Introduction

Mechanical properties are the characteristics of a material that describe how it responds to applied forces and loads. These properties determine a material's ability to withstand deformation, resist failure, and perform effectively under various mechanical conditions. Understanding mechanical properties is essential in engineering, manufacturing, materials science, and design, as they guide the selection of suitable materials for specific applications.

Mechanical properties include behaviors such as elasticity, plasticity, toughness, hardness, ductility, brittleness, and strength. Each property reflects how the material reacts to stresses like tension, compression, shear, torsion, and impact. By evaluating these properties through standardized tests such as tensile tests, hardness tests, and impact tests engineers can predict a material's performance, safety, and reliability in real-world environments.

Definitions of Mechanical Properties of materials :

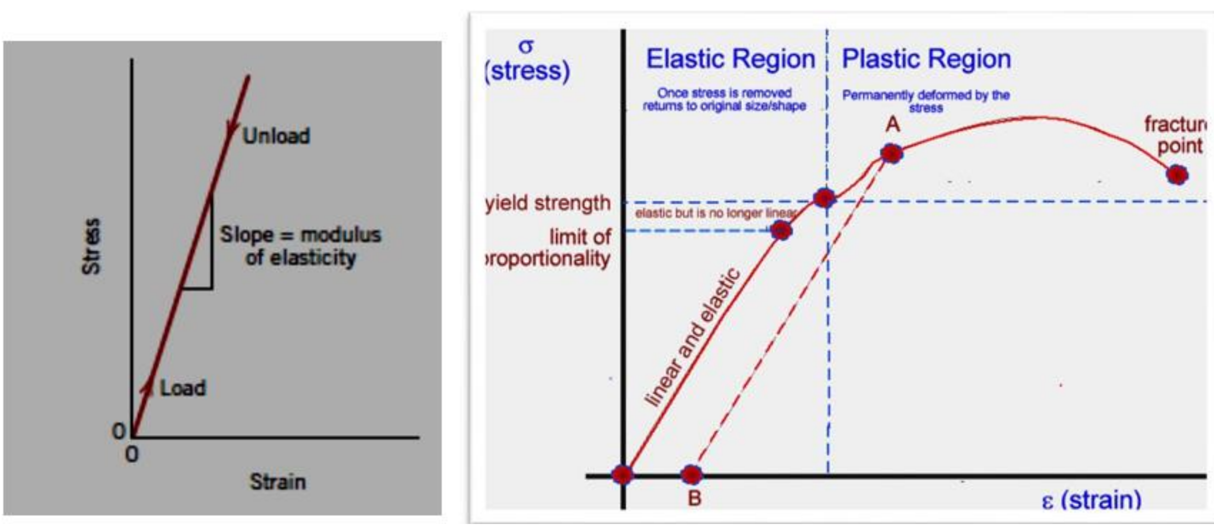
1. Strength: The strength of material is its ability to resist the application of force without rupture . In service, a material may have to withstand tension, compression or shear forces . The unit of strength is (N/m^2).

2. Stress: It is defined as the intensity of the internal distributed forces or components of forces resisting a change in the form of the body . It is measured as the force per unit area . There are three types of stresses namely: tension, compression and shear .

3. Strain: It is a deformation or change produced in material in its dimensions due to the effect of stress on it . It is a ratio or dimensionless number (has no unit) . There are three types of strains corresponding to the type of stresses namely , tensile , compressive , and shearing strain . Strain also known to be of two categories: elastic strain and plastic strain .

- Elastic strain : It is the change in dimensions of a body when some load is applied to it . It is a reversible strain, it disappears after removal of stress or applied load . It is proportional to the applied stress . In this strain , after the removal of load , same atomic neighbors without any displacement are retained. Figure (2.1a) shows an elastic strain .

- Plastic strain : It is the deformation or change in dimensions of a body which remain in it after the release of load .It is a result of the permanent displacement of the atoms inside the material. Figure (2.1b) shows the elastic and plastic strain .



Figure(2.1) : Schematic stress–strain diagram showing linear elastic deformation for loading and unloading cycles.(a) and elastic & plastic region (b).

4. Elasticity : The elasticity of a metal is its power of returning to its original shape after deformation by force .

5. Plasticity : It is the property of the material enabling it to retain the deformation produced by load permanently . Plasticity is necessary for forging, and metals may be rendered plastic by heating them .

6. Modulus of elasticity : It is the ratio of the stress applied and strain produced within the elastic limit of the material .It is the criterion of the stiffness of material.

$$E = \frac{\sigma}{\varepsilon}$$

E = Young's modulus, pressure units

σ = uniaxial stress, or uniaxial force per unit surface, pressure units

ε = strain, or proportional deformation (change in length divided by original length), dimensionless

Values of the modulus of elasticity for ceramic materials are about the same as for metals; for polymers they are lower .These differences are a direct consequence of the different types of atomic bonding in the three materials types. Furthermore, with increasing temperature, the modulus of elasticity diminishes.

7. Stiffness : It is the property of material enabling it to resist deformation under stresses .

8. Toughness : It is the ability of material to resist fracture due to high impact loads like hammer blows .

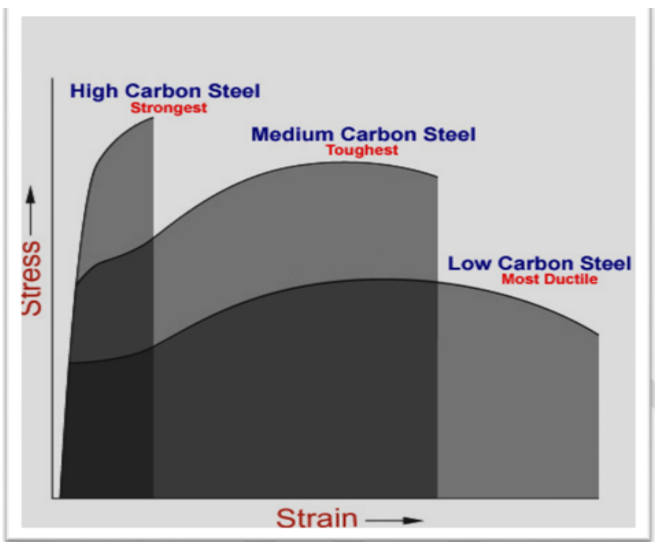
There are several variables that have a profound influence on the toughness of a material. These variables are:

- Strain rate (rate of loading)

- Temperature

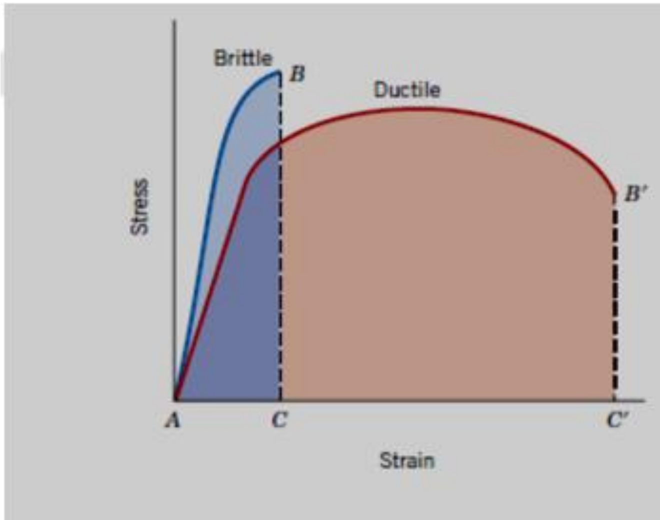
- Notch effect

The area under the curve of stress- strain curve represents the toughness of material shown in figure (2.3).



Figure(2.3): toughness for different type of steel.

9. Ductility : It is the property of a material enabling it to draw into wire with application of a tensile force . a ductile material must be both strong and plastic as shown in figure (2.4). Another expression , It is a measure of the degree of plastic deformation that has been sustained at fracture.



Figure(2.4): Schematic representations of tensile stress–strain behavior for brittle and ductile materials loaded to fracture.

10. Brittleness: It is the property of breaking of a material without much permanent distortion. It is the property apposite to plasticity or ductility . See figure (2.4).

11. Hardness : The hardness of metal is a measure of its ability to withstand scratching , wear and abrasion indentation by harder bodies .

12. Poisson's ratio: is a material property that describes how a material deforms in the direction perpendicular to an applied force.

Material	Poisson's ratio
rubber	≈0.5
gold	0.42
saturated clay	0.40–0.50
magnesium	0.35
titanium	0.34
copper	0.33
aluminium-alloy	0.33
clay	0.30–0.45

Equation Summary

Equation Number	Equation	Solving For	Page Number
6.1	$\sigma = \dfrac{F}{A_0}$	Engineering stress	154
6.2	$\epsilon = \dfrac{l_i - l_0}{l_0} = \dfrac{\Delta l}{l_0}$	Engineering strain	154
6.5	$\sigma = E\epsilon$	Modulus of elasticity (Hooke's law)	156
6.8	$\nu = -\dfrac{\epsilon_x}{\epsilon_z} = -\dfrac{\epsilon_y}{\epsilon_z}$	Poisson's ratio	160
6.11	$\%EL = \left(\dfrac{l_f - l_0}{l_0}\right) \times 100$	Ductility, percent elongation	166
6.12	$\%RA = \left(\dfrac{A_0 - A_f}{A_0}\right) \times 100$	Ductility, percent reduction in area	167