Selection of Material

A particular material is selected is on the basis of following considerations

1. Properties of material
   - **Mechanical properties** - strength, ductility, toughness, hardness, strength to weight ratio etc.
   - **Physical properties** - density, specific heat, thermal expansion, conductivity, melting point etc.
   - **Chemical properties** - oxidation, corrosion, flammability, toxicity etc.
   - **Manufacturing properties** - formed, casting, machined, welding
Selection of Material

2. Cost of material

3. Availability of material (desired shape and size and quantity) & reliability of supply.

4. Service in life of material
   - Dimensional stability of material wear, corrosion etc., shorten life

5. Appearance of material
   - Color
   - Surface texture etc.

Manufacturing Materials

- **Metals**
  - Ferrous
    - Pure iron is rarely used as an engineering material
    - It is used in the form of alloys; composed of two or more elements
    - Generally these are classified on the basis of %C with Fe
    - %C >2.11: Cast Iron; %C<2.11: Steels
  - Non-ferrous

- **Ceramics**

- **Polymers**

- **Composites**
Cast Iron

- Elements added to improve casting properties
  - Carbon = 2.11 – 4%
  - Silicon = 0.5 – 3%
  - Manganese = 0.4 – 1%

- Types of C.I. based on form of carbon present
  - Grey Cast Iron
  - White Cast Iron
  - Malleable Cast iron
  - Ductile or Nodular Cast iron

Grey Cast Iron

- Most commonly used
- Carbon is present as Graphite flakes distributed throughout
- When it is fractured, the exposed surface of metal has gray appearance
- This dispersion of Graphite flakes provides good internal lubricating property hence excellent machinability and vibration damping characteristics.
- It has poor tensile strength and ductility
- It possesses good compressive strength, wear resistance and corrosion resistance
- Commonly used for machine bodies, engine blocks, pumps and motor housings, etc.
White Cast Iron

- Produced by rapid cooling of molten gray CI
- Carbon remains chemically combined in the form of iron carbide (cementite)
- When fractured, it has white shining appearance
- It is hard, brittle and possesses excellent wear resistance
- Used for applications requiring high wear resistance, e.g., railway brake shoes, grinding balls, crushing rollers, etc.

Malleable Cast Iron

- It is obtained by heat treatment of white CI and carbon is present in forms of clusters
- This structure promotes toughness and ductility
- It is used in making small tools, pipe fittings, automobile parts, farm implements, etc.
Ductile or Nodular Cast Iron

- This is obtained by adding Mg or Cesium (nodulizing agents) to molten Gray CI before pouring.
- In this the carbon is present in the form of spheroids.
- It has good ductility, high strength, toughness, wear resistance and excellent casting properties.
- It is popular material for making intricate castings.

Cast irons are often alloyed with various elements and heat treated to achieve special properties like high hardness, temperature resistant, corrosion resistant etc.

Steels

- Carbon: 0.02 - 2.11%
- Other Alloying Elements
  - Mn, Cr, Ni, Mo, etc.
- Type of Steels
  - Plain Carbon Steel
  - Alloy Steel
  - Stainless Steel
  - Tool Steel
Plain Carbon Steel

- The strength increases with increase in %C but ductility decreases.
- **Low carbon steels**
  - Less than 0.2% C
  - Most common steel known as mild steel
  - Plates, sheets, rods, machine components, nut and bolts
- **Medium carbon steels**
  - 0.2 to 0.5 % C
  - Used where high strength is required like engine components
- **High carbon steels**
  - 0.5 to 2.11% C
  - Even high strength applications like tools, blades, springs

Alloy Steel

- Additional alloying elements are added to improve the mechanical properties of plain carbon steel
  - **Commonly added elements**
    - **Mn**: To improve strength and hardness
    - **Cr**: To improve strength and wear resistance and hot hardness
    - **Cu**: To improve strength and corrosion resistance
    - **Mo**: To improve heat resistance and toughness
    - **Ni**: To improve strength and toughness
    - **Si**: To improve strength and toughness
**Alloy Steel**

- Total percentage of alloying elements **<5% by weight**.
- Generally Fe-C alloy containing more than 1.65% Mn or 0.6% Si or 0.6% of Cu are designated as **Alloy steels**.
- They have better **strength to weight ratio**.
- Used in transportation, mining and agriculture equipments. Their structural sections are used in building and other structures.

**Stainless Steel**

- Alloy steels designed to provide **high corrosion resistance** along with high strength and ductility.
- Principal alloying element is **Cr > 12%**.
- Other alloying elements include Ni, Mo, Ti, Si, Mn etc.
- Typical applications of these steel are for kitchen, surgical, chemical and food processing equipments.
Tool Steel

- Highly alloyed steels designed for use as tools and dies in machining and forming process
- They are designed to provide high strength and toughness and wear resistance at both room and elevated temperatures
- In these materials wear resistance and toughness are balanced by various combination of alloying elements

Tool Steel

- Tungsten (W) 1.5 - 20%
- Chromium (Cr) 0.2 - 15%
- Molybdenum (Mo) 0.8 - 15%
- Cobalt (Co) 0.75 - 12%
- Vanadium (V) 0.15 - 3%
- Silicon (Si) 0.5 - 2%
- Manganese (Mn) 0.2 - 1.6%

- A variety of tool steels like high speed steel, mould steels, hot-work tool steels, cold-work tool steels etc. are obtained.
Non Ferrous Metals

- Not iron based
- Wide variety of materials such as Al, Cu, Mn, W, Tantalum and Mo.
- Important because resistance to corrosion, high strength to weight ratio, high electric and thermal conductivity

Aluminium & Alloy

- Extensively used for aircraft, bus, car and marine craft bodies, cooking utensils etc.
- High strength to weight ratio resistance to corrosion, good electrical and thermal conductivity
Copper and Alloys

- Good conduction of heat and electricity
- **Brass** (65%Cu and 35% Zn), high conductivity, adequate strength and ductility
- **Bronze** (90%Cu and 10%tin), Good strength, toughness, wear strength and corrosion resistance

Magnesium and Alloys

- Lightest engineering Material with specific gravity as 1.75
- **Mg alloy** is used for various high-strength to weight ratio applications
- **Applications:** Aircraft & missile components, material handling equipments, sporting goods and general light weight components
Nickel and Alloys

- Silver white metal. Used for electroplating for appearance and for improving corrosion resistance.
- Ni alloys offer high strength and corrosion resistance at elevated temperature
- **Monel** a Ni- Cu alloy is used extensively in chemical and food processing industries due to corrosion resistance property.
- Super alloys of Ni are used for high temperature applications such as for jet engines, gas turbines, and rocket components and in nuclear power plants.

Zinc

- A low melting point metal
- Main use in galvanizing on iron and steel for providing corrosion resistance
- Zinc alloys are primarily used for die casting of components for automobile and appliance industries
Titanium

- High strength to weight ratio and corrosion resistant material at elevated temperature
- Ti- alloys with alloying elements such as Al, Va, Mo, Mn etc. can be used up to 550°C
- Attractive material for aerospace applications, marine, chemical and photo chemical equipments

Ceramics

- Compounds of metallic and non-metallic elements.
- Available in the form of oxides, carbide and nitrides
- Brittle, have high strength and hardness at elevated temperature, low thermal and electrical conductivity
- Clay, Alumina, Quartz, SiC ,WC, Silicon Nitride, CBN etc, are typical examples
- SiC : Abrasives
- CBN,WC: Popular cutting tool material
- Silicon Nitride: Application in gas turbines and rocket engines
- Glass is also ceramic and inorganic non-metallic compound
Polymers

- Compounds of long chain molecules with each molecule made up of repeating units connected together. They are organic compounds.
- Low density, strength, thermal & electrical conductivity, **good chemical resistance**
- Low working range of temperature <350°C
  - Thermoplastics
  - Thermo sets
  - Elastomers

Composite Materials

- Heterogeneous solids consisting of two or more different materials that are **metallurgically** or **mechanically** bonded together.
- The combination of materials provides for superior properties as compared to constituents.
- These materials possess **unique combination of properties**, such as strength, weight stiffness, corrosion resistance, hardness, conductivity etc.
Composite Materials

- Laminar or layer composites:
  - Plywood, coated tools, insulated wires

- Particulate composite:
  - Concrete (cement sand and gravel)
  - Abrasive particles and matrix in grinding wheels
  - Cemented carbides- particle of WC uniformly distributed used as a cutting tool
  - Properties are uniform in all direction

Composite Materials

- Fiber reinforced composite:
  - Thin fibers of one material are embedded in matrix of another material
  - Glass is most widely used fiber with polymer as matrix. Other fibers are carbon, boron etc.
  - Properties depend upon the fibred material volume fraction of fiber, orientation of fiber, properties of matrix, degree of bonding between fiber & matrix etc.
Composite Materials

- **Fiber Reinforced Composite:**
  - Polymeric materials are used for low temperature applications (below 300°C), While MMC are used for high temperature application
  - Steel reinforced concrete used in construction
  - Nylon reinforced tires, glass fiber reinforced plastics for car bodies
  - Boron-reinforced components for aircraft & rocket