

11.1.0 MATERIALS TECHNOLOGY AND METALLURGY

11.1.01 Introduction

Materials technology and metallurgy is the study of engineering materials and their applications in engineering field.

These engineering materials include metals, ceramics, organics, composites, and semiconductors.

The study involves the composition of materials their production processes, mechanical and physical properties.

The module also exposes the trainees to various methods of improving the properties of metals by heat treatment methods

11.1.02 General Objectives:

At the end the module, the trainee should be able to:

- understand various materials and their applications in engineering field
- understand production processes of engineering materials
- apply heat treatment processes on metal to improve their properties
- select the right engineering materials for various applications in the automotive industry
- understand factors to be considered when selecting materials for particular use.

11.1.02 Module Unit Summary and Time Allocation

Materials Technology and Metallurgy

Code	Sub-Module Unit	Content	Time Hrs		
11.1.1	Properties of Engineering Materials	<ul style="list-style-type: none">Types of engineering materialsProperties of engineering materials(physical and mechanical)	4	2	6
11.1.2	Structure of Materials	<ul style="list-style-type: none">Crystalline stateCrystal structuresTerminologies	2	2	4
11.1.3	Production of Iron, Steel and Cast Iron	<ul style="list-style-type: none">Types of ores, charging materialsTypes of furnaces	4	2	6

11.1.4	Cast Irons	<ul style="list-style-type: none"> • Types and structures of cast irons • Properties of C.I. 	2	2	4
11.1.4	Carbon Steels	<ul style="list-style-type: none"> • Classification of carbon steels • Properties of plain carbon steel • Application of plain carbon steel 	2	2	4
11.1.5	Alloy Steels	<ul style="list-style-type: none"> • Alloying elements and their effects • Classification of alloy steels • Corrosion resistant steels and their application • Ferritic, martensitic and austenitic stainless steels • Weld decay and sigma phase • Heat resisting steels • Tool steels 	6	2	8
11.1.6	Non-Ferrous Metals and Alloys	<ul style="list-style-type: none"> • Non-ferrous metals • Production of non-ferrous metals • Properties of non ferrous metals • Forms of supply • Brass, Bronze, Cupronickels • Duralumin • Cast and Wrought Alloys 	6	4	10
11.1.7	Plastics, Wood and Rubber	<ul style="list-style-type: none"> • Types of plastics • Wood • Rubber 	2	2	4
11.1.8	Bearing Materials	<ul style="list-style-type: none"> • Metals/non-metals • Bearing properties 	2	2	4
11.1.9	Corrosion and Its Prevention	<ul style="list-style-type: none"> • Types of corrosion • Corrosion prevention 	2	2	4
11.1.10	Heat Treatment	<ul style="list-style-type: none"> • Annealing • Tempering 	4	8	12

		<ul style="list-style-type: none">• Normalizing• Hardening• Case hardening			
Total Time			36	30	66

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11.1.1 PROPERTIES OF ENGINEERING MATERIALS

Theory

- 11.1.1T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- identify various types of engineering materials
 - describe physical properties of engineering materials
 - define mechanical properties of engineering materials
 - state forms of supply

11.1.1C **Competence**

The trainee should have the ability to:

- identify various types of engineering materials for a given task
- determine various material properties

Content

- 11.1.1T1 Types of engineering materials
- Metals
 - Ceramics
 - Composite
 - Organic
 - Semiconductors

11.1.1T2 Physical properties

- Colour
- Thermal conductivity
- Corrosion resistance
- density
- Melting point
- Electrical conductivity
- Magnetism

11.1.1T3 Mechanical properties

- Tensile strength
- Hardness
- Ductility
- Impact strength
- Malleability
- Brittleness
- Elasticity
- Plasticity
- Weldability

11.1.1T4 Forms of supply

- Sheets
- Plates
- Bars
- Tubes
- Rolled Sections
- Granules
- Pellets
- Powder

Practice

11.1.1P0 *Specific Objectives*

By the end of the sub-module unit, the trainee should be able to:

- identify various types of engineering materials
- determine various material properties

- Content*
- 11.1.1P1 Types of materials
- i) Ferrous
 - ii) Non-ferrous
 - iii) Composites
 - iv) Organic
 - v) Ceramics
 - vi) Semiconductors
- 11.1.1P2 Determination of material properties
- i) Colours
 - ii) Density
 - iii) Conductivity
 - iv) Hardness
 - v) Corrosion resistance

Suggested Learning Resources

- Various metals
- Science laboratory

11.1.2 STRUCTURE OF MATERIALS

Theory

- 11.1.2T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) explain crystalline state
 - b) describe types of crystal structures
 - c) describe terminologies
- 11.1.2P3 **Competence**
The trainee should have the ability to:
- i) Describe crystalline states, structures and terminologies
 - ii) grow crystals

- iii) identify crystal structures
- iv) demonstrate various material states

Content

- 11.1.2T1 Crystalline state
- i) Cell and space lattice
 - ii) Grain and grain boundary
 - iii) Growth of dendrites
- 11.1.2T2 Crystal structures
- i) Simple cubic
 - ii) Body centred cubic (B.C.C)
 - iii) Face centered cubic (F.C.C)
 - iv) Hexagonal close packed (H.C.P)
- 11.1.2T3 Terms for material states:
- i) Mixture, compound, alloy, solid solution, liquids, eutectic, solidus,
 - ii) eutectoid, thermal equilibrium diagrams

Practice

- 11.1.2P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) grow crystals
 - b) identify various crystal structures
 - c) demonstrate various material states

- Content*
- 11.1.2P1 crystal growing (sugar, salt)
- 11.1.2P2 crystal structure models
h.c.p, b.c.c, f.c.c, s.c material states
- 11.1.2P3 material states – compound, mixture, alloy

Suggested Learning Resources

- i) Experiments
ii) Models

11.1.3 PRODUCTION OF IRON, STEEL AND CAST IRON

Theory

- 11.1.3T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- state various types of iron ore
 - state the additional charging material in a furnace and their effects on iron
 - describe the construction and operational principles of furnaces
 - state the care and safety necessary in blast furnace

11.1.3C Competence

The trainee should have the ability to:

- i) identify various ores and charging

materials

- ii) identify various types of furnaces
iii) observe safety

Content

- 11.1.3T1 Types of iron ores
- 11.1.3T2 Additional charging materials
- 11.1.3T3 Features of furnaces
- Blast
 - Cupola
 - Open hearth
 - Bessemer
 - Electric furnace
 - Oxygen process (Kaldo)
- 11.1.3T4 Safety

Practice

- 11.1.3P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- identify various types of ores and charging materials
 - identify various types of furnaces
 - practice safety

Content

- 11.1.3P1 Ores and charging materials
- 11.1.3P2 Types of furnaces
- 11.1.3P3 Safety
- personal
 - equipment

Suggested Learning Resources

- Various ores
- Various charging materials
- Various furnaces

11.1.4 CAST IRONS

Theory

- 11.1.4T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to;
- name various types of cast irons and their applications
 - describe properties of cast irons
 - describe the effects of alloying elements on the properties of cast irons
 - state defects in iron casting

11.1.4C **Competence**

The trainee should have the ability to:

- describe grey and white iron
- describe properties of various cast irons
- Identify different types of cast iron
- Test mechanical properties of cast irons
- state casting defects

Content

- 11.1.4T1 Types of cast iron and their application
11.1.4T2 Properties of cast irons

- 11.1.4T3 Effects of alloying elements
11.1.4T5 Effects of heat treatment defects in iron casting

Practice

- 11.1.4P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- Identify various types of cast iron
 - Test properties of cast iron

Content

- 11.1.4P1 Types of cast iron
11.1.4P2 Mechanical tests on cast iron

Suggested Learning Resources

- Various types of cast iron
- Heating furnace
- Cast iron castings

11.1.5 CARBON STEELS

Theory

- 11.1.5T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- classify various types of plain carbon steels based on carbon content
 - state properties of plain carbon steels

- c) state applications of plain carbon steels

11.1.5

Competence

The trainee should have the ability to:

- i) state different plain carbon steels, their properties and applications
- ii) identify types of plain carbon steels
- iii) identify cold rolled/drop forged items

Content

11.1.5T1 Classification of plain carbon steels dead mild, mild, medium carbon, high carbon

11.1.5T2 Properties of plain carbon steel tensile strength, ductility, hardness, toughness, malleability, brittleness

11.1.5T3 Applications chain, rivets, structural, crankshafts, hammers, drills

Practice

- 11.1.5P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) identify types of plain carbon steels
 - b) identify cold rolled/ drop forged items

Content

11.1.5P1 Types of plain carbon steels

- i) Dead Mild,
- ii) Mild,
- iii) Medium Carbon,
- iv) High Carbon Steel

11.1.5P2 Cold rolled/drop forged items

Suggested Learning Resources

- Various types of plain carbon steel
- Cold rolled/drop forged products

11.1.6 ALLOY STEELS

Theory

11.1.6T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:

- a) list typical alloying elements
- b) classify alloy steels
- c) describe corrosion resistant steels and their applications
- d) describe heat resistant steels, their properties and applications
- e) select steel for specific application

11.1.6C Competence

The trainee should have the ability to identify:

- i) Of stainless steels
- ii) Tool alloying elements
- iii) Uses of alloy steels
- iv) Uses materials and their properties

- ii) Dies
- iii) Kitchenware
- iv) Furnace Conveyor
- v) Turbine Blades

Practice

- 11.1.6P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) identify various alloying elements
 - b) identify uses of alloy steels
 - c) identify applications of stainless steels
 - d) identify various tool materials and their properties

Content

- 11.1.6T1 Alloying elements
 - i) Nickel, molybdenum, chromium, sulphur, titanium, vanadium
- 11.1.6T2 Classification of alloy steels
 - i) Manganese steels
 - ii) Nickel steels
 - iii) Nickel chrome
 - iv) Nickel chrome vanadium steels
 - v) Nickel chromium, molybdenum alloys
 - vi) Chromium steels
- 11.1.6T3 Corrosion resistant steels (stainless steels)
 - i) Nickel, chromium, molybdenum alloys
 - ii) Austenitic, ferritic, martensitic steels
 - iii) Weld decay and sigma phase
 - iv) Applications:
 - v) Cutlery, beer barrel, chemical plant
- 11.1.6T4 Heat resistant steels
 - i) Molybdenum
 - ii) Tungsten
 - iii) Vanadium
- 11.1.6T5 Selection of steels for specific application
 - i) Tools

Content

- 11.1.6P1 Alloying elements
- 11.1.6P2 Uses of alloy steels
- 11.1.6P3 Applications of stainless steels
- 11.1.6P4 Tool materials and properties

Suggested Learning Resources

- Various alloy steels

11.1.7 NON FERROUS METALS AND ALLOYS

Theory

- 11.1.7T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- describe methods of producing non ferrous metals and properties
 - state forms of supply
 - describe non ferrous alloys
 - state alloys for specific application

11.1.7C Competence

The trainee should have the ability to:

- methods of producing non-ferrous metals
- forms of supply of non-ferrous metals
- non-ferrous metals
- electrolysis process
- tests on materials
- non-ferrous alloys
- selection of alloys for specific application

Content

- 11.1.7T1 Non ferrous metals
- Copper, aluminium
 - Electrolysis of aluminium oxide
 - Smelting of copper
 - Properties
 - High electrical conductivity
 - Affinity for oxygen
 - Light weight

- Corrosion resistance
- High thermal conductivity
- Ductility and malleability

- 11.1.7T2 Forms of supply
- Sheets, bars, rolled sections, tubes

- 11.1.7T3 Non ferrous alloys
- Aluminium alloys
 - Wrought, cast, non-heat treatable, heat treatable
 - Copper alloys
 - Brasses, bronzes, cupro-nickels Babbitt

- 11.1.7T4 Applications
- Conductor, heat exchanger, aircraft fuselage and structural construction, thrust bearing, cartridges

Practice

- 11.1.7P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- identify non-ferrous metals
 - perform an electrolysis process
 - determine various material properties
 - identify non-ferrous alloys
 - identify alloying elements in non-ferrous alloys

- f) select alloys for specific applications

- vi) Science laboratory equipment

Content

11.1.7P0 Non-ferrous metals

- i) Aluminium
- ii) Copper

11.1.7P1 Electrolysis process

- i) Use of copper solvents

11.1.7P2 Properties of materials

- i) Hardness, heat conductivity, corrosion resistance, affinity for oxygen, magnetism

11.1.7P3 Non ferrous alloys

- i) Copper based
- ii) Brasses
- iii) Bronzes
- iv) Cupronickels
- v) Aluminium based
- vi) Cast wrought
- vii) Heat treatable/non heat treatable
- viii) Applications
- ix) Cartridges, shell cases, heat exchangers, bearings, aircraft fuselage and seat frames

Suggested Learning Resources

- i) Copper oxide
- ii) Aluminium oxide
- iii) Furnace
- iv) Various non-ferrous metallic samples
- v) Various non-ferrous alloy samples

11.1.8 PLASTICS, WOOD AND RUBBER

Theory

11.1.8T0 *Specific Objectives*

By the end of the sub-module unit, the trainee should be able to:

- a) differentiate thermoplastics from thermosetting plastics
- b) describe properties of plastics
- c) classify polymeric materials
- d) state forms of supply, mechanical properties and engineering applications
- e) state types of polymeric adhesives
- f) explain how joint design affects strength of joint
- g) explain the structure of wood
- h) explain the process of wood preservation
- i) describe various elastomers
- j) state types of

- rubber
- k) describe properties of rubber

11.1.8 Competence

The trainee should have the ability to:

- i) Distinguish thermoplastics/thermosetting plastics
- ii) Explain the effect of joint design on strength of joint
- iii) Distinguish different wood structures
- iv) Season and cure wood
- v) Apply heat test to plastic
- vi) Test plastic for various properties
- vii) Identify applications for plastics
- viii) Identify polymeric adhesives
- ix) Distinguish different types of rubber

Content

- 11.1.8T1 Thermoplastics and thermosetting plastics
- 11.1.8T2 Properties
 - i) Plasticity
 - ii) Low Melting Temperature
 - iii) Light Weight
 - iv) Weldability
 - v) Strength
 - vi) Brittleness
 - vii) Durability
 - viii) Toughness
 - ix) Corrosion Resistance
- 11.1.8T3 Classification

- i) P.V.C., P.T.F.E.
- ii) Thermo plastics
- iii) Cellulose derivatives, polyethylene, terephthylene, nylon, poly carbonate
- iv) Thermosetting plastics
- v) Phenol – formaldehyde, phenol, amino formaldehyde, polyesters, epoxy polyurethane
- vi) Elastomers
- vii) Natural rubber, isobutylene, butadiene, polysulphide, polyurethanic

- 11.1.8T4 Forms of supply
- 11.1.8T5 Adhesives – araldite, epoxies, phenolic resins
- 11.1.8T6 Joint design: butt, lap, contact surface, tension load, cleavage
- 11.1.8T7 Cross section of wood
- 11.1.8T8 Preservation
 - i) Seasoning
 - ii) Curing
- 11.1.8T9 Types of Rubber
 - i) Natural
 - ii) SBR
 - iii) Butyl
 - iv) Nitride
 - v) EPR
 - vi) Polysulphide
- 11.1.8T10 Properties of rubber

Practice

- 11.1.8P0 *Specific Objectives*
By the end of the sub-

module unit, the trainee should be able to:

- a) distinguish plastics by heat application
- b) test plastics for various properties
- c) identify various plastics application
- d) identify various polymeric adhesives

Content

- 11.1.8P1 Types of plastics
 - i) Thermoplastics
 - ii) Thermosetting
- 11.1.8P2 Properties
 - i) Weight, low melting temperature strength, electrical conductivity, elasticity
- 11.1.8P3 Applications
 - i) Machine operations, bearing materials, car trims, seat covers, tiles handles
- 11.1.8P4 Adhesives
 - i) Araldite, epoxies, phenolics
 - ii) Wood
 - iii) Types of rubber

Suggested Learning Resources

- i) Various plastic material
- ii) Science laboratory

11.1.9 BEARING MATERIALS

Theory

11.1.9T0 *Specific Objectives*

By the end of the sub-module unit, the trainee should be able to:

- a) state classification of bearing materials
- b) explain bearing properties
- c) select material for bearing application

11.1.9C **Competence**

The trainee should have the ability to:

- i) identify various types of bearing materials
- ii) carry out tests for bearing properties
- iii) select bearing material for a given application
- iv) produce a plain bearing

Content

- 11.1.9T1 Bearing materials
 - i) Metals
 - ii) White metals (Tin base, Lead base)
 - iii) Copper based
 - iv) Aluminium based
 - v) Non-metals
 - vi) Graphite
 - vii) Nylon
 - viii) P.T.F.E.
- 11.1.9T2 Bearing properties
 - i) Wear resistance
 - ii) Shock resistance
 - iii) Strength
 - iv) Ductility
 - v) Corrosion

- resistance
- 11.1.9T3 Select bearing materials
- i) Metals
 - ii) Non-metals
- Practice*
- 11.1.9P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) identify various types of bearing materials
 - b) carry out tests for bearing properties
 - c) select suitable bearing for a given application
 - d) produce a plain bearing

Content

- 11.1.9P1 Bearing materials
- i) Metal based
 - ii) Tin based
 - iii) Lead based
 - iv) Copper based
 - v) Aluminium based
 - vi) Non-metals
 - vii) Graphite
 - viii) Nylon
 - ix) P.T.F.E.
- 11.1.9P2 Bearing properties
- i) Wear resistance
 - ii) Shock resistance
 - iii) Strength
 - iv) Ductility
 - v) Corrosion
- 11.1.9P3 Bearing applications
- i) End thrust
 - ii) Side thrust

11.1.9P4 Plain bearing production

- i) Bush
- ii) Split

Suggested Learning Resources

- Various bearing materials
- Science laboratory

11.1.10 CORROSION AND ITS PREVENTION

Theory

11.1.10P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:

- a) outline mechanism of corrosion
- b) describe methods available for prevention of corrosion

11.1.10C Competence

- The trainee should have the ability to:
- i) outline types of corrosion
 - ii) describe methods of preventing corrosion
 - iii) subject material to corrosive atmosphere
 - iv) perform corrosion preventive method
 - v) observe safety

- Content*
- 11.1.10T1 Types of corrosion
Chemical attack
- Electrolytic action with reference to electronic chemical – series
- 11.1.10 T2 Corrosion prevention
- i) Electroplating
 - ii) Cladding
 - iii) Spraying
 - iv) Calourising
 - v) Sherardizing
 - vi) Chromizing
 - vii) Phosphading
 - viii) Painting
 - ix) Varnishing
 - x) Cathodic protection

Practice

- 11.1.10P0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) subject materials to corrosive environment
 - b) perform corrosion preventive methods
 - c) observe safety precautions

- Content*
- 11.1.10P1 Corrosive conditions
Acids, salts, air
- 11.1.10P2 Preventive methods
Painting, spraying, varnishing,

- electroplating ,
carbonizing,
sheradising anodizing
- 11.1.10P3 Safety
Personal, equipment

Suggested Learning Resources

- Supply of various corrosive media
- Supply of various material
- Science lab

11.1.11 HEAT TREATMENT

Theory

- 11.1.11T0 *Specific Objectives*
By the end of the sub-module unit, the trainee should be able to:
- a) describe various heat treatment processes
 - b) state advantages and limitations of heat treatment processes
 - c) select heat treatment process for a given task

- 11.1.11C Competence**
The trainee should have the ability to:
- i) describe various heat treatment processes

- ii) state advantages and limitations of heat treatment processes
- iii) observe safety
- iv) identify various carbonaceous material
- v) identify and select heat treatment process

Content

11.1.11T1 Heat treatment process

- i) Annealing
- ii) Tempering
- iii) Normalizing
- iv) Hardening
- v) Surface hardening processes
- vi) Case hardening
- vii) Carburizing
- viii) Refining the case
- ix) Nitriding
- x) Flame hardening
- xi) Induction hardening
- xii) Advantages and limitations of heat treatment
- xiii) Wear resistant
- xiv) Toughness
- xv) Process selection

11.1.11T2 Advantages and limitations

11.1.11T3 Treatment processes

Practice

11.1.11P0 *Specific Objectives*
By the end of the sub-module unit, the

trainee should be able to:

- a) identify various carbonaceous material
- b) identify and select heat treatment process
- c) perform heat treatment process
- d) practice safety when performing heat treatment

Content

11.1.11P1 Heat Treatment Process

- i) Annealing
- ii) Normalizing
- iii) Tempering
- iv) Hardening
- v) Surface hardening

11.1.11P2 Carbonaceous material

- i) Solids
- ii) Liquid
- iii) Gas

11.1.11P3 Surface hardening processes

- i) Case hardening
- ii) Carbon nitriding
- iii) Flame hardening
- iv) Induction hardening

11.1.11P4 Safety precautions

Suggested Learning Resources

- Heat treatment furnaces
- Salt bath furnace
- Carburizing material
- Safety masks/gear