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Applied Physics

Lecture-3

Unit II-Mechanical Properties of solids

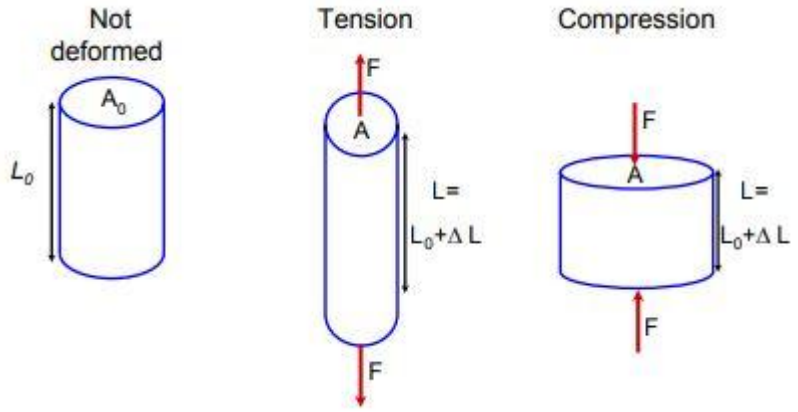
Mechanical Properties refers to the behavior of material when external forces are applied!!

Topics to be discusses in this lecture:

- Introduction to stress and strain in the material
- Deformation and it's types- viz. elastic and plastic deformation

Concept of stress and strain

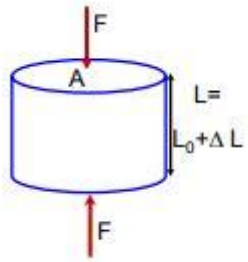
Load can be applied to the material having original length L_o and cross-sectional area A_o by applying axial forces:



ΔL can be measured as a function of the applied force; area A_o changes in response

Stress (σ) and Strain (ε)

For instance say, block of a solid with area A is subjected to compressive force F (as shown below)



Stress (σ)

- Stress σ stays constant

$$\sigma = \frac{F}{A}$$

- Units Force / area = N / m^2 = Pa (usually in MPa or GPa)

Strain (ε) – result of stress

- For tension and compression: change in length of a sample divided by the original length of sample

$$\epsilon = \frac{\Delta L}{L}$$

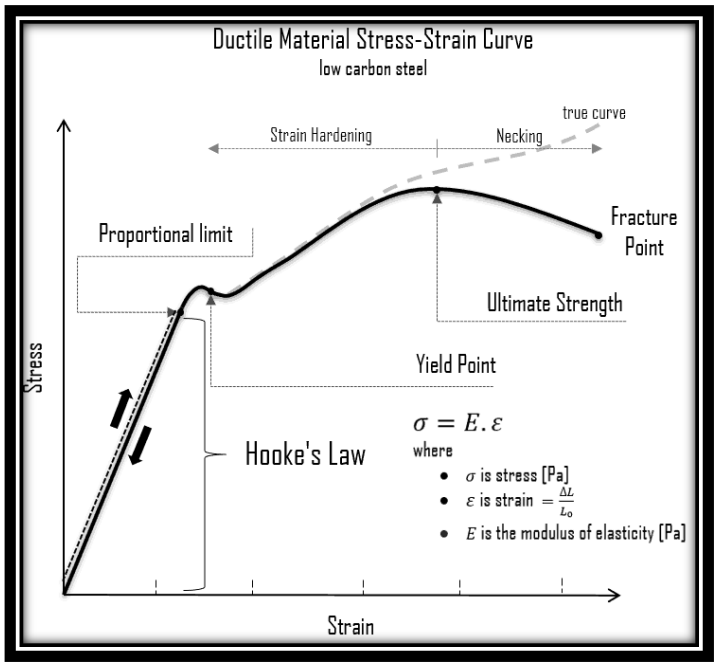
Deformation

The deformation is a measure of how much an object deforms from its original dimensions or size in a given direction. Depending on which deformation you measure, you can calculate different types of strain.

$$strain = \frac{deformation}{reference\ length}$$

A deformation is called **elastic deformation**, if the stress is a linear function of strain. In other words, stress and strain follows **Hooke's law** (which we will be discussing further). Beyond the linear region, stress and strain show nonlinear behavior. This inelastic behavior is called **plastic deformation**.

Elastic Deformation

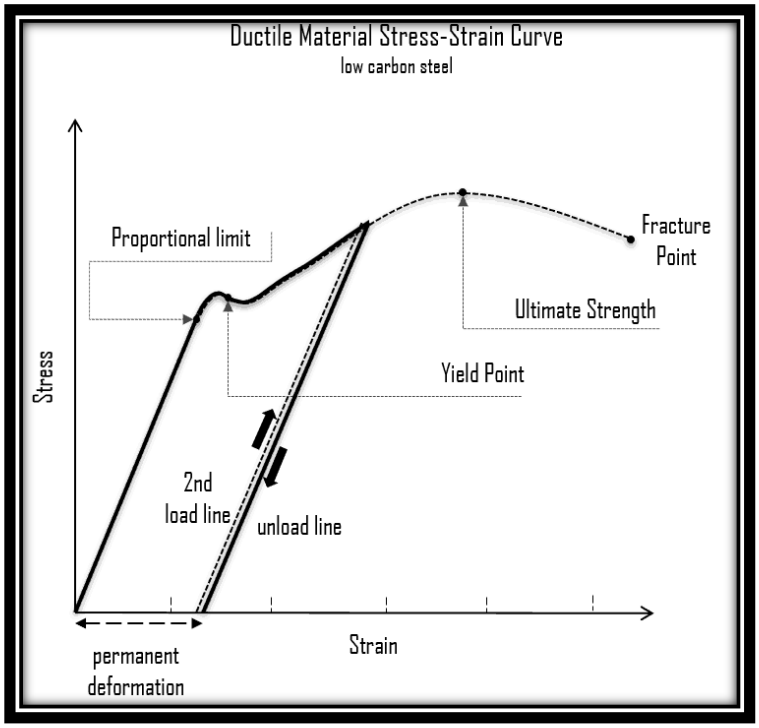


Elastic deformation and elastic strain is a transitory dimensional change that exists only while the initiating stress is applied and disappears immediately upon removal of the stress. When a metal is subjected to a load (force), it is distorted or deformed, no matter how strong the metal or light the load. This deformation may or may not be permanent. Up to a limiting stress, a body will be able to recover its dimensions on removal of the load. The applied stresses cause the atoms in a crystal to move from their equilibrium position. All the atoms are displaced the same amount and still maintain their relative geometry. When the stresses are removed, all the atoms return to their original positions and no permanent deformation occurs.

Plastic Deformation

Plastic deformation and plastic strain is a dimensional change that does not disappear when the initiating stress is removed. It occurs; if the limiting load is exceeded then the body will experience some permanent deformation on removal of the load.

Plastic deformation occurs in material bodies after stresses have attained a certain threshold value known as the **elastic limit** or **yield stress**, and are the result of **slip**, or **dislocation mechanisms** at the atomic level.



Various similarities and differences between elastic deformation and plastic deformation are presented below in table form.

Similarities between elastic and plastic deformations

- Any type of loading (normal, shear or mixed) may result both types of deformations.
- Plastic deformation can occur only after the material is elastically deformed. So without elastic deformation, plastic deformation is not possible.
- Both elastic and plastic deformations are useful; however, based on the application.

Differences between elastic and plastic deformations

Elastic Deformation	Plastic Deformation
Elastic deformation is a temporary deformation under the action of external loading.	Plastic deformation is the permanent deformation.
Once the external load is removed from an	When a body is plastically deformed, it retains

elastically deformed body, it regains its original shape.	its deformed shape even after the removal of external load.
In elastic deformation, atoms of the material are displaced temporarily from their original lattice site. They return back to their original position after the removal of external load.	In plastic deformation, atoms of the solid are displaced permanently from their original lattice site. They don't return back to the original position even after the removal of external load.
Elastic deformation is characterized by the property Elasticity. By definition, elasticity is the property of the solid material by virtue of which it tends to regain its shape after the removal of external load.	Plastic deformation is characterized by the property Plasticity. By definition, plasticity is the property of the solid material by virtue of which it tends to retain its deformed shape even after the removal of external load.
Amount of elastic deformation is very small.	Amount of plastic deformation is quite large.
External force required for elastic deformation of solid is quite small.	Force required for plastic deformation is also higher.
Energy absorbed by the material during elastic deformation is called module of resilience.	Total energy absorbed by the material during elastic and plastic deformation region is called module of toughness.
Hooke's Law of elasticity is applicable within this elastic region.	Hooke's Law is not applicable if the material is plastically deformed.
Most solid materials display a linear stress-strain behavior within this elastic region.	Stress-strain curve is non-linear in plastic region.
Material first undergo elastic deformation under the application of external loading.	Plastic deformation occurs after it is elastically deformed due to the application of external loading.
Mechanical and metallurgical properties of the solid material remain unaltered when it is elastically deformed.	Many properties of the solid material change considerably for plastic deformation.