RRB-JE 2024

Railway Recruitment Board

Junior Engineer Examination

Mechanical Engineering

Material Science

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY PUBLICATIONS

Material Science

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CHAPTER 01

Introduction

1.1 Classification of Engineering Materials

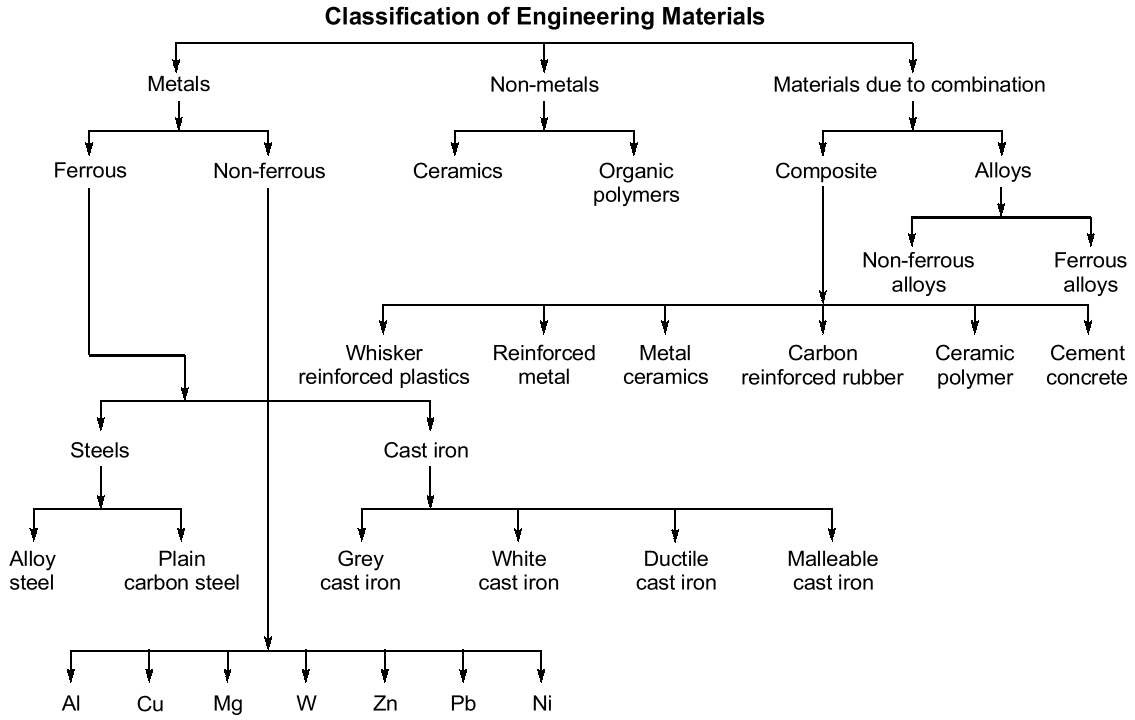

Figure 1.1

1.1.1 Materials Science

- It can be defined as science dealing with the relationships that exist between the structures and properties of materials, which are useful in practice of engineer's profession.

1.1.2 Properties of Materials

- All solid engineering materials are characterized for their properties.
- Engineering use of a material is reflection of its properties under conditions of use.
- All important properties can be grouped into six categories: Mechanical, Electrical, Thermal, Magnetic, Optical, and Decorative.

- Each material possess a structure, relevant properties, which dependent on processing and determines the performance.
- Normally material possessing strength have limited ductility.In such cases a reasonable compromise between two or more properties are important.
- A second selection consideration is any deterioration of material properties during service operations.
- Finally the overriding consideration is economics.

1.1.3 Classification of Materials

Three basic groups of solid engineering materials based on atomic bonds and structures are:

(i) Metals

(ii) Ceramics

(iii) Polymers (Organic Materials)

- Classification can also be done based on either properties (mechanical, electrical, optical), areas of applications (structures, machines, devices). Further we can subdivide these groups. According to the present engineering needs.
- Composites
- Semiconductors
- Biomaterials

(i) Metals

- Characteristics are owed to non-localized electrons (metallic bond between atoms) i.e. electrons are not bound to a particular atom.
- They are characterized by their high thermal and electrical conductivities.
- They are opaque, can be polished to high lustre. The opacity and reflectivity of a metal arise from the response of the unbound electrons to electromagnetic vibrations at light frequencies.
- Relatively heavier, strong, yet deformable.

Example —

- Steel
- Aluminium
- Brass
- Bronze
- Lead
- Titanium, etc.

(ii) Ceramics

- They contain both metallic and nonmetallic elements.
- Characterized by their higher resistance to high temperatures and harsh environments than metals and polymers.
- Typically good insulators to passage of both heat and electricity.
- Less dense than most metals and alloys.
- They are harder and stiffer, but brittle in nature.
- They are mostly oxides, nitrides, and carbides of metals.
- Wide range: traditional (clay, silicate glass, cement) to advanced (carbides, pure oxides, non-silicate glasses).

Example —

- Glass
- Porcelain
- Minerals, etc.

(iii) Polymers

- Commercially called plastics; noted for their low density, flexibility and use as insulators.
- Mostly are of organic compounds i.e. based on carbon, oxygen and other nonmetallic elements.
- Consists large molecular structures bonded by covalent and van der Waals forces.
- They decompose at relatively moderate temperatures (100 - 400°C).

- Application : packaging, textiles, biomedical devices, optical devices, household items, toys, etc.

Example —

- Nylon
- Teflon
- Rubber
- Polyester, etc.

1.1.4 Composites

- Consist more than one kind of material. They are made so as to benefit from combination of best characteristics of each constituent.
- Available over a very wide range: natural (wood) to synthetic (fiberglass).
- Many are composed of two phases; one is matrix . which is continuous and surrounds the other dispersed phase.
- Classified into many groups: (1) depending on orientation of phases; such as particle reinforced, fiber reinforced, etc. (2) depending on matrix; metal matrix, polymer matrix, ceramic matrix.

Example —

- Cement concrete
- Fiberglass
- Special purpose refractory bricks, plywood, etc.

1.1.5 Semiconductors

- Their electrical properties are intermediate when compared with electrical conductors and electrical insulators.
- These electrical characteristics are extremely sensitive to the presence of minute amounts of foreign atoms.
- Have found many applications in electronic devices over decades through integrated circuits. In can be said that semiconductors revolutionized the electronic industry for last few decades.

1.1.6 Biomaterials

- Those used for replacement of damaged or diseased body parts.
- Primary requirements: must be biocompatible with body tissues, must not produce toxic substances.
- Important materials factors: ability to support the forces, low friction, wear, density, reproducibility and cost.
- All the above materials can be used depending on the application.
- A classic example: hip joint.

Example —

- Stainless steel
- Ti-6Al-4V
- High purity dense Al-oxide, etc.
- Co-28Cr-6Mo
- Ultra high molecular weight polyethelene

1.1.7 Advanced materials

- Can be defined as materials used in high-tech devices i.e. which operates based on relatively intricate and sophisticated principles (e.g. computers, air/space-crafts, electronic gadgets, etc.).
- These are either traditional materials with enhanced properties or newly developed materials with high performance capabilities. Thus, these are relatively expensive.
- Typical applications: integrated circuits, lasers, LCDs, fiber optics, thermal protection for space shuttle, etc.

Example —

- Metallic foams
- Inter-metallic compounds

- Multicomponent alloys magnetic alloys
- Special ceramics and high temperature materials, etc.

1.18 Future materials

- Group of new and state-of-the-art materials now being developed, and expected to have significant influence on present-day technologies, especially in the fields of medicine, manufacturing and defense.
- Smart/Intelligent material system consists some type of sensor (detects an input) and an actuator (performs responsive and adaptive function).
- Actuators may be called upon to change shape, position, natural frequency, mechanical characteristics in response to changes in temperature, electric/magnetic fields, moisture, pH, etc.
- Four types of materials used as actuators:
  - Shape memory alloys
  - Piezoelectric ceramics
  - Magnetostrictive materials
  - Electro-/Magneto-rheological fluids
- Materials / Devices used as sensors:
  - Optical fibers
  - Piezoelectric materials
  - Micro-electro-mechanical systems (MEMS) etc.
- Typical applications:
  - By incorporating sensors, actuators and chip processors into system, researchers are able to stimulate biological humanlike behavior.
  - Fibers for bridges, buildings, and wood utility poles.
  - They also help in fast moving and accurate robot parts, high speed helicopter rotor blades.
  - Actuators that control chatter in precision machine tools.
  - Small microelectronic circuits in machines ranging from computers to photolithography prints.
  - Health monitoring detecting the success or failure of a product.

1.2 Non Metals

- The materials in the eight portion of theperiodic table are called non metals.
- These materials are usually brittle and poor conductor of electricity (except graphite).
- They goes not form alloys but combine chemically to forms compounds.

STUDENT'S ASSIGNMENT

Q.1 Consider the following statements:

1. Material science deals with the strength and stiffness behaviour of components (buildings/machines/vehicle facilities) based on their response to imposed stresses (forces, moments, torque etc.).
2. Material properties are dependent on their micro-strucutre and response to force fields and surface interaction.

Which of the above statements is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

ANSWER KEY // STUDENT'S ASSIGNMENT

1. (c)

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENT

1. (c)

Material science is the branch of engineering which deals with the study of structure, properties and applications of materials. Properties of matgerials are greatly influenced by the structure of materials.

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