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Engineering Materials

Mechanical Engineering

Comprehensive Theory *with* Solved Examples

Civil Services Examination

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Engineering Materials

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CHAPTER 1

Introduction

INTRODUCTION

Material Science is a combination of solid state Physics and solid state Chemistry. The elements are divided into categories like metals, nonmetals, polymers and ceramics. A material relates itself to matter. Material comprises a wide range of metals and non-metals which must be operated to form the finished product.

1.1 Material Classification

Most engineering Materials may be classed into one of the following types:

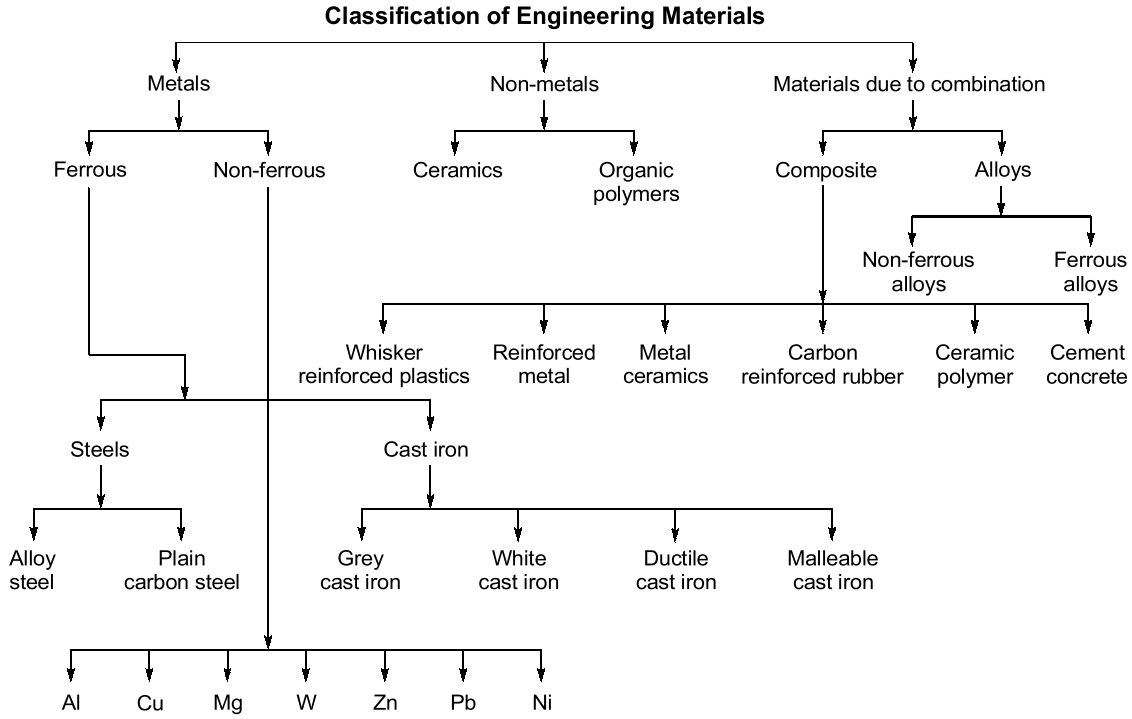

Fig.

1.2 Metals

Metals are the ones which have free electrons. They are capable of changing shape upon machining and gives good finish. At room temperature they are usually solid (except mercury) and to some extent they are malleable and ductile. Metal are good conductors of heat and electricity. Example copper, silver and gold etc.

1.2.1 General Characteristics of Metals

1. Luster
2. Hardness
3. Low specific heat
4. Plastic deformability
5. Good thermal and electrical conductivity
6. Relatively high melting point
7. Strength
8. Ductility
9. Malleability
10. Opaque
11. Stiffness
12. Rigidity
13. Formability
14. Machinability
15. Weldability
16. Castability
17. Dimensional stability.

Examples of commonly employed metals are :
Iron, Aluminium, Copper, Zinc, Magnesium, etc.

1.3 Ceramic Materials

- Ceramics usually consist of oxides, nitrides, carbides, silicates of various metals.
- Ceramics are any inorganic, non-metallic solids (or super-cooled liquids) processed or used at high temperatures.
- Ceramic materials are rock or clay mineral materials.
- Ceramic materials contain compounds of metallic and non-metallic elements, such as MgO, SiO_2, SiC, $BaTiO_3$, glasses, etc. Such compounds contain both ionic and covalent bonds.

Important characteristics of ceramics are :

1. Brittleness
2. Rock-like appearance
3. Resistance to high temperatures
4. Hardness
5. Abrasiveness
6. Insulation (to flow of electric current)
7. Corrosion resistance
8. Opaque to light
9. High temperature strength
10. High strength in compression

Examples of ceramic materials are :
Sand, Glass, Brick, Cement, Concrete, Insulators, Silicon Carbide, Tungsten Carbide, Boron Nitride, Refractories, Abrasives, Plaster.

1.4 Organic Materials

- They are polymeric materials composed of carbon compounds. (Polymers are solids composed of long molecular chains.)
- There are countless organic materials, natural, synthetic or manufactured and based chemically on carbon.

Important characteristics of organic materials (e.g. wood, rubber and plastic) are:

1. Lightweight
2. Combustible
3. Soft

4. Ductile
5. Not dimensionally stable
6. Poor conductors of heat and electricity
7. Poor resistance to temperature, etc.

Examples of organic materials are:
Rubber, Plastics, Paper, Fuels, Wood, Lubricants, Textiles, Paints, Adhesives, Explosives

Organic material find its place in:

1. Electric Insulation
2. For improving appearance
3. Fuels
4. As Vitamins and Medicines
5. For protection against corrosion, high temperature, weather, etc.
6. Refrigerants
7. Adhesives
8. Lubricants
9. Detergents
10. Explosives

1.5 Polymers

Polymers include the familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen and other non-metallic elements; furthermore, they have very large molecular structures. These materials typically have low densities and may be extremely flexible.

1.6 Composites

Composite materials consist of more than one type of material. Most common example is fiberglass in which glass fibers are embedded within a polymeric material. There are two parts in composite namely Reinforcement and Matrix. A composite is designed to display a combination of the best characteristics of each of the component materials. Fiberglass acquires strength from the glass and flexibility from the polymer. Hence fiberglass is the reinforcement and the polymer material is the matrix.

1.7 Semiconductors

Semiconductors have electrical properties that are intermediate between the electrical conductors and insulators. Furthermore, the electrical characteristics of these materials are extremely sensitive to the presence of minute concentrations of impurity atoms, these concentrations may be controlled over very small spatial regions. The semiconductors have made possible the advent of integrated circuitry that has totally revolutionized the electronics and computer industries.

1.8 Engineering Requirements of Materials

- Engineering requirements of a material mean as what is expected of from the material so that the same can be successfully used for making engineering components such a crankshaft, connecting rod, etc.

- When an engineer thinks of fabricating an engineering part, he goes in search of that material which possesses such properties that will permit the component part to perform its functions successfully while in use. For example, one may select high speed steel for making a milling cutter or a power hacksaw blade.
- The main engineering requirements of materials fall under three categories :
  1. Fabrication requirements
  2. Service requirements
  3. Economic requirements.

Fabrication requirements mean that the material should be able to get shaped (**e.g.**, cast, forged, formed, machined, sintered etc.) and joined (**e.g.**, welded, brazed, etc.) easily. Fabrication requirements relate themselves with materials' machinability, ductility, castability, heat-treatability, weldability, etc.

Service requirements imply that the material selected for the purpose must stand up to service demands, e.g., proper strength, wear resistance, corrosion resistance, etc.

Economic requirements demand that the engineering part should be made with minimum overall cost. Minimum overall cost may be achieved by proper selection of both technical and marketing variables.

1.9 Non Metals

The materials in the right portion of the periodic table are called non metals. These materials are usually brittle and poor conductor of electricity (except graphite). They does not form alloys but combine chemically to from compounds.

1.10 Type of Bond

Solid state exhibits a crystal structure which is having a definite geometry except amorphous state like glass. In crystal structure there are four types of bonding force:

1. **Ionic Bond :** Strong electrostatic attraction between cations and anions is called ionic bond. These bonds are permanent and atoms doesn't drift throughout the lattice structure.
2. **Covalent Bond :** In this type of bond there is a sharing of one or more electrons from the adjacent atoms.
3. **Metallic Bond :** Metallic bond is formed when material (metal) have one, two or there valence electrons. These electrons are not bound to any particular atom in the solid and drift through out the entire metal.
4. **Vander Waals Forces :** These are attractive forces that hold molecules close together. These attractive forces are more commonly referred to as intermolecular forces. The bond formation generally takes place in neutral atoms like inert gases.

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