CHAPTER 7: MATERIAL SCIENCE AND METALLURGICAL PROCESSES

7.1 Introduction of the Unit of Learning /Unit of Competency

Material science is the investigation of the relationship among processing, structure, properties, and performance of materials. This unit prepares the trainee to be able to select a material for a given use based on considerations of cost and performance, understand the limits of materials and the change of their properties with use, and create a new material that will have some desirable properties. This branch of science encompasses; determining the structure, measuring the properties of materials, devising suitable ways of processing them i.e. creating materials, transforming existing materials and making useful things out of them, thus materials scientists think about how a material is suited to the purpose it serves already and how it may be enhanced to give better performance for particular applications.

All engineers are involved with materials on a daily basis: They manufacture, process materials, design and construct component or structures using materials, analyze failures in materials. This unit is meant to create awareness to trainees on the types of materials available, to understand their general behavior and capability and to recognize the effects of the environment and service condition and the material performance

7.2 Performance Standard

Test and analyze properties of engineering materials as per material testing method and operation standards procedures, Tabulate, calculate and interpret material testing results, maintain testing machines while observe safety procedures according to OSHA.

7.3 Learning Outcome

7.3.1 List of Learning Outcomes

a. Analyze properties of engineering materials
b. Perform ore extraction processes
c. Produce iron materials
d. Produce alloy materials
e. Produce non-ferrous material
f. Produce ceramic material
g. Produce composite material
h. Utilize other engineering materials
i. Perform heat treatment
j. Perform materials testing
k. Prevent material corrosion

6.3.1.1 Learning Outcome No.1 Analyze Properties of Engineering Materials

Learning Activities

Learning Outcome No1 Analyze Properties Of Engineering Materials	
Learning Activities	**Special Instructions**
Activity 1 Identify materials as per procedures and determine their physical properties Materials emery paper bulb electrical cable magnet ferrous and nonferrous materials , polymers, Metals and alloys ceramics composites	Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace Outline the safety of the engineering materials
Activity 2 Test engineering material properties Determine the Yield Strength, Proportional Limit, Modulus of Elasticity, and Ultimate Strength for each metal.	**EQUIPMENT:** Universal Testing Machine Extensometer (with dial indicator) Blade micrometer, Scale (mm) Dividers Gauge mark punch Hammer **MATERIALS:** Two standard tensile specimens: choose steel, aluminum, brass, or cast iron

Information sheet: 7.3.1.1

Broad classification of engineering materials

Materials are classified into groups, and according to structure, or properties, or use. Based on the mechanical, physical, chemical and manufacturing properties materials are selected according to the application. These types of materials include;

Metals
Ceramics
Polymers
Semiconductors
Composite materials
Advanced materials

Metals – steel, Al, Mg, Zn
Have good electrical and thermal properties
High strength
High stiffness
Are ductile and thus formable
Are shock resistance
Desirable properties in metals can be improved by a combination of metals – alloys.

Ceramics – Bricks, glass, table ware, ceramics, abrasives.
Have low electrical and thermal conductive thus used as insulators.
Strong and hard but brittle.
Have high excellent resistance to high temperature.
Have unusual optical and electrical properties thus used in constructing ICs.

Polymers: Rubber, plastics and adhesives.
Produced by polymerization process that involves creating large molecular structures for organic molecules.
Have low electrical and thermal conductors.
Have low strength.
Thermoplastic are ductile and formable (softer/fuse when heated and harden or becomes rigid again when cooled.)
Thermosetting (becomes permanently hard and rigid when heated or cooled) are strong and brittle.

Semiconductors: Silicon, germanium.
Are brittle but good for electronics, computer and communication application.
Have a controlled electrical conductivity suitable for devices such as transistors, diodes and integrated circuits.

Composite materials: Concrete, plywood, fiber glass, carbon fiber – reinforced polymers

Formed from 2 or more materials aimed at producing properties that cannot be obtained by any single material.
They have light weight, strong and ductile.
High temperature resistance material

Advanced Materials:

Materials used in "High-Tec" applications, usually designed for maximum performance, and normally expensive. Examples are titanium alloys for supersonic airplanes, magnetic alloys for computer disks, special ceramics for the heat shield of the space shuttle, etc.

Properties of engineering materials

Engineering materials are the backbone of an industry, for an engineer it's not possible to keep detailed knowledge of thousands of materials, as well as keep the detailed knowledge of thousands of materials already available as well as keep in touch with new developments discoveries and inventions .therefore to select the most promising materials the evaluation of service condition followed by evaluation of material characteristics and properties

Categorized as either:
Mechanical properties
Physical properties

Mechanical properties:
Describe how a material responds to an applied force. They include strength, ductility, stiffness, impact,fatigue,endurance,creep,malleability,elasticity,toughness,Brittleness,plasticityhardness ,stiffness,resilience
Other mechanical properties include;
Impact – Sudden intense blow,
Fatigue – Cycling continually through an alternating form,
Creep – Exposed to high temperature,
Wear – Subjected to abrasive conditions.

Physical properties:

This depends on structure and processing. They Are inherent in a material and are determined by the electron structure and bond. They include color, luster, density, electric and thermo conductivity, texture, melting point, electrical resistivity.

Tasks

(i) Read more on various mechanical and physical characteristics of materials,

(ii) Experiments carry out various mechanical properties tests using the necessary apparatus/machines

Structure of materials

Atomic structure – Arrangements of electrons surrounding the nuclear affect most of the physical properties. Types of bonding-primary and secondary bonds

Primary bonds –*discuss the various types of bonds-ionic, covalent, metallic*

Secondary bond *Discuss types of secondary bonds*

Crystalline state of metals or metallic space lattices

Crystal structure-regular and repetitious pattern in which groups of atoms of crystalline materials arrange themselves

Space lattice- a distribution of points/atoms in three dimensions if every point has identical surrounding

Unit cell- the fundamental grouping of atoms which is repeated indefinitely in all three dimensions in a crystal's space lattice

The common metal crystallize in one of the three main types of metallic space lattices these are:

Body centred cubic(B.C.C.)

Face centred cubic (F.C.C.)

Hexagonal close packed (H.C.P)

Draw the space lattices and give examples of metals in each category

Dendritic solidification of pure metal

Nuclei formation

Dendrite formation

Dentrite growth

Liquid between the arms of the dendrite solidifies giving homogeneous grains with no evidence of dendrite growth, except where shrinkage occurs ,with the formation of dentritic porosity

Further reading on the following Content;

classification of engineering materials, types of materials, properties of engineering materials, structure of materials, analysis of crystal structure, application of materials, safety

Further reading on defects or imperfections in crystals. R.S. Khurmi and J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

Self-Assessment

1.The tendency of a deformed solid to regain its actual proportions instantly upon unloading known as ______________

a) Perfectly elastic
b) Delayed elasticity
c) Inelastic effect
d) Plasticity

2. The permanent mode of deformation of a material known as _____________
   a) Elasticity
   b) Plasticity
   c) Slip deformation
   d) Twinning deformation

3. The ability of materials to develop a characteristic behavior under repeated loading known as ___________
   a) Toughness
   b) Resilience
   c) Hardness
   d) Fatigue

4. What effect does the addition of thermal energy have on a material?
   a) Thermal contraction
   b) Thermal expansion
   c) No change
   d) Reproduction

5. Which term is used to define the temperature at which a substance changes its status from solid to liquid?
   a) Boiling point
   b) Melting point
   c) Condensation point
   d) Freezing point

6. Define the following terms
   i. Ductility
   ii. Malleability
   iii. Brittleness

7. Identify the types of engineering materials as per the procedures

8. Determine the physical properties of engineering materials

9. Explain how mechanical properties of engineering are tested

10. Observe the crystal structure of materials and analyze it

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

R.S. Khurmi and J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.2 Learning Outcome No 2 Perform Ore Extraction Processes

Learning Activities

Learning Outcome No 2 Perform Ore Extraction Processes	
Learning Activities	**Special Instructions**
Activity Perform ore extraction **Material** Integrated Extraction Simulator (IES) - CRC ORE soft ware *Safety procedures are observed according OSHA* *2Method of extraction is determined as per material properties and its composition* *Procedure in extraction process is determined as per extraction method* *Extraction by- products are stored as per SOPs*	Integrated Extraction Simulator (IES) - CRC ORE software guide Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Extraction by- products are disposed as per SOPs	

Information sheet: 7.3.1.2
Introduction

Extraction is the process that involves the removal of minerals from the ore. Ore are rocks that contains minerals in them.

Safety Tips to Reduce Mining Accidents

- Don't Ignore the Danger
- Dangerous Tasks Require Planning and Communication
- Get Professional Training
- Always Wear Safety Equipment
- Document Your Safety Procedures
- Follow the Latest Safety Standards
- Ensure all safety equipment is serviced regularly and satisfies all the latest safety standards. Never try to save

Reduction of Metals (Extraction from Ore)

There are 3 main methods of extracting metals from their ore.

They are reduction of the ore with carbon, reduction of the molten ore by electrolysis, and reduction of the ore with a more reactive metal.

Extraction using carbon

Metals such as zinc, iron and copper are present in ores as their **oxides.** Each of these oxides is heated with carbon to obtain the metal.

The metal oxide **loses** oxygen, and is therefore **reduced**. The carbon **gains** oxygen, and is therefore **oxidized.**

Electrolysis

Ionic substances can be **broken down** into the elements they are made from by electricity, in a process called **electrolysis.**

For electrolysis to work, the ions must be **free to move**. When an ionic compound is **dissolved** in water, or melts the ions break free from the ionic lattice. These ions are then free to move. The solution or molten ionic compound is called an **electrolyte.**

During electrolysis:

Positively charged ions move to the negative electrode. Metal ions are positively charged, so metals are produced at the negative electrode (cathode).

Negatively charged ions move to the positive electrode. Non-metal ions, such as oxide ions and chloride ions, are negatively charged, so gases such as oxygen or chlorine are produced at the positive electrode (anode).

Reduction of metal halides with metals

In many cases, carbon cannot be used to reduce the metal oxide to the metal as the metal reacts with carbon to form the carbide instead.

It is possible to avoid this problem by first converting the ore to the chloride, and then reducing the chloride with a more reactive metal such as magnesium or sodium. This is the method used to extract titanium.

MINERAL: It is a naturally occurring inorganic compound of one or more metals in association with nonmetals such as oxygen, Sulphur and the halogens. A mineral has fixed composition and well defined physical and chemical properties.

ORE: It is the naturally occurring aggregate or combination of minerals from which one or more metals or minerals may be extracted economically (profitably).

UNIT OPERATIONS: The physical processes like crushing, grinding, classification, concentration etc. are called unit operations.

UNIT PROCESSES: The chemical processes like calcination, smelting, roasting, leaching etc. are called unit processes.

Pyrometallurgy:

Pyro metallurgy deals with the methods of extraction of metals from their ores and their refining and is based on physical and chemical changes occurring at high temperatures.

What are the advantages of high temperature?

As at high temperature, the reaction rate is accelerated which leads to more metal production.

Also at high temperature the inexpensive reducing agent can be used and cheaper raw material can be used

As we know that the reaction rate doubles in each 10ºC rise of temperature which requires small activation energy. It helps in fast reaction.

Shift of reaction is possible.

Brings about a reduction which cannot takes place in presence of water.

Only pyrometallurgy and fused salt electrolysis can extract reactive metals namely the alkaline earth metals zirconium and titanium.

Ability to treat a large tonnage of ore in a compact space, which leads to a saving in capital cost.

There are 4 processes that are included in pyro metallurgical treatment. i.e.

i. Calcination
ii. Roasting
iii. Smelting
iv. Refining

Calcination:

Calcination is the thermal treatment of an ore that brings about its decomposition and elimination of volatile products i.e. carbon dioxide and water.

Temperature required for this process can be calculated from free energy temperature relationship for the reaction under consideration.

As the most decomposition reaction is endothermic, so the temperature of calcination is generally depends on the transfer of heat into the particle. This result in even high temperature of the furnace (kiln) at the expanse of some fuel.

For example, CaCO3 (c) = CaO (c) + CO2. This reaction is endothermic and requires high temperature to decompose it in the kiln

Roasting

Roasting of an ore or a concentrate is a chemical process in which chemical conversion of ore is taken place by employing oxygen or other element.

This process was used to remove Sulphur or other elements such as arsenic and tellurium in the form of a volatile oxide from an ore.

Factors Affecting Roasting

Time (duration)

Availability of oxygen or air

Temperature

Physical condition of the ore

Nature of the mechanical device used

Duration of Roasting Process Varies Greatly

Blast roasting is done in a mere flash of time

Hearth roasting takes hour.

Heap roasting months

Weather roasting year.

Sinter Roasting (Sintering):

Heavy dust loss if agglomeration is not done.

Permeability reduced it jam the furnace

Steps in sinter roasting

The fine concentrate is charged as a layer 15-50 cm thick on to the endless revolving belt or grate or pallets which moves over wind boxes at regular speed.

Burners under the ignition hood is used to start the combustion of the bed surface. This combustion is propagated through the mass or charge by a current of air drawn through the charge into the wind box below which is connected a suction fan sufficient high temperature are develop in the material to cause partial or incipient fusion which produces a pores cinder like material called sinter

When the sinter reaches the end of the machine it is discharged and cooled

The cooled sinter is sized to give a uniform product.

Smelting

Process by which a metal is obtained, either as the element or as a simple compound, from its ore by heating beyond the melting point, ordinarily in the presence of oxidizing agents, such as air, or reducing agents, such as coke.

Heating process of production of metal or matte.

• Reducing agent- C/S/sulphide

• Furnace used- reverberatory furnace, blast furnace, electric arc furnace

• As gangue is less fusible than metal so flux must be added to form slag which is easily fusible.

Mineral + gangue+ reducing agent+ flux = metal/matte + slag + gas

Blast furnace- reduction smelting

Reverberatory furnace- matte smelting

Electric arc furnace- reduction smelting and matte smelting

Further reading on;

ore extraction processes, methods of extraction, procedures, factors affecting extraction methods, storage of by-products, disposal of extracted by-products, safety, application

Watch videos on the operation of furnaces

Self-Assessment

1. Which is the most reactive metal?
    a. Iron
    b. Mercury
    c. Sodium
    d. Potassium

2. What is the maximum permissible amount of ash on carbonization after coal is washed?
    a) 2%
    b) 6%
    c) 14%
    d) 21%

3. What is the solid residue that remains after heating of coal in the absence of air?
    a) Resin

b) Coke
c) Powder
d) Whisker

4. What is the level of fineness to be achieved in crushed coal?
   a) 10-20%
   b) 25-40%
   c) 50-60%
   d) 70-80%

5. For how long must coke be burnt?
   a) 2-3 hours
   b) 6-8 hours
   c) 18-24 hours
   d) 30-36 hours

6. What is the appearance of oven coke?
   a) Bluish-green
   b) Reddish-brown
   c) Dark grey to light silver
   d) Matte black

7. Which of the following factors are not used to evaluate the quality of coke?
   a) Size and shape
   b) Moisture
   c) Ignitability
   d) Electrical resistivity

8. Which of the following is not an advantage of coke over coal?
   a) Purity
   b) Porosity
   c) Low smoke
   d) Water

9. Discuss the working principle of smelting furnaces

10. Determine the method of extraction as per material properties and its composition

11. Determine the process of extraction as per extraction method procedure

12. Carry out extraction by-production storage and disposal as per SOPs

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi, R. S. & Gupta, J. K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.3 Learning Outcome No 3 Produce Iron Material

Learning activities

Learning Activities	**Special Instructions**
Activity 1 Watch you tube video on extraction of iron- Number 7 Blast Furnace - YouTube https://www.youtube.com/watch?v=og-Pzzf2zdM Blast Furnace (1940-1949) - YouTube https://www.youtube.com/watch?v=rvlOmkaxre8 Describe the process **Activity 2** Produce pig iron, cast iron and steel **Material** steeluniversity.org simulator	Simulator manual Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Information sheet: 7.3.1.3

Ferrous Alloys

Metal alloys, by virtue of composition, are often grouped into two classes ferrous, and nonferrous. Ferrous alloys, those in which iron is the principal constituent, include steels and cast irons.

Pig Iron

It's the crude form of iron and is used as the raw material for the production of various other ferrous metals such as cast iron, wrought iron and steel. The pig iron is obtained by smelting iron ores in a blast furnace. The principals raw materials required in the production of pig iron are; iron ore, fuel and flux.

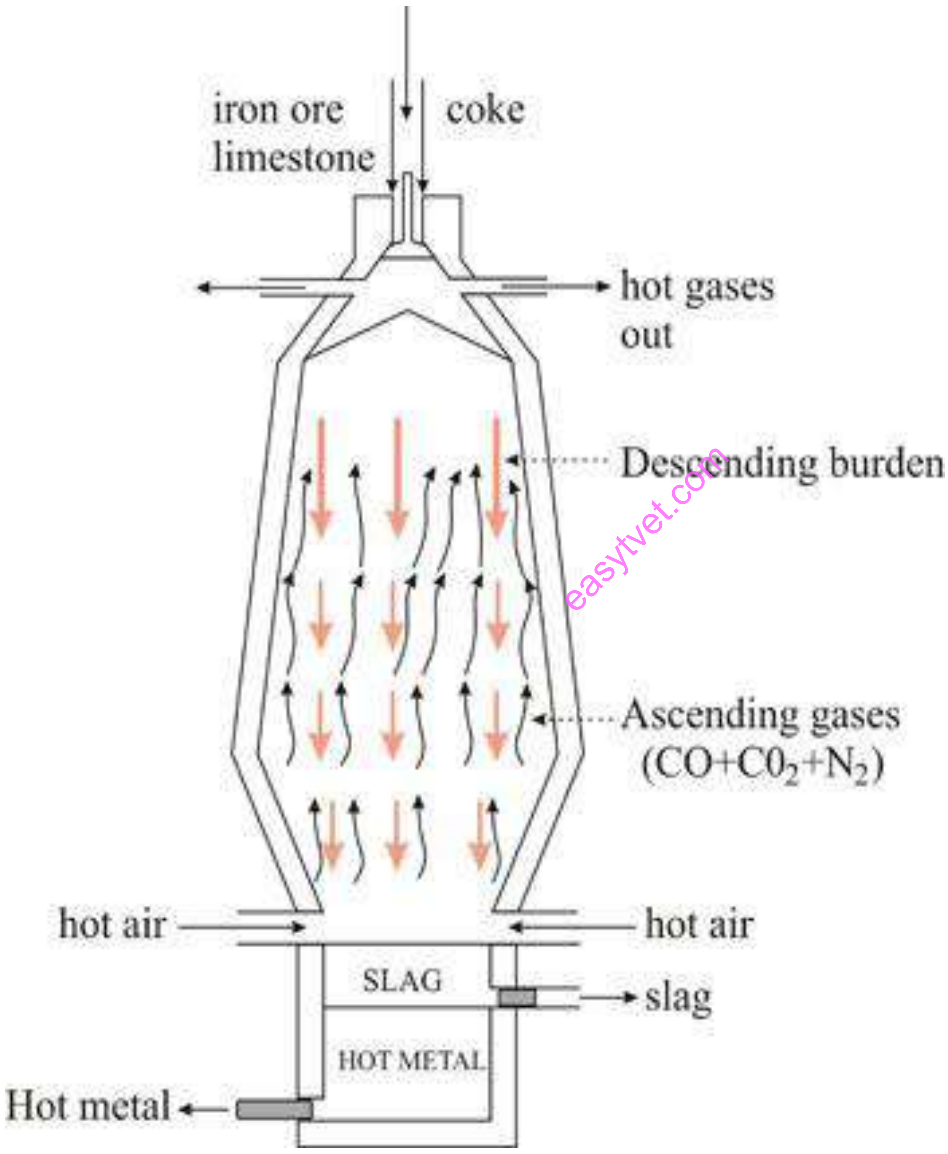
The iron ore itself is usually found in the form

i. Magnetite (Fe_3O_4),
ii. Hematite (Fe_2O_3)
iii. Goethite ($FeO(OH)$)
iv. Limonite ($FeO(OH).n(H_2O)$)
v. Pyrite (FeS_2)
vi. or siderite ($FeCO_3$).

Pig iron is obtained from the iron ore in the following Steps:

Concentration
Calcinations/roasting
Smelting

Blast furnace



Task: Describe the blast furnace, the melting of iron ore in the blast furnace (the reactions)

Watch you tube video on the manufacture of pig iron

Manufacture of cast iron (cupola)

The cupola furnace works on a simple principal that combustion of coke generates carbon dioxide and heat and this causes the iron to melt. The iron drains downward when get melted

Task draw and describe the working principles of a cupola furnace

Broadly, iron's compounds can be divided into two groups known as ferrous and ferric (the old names) or **iron (II)** and **iron (III)**; you can always substitute "iron (II)" for "ferrous" and "iron (III)" for "ferric" in compound names.

In iron (II) compounds, iron has a valency (chemical combining ability) of +2. Examples include iron (II) oxide (FeO), a pigment (coloring chemical); iron (II) chloride ($FeCl_2$), used in medicine as "tincture of iron"; and an important dyeing chemical called iron (II) sulfate ($FeSO_4$).

In iron (III) compounds, iron's valency is +3. Examples include iron (III) oxide (Fe_2O_3), used as the magnetic material in things like cassette tapes and computer hard drives and also as a paint pigment; and iron (III) chloride ($FeCl_3$), used to manufacture many industrial chemicals.

Wrought iron

Puddling process, Aston or Byres process

Manufacture of steel

In all the processes of manufacturing steel, either carbon is added to wrought iron or first decarburizing pig iron and the added the proper amount of carbon

The Bessemer process
Open hearth process
Crucible process
Basic oxygen steelmaking (B.O.S)
Electric furnaces: Direct arc type, induction furnace
Task describe the working principles of the above furnaces

Ferrous Alloys:
Ferrous alloys are those of which iron is the prime constituent—are produced in larger quantities than any other metal type. They are especially important as engineering construction materials. Their widespread use is accounted for by three factors:
iron-containing compounds exist in abundant quantities within the earth's crust;
metallic iron and steel alloys may be produced using relatively economical extraction, refining, alloying, and fabrication techniques; and
Ferrous alloys are extremely versatile, in that they may be tailored to have a wide range of mechanical and physical properties.
The principal disadvantage of many ferrous alloys is their susceptibility to corrosion.
Plain carbon steels

Contain only residual concentrations of impurities other than carbon and a little manganese.

Types of plain carbon steels

Carbon, plain carbon steels are classified into three groups depending on the percentage composition;

Low carbon

Medium carbon

High carbon steels.

Limitations of plain carbon steels

Poor resistance to corrosion and oxidation or scaling at high temperatures.

They suffer rapid softening at elevated temperatures (i.e., above 300^0 C)thus limiting their use in high speed metal cutting operations and other high temperature operations.

They have low hardenability i.e., large sections cannot be effectively hardened hence their use is restricted only to thin sections that can be full-hardened effectively.

Decrease in ductility as the carbon content decreases.

Maximum tensile strength obtainable in plain carbon steels and steels having reasonable toughness and ductility is about 700 MPa.

Steels

Steels are iron–carbon alloys that may contain appreciable concentrations of other alloying elements; there are thousands of alloys that have different compositions and/or heat treatments. The mechanical properties are sensitive to the content of carbon, which is normally less than 1.0 wt%. Some of the more common steels are classified according to carbon concentration, namely, into low-, medium-, and high carbon types. Subclasses also exist within each group according to the concentration of other alloying elements.

Alloy steels

These are steels with other alloying elements in addition to carbon required to introduce new properties that are not available in plain carbon steels. They also improve and extend the existing properties of plain carbon steel.

Alloy steels are classified into:

High–alloy steels - possess microstructures different from plain carbon steels

Low–alloy steels - contains up to 3 or 4 % of one or more alloying elements for the purpose of increasing strength and toughness.

High–Speed Tool Steels

High carbon steels alloyed with tungsten and chromium are used as hard wearing metal–cutting tools, which retain their high hardness at temperatures up to 600^0C. e.g. Composition of commonly used high-speed tool is 18% tungsten, 4% chromium, 1% vanadium and 0.8% carbon.

Stainless Steels

The stainless steels are highly resistant to corrosion (rusting) in a variety of environments, especially the ambient atmosphere. Their predominant alloying element is chromium; a concentration of at least 11 wt% Cr is required.

Stainless steels are divided into three classes on the basis of the predominant phase constituent of the microstructure:

Martensitic Stainless Steels: Are capable of being heat treated in such a way that martensite is the prime micro-constituent. Are iron-chromium alloy steels containing between 12-18%Cr and high carbon content in the range of 0.15-1.2%C.

Properties

Are magnetic under all conditions

Has BCC crystal structure

Have good resistance to corrosion and oxidation at high temperatures.

Applications; pump shafts, turbine blades, springs, ball bearing, surgical instruments, vessels, and regulator valves.

They are magnetic.

Ferritic Stainless Steels: Are composed of the ferrite (BCC) phase. Are the most corrosion resistant because of the high chromium contents and nickel additions; they are produced in the largest quantities. Are hardened and strengthened by cold work because they are not heat treatable.

Properties:

Are magnetic

Relatively soft and ductile

When annealed they are superior than martensite stainless steels in machinability and corrosion resistance

Used extensively in deep drawn parts.

Applications; table ware, beer barrels, cutlery etc.

Austenitic stainless steels:
Have a composition of 18% Cr, 8%Ni and are relatively low carbon content of approximately 0.1%. are generally the most widely used of the stainless steels.
From the composition, the main alloying elements are nickel which is an austenite stabilizer and chromium which is a ferrite stabilizer.

Properties
Non-magnetic in the stabilized austenite structure.
However when cold worked, the austenite stainless steel tends to form ferrite and the material becomes slightly magnetic.
This effect of producing ferrite upon cold working makes the steel difficult to machine
Has FCC crystal structure.
Most ductile compared to the other types of stainless steels.
They do not harden if heat treated, however they can be readily hot worked

Further reading on Content; ferrous materials, composition of iron extraction of pig iron from iron ore, steps to obtain pig iron, blast furnace, manufacture of cast iron, properties, methods of producing iron materials, refinement processes, procedures, safety, application

Further reading; Formation of alloys R. A. Higgins Engineering Metallurgy Part I Applied Physical Met Allurgy By R.A.Higgins (Higgins, Raymond A.)

Self-Assessment
1. What kind of steel requires definite amounts of other alloying elements?
   a) Carbon steel
   b) Alloying steel
   c) Stainless steel
   d) Tool steel

2. Which of these is not a function of alloy steels?
   a) Increases strength
   b) Improves ductility
   c) Reduces cost
   d) Improves machinability

3. Steels containing up to 3% to 4% of one or more alloying elements are known as ________
   a) Low alloy steels
   b) HSLA steels
   c) High alloy steels
   d) Stainless steels

4.What does AISI steel stand for?
a) American-Indian Steel Institute
b) American-Indian Society of Iron
c) American Iron and Steel Institute
d) Alloys, Iron and Steel Institute

5. Which of these is not an application of HSLA steels?
a) Bridges
b) Automobiles and trains
c) Building columns
d) Leaf and coil springs

6. Steels containing more than 5% of one or more alloying elements are known as _________
a) HSLA steels
b) High alloy steels
c) Tool and die steels
d) Stainless steels

7. Which of the following groups of alloying elements stabilize austenite?
a) Ni, Mn, Cu, and Co
b) Cr, W, Mo, V, and Si
c) Cr, W, Ti, Mo, Nb, V, and Mn
d) Co, Al, and Ni

8. Which family of steels are referred to as chromoly?
a) 40xx
b) 41xx
c) 43xx
d) 44xx

9. What is the common name of COR-TEN steel?
a) Weathering steel
b) Control-rolled steel
c) Pearlite-reduced steel
d) Microalloyed steel

10. Alloy steels containing 0.05% to 0.15% of alloying elements are called ________
a) Weathering steel
b) Stainless steel
c) Tool and die steel
d) Microalloyed steel

11. Perform ore smelting according to standard operating procedures
12. Determine composition of iron

13. Establish the methods of producing iron material
14. Identify refinement processes based on iron material required
15. Perform refinement process on iron material

Tools, Equipment, Supplies and Materials for the specific learning outcome

Testing instrument
Extraction materials
Measuring instrument
Inspection tools

References (APA)

R.S. Khurmi & J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.4 Learning Outcome No 4 Produce Alloy Material

Learning Activities

Learning Activities	Special Instructions
Activity 1 **Making an alloy (solder)** **Eye protection** **Thermal protection gloves** **Each working group requires:** **Crucible** **Pipe clay triangle** **Bunsen burner** **Tripod** **Heat resistant mat** **Spatula** **Tongs (Note 1)** **Casting sand (Note 2)** **Metal sand trays or sturdy metal lids, 2 (Note 2)** **Balance (no decimal places needed)** Lead (Toxic, Dangerous For The Environment), about 2 g Tin, about 2 g Carbon powder, about 2 g **Procedure** **Making the alloy** Weigh out 1 g each of lead and tin. Put the lead into the crucible, but keep the tin to one side. If using casting sand, fill one of the sand trays with casting and push your finger into it to make an indent. This is your cast. Put the crucible onto a pipe clay triangle. Make sure that it is stable on a tripod and mat. Heat the crucible strongly with a Bunsen burner until the lead is molten. Add a spatula of carbon powder to the top of it to prevent a skin forming. Add the tin and stir with a spatula until the metals are both molten and thoroughly mixed. Move the Bunsen away from the tripod and put it onto a yellow flame. Wearing thermal protection gloves, pick up the crucible using the tongs, and pour the molten metal into the cast or onto a ceramic	Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

tile. Take great care as you do this to avoid splashing or dripping. Let it cool down completely before you touch it.	

Information sheet: 7.3.1.4

Alloy is a metal that is made by mixing together two or more metals, or a metal and another

Basic properties

Melting point. Mixing two or more metals in the liquid state produces a new material, typically with a lower melting point and often with temperature range for complete melting to occur. This property is the basis for many brazing and soldering alloys , where two or more metal are mixed to reduce the melting point and provide a material that flows into different types of joint gaps.

Process ability

Alloys can be forged into complex shapes or extruded into small wires.

Strength as in Ultimate Tensile strength and Yield strength.

Mixing two or more metals increases the strength and hardness of the material. Which translates to an increase in strength and hardness

Electrical and thermal conductivity.

These are grouped together because they are intrinsically linked by their dependence on their metallic electron cloud. Adding two pure metals to make an alloy nearly always produces a material with higher resistivity (lower conductivity) than either of the pure metals

Further Reading:

Content; alloys, basic properties of alloy, alloys formation, identification of materials in alloy formation, alloy formation processes, procedures, uses of equilibrium diagrams, test of alloys, safety, application

Formation of alloys R. A. Higgins Engineering Metallurgy Part I Applied Physical Met Allurgy By R.A.Higgins (Higgins, Raymond A.) pg 165-183

Self-Assessment

1. How much carbon is present in cast irons?
   a) Less than 0.05%
   b) Up to 1.5%
   c) 1.5% to 2%
   d) More than 2%

2. Cast iron is a _____ alloy.
   a) Eutectic
   b) Eutectoid

c) Peritectic
d) Peritectoid

3. Iron obtained from broken ______ is known as white iron.
a) Cementite
b) Graphite
c) Pearlite
d) Bainite

4. If the iron surface contains graphite, it is known as ________
a) Alloy cast iron
b) White iron
c) Grey iron
d) Spheroidal graphite

5. Which element causes cementite to behave in a stable manner?
a) Silicon
b) Sulphur
c) Manganese
d) Carbon

6. An iron with high-silicon content is a _______
a) White iron
b) Grey iron
c) Malleable iron
d) Pig iron

7. What is the effect of phosphorus and sulphur in cast irons?
a) Induces brittleness
b) Increases strength
c) Destabilizes cementite
d) No effect

8. Decomposition of cementite to form ferrite and graphite is known as _______
a) Decomposition of cast irons
b) Production of cast irons
c) Growth of cast irons
d) Prevention of growth of cast irons

9. Which of these are applications of grey cast iron?
a) Camshafts, engine blocks
b) Wear plates, pump linings
c) Brake shoes, pedals
d) Gears, rocker arms

10. Which of the following cast irons cannot be machined?
a) White cast iron
b) Grey cast iron

c) Malleable cast iron
d) Spheroidal graphite cast iron

11. Draw the various thermal equilibrium diagrams for alloys

12. Perform ore smelting according to standard operating procedures

13. Determine the composition of iron

14. Establish the methods of producing iron materials

15. Identify refinement processes based on iron material required

16. Carry out alloy test based on alloy production requirement

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

R.S. Khurmi & J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.5 Learning Outcome No 5 Produce Non Ferrous Metals

Learning Activities

Learning Outcome No 5 Produce Non Ferrous Metals	
Learning Activities	Special Instructions
Activity 1 To recycle aluminum cans and make a useful product, Alum (potassium aluminum sulfate $KAl(SO_4)_2 \cdot 12H_2O$. To understand the processes involved in recycling, their importance, and the difficulties in doing so. MATERIAL 2 large ice baths 1 full aluminum beverage can Sand paper Scissors 4.00 g KOH 50 mL volumetric flask Distilled water 250 mL beaker 100 mL beaker 2-25 mL graduated cylinders 12.0 mL concentrated sulfuric acid Filter paper (2 pieces; 1) Funnel Universal ring stand assembly Stirring rod Hot plate Electronic balance 12 mL Ethanol	Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

7.3.1.5 Information sheet

Introduction

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 [FAD] and have more shrinkage than ferrous metals.

They are utilized in industry due to following advantages:

High corrosion resistance

Easy to fabricate, i.e., machining, casting, welding, forging and rolling

Possess very good thermal and electrical conductivity

Attractive colour and low density

But these metal are expensive than ferrous metals as they are not abundantly available
However different materials have distinct characteristics, and are used for specific purposes.
The various non-metals used in industry are: copper, aluminium, tin, lead, zinc, and nickel, etc., and their alloys.

Aluminium

Aluminium is white metal which is produced by electrical processes from clayey mineral known as bauxite. However, this aluminium ore bauxite is available in India in plenty and we have a thriving aluminium industry.

Properties:

These are characterized by low density, high thermal & electrical conductivities,
Good corrosion resistant characteristics because of formation of Al_2O_3 protective layer.
As Al has FCC crystal structure, these alloys are ductile even at low temperatures and can be formed easily.
However, the great limitation of these alloys is their low melting point (660 $^{\circ}C$), which restricts their use at elevated temperatures.

Procedure: (This is a two day lab)

Remove the paint from the outside of the aluminium can using sand paper (this is easier to do if the can is full). Why is it important to remove the paint?

Once the paint has been removed, drain the contents of the can and rinse it. Then cut a piece of aluminum approximately 5 cm x 7.5 cm from the can. Using sand paper, remove the polymer coating on the inside of the can. Why do you think there is a coating on the inside of the can? Why is it important to remove it?
Weigh the cleaned piece of aluminium. You need approximately 1.0 g of aluminium (a mass between 0.90 g and 1.20 g is acceptable). If your mass of aluminium is between these values, proceed to step 4. If not, then cut to the appropriate mass range before proceeding to step 4.

Obtain the mass of a labelled 250 mL beaker. Record in the data table provided. Cut your aluminium sample into small pieces. (How will this affect the rate of the reaction compared with leaving the aluminium in one large piece?) Place the small pieces of aluminium into the 250 mL beaker.

Obtain the mass of the beaker containing the aluminium (to the nearest 0.01 g). Record in the data table provided.

Determine the mass of the aluminium by subtracting the mass of the beaker from the mass of the beaker containing the aluminium pieces. Record in the data table provided.

Mass (to the nearest 0.01 g) approximately 4.0 g of KOH and add it to 50 mL volumetric flask. Record the exact mass of the KOH in the data table provided. Add about 25 mL of distilled water and swirl to dissolve the KOH. Once the KOH has been dissolved, fill the volumetric flask with distilled water to the 50 mL mark.

Which ions/molecules are present in the volumetric flask?

Add this KOH solution the 250 mL beaker containing the aluminium pieces.

Place the 250 mL beaker in the fume hood for about 15 minutes or until all of the aluminium pieces have finished reacting. The reaction is complete when no more aluminium pieces are visible and no more H_2 gas is evolving.

The reaction is: $2KOH(aq) + 2Al(s) + 6H_2O(l) \rightarrow 2KAl(OH)_4(aq) + 3H_2(g)$

Record qualitative observations while the aluminum is reacting with the KOH. Is this an endothermic or exothermic reaction?

Note the periodic rise and fall of aluminum pieces during the reaction. Suggest an explanation.

During the 15 minute waiting period, place 13 mL of distilled water into a labelled 100 mL beaker and very slowly add 12 mL of concentrated H_2SO_4 (pre-measured for you in a 25 mL graduated cylinder). Always add acid to water. This step should be performed in a fume hood. Use gloves if available.

Carefully place the beaker of hot H_2SO_4 solution in an ice bath for approximately 10 minutes.

After the aluminium has finished reacting with the KOH solution, place the 250 mL beaker into an ice bath. Allow the black residue to settle to the bottom of the beaker. This black residue may be a result of the decomposition of residual paint or plastic lining.

While both solutions are cooling, set up the filtration apparatus using the universal stand and ring assembly.

Filter the $KAl(OH)_4$ through a funnel into the cold sulphuric acid solution. Slowly stir the white precipitate (which is $Al(OH)_3$).

The reaction is: $2KAl(OH)_4(aq) + H_2SO_4(aq) \rightarrow 2Al(OH)_3(s) + K_2SO_4(aq) + 2H_2O(l)$

Some of the solid aluminium hydroxide reacts with the sulphuric acid, forming aluminium sulphate which reacts with potassium sulfate in the solution to form the final product alum. The overall reaction is shown in step 18 below.

Once filtering is complete, warm the white precipitate gently on a hot plate until it has all dissolved.

Leave the beaker to sit undisturbed overnight. As the solution cools, solid alum will precipitate forming crystals.

The overall balanced reaction is:

$$2Al(s) + 2KOH(aq) + 4H_2SO_4(aq) + 22H_2O(l) \rightarrow 2KAl(SO_4)_2\bullet 12H_2O(s) + 3H_2(g)$$

Applications:

Aerospace: The absolute requirement for light structures, make aluminium and its alloys now more than ever the number one material in the sky.

Automotive: Chassis, bodies, engine blocks, radiators, hubcaps etc. because of its lightweight and corrosion resistance

Marine: Marine transport is increasing its use of aluminium by capitalizing on its two leading qualities: lightness and corrosion resistance. Advanced alloys have enabled the design of high-speed ships, by lightening hulls by 40% to 50% over steel.

Alloys of Aluminium

Aluminium may be alloyed with one or more alloying elements such as copper, manganese, magnesium, silicon and nickel.

Advantage of alloy addition

The addition of small quantities of alloying elements converts the soft and weak aluminium into hard and strong metal, while it retains its light weight.

The main **alloys of aluminium** are: Duralumin, Y-alloy, Magnalium and Hindalium which are discussed as follows

a) Duralumin

Composition:

This is a famous alloy of aluminium containing 4% copper, 0.5% manganese, 0.5% magnesium and a trace of iron with remainder as aluminium is known as duralumin.

Properties:

It possesses high strength comparable with mild steel and low specific gravity

However, its corrosion resistance is much lower as compared with pure aluminium

The strength of this alloy increases significantly when heat treated and allowed to age for 3 to 4 weeks, it will be hardened.

To improve upon the corrosion resistance of it, a thin film of aluminium is rolled on the duralumin sheets.

Applications:

These aluminium rolled sheets are known as Alclad by trade name and are widely used in aircraft industry.

Due to lightweight and high strength this alloy may be used in automobile industry.

b) Y-Alloy

It is also known as copper-aluminium alloy.

Composition:

The addition of copper to pure aluminium improves its strength and machinability.

Y-alloy contains 93% aluminium, 2% copper, 1% nickel and magnesium.

Properties:
This alloy is heat treated as well as age hardened just like duralumin.
A heat treatment of Y-alloy castings, consisting of quenching in boiling water from 510°C and then aging for 5 days develops very good mechanical characteristics in them.
Applications:
Since Y-alloy has better strength at elevated temperature than duralumin therefore it is much used in aircraft cylinder heads and piston.
It is also used in strip and sheet form.

c) Magnalium
It is produced by melting the aluminium and 2 to 10% magnesium in a vacuum and then cooling it in vacuum or under a pressure of 100 to 200 atmospheres.
About 1.75% copper is also added to it.
Applications:
Due to its light weight and good mechanical characteristics, it is mainly used for aircraft and automobile components.

d) Hindalium
It is an alloy of aluminium and magnesium with small quantity of chromium.
It is manufactured as rolled product in 16 gauge mainly used in manufacture of anodized utensils.

Further reading materials and Metallurgy by V.K.Machada and G.B.S . Narang p.g 132-141

Copper
The crude form of copper extracted from its ores through series of processes contains 68% purity known as Blister copper. By electrolytic refining process, highly pure (99.9%) copper which is remelted and casted into suitable shapes.
Copper is a corrosion resistant metal of an attractive reddish brown colour.
Properties and Uses:
High Thermal Conductivity: Used in heat exchangers, heating vessels and appliances, etc.
High Electrical Conductivity: Used as electrical conductor in various shapes and forms for various applications.
Good Corrosion Resistance: Used for providing coating on steel prior to nickel and chromium plating
High Ductility: Can be easily cold worked, folded and spun. Requires annealing after cold working as it loses its ductility.
Further reading on manufacture of copper: Reverberatory furnace process (welsh process) and Blast furnace process (Manhe's Process)
Commercial grades of copper

Alloys of Copper

Most copper alloys cannot be hardened or strengthened by heat-treating procedures. Consequently, cold working and/or solid-solution alloying must be utilized to improve these mechanical properties.
Copper alloys are among the best conductors of heat and electricity and they have good corrosion resistance.
The common types of copper alloys are brasses and bronzes.

a) Brass
All brasses are basically alloys of copper and zinc.
Commercially there are two main varieties of brasses:
Alpha brass: Contains up to 36% Zn and rest copper for cold working.
Alpha-Beta brass: Contains 36 to 45% Zn and remainder is copper for hot working.

Effect of Zinc on Copper:
The tensile strength and ductility of brass both increase with increase in content of Zn up to 30% zinc.
With further increase in zinc content beyond 30%, the tensile strength continues to increase up to 45% of Zn, but ductility of brasses drops significantly.
β- phase is less ductile than α-phase but it is harder and stronger.
There are various types of brasses depending upon proportion of copper and zinc.
Fundamentally brass is a binary alloy of copper with as much as 50% zinc.
Various classes of brasses such as cartridge brass, Muntz Metal leaded brass, Admiralty brass, naval brass and nickel brass depending upon the proportion of copper and zinc plus third alloying metal are available for various uses.
Applications:
Brasses possess very good corrosion resistance and can be easily soldered.
Costume jewelry, cartridge casings, automotive radiators, musical instruments, electronic packaging, and coins.

b) Bronze
The alloy of copper and tin are usually termed bronzes.
The useful range of composition is 75 to 95% copper and remainder tin.
In general, it possesses superior mechanical properties and corrosion resistance to brass.
Properties:
The alloy can be easily cold rolled into wire, rods and sheets.
With increase in tin content, the strength of this alloy and its corrosion resistance increases. It is then known as hot working bronze.
Applications:
Bronze is generally utilized in hydraulic fittings, bearings, bushes, utensils, sheets, rods and many other stamped and drawn products.

The properties of bronzes are modified with different alloying elements as below

Phosphor bronze

When bronze contains phosphorus, it is known as phosphor bronze.

Properties:

The composition of the alloy varies according to whether it is to be forged, wrought or cast.

A common type of phosphor bronze has the following composition as per Indian standards.

Copper is 93.6%, tin is 9%, and phosphorus is 0.1 to 0.3%.

The alloy possesses good wearing qualities and high elasticity.

The alloy is resistant to saltwater corrosion.

Applications:

Cast phosphor bronze is utilized for production of bearings and gears.

Bearings of bronze contain 10% tin and small addition of lead.

This is also used in making gears, nuts, for machine lead screws, springs, pump parts, linings and many other such applications.

Gun metal

Composition:

Gun metal contains 2% zinc, 10% tin and 88% copper.

Properties:

Sometimes very small amount of lead is also added to improve castability and machinability.

The presence of zinc improve its fluidity.

Applications:

This bronze is used for bearing bushes, glands, pump valves and boiler fittings, etc.

Silicon bronze

Composition: Silicon bronze has an average composition of 3% silicon, 1% manganese and rest copper.

Properties:

It possesses good general corrosion resistance of copper with higher strength and toughness.

It can be cast rolled, stamped, forged and pressed either hot or cold and can be welded by all the usual methods.

Applications:

Silicon bronze is widely utilized for parts of boilers, tanks, stoves or where high strength as well as corrosion resistance is required.

Bell metal

Composition: This alloy contains 20 to 21% tin and rest copper.

Properties:

It is hard and resistant to surface wear.

It can be readily cast

Applications: Generally utilized for casting bells, gongs and utensils, etc.

Manganese Bronze

Composition: It contains 55 to 60% copper, 40% zinc, with 3.5% manganese.

Properties:

This alloy is highly resistant to corrosion.

It is stronger and harder than phosphor bronze. It has poor response to cold working but can be easily hot worked.

Applications:

It is generally utilized for producing bushes, plungers, feed pumps and rods, etc.

Worm gears are frequently made of manganese bronze.

Muntz Metal

Composition: 60% copper and 40% zinc. Sometimes a small quantity of lead is also added.

Properties:

This alloy is stronger, harder and more ductile than normal brass.

While hot working between 700°C to 750, it responds excellently for process but does not respond to cold working.

Applications:

This alloy is utilized for a wide variety of small components of machines, bolts, rods, tubes, electrical equipment as well as ordnance works.

It is widely employed in producing such articles which are required to resist wear.

Lead

Lead is the heaviest of the common metal. Lead is extracted from its ore known as galena. It is bluish grey in colour and dull lusture which goes very dull on exposure to air.

Properties and Uses:

Its specific gravity is 7.1(w.r.to water) and melting point is 360°C.

It is resistant to corrosion and many chemicals do not react with it (even acids).

It is soft, heavy and malleable, can be easily worked and shaped.

Lead is utilized as alloying element in producing solders and plumber’s solders.

It is alloyed with brass as well as steel to improve their machinability.

It is utilized in manufacturing of water pipes, coating for electrical cables, acid tanks and roof covering etc.

Tin

It is a brilliant white metal with yellowish tinge. Melting point of tin is 240°C

Properties and Uses:

Tin is malleable and ductile, it can be rolled into very thin sheets.

It is used for tinning of copper and brass utensils and copper wire before its conversion into cables.

It is useful as a protective coating for iron and steel since it does corrode in dry or wet atmosphere.
It is utilized for making important alloys such as fine solder and moisture proof packing with thin tin sheets.

Zinc
The chief ores of zinc are blende (ZnS) and calamine (ZnCO3).
Zinc is a fairly heavy, bluish-white metal principally utilized in view of its low cost, corrosion resistance and alloying characteristics. Melting point of zinc is 420°C and it boils at 940°C.
Properties and Uses:
High corrosion resistance: Widely used as protective coating on iron and steel. Coating may be provided by dip galvanizing or electroplating.
High fluidity and low melting point: Most suitable metal for pressure die casting generally in the form of alloy.
When rolled into sheets, zinc is utilized for roof covering and for providing a damp proof non-corrosive lining to containers.
The galvanized wires, nails, etc. are produced by galvanizing technique and zinc is also used in manufacture of brasses.

Nickel
About 85% of all nickel production is obtained from sulphide ores.

Properties and Uses:
Pure nickel is tough, silver coloured metal, harder than copper having some but less ductility but of about same strength.
It is plated on steel to provide a corrosion resistance surface or layer.
Widely used as an alloying element with steel. Higher proportions are advantageously added in the production of steel such as monel or inconel.
It possesses good resistance to both acids and alkalis regarding corrosion so widely utilized in food processing equipment.

Alloys of Nickel

a) German silver
Composition:
The composition of this alloy is 60% Cu, 30% Ni and 10% zinc.
Properties:
It displays silvery appearance and is very ductile and malleable.

Applications:
It is utilized for electrical contacts, casting of high quality valves, taps and costume jewellery.
It is also used in producing electrical wires.

b) Monel metal
Composition:
It contains 68% Ni, 30% Cu, 1% iron and remainder small additions of Mn and other elements.
Properties:
It is corrosion resistant and possesses good mechanical properties and maintains them at elevated temperatures.

c) Nichrome
It is an alloy of nickel and chromium which is utilized as heat resistant electrical wire in electrical appliances such as furnaces, geysers and electric iron, etc.

d) Inconel and incoloy
These alloys principally contain, Ni, Cr, Fe, Mo, Ti and very small proportions of carbon. These are used as high temperature alloys. Inconel does not respond to heat treatment.

Magnesium
Principal Ores of magnesium are magnesite, carnallite and dolomite. Magnesium is extracted by electrolytic process.
Properties and Uses:
It is the lightest of all metals weighing around two-thirds of aluminium.
The tensile strength of cast metal is the same as that of ordinary cast aluminium, i.e., 90 MPa.
The tensile strength of rolled annealed magnesium is same as that of good quality cast iron.
Magnesium can be easily formed, drawn forged and machined with high accuracy. (5) In powdered form it is likely to burn, in that situation adequate fire protection measures should be strictly observed.
It's castings are pressure tight and achieve good surface finish. Magnesium castings include motor car gearbox, differential housing and portable tools.

Vanadium
It occurs in conjunction with iron pyrite, free sulphur and carbonaceous matter.
Properties and Uses:
It is silvery white in colour.
Its specific gravity is 5.67.
Its melting point is 1710°C.
When heated to a suitable temperature it can be hammered into any shape or drawn into wires.
It is used in manufacture of alloy steels.
Vanadium forms non-ferrous alloys of copper and aluminium from which excellent castings can be produced.

Antimony

Chief ore of antimony is **stibnite**. To a small extent, antimony is obtained as a by-product in refining of other metals such as lead, copper silver and zinc.

Properties and Uses:

It is silvery white, hard, highly crystalline and so brittle that it may be readily powdered.

Its specific gravity is 6.63 and melting point is 630°C.

It is generally used as an alloying element with most of heavy metals.

Lead, tin and copper are the metals which are most commonly alloyed with antimony.

Cadmium

It is obtained commercially as a by-product in the metallurgy of zinc and to some extent of lead.

Properties and Uses:

White metal with bluish tinge, capable of taking a high polish.

Its specific gravity is 8.67 and melts at 321°C.

It is slightly harder than tin but softer than zinc.

It is malleable and ductile and can be readily rolled and drawn into wires.

It is chiefly utilized in antifriction alloys for bearings. It is also used as rust proof coating for iron and steel. Components of automobiles and refrigerator such as nuts, bolts and trimmings, locks and wire products are plated with it.

Bearing Materials

A bearing material should possess the following characteristics:

It should possess enough compressive strength to provide adequate load carrying capacity.

It should possess good plasticity to negate small variations in alignment and fitting.

Its wear resistance should be adequate to maintain a specified fit.

The coefficient of friction of the bearing material should be low to avoid excessive heating.

Some significant bearing metals are as follows:

Babbitt's metal: It is utilized for production of heavy duty bearings. It is white in colour containing 88% tin, 8% antimony and 4% copper. It is a soft material with a low coefficient of thermal expansion.

Titanium alloys

Ti and its alloys are of relatively low density, high strength and have very high melting point. At the same time they are easy to machine and forge.

However the major limitation is Ti's chemical reactivity at high temperatures, which necessitated special techniques to extract. Thus these alloys are expensive.

They also possess excellent corrosion resistance in diverse atmospheres, and wear properties.

Applications:

Common applications include: space vehicles, airplane structures, surgical implants, and petroleum & chemical industries.

Refractory metals
These are metals of very high melting points. For example: Nb, Mo, W and Ta.
They also possess high strength and high elastic modulus.

Applications:
Space vehicles, x-ray tubes, welding electrodes, and where there is a need for corrosion resistance.

Noble metals
These are eight altogether: Ag, Au, Pt, Pa, Rh, Ru, Ir and Os.
All these possess some common properties such as: expensive, soft and ductile, oxidation resistant.
Ag, Au and Pt are used extensively in jewelry, alloys are Ag and Au are employed as dental restoration materials; Pt is used in chemical reactions as a catalyst and in thermocouples.

Content; non-ferrous materials extraction, non-ferrous material smelting and purification, test of non-ferrous material, identification of alloying elements in non-ferrous material, alloy formation process, test for non-ferrous alloys, procedures, application, safety

Self-Assessment
1.Which of the metal if present will make the alloy ferrous?
a) Aluminium
b) Lead
c) Zinc
d) Iron

2. Which of the following is costliest among the non-ferrous materials?
   a) Magnesium
   b) Aluminum
   c) Titanium
   d) Copper

3. Which of the following is the lightest among the following?
   a) Magnesium
   b) Aluminum
   c) Titanium
   d) Copper

4. Which of the following element when alloyed with magnesium does not reduce the tendency to crack under stress?
   a) Aluminum
   b) Silicon
   c) Zinc
   d) Copper

5. Which of the following is an alloy of tin?
   a) Brass
   b) Bronze
   c) Pewter
   d) Steel

6. Which of the metal is alloyed with silver to make sterling silver?
   a) Zinc
   b) Copper
   c) Magnesium
   d) Aluminum

7. Tin has low viscosity.
   a) True
   b) False

8. Which of the following is highly resistant to corrosion?
   a) Aluminum
   b) Copper
   c) Iron
   d) Zinc

9. Monel is an alloy of nickel.
   a) True
   b) False

10. Extract non-ferrous materials according to SOP
11. Smelt and purify the extracted non-ferrous as per the SOP
12. Perform the test for non-ferrous material according to SOP
13. Identify alloying elements for non-ferrous materials
14. Identify alloy formation process based on alloy to be produced
15. Perform the test for alloys for non-ferrous material based on production requirement

Tools, Equipment, Supplies and Materials for the specific learning outcome
Testing instrument
Extraction materials
Measuring instrument
Inspection tools

References (APA)
Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.6 Learning Outcome 6 Produce Ceramics

Learning Activities

Learning Outcome No 6 PRODUCE CERAMICS	
Learning Activities	**Special Instructions**
Activity1 **POTTERY MAKING** MATERIAL Kiln clay model drawings Activity 2 **Production of ceramic material** Materials Ceramic material as per the required product Production machine as per the product Finishing machine-lapping, grinding, polishing.as per the quality of the final product .	Observe safety Manufacturing process guidance Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Information sheet: 7.3.1.6
Ceramic

A ceramic is a material that is neither metallic nor organic. It may be crystalline, glassy or both crystalline and glassy. Ceramics are typically hard and chemically non-reactive and can be formed or densified with heat. Ceramics are more than pottery and dishes: clay, bricks, tiles, glass, and cement are probably the best-known examples. Ceramic materials are used in electronics because, depending on their composition, they may be semiconducting, superconducting, ferroelectric, or an insulator. Ceramics are also used to make objects as diverse as spark plugs, fiber optics, artificial joints, space shuttle tiles, cooktops, race car brakes, micro positioners, chemical sensors, self-lubricating bearings, body armor, and skis

The dominant characteristics of ceramics are summarized by the following:
They are stable and resistant to chemical attack.
They are brittle, hard, and wear resistant.
They have high temperature strength.
They are good electrical insulators at room temperature.
Their thermal conductivities lie between those of polymers and of metals

CARBON: Carbon occurs in two alternative forms of engineering and commercial importance: graphite and diamond. They compete with ceramics in various applications:

Graphite in situations where its refractory properties are important, and

Diamond in industrial applications where hardness is the critical factor (such as cutting and grinding tools

METALCARBIDE TOOL MATERIALS

Silicon carbide (SiC), tungsten carbide (WC), titanium carbide (TiC), tantalum carbide (TaC) and chromium carbide (Cr_3C_2) are examples of materials for making cutting tools.

They are valued for their hardness and wear resistance in cutting tools and other applications requiring these properties.

WC, TiC, and TaC must be combined with a metallic binder such as cobalt or nickel in order to make/ fabricate useful products. In effect, the carbide powders bonded in a metal framework creates what is known as a cemented carbide

Task Further reading on ceramics V.K. MANCHANDA AND G.B.S.NARANG (1996) Materials and Metallurgy

Content; ceramic materials, composition of ceramic materials, identification of manufacturing processes, ceramic materials production, finishing processes identification, procedures, safety, applications

Self-Assessment

1.Graphite is a good conductor of electricity.
   a) True
   b) False

2. Which of the following is false about ceramic structures?
   a) They are made up of two or more different elements
   b) More complex than metal structures
   c) They are electrically neutral
   d) Less complex than metal structures

3. Which of the following bonds are present in ceramic structures?
   a) Ionics bonds only
   b) Covalent bonds only
   c) Ionic, covalent and a mix of ionic and covalent bond
   d) Mix of ionic and covalent bond only

4. Which of the following is an aluminosilicate?
   a) Steatite
   b) Cordierite
   c) Forsterite
   d) Porcelain

5. Which of the following is magnesium silicates?
   a) Porcelain
   b) Earthenware
   c) Stoneware
   d) Steatite

6. According to the percentage of water absorption in dense silicate ceramic which of the following is has fine microstructure?
   a) 1%
   b) 3%
   c) 4%
   d) 5%

7. There are ceramics which are electric resistant.
   a) True
   b) False

8. According to the percentage of water absorption in porous silicate ceramic which of the following has fine microstructure?
   a) 1%
   b) 1.9%

c) 0.4%
d) 2.1%

9. Which of the following is the firing temperature of earthenware?
a) 1400 °C
b) 1300 °C
c) 1500 °C
d) 1200 °C

10. Carbon is a ceramic.
a) True
b) False

11. What kind of bonds are present in diamond?
a) Covalent bond only
b) Ionic bond only
c) Mix of covalent and ionic bond
d) Metallic bonds

12. Which of the following materials can be used as a substitute ceramic?
a) Diamond
b) Brass
c) Bismuth
d) Lead

13. What is a difference between carbon and ceramic?
a) Both are hard
b) Both are non metallic
c) Both have covalent bonds
d) Both have very high thermal conductivity

14. Identify the composition of ceramic materials
15. Identify the manufacturing process Produce ceramic materials according to manufacturing processes
16. identify the finishing processes

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi, R. S. & Gupta, J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.7 Learning Outcome No 7 Produce Composites

Learning activities

Learning Outcome No 7 PRODUCE COMPOSITES	
Learning Activities	**Special Instructions**
Activity 1 make composite materials Select composite materials as per instruction manual Composite formation instruction manual testing machine Activity 2 **Carryout finishing processes** Requirements Emery cloth, lapping machine Grinding machine Polishing machine Testing machine	Test the test piece as per composite production requirements Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Information sheet: 7.3.1.7

Composite

A composite, in the present context, is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as a consequence of natural phenomena many composite materials are composed of just two phases; one is termed the matrix, which is continuous and surrounds the other phase, often called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phase. "Dispersed phase geometry" in this context means the shape of the particles and the particle size, distribution, and orientation a

Definition of a Composite Material

A composite material is defined as a material which is composed of two or more materials at a microscopic scale and has chemically distinct phases.

The following conditions must be satisfied to be called a composite material:

The combination of materials should result in significant property changes. One can see significant changes when one of the constituent material is in platelet or fibrous from.

The content of the constituents is generally more than 10% (by volume).

In general, property of one constituent is much greater than the corresponding property of the other constituent.

In a composite, typically, there are two constituents. One of the constituent acts as a reinforcement and other acts as a matrix. Sometimes, the constituents are also referred as phases.

The reinforcements in a composite material come in various forms:

1. **Fibre:**

Fibre is an individual filament of the material. A filament with length to diameter ratio above 1000 is called a fibre. The fibrous form of the reinforcement is widely used. The fibres can be in the following two forms:

Continuous fibres: If the fibres used in a composite are very long and unbroken or cut then it forms a continuous fibre composite. A composite, thus formed using continuous fibres is called as fibrous composite. The fibrous composite is the most widely used form of composite.

Short/chopped fibres: The fibres are chopped into small pieces when used in fabricating a composite. A composite with short fibres as reinforcements is called as short fibre composite.

In the fibre reinforced composites, the fibre is the major load carrying constituent

2. Particulate:

The reinforcement is in the form of particles which are of the order of a few microns in diameter

Flake: Flake is a small, flat, thin piece or layer (or a chip) that is broken from a larger piece

Whiskers: These are nearly perfect single crystal fibres. These are short, discontinuous and polygonal in cross-section.

Types of fibre

A. Natural fibres- Mineral fibres, Plant/vegetable fibre, Animal fibre.

B. Advanced fibres- Carbon and/or Graphite, Glass fibres, Alumina, Aramid, Silicon carbide, Sapphire

Particle-Reinforced Composites,

Large-particle and dispersion-strengthened composites are the two sub classifications of particle-reinforced composites

Large–Particle Composites

Concrete is a common large-particle composite in which both matrix and dispersed phases are ceramic materials. Since the terms “concrete” and “cement” are sometimes incorrectly interchanged, perhaps it is appropriate to make a distinction between them

Portland cement Concrete The ingredients for this concrete are portland cement, a fine aggregate (sand), a coarse aggregate (gravel), and water

Reinforced Concrete The strength of Portland cement concrete may be increased by additional reinforcement. This is usually accomplished by means of steel rods, wires, bars (rebar), or mesh, which are embedded into the fresh and uncured concrete

Dispersion-strengthened composites

Metals and metal alloys may be strengthened and hardened by the uniform dispersion of several volume percent of fine particles of a very hard and inert material

Task: Explain properties of composite

Reinforced concrete, fibre, reinforced plastics, resin metal, bonded sintered powders, ceramics

Further reading Ning Hu (2012), composite and their properties, Chiba University, Japan

Content; composite materials, types of composite, production of composite materials, formation of composite, elements involved in composite formation, test of composite, safety

Self-Assessment

1. The continuous phase of a composite material is known as its _______
   a) dispersed phase
   b) surrounding phase

c) matrix phase
d) fiber phase

2. Which of the following is a glass forming technique?
a) Powder pressing
b) Hydro-plastic forming
c) Slip casting
d) Fiber forming

3. Drawing and firing operations are done on which of these processes?
a) Pressing
b) Fiber forming
c) Blowing
d) Slip casting

4. Which of the following is not a form of powder pressing?
a) Hot pressing
b) Cold pressing
c) Uniaxial
d) Isostatic

5. What is the firing temperature for particulate forming processes?
a) 50-100oC
b) 150-250oC
c) 300-700oC
d) 900-1400oC

6. What does the term ‘green’ refer to for drying and firing operations?
a) Fired but not dried
b) Dried but not fired
c) Dried then fired
d) Fired then dried

7. Which pressing technique employs a rubber envelope and application of pressure by fluid?
a) Hot pressing
b) Uniaxial pressing
c) Isostatic pressing
d) Powder pressing

8. Which of these holds true for cementitious bonds?
a) High cost

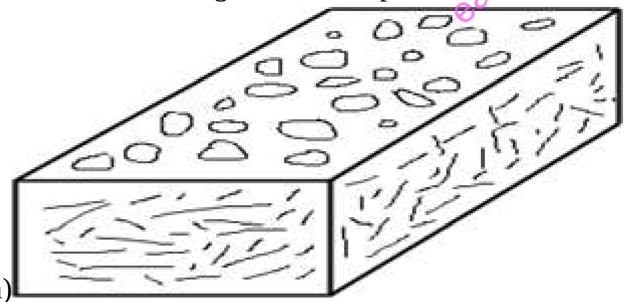
b) Easy to repair
c) Short curing time
d) Hard to repair

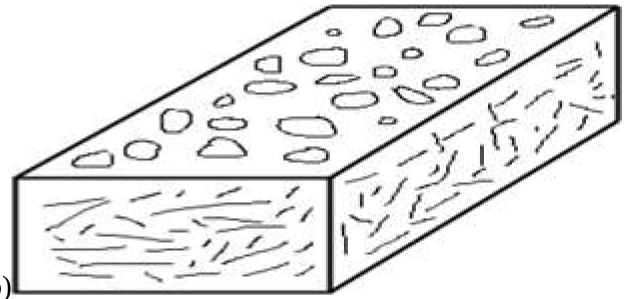
9. Injection molding can be used for parts of thickness up to __________
   a) 4 mm
   b) 6 mm
   c) 8 mm
   d) 12 mm

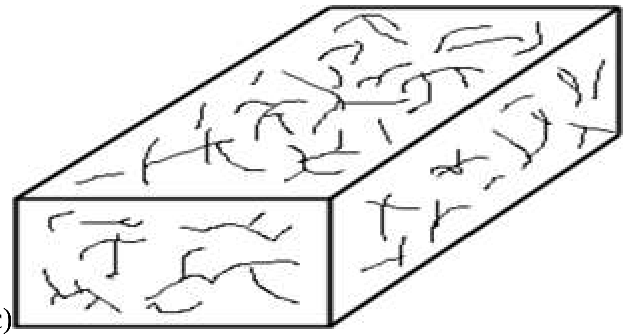
10. What is the common name for fired clay wares?
   a) Porcelain
   b) Ceramic
   c) Pottery
   d) China

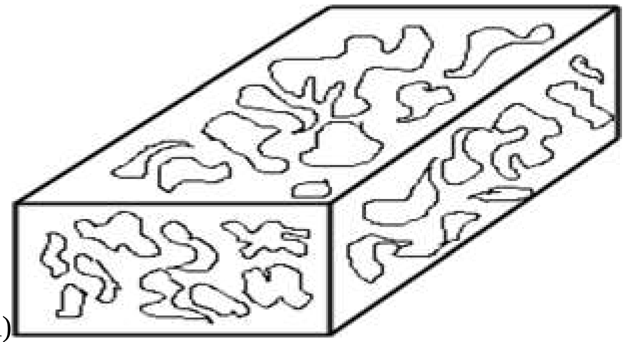
11. The shape forming process PIM known as __________
   a) Porcelain Injection Molding
   b) Plastic Injection Molding
   c) Particulate Injection Molding
   d) Pottery Injection Molding

12. Which of the following structures represents that of a fiber composite?

a) 

b) 

c) 

d) 

13. The classification of fibers having thin crystals is known as _______
   a) Whisker
   b) Fiber
   c) Wires
   d) Matrix

14. Which of the following materials are common for whiskers?
   a) Graphite, silicon carbide
   b) Glass, boron
   c) Steel, tungsten
   d) Polymers, ceramics

15. Kevlar is a ______ type of material.
   a) Glass
   b) Thermoplastic
   c) Whisker
   d) Polymer

16. Which of the following is not a characteristic trait of composite materials?
   a) High strength, toughness, modulus
   b) Lightweight
   c) Easy to assemble
   d) Sensitive to temperature change

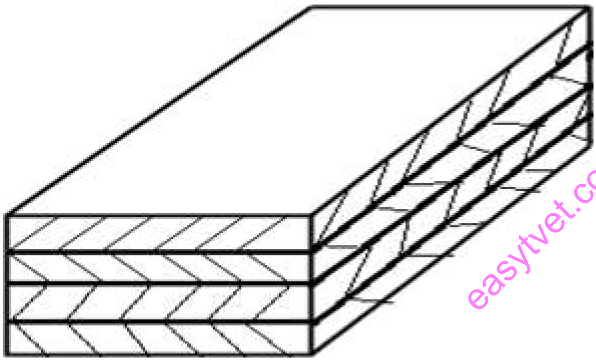
17. How much SiO2 is present in the glass which is drawn into fibers?
   a) 55%
   b) 15%

c) 10%
d) 4%

18. Fiberglass materials have a usable temperature up to ______
a) 50oC
b) 100oC
c) 200oC
d) 500oC

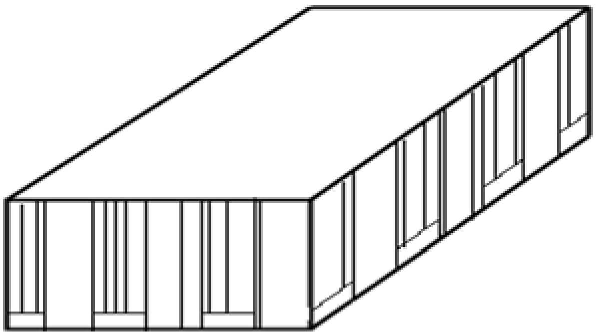
19. What is the purpose of fiberglass that is made as a thread?
a) Insulating material
b) Conductive material
c) Heat resistant
d) Cloth

20. The below figure depicts the structure of ________ composite materials.



a) Discontinuous
b) Aligned
c) Laminate
d) Dispersion-strengthened

21. The below figure is an example of ______ type of structural composites.



a) Laminar
b) Sandwich panel
c) Discontinuous
d) Randomly oriented

22. Manufacturing of components having continuous lengths and the constant cross-sectional shape is done by _____ process.
    a) Roving
    b) Pultrusion
    c) Curing
    d) Pulling

23. What amount of principle reinforcement materials is used in pultrusion process?
    a) 10-20%
    b) 25-35%
    c) 40-70%
    d) 75-90%

24. Identify the type of composite
25. Identify the elements involved in composite formation
26. Identify the formation process of composite production
27. Test the composite as per composite production requirement

Tools, Equipment, Supplies and Materials for the specific learning outcome

Testing instrument

Extraction materials

Measuring instrument

Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.8 Learning Outcome No 8 Utilize Other Engineering Materials

Learning Activities

Learning Outcome No 8 Utilize Other Engineering Materials	
Learning activities	**Special Instructions**
POLYMER EXTRUSION LAB Activity 1 **Objective** To demonstrate about polymer direct extrusion process using portable PITSCO polymer extruder. **Introduction** Figure 1: Screw extruder **Materials and equipment** **Requirements** polymer extruder Polymer pellets Graduated measuring cylinder and water Measuring weight. **ACTIVITY 2** Natural seasoning of timber Wood seasoning Materials Freshly felled timber Make wood joints Materials Bevel and miter square Cutting tools :saw, chisels Planning tools Boring Sticking tools ;hammers ,mallet Holding Tools; bench vice-cramp-clamp, Bench stop etc Miscellaneous tools; screw driver, pincer ,raphs and file, oil stone etc	Knowledge of various materials

Information sheet: 7.3.1.8

Plastics

Plastics are organic substances formed by microcells called polymers. These polymers are large groups of monomers linked by a chemical process called polymerization. Plastics provide the necessary balance of properties that cannot be achieved with other materials such as: color, lightweight, soft touch and resistance to environmental and biological degradation.

Discuss the general properties of plastics

Polymers
Classification of Polymers
Polymers can be classified in several different ways-according to their;

- structures,
- the types of reactions by which they are prepared,
- their physical properties, or
- Their technological uses.

From the physical point of view polymers are categorized into

- thermoplastics
- thermosetting
- elastomers

Thermoplastics
Thermoplastic polymers are hard at room temperature, but on heating become soft and more or less fluid and can be molded.
Read and make short notes on different types of thermosetting plastics and their applications.
Identify the different thermosetting plastics in the locality

Thermosetting

Thermosetting polymers normally are made from relatively low molecular weight, usually semi-fluid substances, which when heated in a mold become highly cross-linked, thereby forming hard, infusible, and insoluble products having a three-dimensional network of bonds interconnecting the polymer chains. Thermosetting polymers can be molded at room temperature or above, but when heated more strongly become hard and infusible
Read and make short notes on different types of thermosetting plastics and their applications.
Identify the different thermosetting plastics in the locality
Elastomers
Elastomers are rubbers or rubberlike elastic materials.
Read and make notes on the different types of rubbers (elastomers)
NB: These categories overlap considerably but are nonetheless helpful in defining general areas of utility and types of structures.

Polymerization
Polymerization: It is the process of forming a polymer
Degree of polymerization: It is the number of repetitive units (or mers) present in one molecule of a polymer.
Mathematically, $\text{Degree of polymerization} = \frac{\text{Molecular weight of a polymer}}{\text{Molecular weight of a single monomer}}$
The molecular weight (MW) of a polymer is the sum of the molecular weights of the mers in the molecule; it is n times the molecular weight of each repeating unit.
Types of polymerization

Addition polymerization

This is the process in which two or more chemically similar monomers are polymerized to form long chain molecules. It takes place in unsaturated organic compounds. E.g. Ethene forms polyethene and vinyl chloride forms PVC.

Condensation polymerization

This is the process through which two or more chemically different monomers are polymerized to form a cross linked polymer along with a by-product such as water or ammonia. It takes place in unsaturated organic compounds and requires suitable conditions such as high pressure, temperature and presence of a catalyst.

Example is, methyl alcohol (CH_3OH) and acetic acid (CH_3COOH) condenses to form an ester with water as a by product

Polymer structure

Physical properties of polymers depend not only on their molecular weight/shape, but also on the difference in the chain structure

Four main structures

Linear polymers

Branched polymers

Cross-linked polymers

Network polymers

Linear polymers

Polymers in which the mer units are connected end-to-end along the whole length of the chain

These types of polymers are often quite flexible

Van der waal's forces and H-bonding are the two main types of interactions between chains

Some examples – polyethylene, teflon, PVC, polypropylene

Branched polymers

Polymer chains can branch:

The fibers may aligned parallel, as in fibers and some plastic sheets.

chains off the main chain (backbone)

This leads to inability of chains to pack very closely together

These polymers often have lower densities

These branches are usually a result of side-reactions during the polymerization of the main chain

Most linear polymers can also be made in branched forms

The presence of branching and cross-linking in polymers has a significant effect on properties.

It is the basis of the difference between the three categories of polymers: Thermoplastic polymers

Always possess linear or branched structures, or a mixture of the two.

Branching increases entanglement among the molecules, usually making the polymer stronger in the solid state and more viscous at a given temperature in the plastic or liquid state.

Thermosetting plastics

Are cross-linked polymers.

Are chemically set; the reaction cannot be reversed. The effect is to permanently change the structure of the polymer; upon heating, it degrades or burns rather than melts.

- possess a high degree of cross-linking
- are hard and brittle

Example.

Amino resins

Epoxies

Phenolic

Polyesters

Elastomers

Are cross-linked polymers.

Possess a low degree of cross-linking.

Are elastic and resilient.

Polymer Additives

In most cases, it becomes very essential to add some extra materials into the monomers before or during the process of polymerization in order to impart certain desired properties to the polymers. The various substances which are usually added into the monomers are:

Plasticizers: They act as internal lubricants and prevent crystallization by keeping the chains separated from one another

Fillers: They are added to improve strength, dimensional stability and heat resistance. Examples include wood, asbestos, glass, fibres, mica and slate powder

Catalyst: Are added to expedite as well as complete the polymerization reaction. Are also called accelerators or hardeners

Initiators: Are added to initiate the reaction among monomers and to stabilize the end reaction of the molecular chains. Example is hydrogen peroxide (H_2O_2)

Dyes and pigments: These are added to impart the desired colour to the finished polymers

Mechanical Properties of Polymers

Specified with many of the same parameters that are used for metals, that is,

modulus of elasticity, and
Yield and tensile strengths.
For many polymeric materials, the simple stress–strain test is employed for the characterization of some of these mechanical parameters.
The mechanical characteristics of polymers, for the most part, are highly sensitive to the rate of deformation (strain rate), the temperature, and the chemical nature of the environment (the presence of water, oxygen, organic solvents, etc.).
Some modifications of the testing techniques and specimen configurations used for metals are necessary with polymers, especially for the highly elastic materials, such as rubbers.

Modulus of elasticity and **ductility** in percent elongation are determined for polymers in the same manner as for metals
For plastic polymers, the yield point is taken as a maximum on the curve, which occurs just beyond the termination of the linear-elastic region the stress at this maximum is the yield strength (σ_y).
Tensile strength (TS) corresponds to the stress at which fracture occurs. It may be greater than or less than (σ_y) Strength, for these plastic polymers, is normally taken as tensile strength

Mechanical properties of polymers are highly influenced by temperature. See graph below;
Increasing the temperature produces;
decrease in elastic modulus,
reduction in tensile strength, and
an enhancement of ductility
at 4 ^{0}C the material is totally brittle, whereas considerable plastic deformation is realized at both 50 and 60 ^{0}C

Polymer Recycling
Recycling means recovering the discarded plastic items and reprocessing them into new products, in some cases products that are quite different from the original discarded items.
Trainees to
Carryout recycling of thermoplastics
Apply heat test to plastics
Test plastics for various properties
Identify applications for plastics
Identify polymeric adhesive
Distinguish different types of rubbers
carry out plastic molding

WOOD

Structure of a timber tree

- The cross-section of an exogenous trees shows the following structure

- Pith or Medulla
- Annual Rings
- Heart wood
- Sap wood
- Cambium layer
- Metullary rays
- Bark
- Task
- Identify and discuss the uses of the above listed sections of a exogenous tree
- Differentiate between exogenous tree and endogenous tree in the locality-give examples Characteristics of hard and soft wood

Glass

Definition of glass:

The glass is an amorphous solid completely lacking in long range, periodic atomic structure, and exhibiting a region of glass transformation (transition) behavior. Any material, inorganic, organic, or metallic, formed by any technique, which exhibits glass transformation (transition) behavior, is a glass.

Common types of glass

The following is a list of the more common types of silicate glasses, and their ingredients, properties, and applications:

Fused quartz, also called fused silica glass, vitreous silica glass, is silica (SiO_2) in vitreous or glass form (i.e., its molecules are disordered and random, without crystalline structure). It has very low thermal expansion, is very hard, and resists high temperatures (1000–1500°C). It is also the most resistant against weathering (caused in other glasses by alkali ions leaching out of the glass, while staining it). Fused quartz is used for high temperature applications such as furnace tubes, lighting tubes, melting crucibles, etc.

Soda-lime-silica glass, window glass: silica (SiO_2) 72% + sodium oxide (Na_2O) 14.2% + lime (CaO) 10.0% + magnesia (MgO) 2.5% + alumina (Al_2O_3) 0.6%. It is transparent, easily formed, and most suitable for window glass (flat glass). It has a high thermal expansion and poor resistance to heat (500–600°C). It is used for windows, some low temperature incandescent light bulbs, and tableware. Container glass is a soda-lime glass that is a slight variation on flat glass, which uses more alumina and calcium, and less sodium and magnesium which are more water-soluble. This makes it less susceptible to water erosion.

Sodium borosilicate glass, Pyrex: silica (SiO_2) 81% + boric oxide (B_2O_3) 12% + soda (Na_2O) 4.5% + alumina (Al_2O_3) 2.0%. Stands heat expansion much better than window glass. Used for chemical glassware, cooking glass, car headlamps, etc. Borosilicate glasses (e.g. Pyrex) have as main constituents: silica and boron oxide. They have fairly low coefficients of thermal expansion (7740 Pyrex CTE is 3.25×10^{-6}/°C as compared to about 9×10^{-6}/°C for a typical soda-lime glass, making them more dimensionally stable. The lower CTE also makes them less subject to stress caused by thermal expansion, thus less vulnerable to cracking from thermal shock. They are commonly used for reagent bottles, optical components, and household cookware.

Lead-oxide glass, crystal glass: silica 59% + lead oxide (PbO) 25% + potassium oxide (K_2O) 12% + soda (Na_2O) 2.0% + zinc oxide (ZnO) 1.5% + alumina 0.4%. Because of its high density (resulting in a high electron density) it has a high refractive index, making the look of glassware more brilliant (called "crystal", though of course it is a glass and not a crystal). It also has a high elasticity, making glassware 'ring'. It is also more workable in the factory, but cannot stand heating very well.

Aluminosilicate glass: silica 57% + alumina 16% + lime 10% + magnesia 7.0% + barium oxide (BaO) 6.0% + boric oxide (B_2O_3) 4.0%. Extensively used for fiberglass, used for making glass-reinforced plastics (boats, fishing rods, etc.) and for halogen bulb glass.

Oxide glass: alumina 90% + germanium oxide (GeO_2) 10%. Extremely clear glass, used for fiber-optic waveguides in communication networks. Light loses only 5% of its intensity through 1 km of glass fiber. However, most optical fiber is based on silica, as are all the glasses above.

Content; identification of engineering materials, selection of engineering materials, properties of materials, operation plan development, machine set up, production parameters, production performance, safety in production, application

Self-Assessment

1. Which of the following is not a characteristic trait of polymer materials?
   a) Low density
   b) Resistant to chemical attack
   c) Low cost
   d) High strength

2. The number of repeating units in a polymer is known as __________
   a) monomer
   b) degree of polymerization
   c) molecule
   d) chain

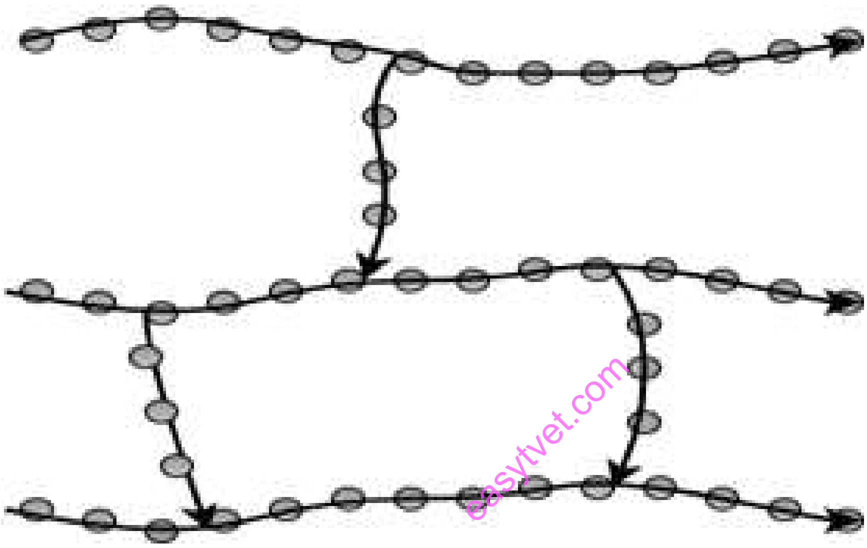
3. A polymer made of identical monomer units is called ______
   a) Homopolymer

b) Linear polymer
c) Copolymer
d) Branched polymer

4. Liquid or gas polymers having short chains and low molecular weights are known as ______

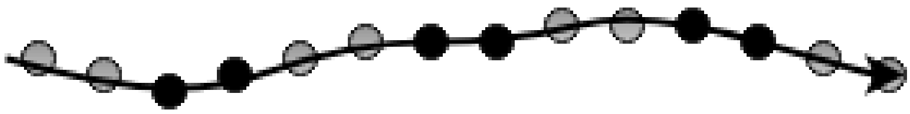
a) High-polymers
b) Homopolymers
c) Copolymers
d) Oligo-polymers

5. Which molecular structure does the below figure represent?



a) Linear
b) Branched
c) Cross-linked
d) Network

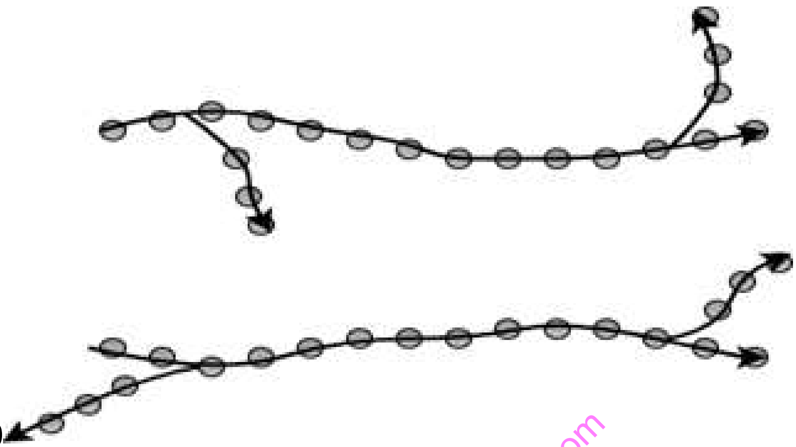
6. Which molecular structure does the figure represent?



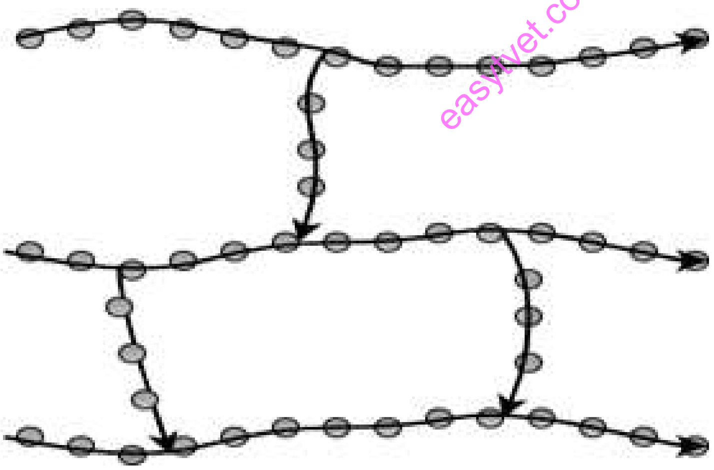
a) Random
b) Alternating
c) Block
d) Graft

7. Which figure represents the branched molecular structure?

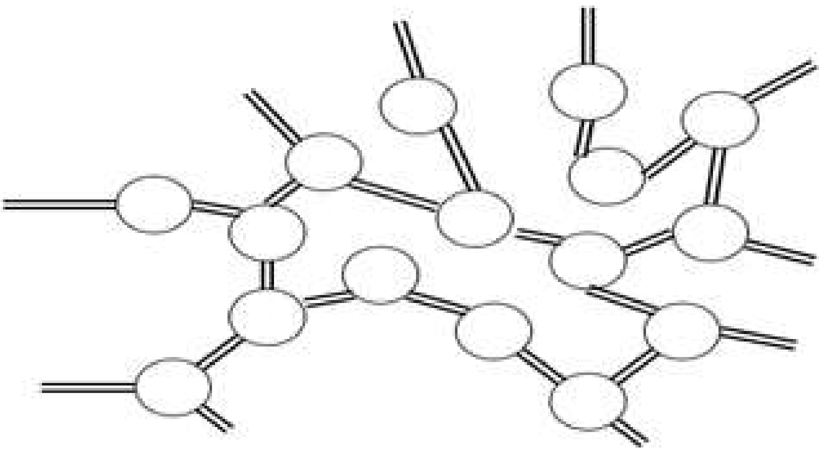
a)



b)



c)



d)

8. Which of the following types of polymers is a copolymer?
   a) Graft
   b) Network
   c) Linear
   d) Branched

9. Which of the following is not a stage of addition polymerization?
   a) Initiation
   b) Propagation
   c) Termination
   d) Recrystallisation

10. Thermosetting plastics are formed by _________
    a) addition polymerization
    b) copolymerization
    c) condensation polymerization
    d) isomerism

11. Which of the following is a property of thermosetting plastics?
    a) Can be molded
    b) Soft
    c) Recyclable
    d) Can be used at high temperatures

12. Which among these is an example of a commodity thermosetting plastic polymer material?
    a) Polyethylene
    b) Polypropylene
    c) Polystyrene
    d) Phenolic

13. Which of the following is not an example of a thermoplastic polymer?
    a) Urethane
    b) Melamine
    c) Epoxide
    d) Acetal

14. Phenolics are otherwise commonly known as ______
    a) Bakelite
    b) Polyformaldehyde
    c) Urea formaldehyde
    d) Melamine formaldehyde

15. Chilled castings are made by using __________
    a) Natural sand
    b) Synthetic sand
    c) Zircon sand
    d) Chromite sand

16. Why are Kaolinite and Bentonite used as clay in molding sand?
    a) High expansion ratio
    b) High thermo-chemical stability
    c) High coefficient of expansion
    d) Non-reactive with molding sand

17. ___________ additives improve the permeability of the molds.
    a) Sawdust
    b) Seacoal
    c) Cereals
    d) Silica flour

18. Identify and select engineering material according to production requirements
19. Develop operation plan according to engineering drawing
20. Set up appropriate machine according to manufacturer's manual
21. Set production parameters according to production requirement
22. Carryout glass blow molding

Tools, Equipment, Supplies and Materials for the specific learning outcome

Testing instrument
Extraction materials
Measuring instrument
Inspection tools

References (APA)

R.S. Khurmi and J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.9 Learning Outcome No 9 Perform Heat Treatment

Learning Activities

Learning Outcome N0. 9 Perform Heat Treatment	
Learning Activities	**Special Instructions**
Activity 1 **Heat treatment** MATERIALS Muffle furnace with temperature control and thermocouple pyrometer, quenching medium , hardness testing machine, tongs, emery cloth, smooth file, bench vice number of punches and a hand hammer, plain carbon steel test piece. Cary out Hardening, annealing, normalizing, tempering follow the heat treatment required procedure/manual	Avoid overheating of the specimen Observe safety according to OSHA 2007

Information sheet: 7.3.1.9

Heat treatment can be defined as the combination of processes or in which the heating and cooling of a metal or alloy is done in order to obtain desirable characteristics or properties.

Stages of Heat Treatment

Heat treating is accomplished in three major stages

Stage 1: **Heating 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 the metal to room temperature

Heat treatment processes

The processes include

Annealing

Normalising

Hardening

Tempering

Case hardening/case hardening: carburizing, cyaniding, nitriding, induction hardening, flame hardening

Surface hardening

Annealing
Annealing involves heating the material to a predetermined temperature and hold the material at the temperature and cool the material to the room temperature slowly.

Normalising
The processes consist of heating the) steel 30^0c- 50 ^{0}c above its upper critical temperature(for hypo-eutectoid steel) or Acm line for (hyper-eutectoid steels) .it's held at this temperature for about fifteen minutes and then allowed to cool down in still air.

Hardening
The process consists of heating the metal to a temperature of 30-50 0c above the upper critical point for hypo-eutectoid steels and by the same temperature above the lower critical temperature for hyper-eutectoid steels
Keeping the metal at this temperature for a considerable time depending upon its thickness.
Quenching in a suitable medium

Surface Hardening

Toughness of a materials decreases as hardness and strength increases. Shafts and gears, for example, require a tough material of high surface hardness. The solution for this problem would be to create a very hard surface layer on a comparatively soft and tough material. Surface hardening of steels is accomplished by a variety of methods.

Case Carburising Is a method used for producing hard surface on ductile steel. It involves introduction of additional carbon into the surface of mild steel, producing a composite material consisting of low carbon steel within a thin case of 0.5-0.7 mm thickness of high carbon steel. The principal methods of carburising are:

Pack carburising: parts are heated above the upper critical temperature in contact with wood or barium carbonate, within a cast iron container.

Gas carburising: parts are heated above the upper critical temperature in a furnace with an atmosphere of methane or mixed hydrocarbon gases. Three stage heat treatment is given to carburised parts to achieve desired properties:

Cyaniding
Steel components are heated in a bath of molten sodium cyanide and sodium carbonate at temperature of 950^0C. During the treatment, both carbon and nitrogen diffuse into the surface

of the steel. Formation of hard iron nitride contributes to the surface hardening of the steel. After cyaniding, parts undergo the three stage heat treatment mentioned above.

Nitriding

Not suitable for plain carbon steels. Suitable for low-alloy steels containing chromium and molybdenum. Parts for nitriding are first heat treated to produce the best core properties. Machining to final dimensions is then carried out, while the material is still in soft condition, allowing for the small growth of 0.02 mm that occurs during nitriding. Nitriding is, then, carried out by heating the steel parts at about 500^0C in a gas–tight chamber, in atmosphere of ammonia. The ammonia dissociates at the steel surface into nitrogen and hydrogen and nitrogen is absorbed by the steel. Advantages of nitriding include:

An extremely hard surface is formed

Treatment is conducted at comparatively low temperatures, minimizing cracking and distortion

No subsequent heat treatment is necessary

Content; heat treatment processes, procedure in heat treatment processes, performance of heat treatment in metals, safety practices in heat treatment

Self-Assessment

1. Heat treatment is a process which alters the mechanical properties of metal by changing the pro duct shape.
   a) True
   b) False

2. Proper equipment with close control must be implemented in the heat treatment of metals.
   a) True
   b) False

3. In heat treatment of metals, quenching is a method which induces ductility in the metal.
   a) True
   b) False

4. The heating rate of metals mainly depends on the thermal conductivity of metal which being treated.
   a) True
   b) False

5. In heat treatment, soaking is a stage in which metal product is cleaned by finishing operation.

a) True
b) False

6. In heat treatment of materials, the purpose of annealing is totally opposite to that of hardening.
   a) True
   b) False

7. Annealing of ferrous materials, the material is heated with a faster rate to get the desired properties.
   a) True
   b) False

8. In the heat treatment, normalizing method cannot be applicable for non-ferrous materials.
   a) True
   b) False

9. Carburizing is a case hardening process in which carbon is added to the surface of a metal.
   a) True
   b) False
10. Discuss main objective of various heat treatment processes
11. Factors which determine hardenability of steel
12. Carryout hardenability test-jominy end quench test
13. Identify heat treatment processes
14. Carryout heat treatment processes
15. Observe safety practices according to OSHA 2007

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.10Learning Outcome No 10 Perform Material Testing

Learning Activities

Learning Activities	**Special Instructions**
Activity 1 Dye penetrant test Material - Dye - Developer - Test piece Activity 2 Magnetic particle test Material Magnetic particle/dust Magnet Test piece Activity 3 Ultrasonic testing Material Ultrasonic machine/ Test piece Activity iv Radiography - X And Gamma Radiography - X And Gamma testing Material Radiographic machine/simulators, test piece Activity v Hardness test Material Hardness testing machine Indentors Activity (vi) Impact test: **Material** Impact testing machine Activity (vii) Macro and micro examination **Material** Metallurgical microscope, hack saw, emery cloth ,polishing machine, buffing machine, etchant (dil sulphuric acid/ Hydro choric acid	Follow material testing procedure Observe safety in material testing procedures Identify material testing method depending on material to be tested. Follow procedure of material testing as per material testing method

Information sheet: 7.3.1.10

Non- destructive tests

That testing of a component or material which does not impair the function of the component or material is known as non-detractive test and all such tests are termed as non-destructive tests

Commonly used non-destructive tests are

Liquid penetrant tests

Magnetic particle tests

Acid pickling tests

The above for detection of surface defects

Ultrasonic tests

Radiographic tests

Liquid penetrant tests

This type of test help to examine non –porous materials for defects that are open to the surface. There are two types of liquid penetrant tests.

Dye penetrant test

Fluorescent penetrant test

Dye penetrant test

In this test the dye penetrant is applied to clean dry surface and allowed to soak for a while. The dye penetrates the surface defects .Extra dye is wiped off, and a thin coating of developer chemical is applied. The developer draws the dye to the surface. Contrast between the colour of the developer (usually white) and the dye penetrant (usually red) helps to locate the defects.

Fluorescent penetrant test

In this test the fluorescent penetrant is applied to clean and degreased ,dry surface and allowed to soak for a while the fluorescent liquid penetrant enters the into the defects Excess liquid is wiped off. The surface is the inspected under black light. Cracks or flaws glow brightly under this light

Magnetic particle test

These tests can be applied only to magnetic materials .in this type of test, magnetic lines of force are generated in the component

Radiography - X and Gamma

Radiography This technique is suitable for the detection of internal defects in ferrous and nonferrous metals and other materials.

X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes, are penetrating radiation which is differentially absorbed by the material through which it passes; the greater the thickness, the greater the absorption. Furthermore, the denser the material the greater the absorption.

X and Gamma rays also have the property, like light, of partially converting silver halide crystals in a photographic film to metallic silver, in proportion to the intensity of the radiation reaching the film, and therefore forming a latent image. This can be developed and fixed in a similar way to normal photographic film

Ultrasonic

This test method uses high frequency sound waves to conduct examinations and take measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, flaw sizing and more. Produces a 100% volumetric inspection of the mater

Eddy current

Eddy current testing is used to detect surface and near-surface irregularities in ferrous and non-ferrous materials by inducing an eddy current field in the part under test.

Destructive testing

Destructive physical analysis, (DPA) tests are carried out to the specimen's failure, in order to understand a specimen's performance or material behaviour under different loads they include:

Hardness test : used to determine the hardness value it includes
Brinell hardness test
Rockwell hardness test
Vickers hardness test
Knoops /microhardness hardness test
Impact test:
Charpy test
Izod test
Fatigue test
Creep test

Content; materials testing procedures, material testing methods, tabulation and calculation of material testing results, material testing equipment care and maintenance, safety in material testing procedures

Self-Assessment

1. What is the disadvantage of LPI?
   a) Expensive
   b) Slow
   c) Not reliable
   d) Depth restriction

2. LPI can't be used on __________ specimen.
   a) Large
   b) Simple
   c) Complex
   d) Internally defected

3. Which order is right for LPI?
   a) Penetrant apply, development, inspection, surface preparation
   b) Surface preparation, penetrant apply, development, inspection
   c) Penetrant apply, development, surface preparation, inspection
   d) Development, surface preparation, penetrant apply, inspection

4. What is general dwell time?
   a) 20 seconds
   b) 2 minutes
   c) 20 minutes
   d) 2 hours

5. __________ increases the visibility of the flaw in LPI.
   a) Developer
   b) Penetrant
   c) Benzene
   d) Spirit

6. Developer is chosen such as benzene.
   a) True
   b) False

7. Small components are dipped in penetrant.
   a) True
   b) False

8. Which materials can be tested by MPI?
   a) Magnetic
   b) Non-magnetic

c) Paramagnetic
d) Ferromagnetic

9. Which material can't be tested by MPI?
a) Co
b) Fe
c) Ni
d) Mg

10. What is Curie point for most of the ferrous magnetic materials?
a) 550˚C
b) 760˚C
c) 910˚C
d) 1133˚C

11. The minimum width of crack, which can be inspected by MPI, is _________
a) 1nm
b) 1µm
c) 10µm
d) 1mm

12. What is the advantage of using DC in MPI?

a) Battery maintenance
b) Demagnetize easy
c) Variable voltage supply
d) Subsurface detection

13. Benzene and alcohol are used to decrease component.
a) True
b) False

14. Plain carbon steels are applied with magnetic particles by a residual method?
a) True
b) False

15. In what terms, fatigue life is measured?
a) Time of failures
b) Number of cycles of failure
c) Stress of failure
d) Appearance of fracture

16. Fatigue curves are popularly known as __________ curves.
a) S
b) R

c) N
d) S-N

17. What term is used for the maximum stress at which material fail on a specified number of cycle?
    a) Fatigue strength
    b) Fatigue life
    c) Ultimate tensile strength
    d) Endurance limit

18. Word “endurance limit” is used for _____________
    a) Plastics
    b) Ferrous materials
    c) Nonferrous materials
    d) Alloys

19. Which ferrous material doesn’t show fatigue limit?
    a) Cast iron
    b) Wrought iron
    c) Austenitic stainless steel
    d) Low carbon steel

20. Which of the following show a fatigue limit?
    a) Titanium
    b) Cast iron
    c) Magnesium
    d) Al-Mg alloys

21. What is the reason for fatigue failure?
    a) Movement of Dislocations
    b) Submicroscopic cracks
    c) Dynamic recovery
    d) Vacancy coalescence

22. Trainers to perform the above destructive tests and nondestructive tests
23. Observe safety in material testing procedures
24. Identify material testing methods depending on material to be tested
25. Follow procedure of material testing as per material testing method
26. Tabulate, calculate and interpret material testing results
27. Trainee to take care of and maintain material testing equipment

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.4 Learning Outcome No 11 Prevent Material Corrosion

Learning Activities

Learning Outcome No 11 Prevent Material Corrosion	
Learning Activities	**Special Instructions**
ACTIVITY 1 **Understanding the mechanism of corrosion** Carry out electrolytic action /wet corrosion involving dissimilar elements MATERIALS Copper strip, zinc strip, electrolyte (Dil.sulphuric acid), Ammeter Carry out electrolytic action /wet corrosion involving Electrolytes of non-uniform composition MATERIALS Porous plate, dil. Iron Chloride sol, Conc. Iron (Chloride sol., pure iron strip 2 pieces **ACTIVITY 2** Identify different form of corrosion in the locality and their possible causes MATERIALS corroded materials **ACTIVITY 4** *Carryout different forms of corrosion protection method:* ***Cathodic Protection*** *Sacrificial Coatings, Protective Coatings painting* MATERIALS Paint ,paint brush, turpentine,	Sources of corrosion

Information sheet: 7.3.4

Corrosion is the deterioration of materials due to chemical reaction with the environment. It is reverse extractive metallurgy, which is dependent on temperature and concentration of environment. Other factors such as stress and erosion also affect the corrosion rate corrosion is termed as the chemical or electrochemical reaction between a material and its environment that leads to deterioration of the material and/or its properties.

The most important types are:
Uniform corrosion.
Galvanic corrosion, concentration cells, water line attack
Pitting

Dezincification, Dealloying (selective leaching)
Atmospheric corrosion.
Erosion corrosion Fretting Crevice corrosion; cavitation
Stress corrosion, intergranular and transgranular corrosion, hydrogen cracking and embitterment
Corrosion fatigue

Crevice corrosion is a localized attack on a metal adjacent to the crevice between two joining surfaces (two metals or metal-nonmetal crevices). The corrosion is generally confined to one localized area to one metal

Pitting corrosion is a localized phenomenon confined to smaller areas. Formation of micro-pits can be very damaging. Pitting factor (ratio of deepest pit to average penetration) can be used to evaluate severity of pitting corrosion which is usually observed in passive metals and alloys. Concentration cells involving oxygen gradients or ion gradients can initiate pitting through generation of anodic and cathodic areas. Chloride ions are damaging to the passive films and can make pit formation auto-catalytic. Pitting tendency can be predicted through measurement of pitting potentials. Similarly critical pitting temperature is also a useful parameter

Uniform corrosion is a very common form found in ferrous metals and alloys that are not protected by surface coating or inhibitors. A uniform layer of „rust" on the surface is formed when exposed to corrosive environments Atmospheric corrosion is a typical example of this type.

Galvanic corrosion often referred to as dissimilar metal corrosion occurs in galvanic couples where the active one corrodes. EMF series (thermodynamic) and galvanic series (kinetic) could be used for prediction of this type of corrosion. Galvanic corrosion can occur in multiphase alloys Eg: - Copper containing precipitates in aluminium alloys. Impurities such as iron and copper in metallic zinc

Erosion corrosion The term "erosion" applies to deterioration due to mechanical force. When the factors contributing to erosion accelerate the rate of corrosion of a metal, the attack is called "erosion corrosion". It is the result of a combination of an aggressive chemical environment and high fluid surface velocities

You can prevent corrosion by selecting the right:
Metal Type
Protective Coating
Environmental Measures
Sacrificial Coatings
Corrosion Inhibitors
Design Modification

There are two main techniques for achieving sacrificial coating: cathodic protection and anodic protection.

Cathodic Protection

The most common example of cathodic protection is the coating of iron alloy steel with zinc, a process known as galvanizing. Zinc is a more active metal than steel, and when it starts to corrode it oxides which inhibits the corrosion of the steel. This method is known as cathodic protection because it works by making the steel the cathode of an electrochemical cell. Cathodic protection is used for steel pipelines carrying water or fuel, water heater tanks, ship hulls, and offshore oil platforms.

Anodic

Anodic protection involves coating the iron alloy steel with a less active metal, such as tin. Tin will not corrode, so the steel will be protected as long as the tin coating is in place. This method is known as anodic protection because it makes the steel the anode of an electrochemical cell.

Anodic protection is often applied to carbon steel storage tanks used to store sulfuric acid and 50% caustic soda. In these environments cathodic protection is not suitable due to extremely high current requirements.

Corrosion Inhibitors

Corrosion inhibitors are chemicals that react with the surface of the metal or the surrounding gases to suppress the electrochemical reactions leading to corrosion. They work by being applied to the surface of a metal where they form a protective film. Inhibitors can be applied as a solution or as a protective coating using dispersion techniques. Corrosion inhibitors are commonly applied via a process known as passivation.

Passivation

In passivation, a light coat of a protective material, such as metal oxide, creates a protective layer over the metal which acts as a barrier against corrosion. The formation of this layer is affected by environmental pH, temperature, and surrounding chemical composition. A notable example of passivation is the Statue of Liberty, where a blue-green patina has formed which actually protects the copper underneath. Corrosion inhibitors are used in petroleum refining, chemical production, and water treatment works.

Design Modification

Design modifications can help reduce corrosion and improve the durability of any existing protective anti-corrosive coatings. Ideally, designs should avoid trapping dust and water, encourage movement of air, and avoid open crevices. Ensuring the metal is accessible for regular maintenance will also increase longevity

Self-Assessment

1. The compressive test is done on which of the following materials?
   a) Cast iron
   b) Aluminum
   c) Gold
   d) Thermocouple

2. Which of the following is not a method of shear test?
   a) Double sheer system for round bar
   b) Double knife shear system for rectangular section
   c) Double shear system for conical surfaces
   d) Shearing of disc using punch and die

3. _________ plating is used for protection against wear in lead bearings.
   a) Gallium
   b) Arsenic
   c) Indium
   d) Helium

4. What are the applications of chromium plating?
   a) Plastics
   b) Wheel and rims
   c) IC engine parts
   d) Castings

5. What is the hardness of a rhodium plate?
   a) 140-425 Vickers
   b) 540-640 Vickers
   c) 720-880 Vickers
   d) 950-1050 Vickers

6. The alumilite process uses _________ as an electrolyte for anodizing.
   a) Sulfuric acid
   b) Hydrogen peroxide
   c) Nitric acid
   d) Ammonium sulfate

7. Which of the following is a use for flash anodic coatings?
   a) Cartridge cases
   b) Airplane propeller
   c) Paint adherence
   d) Hydraulic pistons

8. Chromizing is carried out at a temperature of __________
   a) 400-600 F
   b) 800-1200 F
   c) 1650-2000 F
   d) 2250-2750 F

9. Siliconizing is otherwise known as _________
   a) Chromizing
   b) Nitriding
   c) Ihrigizing
   d) Oxy-cyaniding

10. __________ is used as a catalyst in siliconizing.
   a) Hydrogen peroxide
   b) Chlorine gas
   c) Sulfuric acid
   d) Magnesium sulfate

11. Observe the safety in material testing procedures
12. Carryout different forms of corrosion protection methods
13. Identify different type of corrosion in the locality and their possible causes
14. Identify methods of corrosion prevention

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

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