MECHANICAL PROPERTIES OF SOLIDS

STRESS AND STRAIN

Stress

Stress is defined as force per unit area within materials that arises from externally applied forces, uneven heating, or permanent deformation and that permits an accurate description and prediction of elastic, plastic, and fluid behaviour.

Stress is given by the following formula:

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

where, σ is the stress applied, F is the force applied and A is the area of the force application.

The unit of stress is N/m^2.

Types of Stress

Stress applied to a material can be of two types as follows:

Tensile Stress

The external force per unit area of the material resulting in the stretch of the material is known as tensile stress.

Compressive Stress

Compressive stress is the force that is responsible for the deformation of the material, such that the volume of the material reduces.

Strain

Strain is the amount of deformation experienced by the body in the direction of force applied, divided by the initial dimensions of the body.

The following equation gives the relation for deformation in terms of the length of a solid:

$$\epsilon = \frac{\delta l}{L}$$

where ε is the strain due to the stress applied, δl is the change in length and L is the original length of the material.

The strain is a dimensionless quantity as it just defines the relative change in shape.

Types of Strain

Strain experienced by a body can be of two types depending on stress application as follows:

Tensile Strain

The deformation or elongation of a solid body due to applying a tensile force or stress is known as Tensile strain. In other words, tensile strain is produced when a body increases in length as applied forces try to stretch it.

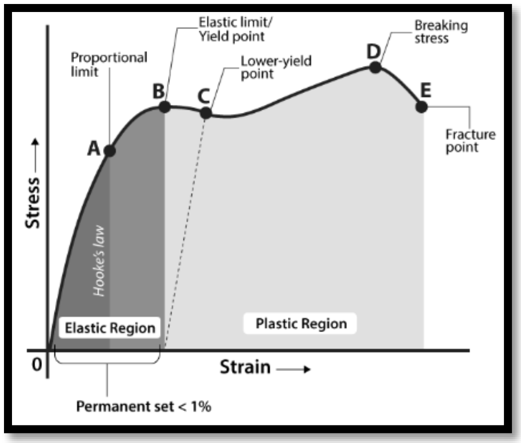
Compressive Strain

Compressive strain is the deformation in a solid due to the application of compressive stress. In other words, compressive strain is produced when a body decreases in length when equal and opposite forces try to compress it.

Stress-Strain Curve

When we study solids and their mechanical properties, information regarding their elastic properties is most important. We can learn about the elastic properties of materials by studying the stress-strain relationships, under different loads, in these materials.

The material's stress-strain curve gives its stress-strain relationship. In a stress-strain curve, the stress and its corresponding strain values are plotted. An example of a stress-strain curve is given below.



Explaining Stress-Strain Graph

The different regions in the stress-strain diagram are:

(i) Proportional Limit

It is the region in the stress-strain curve that obeys Hooke's Law. In this limit, the stress-strain ratio gives us a proportionality constant known as Young's modulus. The point OA in the graph represents the proportional limit.

(ii) Elastic Limit

It is the point in the graph up to which the material returns to its original position when the load acting on it is completely removed. Beyond this limit, the material doesn't return to its original position, and a plastic deformation starts to appear in it.

(iii) Yield Point

The yield point is defined as the point at which the material starts to deform plastically. After the yield point is passed, permanent plastic deformation occurs. There are two yield points (i) upper yield point

(ii) lower yield point.

(iv) Ultimate Stress Point

It is a point that represents the maximum stress that a material can endure before failure. Beyond this point, failure occurs.

(v) Fracture or Breaking Point

It is the point in the stress-strain curve at which the failure of the material takes place.

Hooke’s Law

In the 19th-century, while studying springs and elasticity, English scientist Robert Hooke noticed that many materials exhibited a similar property when the stress-strain relationship was studied. There was a linear region where the force required to stretch the material was proportional to the extension of the material, known as Hooke’s Law.

Hooke’s Law states that the strain of the material is proportional to the applied stress within the elastic limit of that material.

Mathematically, Hooke’s law is commonly expressed as:

$$F = -k.x$$

Where F is the force, x is the extension in length, and k is the constant of proportionality known as the spring constant in N/m.

Material	Young’s modulus (E) in GPa	Shear modulus (G) in GPa	Bulk modulus (K) in GPa
Glass	55	23	37
Steel	200	84	160
Iron	91	70	100
Lead	16	5.6	7.7
Aluminum	70	24	70

Note: GPa is gigapascal and 1 GPa = 1,00,00,00,000 Pa.