# UNIT I ENGINEERING MATERIALS

Introduction – classification of engineering materials – selection of materials for engineering purposes –selection of materials and shape –classification metal and alloys, polymers, ceramics and glasses, composites, natural materials, -nonmetallic materials-smart materials - physical, metrical properties of metals **Classification of Materials**

**Metal**

A large number of metals are available in nature. They can be classified in a variety of ways depending on property

- The most common way of classifying them is by their iron content.
- When a metal contains iron, it is known as a ferrous
- The iron imparts magnetic properties to the material and also makes them prone to corrosion.
- Metals that do not have any iron content are non-ferrous metals.
- These metals do not possess any magnetic properties.
- Examples include but are not limited to aluminum, lead, brass, copper and zinc.



**Magnetic and Non-Magnetic Metals**

- Another way to differentiate metals is by looking how they interact with magnets. It is possible to divide metals as magnetic and non-magnetic.
- While ferromagnetic metals attract strongly to magnets, paramagnetic ones only show weak interactions.
- Lastly, there is a group called diamagnetic metals that rather show a weak repulsion to magnets.

**Iron, Alloys – Properties**

- All the metals have similar mechanical properties of the materials.

- But when judged closely, one metal will have a slight edge over another in certain properties. It is possible to change the properties when creating alloys by mixing pure elements.
- When selecting a metal for a particular application, there's quite a few factors to consider to find the most suitable option.
- These factors include melting point, cost, ease of machining, sufficient safety factor, space available, temperature coefficient, thermal and electrical conductivity, density, etc. The Eiffel Tower is made of wrought iron
- Approximately 5 per cent of the Earth's crust is iron. Thus, it is an incredibly easy metal to find.
- Pure iron is an unstable element it reacts with the oxygen in the air to form iron oxide.
- Extracting iron from its ores uses a blast furnace.
- Pig iron is achieved from the first stage of the blast furnace which can be further refined to obtain pure iron. This iron often ends up in steels and other alloys.
- Almost 90 per cent of manufactured metals are ferrous metals.



**Steel**

- Pure iron is stronger than other metals but it leaves much to be desired. For one, pure iron is not resistant to corrosion. To keep iron from corroding, a lot of money and energy must be spent.
- Secondly, it is also extremely heavy due to its high density. These disadvantages can make structures harder to build and maintain.
- Adding carbon to iron reduce these weaknesses to a certain extent. This mixture of iron and carbon up to specified limits is known as carbon steel.
- Adding carbon to iron makes the iron much stronger along with imparting other great characteristics.

- Steel is a popular building material thanks to its excellent properties. Over 3500 grades of steel are available today. It has high tensile strength and a high strength-to-weight ratio.
- This means more strength per unit mass of steel. This allows usage of steel parts and components that are small in size.
- Steel is also extremely durable. This means a steel structure can last longer and withstand external factors better than other alternatives.
- It is also ductile and can be shaped into required forms without compromising its properties. Depending on the iron content, steel is classified into three categories.

   a) Plain steel

   b) Carbon Steel

   c) Alloy steels



**Low carbon steel.** Up to 0.25% of carbon in iron give us low carbon steel, also known as mild steel. Reinforcing bars and in I-beams in construction are usually from low carbon steel. Any applications that require a high amount of steel without much forming or bending are also suitable for it.

**Medium carbon steel.** Contains 0.25% to 0.6% of carbon. Medium carbon steel's applications include ones that need high tensile strength and ductility. They find applications in gearing and shafts, railway wheels and rails, steel beams in buildings and bridges etc. Another use is pressure vessels, except if it contains cold gases or liquids because of its tendency to cold cracking.

**High carbon steel.** Steel that contains more than 0.6% of carbon is high carbon steel. This steel is harder and more brittle than the previous two. It finds applications in making chisels and cutting tools. Great qualities include hardness and good resistance to material wear. It may also be used in presses and for manufacturing drill bits.

**Alloy steels**

This type of metal contains multiple elements to enhance various properties. Metals such as manganese, titanium, copper, nickel, silicon, and aluminium may be added in different proportions. This improves steel's hardenability, weldability, corrosion resistance, ductility and formability. Applications for alloy steels are electric motors, bearings, heating elements, springs, gears, and pipelines.

**Stainless steel**: Stainless steel contains high amounts of chromium. This is why it has 200 times higher resistance to corrosion than mild steel. It makes it the ideal candidate to manufacture kitchen utensils, piping, surgical and dental equipment. Also, as no coating is necessary, you can have a metallic look like you want with the right surface finish.

**Tool steel:** Tool steels are used for making cutting and drilling tools. Their high hardness make them an ideal choice for these applications. They contains molybdenum, vanadium, cobalt, and tungsten as constituent metals.

**Different Types of Metals**

- In addition to ferrous metals, we have a large selection of non-ferrous ones. Each has certain qualities that make them useful in different industries.
- Aluminum derives primarily from its ore bauxite. It is light, strong and functional. It is the most widespread metal on Earth and its use has permeated applications everywhere.
- This is because of its properties such as durability, light weight, corrosion resistance electrical conductivity and ability to form alloys with most metals. It also doesn't magnetise and is easy to machine.



**Copper**

When talking about different types of metals, copper and its alloys can not be overlooked. It has a long history because it is easy to form. Even today, it is an important metal in the industry. It does not occur in nature in its pure form. Thus, smelting and extracting from ore is necessary. Metals are good conductors and copper stands out more than the others. Due to its excellent electrical conductivity, it finds application in electrical circuits as a conductor. Its conductivity is second only to silver. It has also excellent heat conductivity. This is why many cooking utensils are from copper.

**Brass**

The amount of each of the metals may vary depending on the electrical and mechanical properties sought of the metal. It also contains trace amounts of other metallic elements such as aluminium, lead, and manganese. Brass is a great candidate for low friction applications such as locks, bearings, plumbing, musical instruments, tools and fittings. It is indispensable in intrinsically safe applications to prevent sparks and allow usage in flammable environments.

**Bronze**

Bronze is also an alloy of copper. It also has good electrical and thermal conductivity and corrosion resistance. Bronze finds application in the manufacturing of mirrors and reflectors. It is used for electrical connectors. Due to its corrosion resistance, it finds usage in submerged parts and ship fittings.



**Titanium**

Titanium is an important engineering metal due to being strong and lightweight. It also has high thermal stability even at temperatures as high as 480 degrees Celsius. Due to these properties, it finds application in the aerospace industry. Military equipment is one use-case for this metal. Since titanium is also corrosion resistant, medical applications also use it. Titanium is also used in the chemical and sporting goods industry.

**Zinc**

Zinc is a widespread metal and finds a lot of use in the medical and industrial sector. Its primary use is to galvanise steel. This protects the steel from corrosion. Zinc is also used to manufacture die castings for the electrical, hardware, and automobile industry. Since zinc has low electrochemical potential, its uses include marine applications to prevent corrosion of other metals through cathodic protection.

**Lead**

Lead is a highly machinable, corrosion resistant metal. Piping and paint represent some use-cases. Lead was used as an anti-knocking agent in gasoline. Later, it was discovered that the byproduct of this lead was responsible for serious health complications. Lead is still common in ammunition, car batteries, radiation protection, lifting weights, cable sheathing etc.

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**composite material**

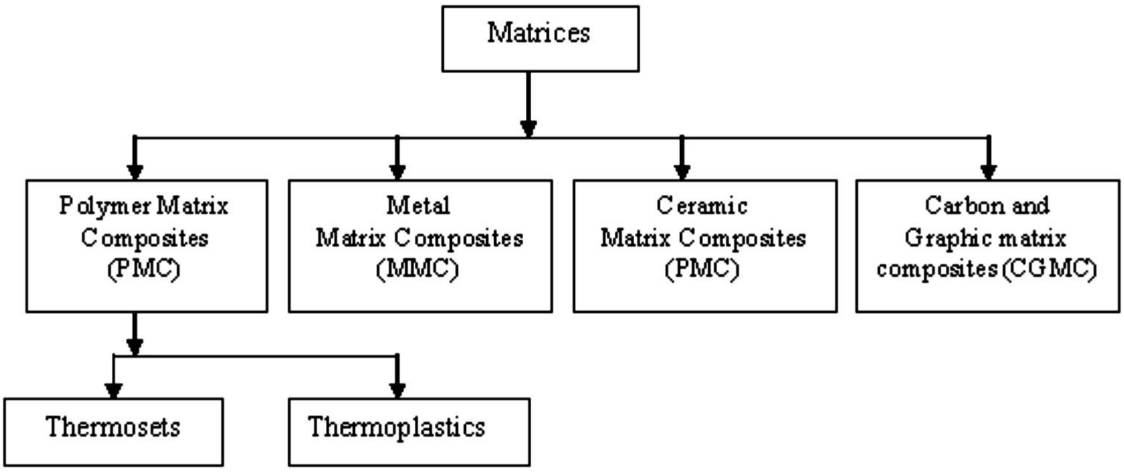
- A composite material (also called a composition material or shortened to composite, which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.



Typical engineered composite materials include:

- Reinforced concrete and masonry
- Composite wood such as plywood
- Reinforced plastics, such as fibre-reinforced polymer or fiberglass
- Ceramic matrix composites (composite ceramic and metal matrices)
- Metal matrix composites and other advanced composite materials

Fibers or particles embedded in matrix of another material are the best example of modern-day composite materials, which are mostly structural. Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.




**Classification of Composites**

Composite materials are commonly classified at following two distinct levels:

- The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.
- The second level of classification refers to the reinforcement form - fibre **reinforced composites**, **laminar composites** and **particulate composites**. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres.
- **Fibre Reinforced Composites** are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.
- **Laminar Composites** are composed of layers of materials held together by matrix. Sandwich structures fall under this category.
- **Particulate Composites** are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category

**Organic Matrix Composites**

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications. Two main kinds of polymers are **thermosets** and **thermoplastics**. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the **chopped fiber composites** form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

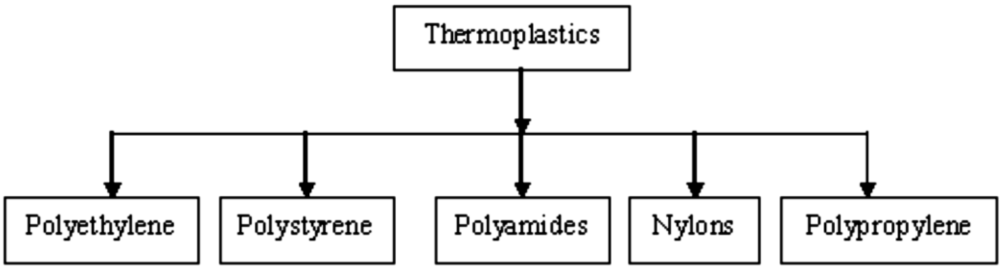



**Figure: Thermoplastics**

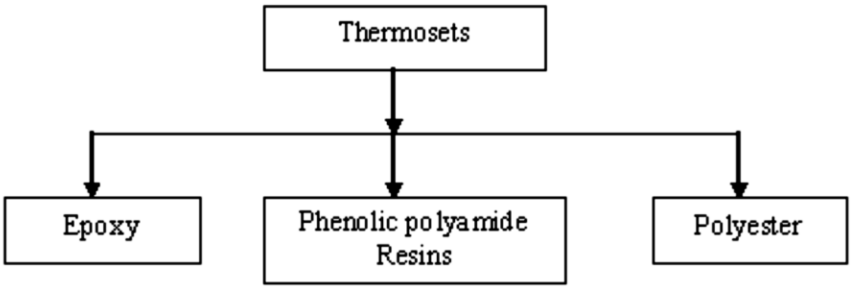



**Figure: Thermoset Materials**

**Classification Based on Reinforcements**

Reinforcements for the composites can be fibers, fabrics particles or **whiskers**. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape.

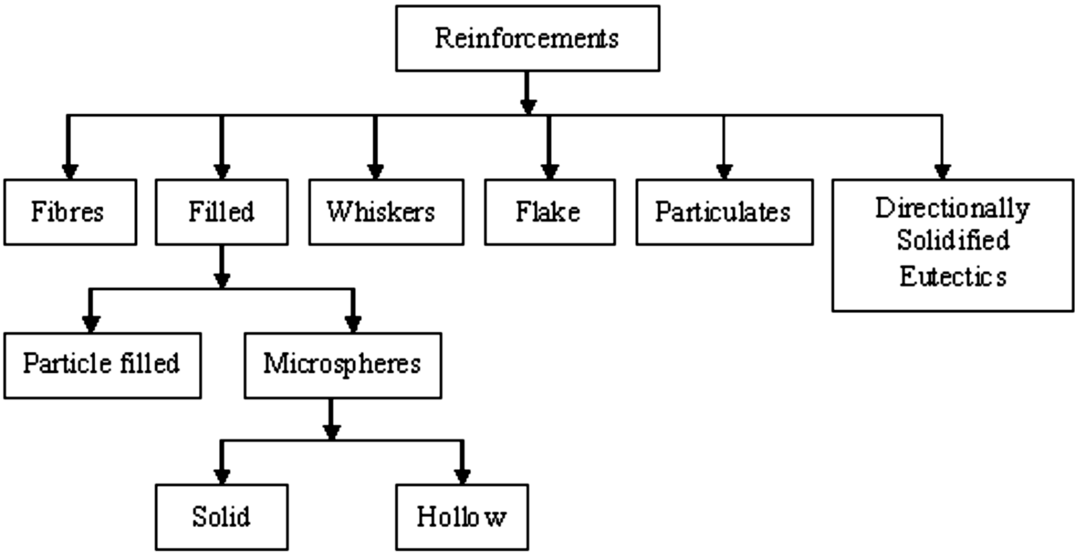



**Figure: Reinforcements**

Reinforcing constituents in composites, as the word indicates, provide the strength that makes the composite what it is. But they also serve certain additional purposes of heat resistance or conduction, resistance to corrosion and provide rigidity. Reinforcement can be made to perform all or one of these functions as per the requirements. A reinforcement that embellishes the matrix strength must be stronger and stiffer than the matrix and capable of changing failure mechanism to the advantage of the composite. This means that the ductility should be minimal or even nil the composite must behave as brittle as possible.



**Fiber Reinforced Composites/Fibre Reinforced Polymer (FRP) Composites**

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat.

Fibers fall short of ideal performance due to several factors. The performance of a fiber composite is judged by its length, shape, orientation, and composition of the fibers and the mechanical properties of the matrix.

The orientation of the fiber in the matrix is an indication of the strength of the composite and the strength is greatest along the longitudinal directional of fiber. This doesn’t mean the longitudinal fibers can take the same quantum of load irrespective of the direction in which it is applied. Optimum performance from longitudinal fibers can be obtained if the load is applied along its direction. The slightest shift in the angle of loading may drastically reduce the strength of the composite.

**Examples for composite materials**

Fibre reinforced plastics:

Classified by type of fiber:

- Wood (**cellulose fibers** in a lignin and hemicellulose matrix)
- **Carbon-fibre reinforced plastic (CRP)**
- **Glass-fibre reinforced plastic (GRP)** (informally, "fiberglass")

Classified by matrix:

**Thermoplastic Composites**

- short fiber thermoplastics
- long fiber thermoplastics or long fiber reinforced thermoplastics
- glass mat thermoplastics
- continuous fiber reinforced thermoplastics

**Thermoset Composites**



- **Reinforced carbon-carbon** (carbon fibre in a graphite matrix)
- **Metal matrix composites (MMCs)**:
- White cast iron
- Hardmetal (carbide in metal matrix)
- Metal-intermetallic laminate

**Ceramic matrix composites**:

- Bone (hydroxyapatite reinforced with collagen fibers)
- Cermet (ceramic and metal)
- Concrete

**Organic matrix/ceramic aggregate composites**

- Asphalt concrete
- Dental composite
- Syntactic foam
- Mother of Pearl

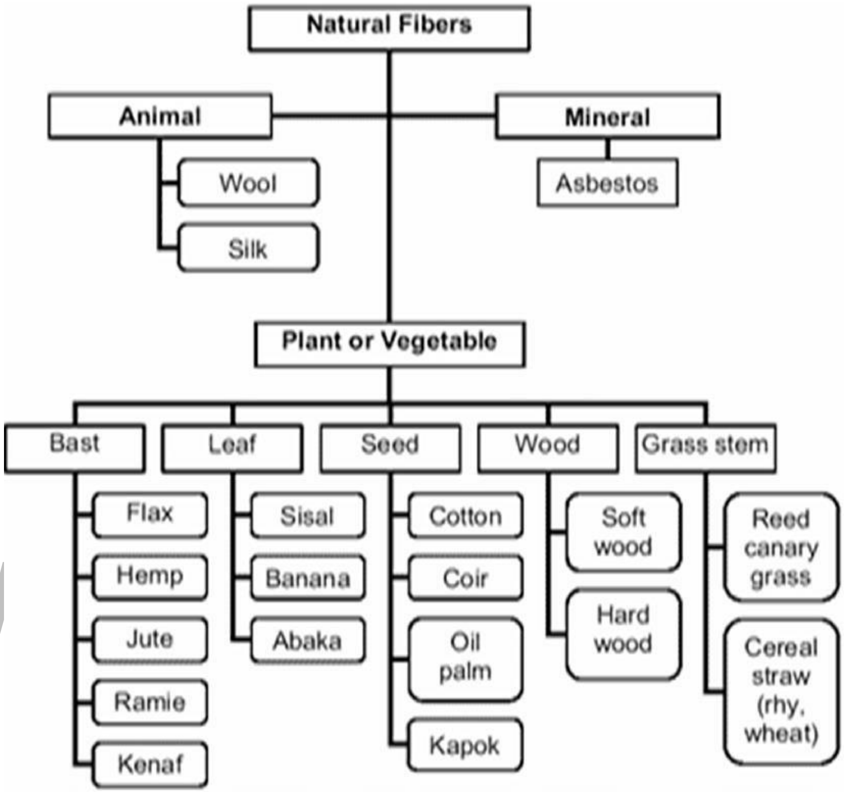
**Engineered wood**

- Plywood

- Oriented strand board
- Wood plastic composite (recycled wood fiber in polyethylene matrix)

**Natural materials**

A product that is made from materials and ingredients found in nature, with little or no human intervention. Natural materials include stone, glass, lime or mud plasters, rammed earth, bri cks, tiles, untreated wood, cork, paper, bamboo, canes and grasses as well as all natural fibers.



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## Introduction

Material selection is the act of choosing the material best suited to achieve the requirements of a given application. One of the most challenging tasks of materials engineer is the proper selection of the material for a particular job, e.g., a particular component of a machine or structure. An engineer must be in a position to choose the optimum combination of properties in a material at the lowest possible cost without compromising the quality. Many different factors go into determining the selection requirements, such as mechanical properties, chemical properties, physical properties, electrical properties and cost. These must be weighed during the material selection process. When we talk about choosing materials for a component, we take into account many different factors. These factors can be broken down into the following areas

- **Material Selection**
- **Material Property**
- **Material selection Process**
- **Material Selection Methods**



**Factors affecting the selection of materials:**

**Component shape:** The shape and size of a component has great effect on the choice of the processing unit which ultimately effects the choice of the material. To make it clearer, we consider an example, let the best possible production method is selected, under given conditions, it is die casting, obviously, now the choice of the material becomes limited, i.e. one can only choose materials with lower melting points, e.g. aluminium, zinc, magnesium and thermoplastics.

**Dimensional tolerance:** There are some materials which can be finished to close tolerance while others cannot. Obviously, the required dimensional tolerance for finished components will, influence the choice of materials.

**Mechanical properties:** To select a suitable material for specific conditions, all mechanical properties, e.g., toughness, hardness, strength, etc. guide us.

**Fabrication (Manufacturing) requirements:** Method of processing of the material also affects the properties of a component, e.g., forged components can be stronger than the casted components. Different types of working processes may also give different types of fibre structure. However, investment casting can provide precise dimensions at low cost in comparison to machine operations.



**Service requirements**

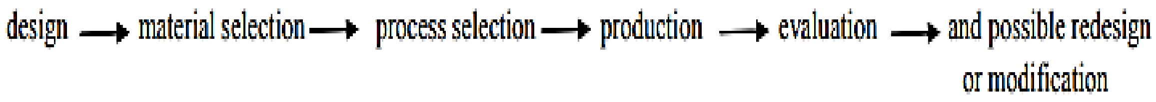
Service requirements are:

- Dimensional Stability
- Strength
- Toughness
- Heat Resistance
- Corrosion Resistance
- Fatigue
- Creep Resistance
- Electrical and Thermal Conductivity
- Cost

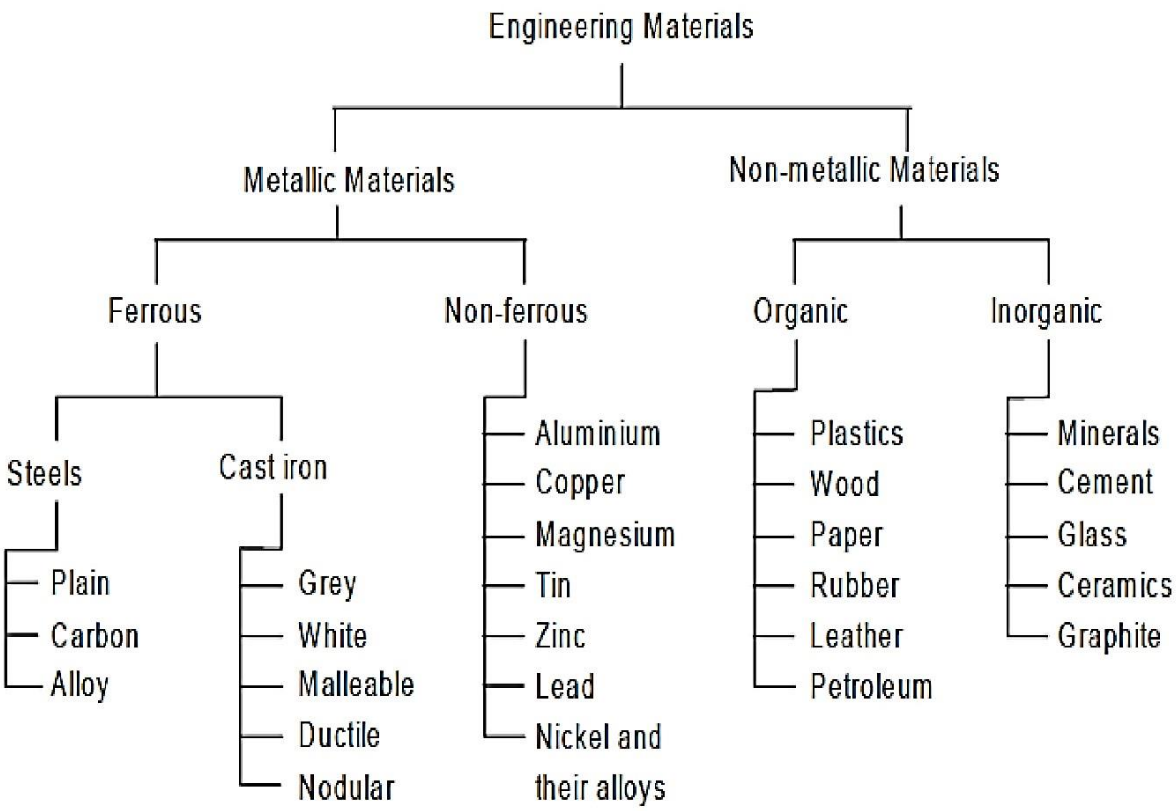
**Availability of the material:** We may find that sometimes the availability of the material becomes a governing factor. When the desired material supply is limited, then a costly material which is available in ample quantity may be chosen.

**Procedure for materials selection:**

The selection of an appropriate material and its subsequent conversion into a useful product with desired shape and properties can be a rather complex process. Nearly every engineered item goes through a sequence of activities that includes:




**Classification of Engineering Materials**




**Metals**

Metals are polycrystalline bodies which are having number of differentially oriented fine crystals. Normally major metals are in solid states at normal temperature. However, some metals such as mercury are also in liquid state at normal temperature. All metals are having high thermal and electrical conductivity. All metals are having positive temperature coefficient of resistance. Means resistance of metals increases with increase in temperature. Examples of metals – Silver, Copper, Gold, Aluminium, Iron, Zinc, Lead, Tin etc.

**Non-Metals**

Non-Metal materials are non-crystalline in nature. These are available in both solid and gaseous forms at normal temperature. Normally all non-metals are bad conductor of heat and electricity. As these non-metals are having very high resistivity which makes them suitable for insulation purpose in electrical machines Examples: Plastics, Rubber, Leathers, Asbestos etc

| Sl. No. | Property | Metals | Non-Metals |
|---|---|---|---|
| 1. | Structure | All metals are having crystalline structure | All Non-metals are having amorphic & mesomorphic structure |
| 2. | State | Generally metals are solid at normal temperature | State varies material to material. Some are gas state and some are in solid state at normal temperature. |
| 3. | Valance electrons and conductivity | Valance electrons are free to move within metals which makes them good conductor of heat & electricity | Valence electrons are tightly bound with nucleus which are not free to move. This makes them bad conductor of heat & electricity |
| 4. | Density | High density | Low density |
| 5. | Strength | High strength | Low strength |
| 6. | Hardness | Generally hard | Hardness is generally varies |
| 7. | Malleability | Malleable | Non malleable |
| 8. | Ductility | Ductile | Non ductile |

| | | | |
|---|---|---|---|
| 9. | Brittleness | Generally non brittle in nature | Brittleness varies material to material |
| 10. | Lustre | Metals possess metallic lustre | Generally do not possess metallic lustre (Except graphite & iodine) |

**Ferrous Metals**

All ferrous metals are having iron as common element. All ferrous materials are having very high permeability which makes these materials suitable for construction of core of electrical machines. Examples: Cast Iron, Wrought Iron, Steel, Silicon Steel, High Speed Steel, Spring Steel etc.

**Non-Ferrous Metals**

All non-ferrous metals are having very low permeability. Example: Silver, Copper, Gold, Aluminum etc.

**Organic Materials**



All organic materials are having carbon as a common element. In organic materials carbon is chemically combined with oxygen, hydrogen and other non-metallic substances. Generally organic materials are having complex chemical bonding. Example: Plastics, PVC, Synthetic Rubbers etc.

**Inorganic materials**

Inorganic materials are generally derived from non-living sources, such as rocks or minerals, and encompass such categories as glass, ceramics, and metals. The following outline describes categories of inorganic materials that a conservator might use in determining condition or treatment strategies.

**Cast Iron**

Cast iron is a ferrous alloy containing high levels of carbon, generally greater than 2%. The carbon present in the cast iron can take the form of graphite or carbide. Cast irons have a low melting temperature which makes them well suited to casting.

**Gray Cast Iron**

Gray cast iron is the most common type. The carbon is in the form of graphite flakes. Gray cast iron is a brittle material and its compressive strength is much higher than its tensile strength. The fracture surface of gray cast iron has a gray color, which is how it got its name.

**Ductile Cast Iron (Nodular Cast Iron)**

The addition of magnesium to gray cast iron improves the ductility of the material. The resulting material is called *nodular cast iron* because the magnesium causes the graphite flakes to form into spherical nodules. It is also called *ductile cast iron*. Nodular cast iron has good strength, ductility, and machinability. Common uses include crankshafts, gears, pump bodies, valves, and machine parts.

**White Cast Iron**

White cast iron has carbon in the form of carbide, which makes the material hard, brittle, and difficult to machine. White cast iron is primarily used for wear-resisting components as well as for the production of *malleable cast iron*.

**Malleable Cast Iron**



Malleable cast iron is produced by heat treating white cast iron. The heat treatment improves the ductility of the material while maintaining its high strength.

**Carbon Steel**

Carbon steels are basically just mixtures of iron and carbon. They may contain small amounts of other elements, but carbon is the primary alloying ingredient. The effect of adding carbon is an increase in strength and hardness. Most carbon steels are *plain carbon steels*, of which there are several types.

**Low-Carbon Steel**

Low-carbon steel has less than about 0.30% carbon. It is characterized by low strength but high ductility. Some strengthening can be achieved through cold working, but it does not respond well to heat treatment. Low-carbon steel is very weldable and is inexpensive to produce. Common uses for low-carbon steel include wire, structural shapes, machine parts, and sheet metal.

**Medium-Carbon Steel**

Medium-carbon steel contains between about 0.30% to 0.70% carbon. It can be

High-carbon steel contains between about 0.70% to 1.40% carbon. It has high strength but low ductility. Common uses include drills, cutting tools, knives, and springs.

**Alloys**

Alloys are the composition of two or more metals or metal and non-metals together. Alloys are having good mechanical strength, low temperature coefficient of resistance. Example: Steels, Brass, Bronze, Gunmetal, Invar. Super Alloys etc.

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### Physical Properties of Engineering Materials

- These properties concerned with such properties as melting, temperature, electrical conductivity, thermal conductivity, density, corrosion resistance, magnetic properties, etc.

**Density:**

- Density is defined as mass per unit volume for a material. The derived unit usually used by engineers is the $kg/m^3$. Relative density is the density of the material compared with the density of the water at 4°C.
- The formulae of density and relative density are:
- Density (p) = Mass (m)/volume (V)
- Relative density (d) = Density of the material/Density of pure water at 4°C

**Electrical Conductivity:**

- Figure shows a piece of electrical cable. In this example copper wire has been chosen for the conductor or core of the cable because copper has the property of very good electrical conductivity.

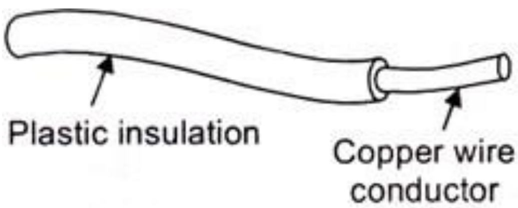



**FIGURE** : Electrical conductivity.

**Melting Temperature of Material**

The melting temperatures and the recrystallisation temperatures have a great effect on the materials and the alloys of the materials properties and as a result on its applications.

**Thermal Conductivity:**

- This is the ability of the material to transmit heat energy by conduction. The bit is made from copper which is a good conductor of heat and so will allow the heat energy stored in it to travel easily down to the tip and into the work being soldered. The wooden handle remains cool as it has a low thermal conductivity and resists the flow of heat energy.

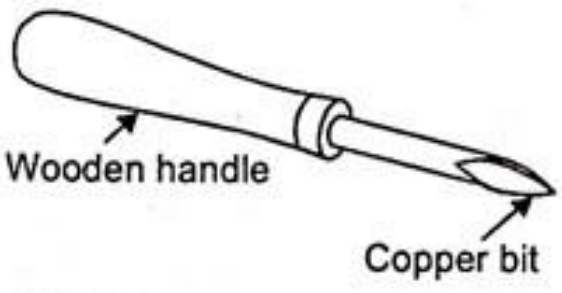



FIGURE : Thermal conductivity.



**Fusibility:**

- This is the ease with which materials will melt. It can be seen from figure that solder melts easily and so has the property of high fusibility. On the other hand, fire bricks used for furnace linings only melt at very high temperatures and so have the properties of low fusibility.
- Such materials which only melt a very high temperatures are called refractory materials. These must not be confused with materials which have a low thermal conductivity and used as thermal insulators. Although expanded polystyrene is an

excellent thermal insulator, it has a very low melting point (high fusibility) and in no way can it be considered a refractory material.

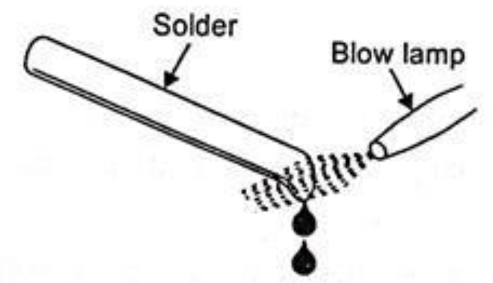



**FIGURE:** Solder melts at a low temperature and therefore it has a high fusibility.

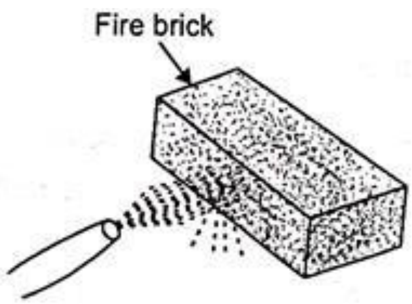



**FIGURE:** Fire brick only melts at very high temperatures and therefore it has a low fusibility and is called a refractory.

**Reluctance (as Magnetic Properties):**

Just as some materials are good or bad conductors of electricity, some materials can be good or bad conductors of magnetism. The resistance of magnetic circuit is referred to as reluctance. The good magnetic conductors have low reluctance and examples are the ferromagnetic materials which get their name from the fact that they are made from iron, steel and associated alloying elements such as cobalt and nickel. All other materials are non-magnetic and offer a high reluctance to the magnetic flux felid.

**Temperature Stability:**

Any changes in temperature can have very significant effects on the structure and properties of materials. However, there are several effects can appear with changes in temperature such as creep. For example, gas-turbine blades. The creep rate increases if the temperature is raised, but becomes less if the temperature

**Mechanical Properties of Engineering Materials**

- Tensile Strength
- Toughness
- Malleability
- Hardness
- Ductility

- Stiffness
  - Brittleness
  - Elasticity
  - Plasticity
  - Creep
  - Fatigue

1. Tensile Strength:

- It is the ability of a material to withstand tensile (stretching) loads without breaking. As the force of gravity acting on the load is trying to stretch the rod, the rod is said to be in tension. Therefore, the material from which the rod is made needs to have sufficient tensile strength to resist the pull of the load. Strength is the ability of a material to resist applied forces without fracturing.

2. Toughness:



- It is the ability of the materials to withstand bending or it is the application of shear stresses without fracture, so the rubbers and most plastic materials do not shatter, therefore they are tough. For example, if a rod is made of high-carbon steel then it will be bend without breaking under the impact of the hammer, while if a rod is made of glass then it will broke by impact loading.

3. Malleability:

- It is the capacity of substance to withstand deformation under compression without rupture or the malleable material allows a useful amount of plastic deformation to occur under compressive loading before fracture occurs. Such a material is required for manipulation by such processes as forging, rolling and rivet heading.

4. Hardness:

It is the ability of a material to withstand scratching (abrasion) or indentation by another hard body, it is an indication of the wear resistance of the material. The ball only makes a small indentation in the hard material but it makes a very much

deeper impression in the softer material.

5. Ductility:
   - It refer to the capacity of substance to undergo deformation under tension without rupture as in wire drawing (as shown in figure), tube drawing operation. For more ductile material $\varepsilon_p > 15\%$, for less ductile material $\varepsilon_p > 5.1$ $\varepsilon_p < 15\%$.

6. Stiffness
   - It is the measure of a material's ability not to deflect under an applied load.For example, steel is very much stronger than cast iron, then the cast iron is preferred for machine beds and frames because it is more rigid and less likely to deflect with consequent loss of alignment and accuracy.

7. Brittleness:
   - It is the property of a material that shows little or no plastic deformation before fracture when a force is applied. Also it is usually said as the opposite of ductility and malleability. For brittle material $\varepsilon_D < 5\%$.

8. Elasticity:

   It is the ability of a material to deform under load and return to its original size and shape when the load is removed. If it is made from an elastic material it will be the same length before and after the load is applied, despite the fact that it will be longer whilst the load is being applied. All materials possess elasticity to some degree and each has its own elastic limits.

9. Plasticity:
   - This property is opposite to elasticity, while the ductility and malleability are particular cases of the property of the plasticity. It is the state of a material which has been loaded beyond it elastic limit so as to cause the material to deform permanently. Under such conditions the material takes a permanent set and will

not return to its original size and shape when the load is removed. When a piece of mild steel is bent at right angles into the shape of a bracket, it shows the property of plasticity since it does not spring back strength again.

10. Creep:
    - The permanent deformation (strain) of a material under steady load as a function of time is called creep. Length of our waist belt increases after some duration, is due to creep effect. Thermally actuated process, and hence is influenced by temperature. Appreciable at temperature above 0.4. $T_m$ where $T_m$ is melting point of material in degree kelvin. Creep occurs at room temperature in many materials such as lead, zinc, solder wire
11. Fatigue:
    - The behavior of materials under fluctuating and reversing loads (or stresses) is termed as fatigue.

# UNIT I ENGINEERING MATERIALS

Introduction – classification of engineering materials – selection of materials for engineering purposes –selection of materials and shape –classification metal and alloys, polymers, ceramics and glasses, composites, natural materials, -nonmetallic materials-smart materials - physical, metrical properties of metals

## Polymer

• A polymer is a large molecule or a macromolecule which essentially is a combination of many subunits. The term polymer in Greek means 'many parts'. Polymers can be found all around us. Polymers may be naturally found in plants and animals (**natural polymers**) or may be man-made (**synthetic polymers**)

### Types

- **Organic Polymers**: Carbon backbone.
- **Inorganic Polymers**: Backbone constituted by elements other than carbon.



### Properties of Polymers

### Physical Properties

- As chain length and cross-linking increases the tensile strength of the polymer increases.Polymers do not melt, they change state from crystalline to semi-crystalline.
-

### Chemical Properties

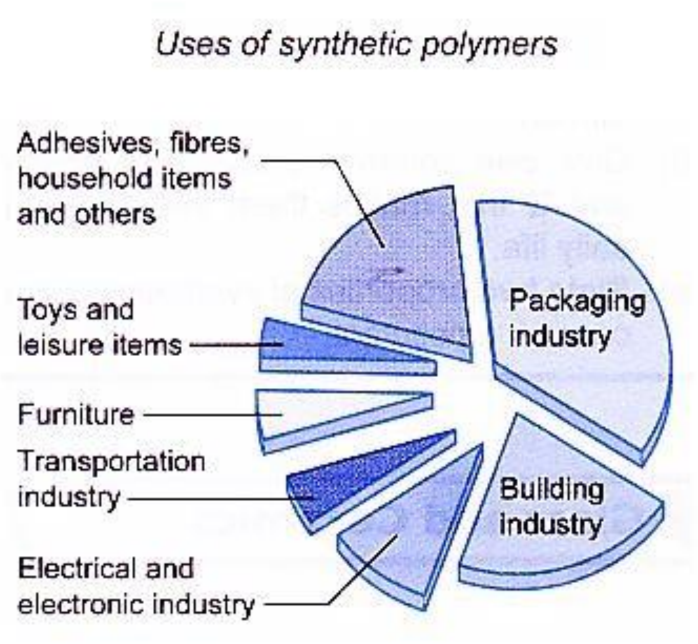
- The polymer is enabled with hydrogen bonding and ionic bonding resulting in better cross-linking strength. The polymer for high flexibility.Polymers with linking chains are known to be weak, but give the polymer a low melting point.

### Optical Properties

- Due to their ability to change their refractive index with temperature they are used in lasers for applications in spectroscopy and analytical applications.

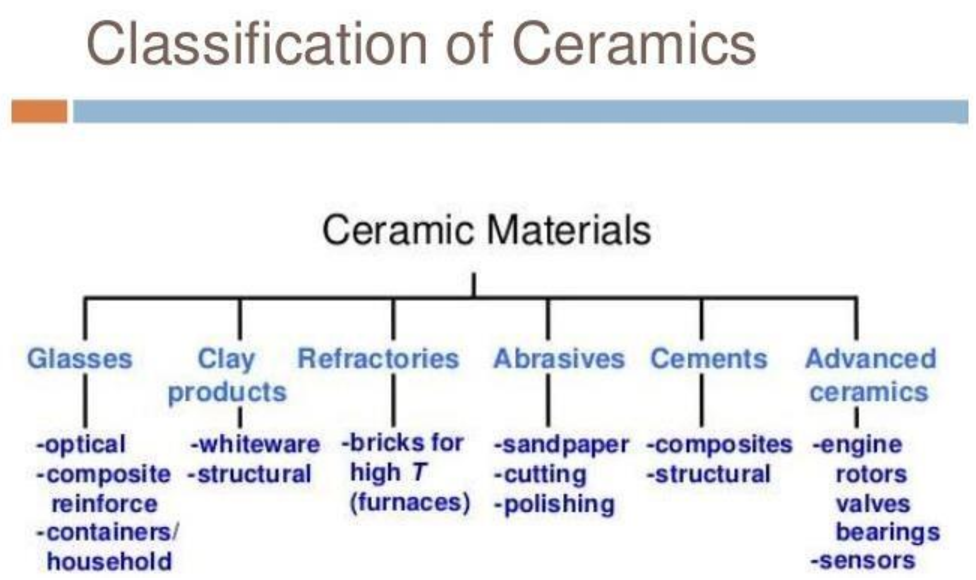
**Uses of Polymers**

- Polypropene finds usage in a broad range of industries such as textiles, packaging, stationery, plastics, aircraft, construction, rope, toys, etc.
- Polystyrene is one of the most common plastic, actively used in the packaging industry. Bottles, toys, containers, trays, disposable glasses and plates, TV cabinets and lids are some of the daily-used products made up of polystyrene. It is also used as an insulator.
- The most important use of polyvinyl chloride is the manufacture of sewage pipes. It is also used as an insulator in the electric cables.
- Polyvinyl chloride is used in clothing and furniture and has recently become popular for the construction of doors and windows as well. It is also used in vinyl flooring.
- Urea-formaldehyde resins are used for making adhesives, moulds, laminated sheets, unbreakable containers, etc.
- Bakelite is used for making electrical switches, kitchen products, toys, jewellery, firearms, insulators, computer discs, etc.




**Ceramic**

A ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension. In our everyday life, we are surrounded by ceramics and glass. The house where we live and the place where we work may have been built, at least partially, with bricks, mortar, cement, and concrete. Ceramic tiles may decorate the floors of one or more rooms, as well as walls and kitchen countertops. Ceramic roof tiles are often used to insulate buildings, to create a water barrier and allow for proper water drainage. Glass windows and skylights provide natural illumination and protection from the outside elements. Low-emissivity coatings and smart glass are helping to create windows that are capable of controlling the amount of light coming in, while achieving energy savings. Glass fibers may be used to create an extra layer of insulation to keep the house cool in the summer and warm during the winter.




**USES**

- For convenience ceramic products are usually divided into four main types; these are shown below with some examples: Structural, including bricks, pipes, floor and roof tiles
- Refractories, such as kiln linings, gas fire radiant, steel and glass making crucibles
- White wares, including tableware, cookware, wall tiles, pottery products and sanitary ware

# UNIT I ENGINEERING MATERIALS

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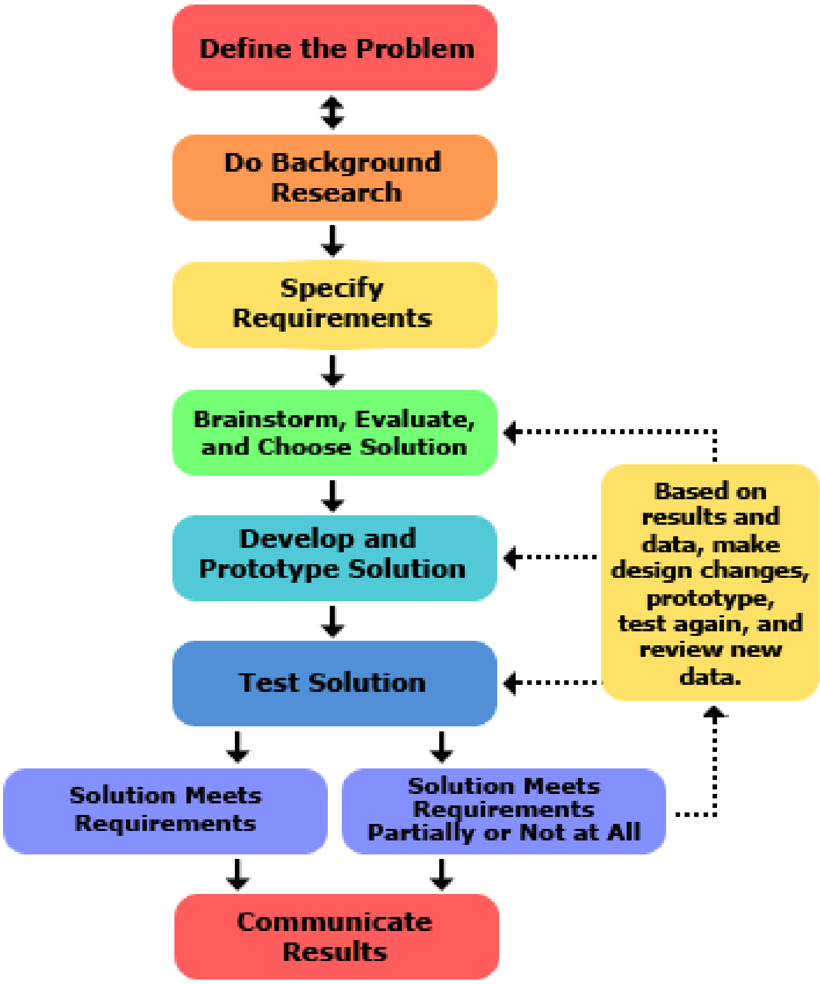
**Selection of materials for engineering Purposes :**

In Material Science Engineering understanding the material selection process is the key to engineering any application and/or part design. Material selection is the foundation of all engineering applications and design. This selection process can be defined by application requirements, possible materials, physical principles, and selection. The design or function of the part/application is the application requirements. The application requirements are specific given the application.

The Functional Requirements of the Design: e.g : the design should have a certain load carrying capacity, ability to transfer heat etc.The Main Objective of the Design: e.g : Improve durability, reduce overall weight of the product/component. The Constrains of a Design: e.g : Fixed dimensions, material should not buckle under pressure, should be able to retain shape and strength at high temperatures etc.

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The possible materials are simply the only materials that can be used in the application. Possible Materials are defined by the application requirements. For an example you cannot use clothe to build a bicycle. Physical principles are methods of changing a material that are learned through material science techniques. Using material science physical principles, we can change material properties. Three common physical principles we can use for functional material strengthening are densification, composites, and alloying. There many manufacturing techniques used to strengthen and form materials as well. Densification is the most common and necessary way to strengthen any material. In general, this increases the tensile strength by reducing the porosity of the material.

The standard composite rule of mixtures is when the standard matrix is soft/pliable and the reinforcing material is tensile strong. One the major reasons for the prevalent use of composite materials in construction is the adaptability of the composite to many kinds of applications. The selection of mixture proportions can be aimed to achieve optimum mechanical behavior of the harden product. Selection can result in the change of the strength, consistency, density, appearance, and durability. The alloying of metals is one of the oldest and most fundamental material processing techniques. An Alloy is a solid solution that is composed of two or more elements. There is a solvent (majority composition) and a solute. The Solute element can strengthen the overall solid solution by different element size, density, and other material properties. Given the application requirements, possible materials, and physical principles we can select the best material. Thus, in the selection of a material: First, we decide on the requirements of the application. Second, we decide on the possible materials we can use in the application. Third, we decide what changes in the material properties are needed. Lastly, we decide which material out of the possible materials best fulfills the requirements of the application given possible changes in the material properties.



**Factors that should be considered before selecting a material**

- Cost of the material
- Its ability to manufacture
- Environmental considerations
- Chemical properties
- Physical properties
- Mechanical attributes

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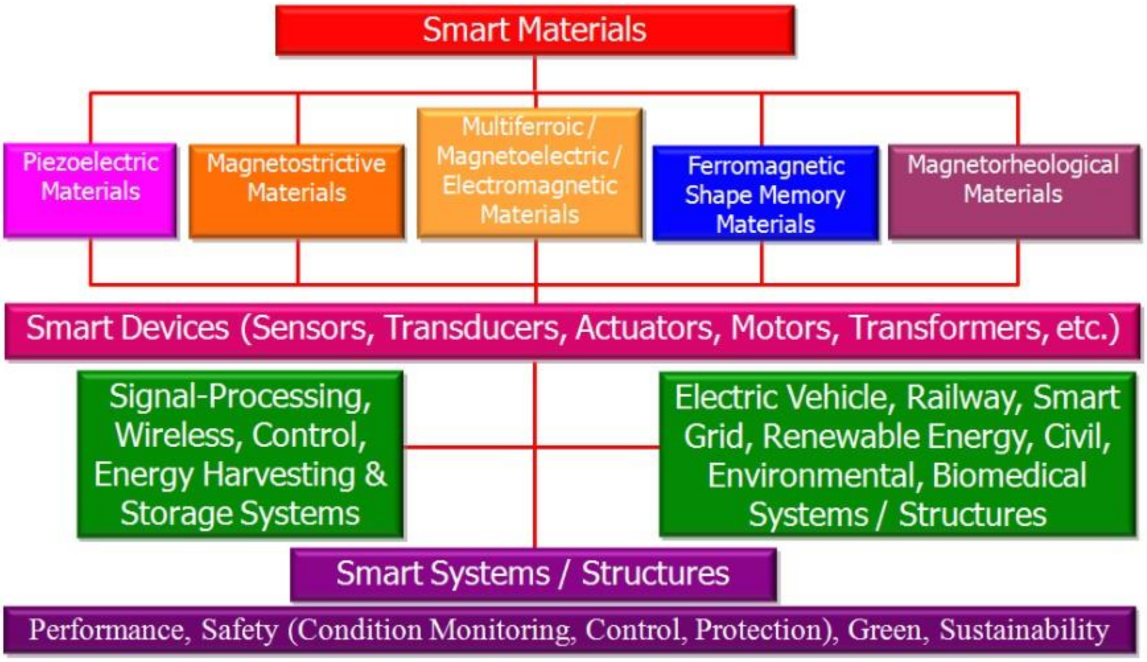
**Smart Materials:**

Smart materials, also called intelligent or responsive materials, are designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, moisture, electric or magnetic fields, light, temperature, pH, or chemical compounds.




- Act simultaneously as actuators and sensors
- Perform controlled mechanical actions without any external mechanism
- Are adaptive with the environmental condition
- Create the potential for new function development within applications.




**Benefits of smart materials**

Smart materials are compelling because they are often an efficient way to fulfil a specific performance objective. Effective implementation of smart materials can simplify design, reduce the part count, and increase the lifespan of an object. The primary benefit of smart materials is that their performance is inherent to the material itself. It's up to the engineer or designer is to use that property effectively. To help make the classes and use-cases of smart materials more tangible, I have described use cases within the five major categories of smart materials. In each case, the use of a Smart Material has made a design less complicated and more robust. Devices using smart materials might eventually replace more traditional technologies in the construction of buildings, vehicles, and consumer products. Lower component weight, component size, and complexity combined with improved design flexibility, functionality, and reliability, make smart materials an attractive option. In addition, smart materials offer a level of environmental robustness not easily achieved through other technologies as they are not typically impervious to water, moisture, or dust.

**Types of smart material**

Some types of smart materials include:

Piezoelectric – On applying a mechanical stress to these materials it generates an electric current. Piezoelectric microphones transform changes in pressure caused by sound waves into an electrical signal.

Shape memory – After deformation of these materials they remember their original shape and return back to its original shape when heated. Applications include shape memory stents – tubes threaded into arteries that expand on heating to body temperature to allow increased blood flow.

Thermo chromic – These are the materials which change their color in response to changes in temperature. They have been used in bathplugs that change color when the water is too hot.

Photo chromic – These materials change color in response to changes in light conditions. Uses include security ink sand dolls that 'tan' in the sun.



Hydrogels: Hydrogels can be tailored to absorb and hold water, or other liquids, under certain environmental conditions. Hydrogels have been around for a long time, specifically in disposable diapers. A key feature however is the gels can be tailored chemically to respond to different stimuli.

Magneto rheological: it is a fluid that fluids become solid when placed in a magnetic field. They can be used to construct dampers that suppress vibrations. These can be used for buildings and bridges to suppress the damaging effects of,

For example, high winds or earthquakes.

**Applications of Smart Materials**

There are many possibilities for such materials and structures in the manmade world.

Engineering structures could operate at the very limit of their performance envelopes and to their structural limits without fear of exceeding either. These structures could also give maintenance engineers a full report on performance history, as well as the location of defects, whilst having the ability to counteract unwanted or potentially dangerous conditions such as excessive vibration, and affect self-repair.