Unit 4
Materials And Manufacturing Processes

ENGINEERING MATERIALS AND THEIR CLASSIFICATION

Engineering materials are substances used in the design and construction of machines, components, structures, and tools. Their selection is based on performance, availability, cost, and environment.

Classification Based on Composition

A. Metals

1. *Ferrous Metals*
    - Contain iron as the main constituent.
    - High strength, magnetic, prone to rust without coating.
    - Examples:
        - Cast Iron: Brittle, excellent compressive strength. Used in machine bases, pipes.
        - Mild Steel: Low carbon steel, used in construction.
        - Tool Steel: Contains carbon + alloying elements like tungsten, vanadium – used in cutting tools.
2. *Non-Ferrous Metals*
    - Do not contain iron. Usually more corrosion-resistant and lighter.
    - Examples:
        - Aluminium: Lightweight, corrosion-resistant; used in aircraft, packaging.
        - Copper: Excellent conductor; used in wiring, plumbing.
        - Zinc, Nickel, Tin, Lead, Titanium: Used in alloys, batteries, corrosion resistance.

B. Polymers (Plastics and Rubber)

- Polymers are organic materials with long molecular chains.
- Thermoplastics: Soften when heated (PVC, PET, HDPE)
- Thermosetting plastics: Harden permanently when heated (Bakelite, Epoxy)
- Rubber: Elastic, natural or synthetic; used in tires, gaskets

C. Ceramics

- Inorganic, non-metallic solids processed by heat.
- Hard, brittle, high melting point.
- Examples: Glass, porcelain, silicon carbide, alumina.
- Uses: Tiles, bricks, electrical insulators.

D. Composites

- Combine two or more distinct materials to get better properties.
- Matrix + Reinforcement
- Example: Fiberglass (glass fibres in resin), Carbon fibre, Metal matrix composites (MMC)

E. Smart Materials

- Adapt their properties based on external stimuli (heat, light, electricity).
    - Shape Memory Alloys (SMAs): Change shape with heat (e.g., Nitinol)
    - Piezoelectric Materials: Generate voltage when pressure is applied

- Thermochromic/Photochromic: Change colour with heat/light

F. Crystalline vs. Amorphous

- Crystalline Materials: Atoms arranged in repeating 3D lattice (e.g., metals, salts)
- Amorphous Materials: Random atom arrangement (e.g., glass, polymers)

PROPERTIES OF ENGINEERING MATERIALS

Understanding properties is essential for material selection and product performance.

Mechanical Properties

- Strength: Resistance to deformation or fracture
- Ductility: Ability to deform under tensile stress (e.g., copper wires)
- Hardness: Resistance to indentation (tested via Brinell, Rockwell)
- Toughness: Ability to absorb energy before breaking
- Elasticity: Regains shape after stress removal
- Plasticity: Retains new shape after deformation

Thermal Properties

- Thermal Conductivity: Ability to conduct heat (metals > ceramics > polymers)
- Thermal Expansion: Change in size due to heat
- Specific Heat: Heat capacity per unit mass

Electrical Properties

- Conductivity: Ability to conduct electricity
  - Metals: High (copper, silver)
  - Ceramics/Polymers: Low (used as insulators)

Chemical Properties

- Corrosion Resistance: Ability to resist chemical attack
- Reactivity: Tendency to form chemical bonds

Magnetic Properties

- Ferromagnetic: Strongly magnetic (iron, nickel, cobalt)
- Paramagnetic: Weakly attracted to magnetic field
- Diamagnetic: Repelled by magnetic fields

ALLOYS AND THEIR APPLICATIONS

Alloys = mixture of two or more elements (at least one metal) to enhance properties.

Alloy	Constituents	Properties	Applications
Brass	Copper + Zinc	Malleable, corrosion-resistant	Musical instruments, plumbing
Bronze	Copper + Tin	Tough, corrosion-resistant	Statues, bearings, marine hardware
Stainless Steel	Iron + Chromium + Nickel	Corrosion-resistant, strong	Utensils, medical tools, machinery
Duralumin	Aluminium + Copper (with Mg)	Strong, lightweight	Aircraft frames
Gun Metal	Copper + Tin + Zinc	Wear resistance	Valves, pumps
Invar	Iron + Nickel	Low thermal expansion	Measuring devices, clocks

SMART MATERIALS

These materials alter their behaviour when exposed to heat, electric/magnetic fields, pressure, or light.

Material	Stimulus	Response	Application
Shape Memory Alloy	Temperature	Returns to original shape	Medical stents, actuators
Piezoelectric Material	Mechanical stress	Generates electricity	Sensors, lighters, sonar systems
Thermochromic Material	Temperature	Changes colour	Baby spoons, thermometers
Photochromic Material	Light	Changes colour	Eyeglass lenses, smart windows
Magneto strictive	Magnetic field	Changes shape	Precision actuators, sonar devices

COMPOSITE MATERIALS

Composites combine properties of different materials, offering strength, stiffness, and corrosion resistance.

Types:

1. **Fiber-Reinforced Composites (FRC)**
    - Reinforced with glass, carbon, or aramid fibres
    - High strength-to-weight ratio
    - Used in aircraft, bicycles
2. **Particle-Reinforced Composites**
    - Small particles dispersed in a matrix
    - Examples: Concrete, metal carbide tools
3. **Structural Composites**
    - Laminated or layered composites
    - Example: Plywood, sandwich panels

Applications:

- Aerospace (lightweight parts)
- Automotive (body panels)
- Sports (rackets, helmets)
- Wind energy (turbine blades)

MANUFACTURING PROCESSES

Manufacturing transforms raw materials into finished products using various processes.

6.1 Industrial Revolution

- Originated in the 18th century with mechanized production.
- Introduced:
    - Steam engines
    - Spinning jennies
    - Assembly lines
    - Mass production techniques

6.2 Sustainable Manufacturing

- Focus on:
    - Minimizing energy and water usage
    - Reducing waste and emissions
    - Recycling materials
    - Using eco-friendly materials

METAL FORMING PROCESSES

These are plastic deformation processes where shape is changed without material removal.

Forging

- Compressive force applied through hammering or pressing
- Types:
  - Open die
  - Closed die
  - Drop forging
- Products: Wrenches, crankshafts, axles

Rolling

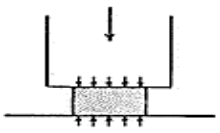
- Material passed between two rotating rollers
- Types:
  - Hot rolling: Better ductility
  - Cold rolling: Better surface finish
- Applications: Beams, rails, sheets

Extrusion

- Metal pushed through a die to get fixed cross-section
- Types:
  - Direct and indirect extrusion
- Products: Pipes, rods, window frames

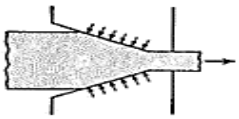
Drawing

- Metal pulled through a die to reduce diameter
- Used in making: Wires, tubes



Forging

Rolling Extrusion



Wire Drawing

JOINING PROCESSES

Methods to permanently or temporarily join two materials.

Gas Welding

- Combustion of oxygen and acetylene
- Temperature up to 3500°C
- Used in sheet metal, plumbing

Manual Arc Welding (SMAW)

- Electric arc formed between electrode and base metal
- Electrode melts and fills joint
- Used in construction, fabrication

Brazin

- Filler metal melts above 450°C, base metal not melted
- Capillary action fills the gap
- Stronger than soldering

Soldering

- Filler melts below 450°C
- Used for delicate joints in electronics