this, carbon and nitrogen atoms are deposited on the surface of steel and make it hard.

- **Purpose of Cyaniding**
  - This method is effective for increasing the fatigue limit of medium and small-sized parts such as gears, shafts, wrist pins etc.
  - To increase surface hardness.
  - Increase wear resistance.
  - To give the clean, bright and pleasing appearance to the hardened surface.

- **Produce for Cyaniding**

The parts to be treated is dipped in a molten cyanide salt bath maintained at a temperature of 950°C. The molten salts used are sodium chloride, sodium carbonate, sodium cyanide and soda ash. The immersed article is left in the molten cyanide salt at a temperature of 950°C for about 15 to 20 minutes. The decomposition of sodium cyanide yield nitrogen and carbon from carbon monoxide, which is diffused into the surface resulting in hardening the surface. The part is then taken out of the bath and quenched in water or oil.

- **Application of Cyaniding**

It is applied to small articles like gears, bushing, screws, pins and small hand tools, which require a thin and hard wear-resisting surface.

- ***Flame Hardening***

Inflame hardening, only a portion of the metal piece is hardened. This is different from differential hardening where the whole metal piece getting hardened by the different heat-treatment processes.

- **Quenching**

Quenching is a process of cooling a metal piece quickly after it was heated. Quenching helps metals to become harder or softer depending upon whether it’s a ferrous or non-ferrous alloy. In the case of ferrous alloy, quenching helps to make it harder, but it becomes softer in the case of non-ferrous.

For quenching, the metal needs to be heated above the upper critical temperature and then cool rapidly under forced air, water, oil, nitrogen, etc., depending upon the type of alloy and the desired mechanical properties. Sometimes when you do quenching too quickly, metal forms crack due to excessive internal stress.

4.2 Metal properties caused by heating

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

4.3 Rreasons for heat treatment

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 -4	Written Test

PART-I:

Write "TRUE" if the statement is correct and "FALSE" if it is wrong statement. (----%)

1. Case herding of non ferrous materials can be done easily as compare to that of ferrous metal
2. Quenching involves submerged a heated metl in a liquid to speed up its cooling process.
3. Heat treatment is a process which alters mechanical properties of metal by changing the product
4. Proper equipments with close control must be implemented in the heat treatment of metal
5. In heat treatment of metal quenching is method which induce ductility in metal

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

1. what is the purpose of annealing process

 A. to increase hardiness B. for surface hardness
 C. to decrease machine ability D to remove internal stress

2. the machine tool guide ways are usually hardend by
 A. Induction hardening C. Vacuum Hardness
 B. flame Hardness D. martempering
3. What is the effect of heat treatment on a metal?
 A. improvement availability C. decreased color
 B. Improvement physical properties D. decreased availability
4. The information contained in the test report should include
 A. Identification of the testing equipment C. Test procedure
 D. The material tested E. All
 B. The raw and calculated data for each specimen
5. Caseharden refers to __________the material, after which necessarily heat treatment is done to it.
 A. annealing B. critical range

C. caberzing D. hardening

6. What is the various stage of heat treatment?
   A. Heating, Cooling and Quenching
   B. Heating. soaking and Quenching
   C. Quenching, Cooling and Heating
   D. soaking Quenching and Cooling

7. Fastest cooling is obtainable by cooling in
   A. Water
   B. Air
   C. Brine
   D. None

8. Cyaniding and nitriding are method of which of following process
   A. Harding
   B. Case Harding
   C. tempering
   D. normalizing

9. The hardness of steel increases
   A. by slow cooling in air
   B. by fast cooling in air
   C. by increasing the carbon percentage
   D. All

10. in which of the following type of heat treatment, more depth of hardness is achieved for
    A. Nitriding
    B. Carburising
    C. Chrome plating Induction
    D. Harding

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

"Column A"	**"Column B"**
______1. Tempering	A. strengthening
______2. Quenching	B. Toughening
______3. Annealing	C. Hardening
______4. normalizing	D. softening
______5. Case hardening	E. soft and tough

PART-III:

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?

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