Material Properties

INTRODUCTION

Property of a material (or Material Property) is a factor that influences qualitatively or quantitatively the response of a given material to imposed stimuli and constraints, eg. forces, temperatures, etc.

Mechanical properties include those characteristics of material that describe its behaviour under the action of external forces. Different mechanical properties are :

1. Elasticity	2. Plasticity	3. Toughness	4. Resilience
5. Tensile strength	6. Yield strength	7. Impact strength	8. Ductility
9. Malleability	10. Brittleness	11. Hardness	12. Fatigue
13. Creep	14. Wear resistance		

4.1 Elasticity

- Loading a solid will change its dimensions, but the resulting deformation will disappear upon unloading. This tendency of a deformed solid to seek its original dimensions upon unloading is ascribed to a property called elasticity.
- The recovery from the distorting effects of the loads may be instantaneous or gradual, complete or partial. A solid is called perfectly elastic if this recovery is instantaneous and complete; it is said to exhibit delayed elasticity or inelastic effects, respectively, if the recovery is gradual or incomplete. Accurate measurements reveal some delayed elasticity and inelastic effects in all solids.
- Giving a precise definition of elasticity and setting forth the rudiments of the theory of elasticity require a discussion of the concepts of strain, stress and modulus of elasticity.

$$\text{Stress} = \frac{\text{Load } (P)}{\text{Area } (A)}$$

$$\text{Strain} = \frac{\text{Change in length } (\Delta l)}{\text{Original length } (l)}$$

Young's modulus of Elasticity, $$E = \frac{\text{Change in length } (\Delta l)}{\text{Original length } (l)}$$

4.2 Plasticity

- Plasticity is that property of a material by virtue of which it may be permanently deformed when it has been subjected to an externally applied force great enough to exceed the elastic limit.
- The subject of plasticity is of great importance to an engineer for it is this property that, in most cases, enables him to shape (e.g., roll, forge) metals in the solid state.
- The minimum stress that should cause permanent deformation can be computed from a knowledge of the bond strength. The result of such computations gives values that are from 100 to 1000 times the stress required to initiate plastic deformation of a crystal as determined by testing.
- For most materials, the plastic deformation follows, the elastic deformation material obeys the law of elastic solids for stresses below the yield stress and this is followed by the plastic deformation.
- The mechanism of plastic deformation is essentially different in crystalline materials and amorphous materials. Crystalline materials undergo plastic deformation as the result of slip along definite crystallographic planes whereas, in amorphous materials, plastic deformation occurs when individual molecules or groups of molecules slide past one another.

4.3 Toughness

- Toughness is the ability of the material to absorb energy during plastic deformation up to fracture.
- Toughness refers to the ability of a material to withstand bending or the application of shear stresses without fracture. By this definition, copper is extremely tough but cast iron is not.
- Specimen geometry as well as the manner of load application are important in toughness determinations. For dynamic loading conditions and when a notch (or point of stress concentration) is present, notch toughness is assessed by using an impact test. Furthermore, fracture toughness is a property indicative of a material's resistance to fracture when a crack is present.
- For the static situation, toughness may be ascertained from the results of a tensile stress-strain test.
- Toughness of a material, then, is indicated by the total area under the material's tensile stress-strain curve up to the point of fracture.

4.4 Resilience

- Resilience is closely related to toughness. Resilience is the capacity of a material to absorb energy when it is elastically deformed and then upon unloading, to have this energy recovered.
- The associated property is the modulus of resilience, which is the strain energy per unit volume required to stress a material from an unloaded state up to tie point of yielding.
- Resilience is usually measured by determining the rebound of a pendulum or ball after a single impact. It represents the ratio of energy given up on recovery from deformation to energy required to produce deformation. For perfect elastic materials' this ratio should be one but, in real materials, there is always some amount of energy that is dissipated as heat because of the internal friction of the material. The temperature affects resilience more than any other factor.

4.5 Tensile strength

- In a tensile test, the ratio of the maximum load to original cross-sectional area is called Tensile Strength or Ultimate tensile strength. The units of tensile strength are kg/cm^2.

- Ultimate tensile strength refers to the force needed to fracture the material.
- Tensile strength or ultimate strength is the maximum point shown on the stress-strain curve.
- Tensile strength is a measure of the strength and ductility of a material.
- Tensile strength value is commonly taken as a basis for fixing the working stresses especially brittle materials.

4.5.1 Tensile Test

Tensile test are being carried out to fined the mechanical properties of material. Samples are prepa generally according to the ASTM standards and located in a UTM machine.

1. Once the stress goes beyond the yield strength there will be decrease in cross sectional area. Hen increase is stress.
2. This increase in stress is compensated by increase in strength by work hardening.
3. A unique neck will appear at a point of plastic instability where the increase in strength due to w hardening fails to compensate for the decrease in cross-sectional area. Gradually the sample fail like cup and cone fractures.

4.5.2 Yield Point Phenomenon

- Carbon in iron is an interstitial impurity but the interstitial space is much smaller than size of carb atoms. So by the process of diffusion, carbon get accumulated at the dislocation site it is calle cattrell atmosphere.

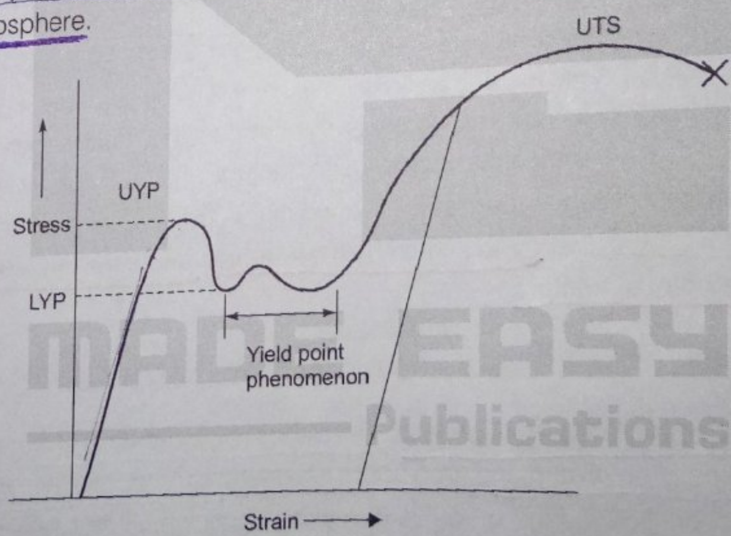

Figure 4.1 Yield Point Phenomenon

- This produces lattice strains. So extra stresses are required to break this cattrell atmosphere an jump the dislocation to the new site. That is why upper yield point appears.
- Once the dislocation jumps to the new position since there is no cattrell atmosphere lesser stress ar required to keep the dislocation moving so lower yield point and yield point phenomenon appears the low carbon steel material.

4.6 Yield strength

- When metals are subjected to a tensile force, they stretch or elongate as the stress increases. Th point where the stretch suddenly increases, is known as the yield strength of the material.

- Yield strength of a material represents the stress below which the deformation is almost entirely elastic.
- Yield strength is that value of stress at which a material exhibits a specified deviation from proportionality of stress and strain.
- The ability of a material to resist plastic deformation is called the yield strength and is calculated by dividing the force initiating the yield by the original cross-sectional area of the specimen.
- In materials where the proportional limit or the elastic limit is less obvious, it its common to define the yield load as that force required to give 0.2% plastic offset. In other words, the yield strength is defined as the stress required to produce an arbitrary permanent deformation. The deformation most often used is 0.2%.

4.6.1 Yield Point Phenomenon

- Carbon is interstitial impurity in iron.
- But the size of interstitial nod is much smaller than carbon atom. So carbon diffuses through atom structure and gets accumulated to dislocation site.
- Thus a carbon rich atmosphere is produced called "Cottrel atmosphere".
- These cottrel atmosphere (produces atomic strains) in the host iron atoms, as when external load is applied on the material larger stresses are required to break the cottrel atmosphere.

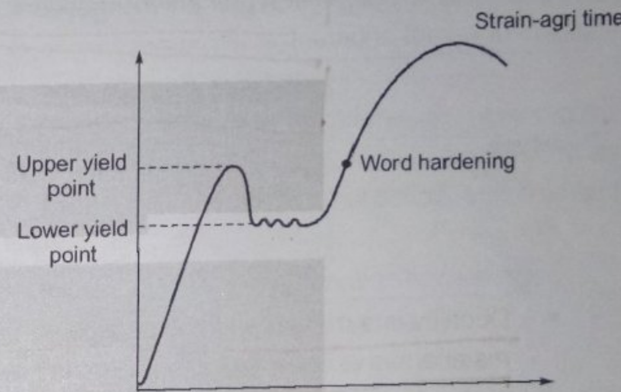

Figure 4.2 Yield Point Phenomenon

- That why upper yield point appears in the materials.
- One the dislocation jumps the new site relatively lower stress are required to keep the dislocation moving.
- That's why lower yield point appears in the material.
- Upon unloading the material from the region of work hardening and loading again yield point phenomenon will not appear.
- After a certain period (2 years) yield point phenomenon repeats and the period after which the process re appears in material is called strain aging time.
- These phenomenon does not appear in medium and high carbon steels because carbon is not only present at dislocation site but on the other inlets, site as well. So once dislocation jumps to new position, carbon is already there to diffuse.

4.7 Impact strength

- Impact strength is a complex characteristic which takes into account both toughness and strength of a material. The capacity of a material to resist or absorb shock energy before it fractures is called its impact strength.
- Impact strength depends upon the structure of a metal. Course grain structure and precipitation of brittle layers at the grain boundaries do not appreciably alter the mechanical properties in static tension, but they substantially reduce the impact strength. Impact strength is sensitive to rate of loading and to temperature, as well as to stress raisers (e.g., notches).