Lecture#(5)

General Properties of Engineering Materials

The principle properties of materials which are of importance to the engineer in selecting materials. These can be broadly divided into:

Physical properties of materials

These properties concerned with such properties as melting, temperature, electrical conductivity, thermal conductivity, density, corrosion resistance, magnetic properties, etc. and the more important of these properties will be considered as follows :

1. Density

Density is defined as mass per unit volume for a material. The derived unit usually used by engineers is the kg/m3 . 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:

$$density\ (\rho) = \frac{mass\ (m)}{volume\ (V)}$$

$$\text{Relative density (d)} = \frac{\text{Density of the material}}{\text{Density of pure water at } 4^{\circ}\text{C}}$$

2. Electrical conductivity

Figure 1 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. That is, it offers very little resistance to the flow of electrons (electric current) through the wire. A plastic materials such as polymerized has been chosen for the insulating sheathing surrounding the wire conductor. This material has been chosen because it is such a bad conductor, where very few electrons can bass through it. Because they are ***very bad conductors*** they are called as ***insulators***.

There is no such thing as a perfect insulator, only very bad conductors

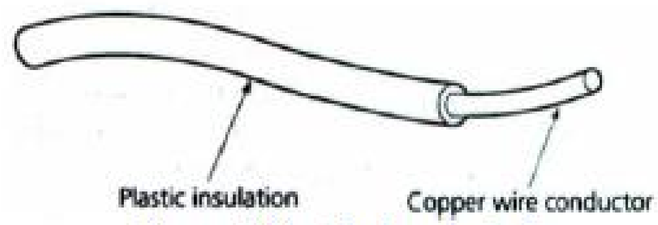

Figure 1. Electrical conductivity.

For example, metallic conductors of electricity all increase in resistance as their temperatures rise. Pure metal shows this effect more strongly than alloys. However, pure metals generally have a better conductivity than alloys at room temperature. The conductivity of metals and metal alloys improves as the temperature falls. Conversely, non-metallic materials used for insulators tend to offer a lower resistance to the passage of electrons, and so become poorer insulators, as their temperatures rise. Glass, for example, is an excellent insulator at room temperature, but becomes a conductor if raised to red heat.

3. Melting temperature of material

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

4. Semiconductors

So far we have examined the conductivity of the metals and the insulating properties of the non-metals (exception : carbon). In between conductors and isolators lies a range of materials known as semiconductors. These can be good or bad conductors depending upon their temperatures. The conductivity of semiconductor materials increases rapidly for relatively small temperature increases.

This enable them to be used as temperature sensors in electronic thermometers.

Semiconductor materials are capable of having their conductors properties changed during manufacture. Examples of semiconductor materials are **silicon** and **germanium**.

They are used extensively in the electronics industry in the manufacture of solid-state devices such as diodes, thermistors, transistors and integrated circuits.

5. **Thermal conductivity**

This is the ability of the material to transmit heat energy by conduction. Figure 2 shows a soldering iron. 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.

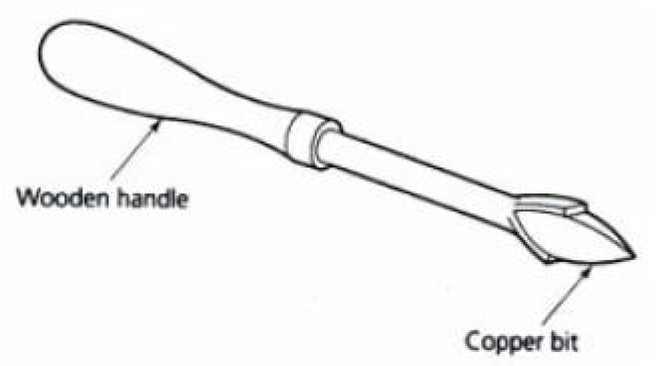

Figure 2. Thermal conductivity.

6. Fusibility

This is the ease with which materials will melt. It can be seen from figure 3 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.

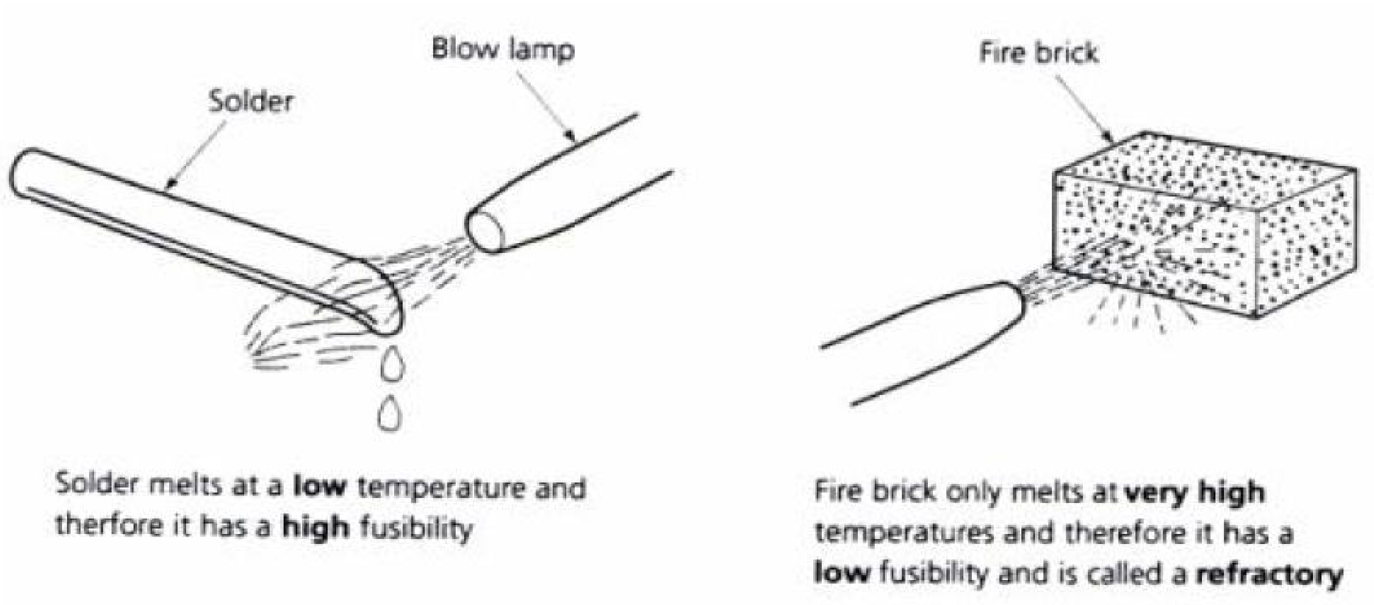

Figure 3. Fusibility.

7. 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 ahigh reluctance to the magnetic flux felid.

8. 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***. Creep is defined as the gradual extension of a material over a long period of time whilst the applied load is kept constant. It is also an important factor when considering plastic materials, and it must be considered when metals work continuously at high temperatures.

For example gas-turbine blades. The creep rate increases if the temperature is raised, but becomes less if the temperature is lowered.

Mechanical properties of materials

These properties are concerned with the following properties :

1. Tensile strength TS

It is the ability of a material to withstand tensile (stretching) loads without breaking. For example, figure 4 shows a heavy load being held up by a rod fastened to beam. 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.

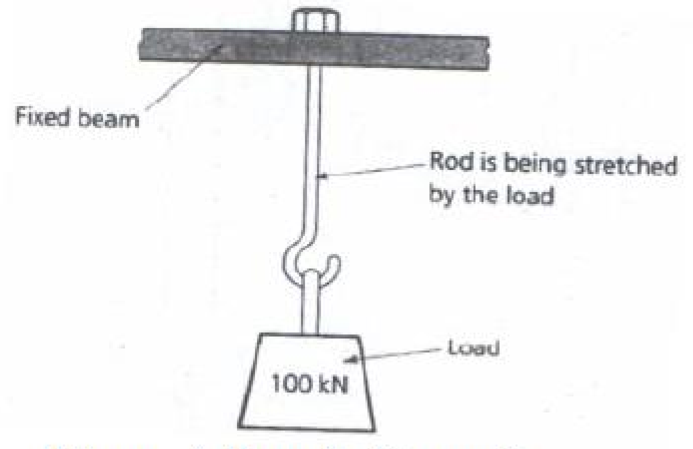

Figure 4. Tensile Strength

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 broken by impact loading as shown in figure 5.

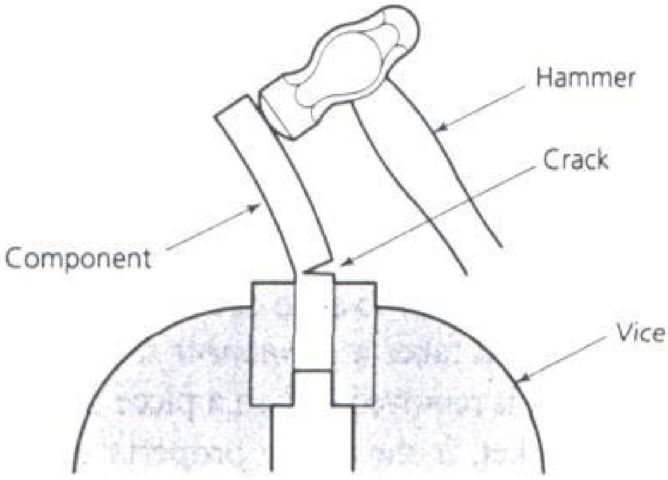

Figure 5. Toughness (Impact Resistance).

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 as shown in figure 6.

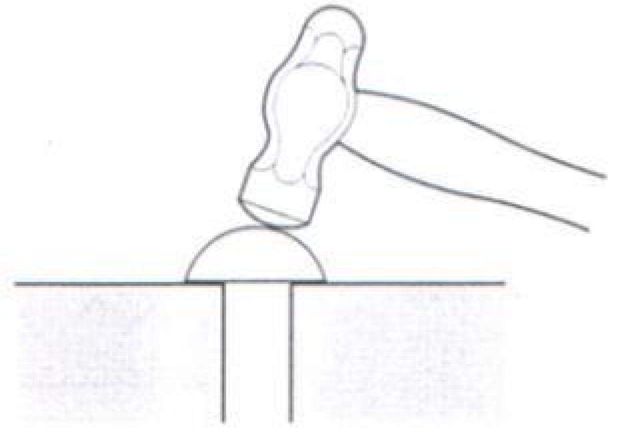

Figure 6. Malleability

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. For example, figure 7 shows a hardened steel ball being pressed first into a hard material and then into a soft material by the same load. As seen that the ball only makes a small indentation in the hard material but it makes a very much deeper impression in the softer material.

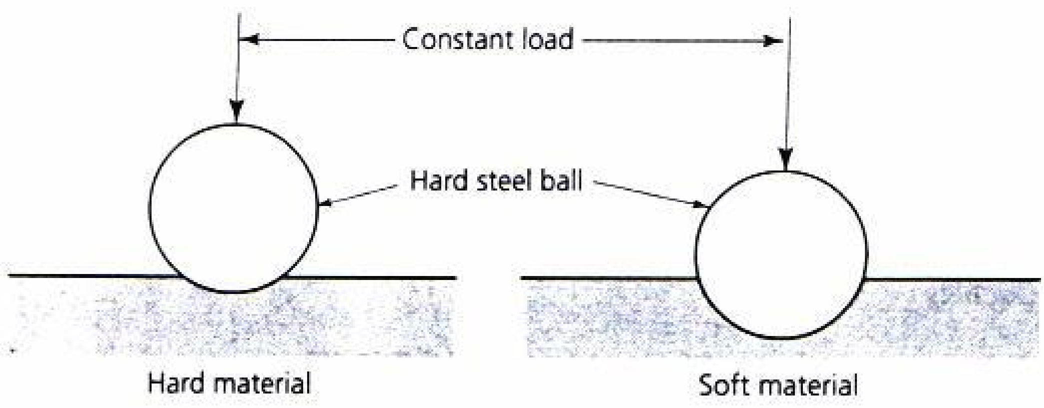

Figure 7. Hardness.

5. Ductility

It refer to the capacity of substance to undergo deformation under tension without rupture as in wire drawing (as shown in figure 8), tube drawing operation.

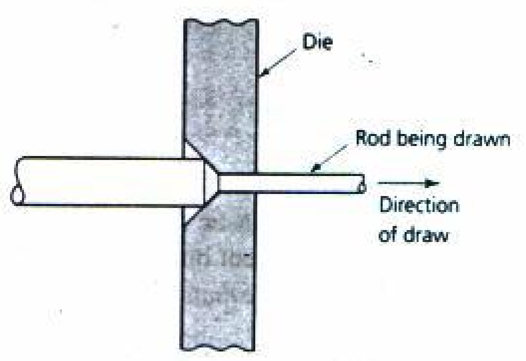

Figure 8. Ductility

6. **Stiffness**

It is the measure of a material's ability not to deflect under an applied load. For example, although 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.

Consider figure 9 (a): for a given load the cast iron beam deflect less than the steel beam because cast iron is more rigid material.

However, when the load increased as shown in figure 9 (b), the cast iron beam will break, whilst the steel beam deflects little further but not break. Thus a material which is rigid is not necessarily strong.

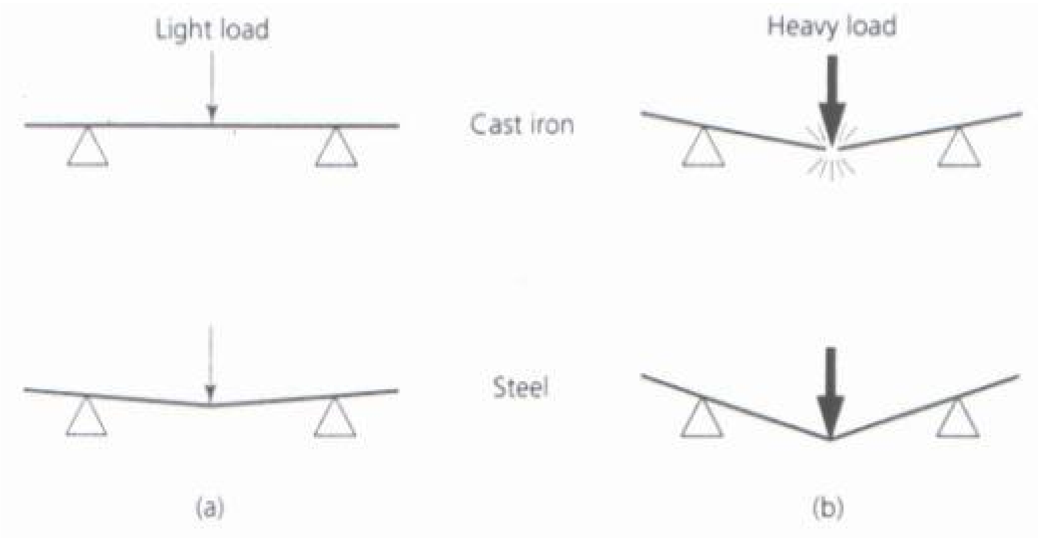

Figure 9. Stiffness (rigidity):
(a) The tested materials deflect under a light load
(b) The tested materials deflect under a heavy load.

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.

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 posses elasticity to some degree and each has its own ***elastic limits***. As in figure 10.

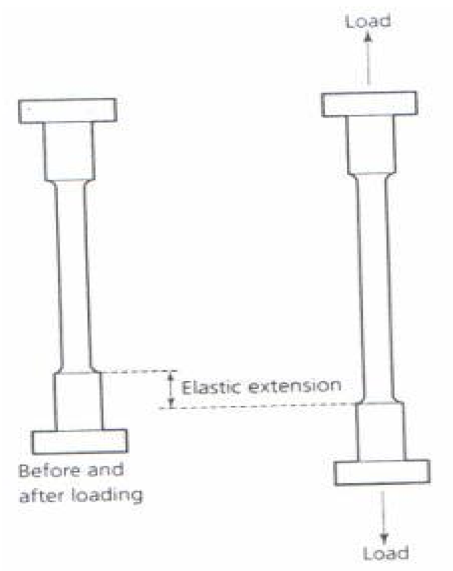

Figure 10. Elasticity.

9. Plasticity

This property is the exact 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 its 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 dose not spring back strength again, this is shown in figure 11.

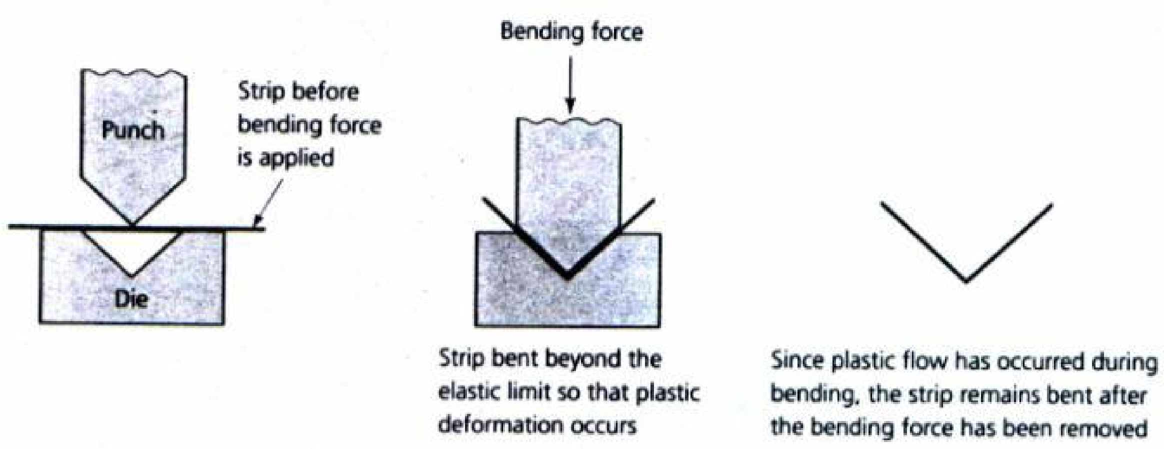

Figure 11. Plasticity.

Some metals such as lead have a good plastic range at room temperature and can be extensively worked (where working of metal means squeezing, stretching or beating it to shape). This is

advantage for plumber when beating lead flashings to shape on building sites.