SIMPLE STRESS AND STRAIN

1. Load

In any engineering structure or mechanism the individual components will be subjected to external forces arising from the service conditions or environment in which the component works. If the component or member is in equilibrium, the resultant of the external forces will be zero but, nevertheless, they together place a load on the member which tends to deform that member and which must be reacted by internal forces which are set up within the material. If a cylindrical bar is subjected to a direct pull or push along its axis as shown in Figure1, then it is said to be subjected to ***tension*** or ***compression.*** Typical examples of tension are the forces present in towing ropes or lifting hoists, whilst compression occurs in the legs of your chair as you sit on it or in the support pillars of buildings.

$$Stress(\sigma) = \frac{P}{A}$$

Where:

P: Load [N, KN, MN]

A: Area [mm^2,cm^2,m^2,….etc]

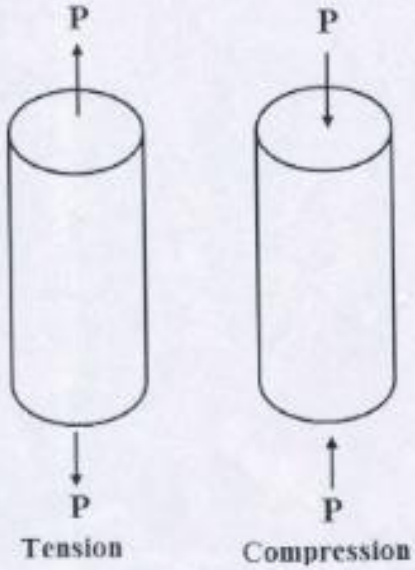


Figure 1. Types of direct stress

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2. Direct or normal stress (σ)

It has been noted above that external force applied to a body in equilibrium is reacted by internal forces set up within the material. If, therefore, a bar is subjected to a uniform tension or compression, i.e. a direct force, which is uniformly or equally applied across the cross section, then the internal forces set up are also distributed uniformly and the bar is said to be subjected to a uniform direct or normal stress, the stress being defined as:

$$Stress(\sigma) = \frac{load}{Area} = \frac{P}{A}$$

Stress (σ) may thus be compressive or tensile depending on the nature of the load and will be measured in units of Newton's per square meter (N/m^2).

3. Direct strain (ε)

If a bar is subjected to a direct load, and hence a stress, the bar will change in length. If the bar has an original length (L) and changes in length by an amount (δL), the strain produced is defined as follows:

$$Strain(\varepsilon) = \frac{change\ in\ length}{original\ length} = \frac{\delta L}{L}$$

Strain is thus a measure of the deformation of the material and is non-dimensional, i.e. it has no units; it is simply a ratio of two quantities with the same unit Figure 2.

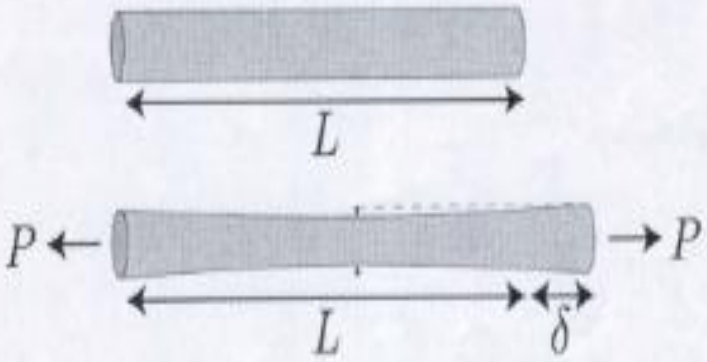


Figure2. Strain of *X*-direction causes

Strain can be expressed as a percentage strain:

$$Strain(\varepsilon) = \frac{\delta L}{L} * 100\%$$

4. Elastic materials - Hooke's law

A material is said to be elastic if it returns to its original, unloaded dimensions when load is removed. A particular form of elasticity which applies to a large range of engineering materials, at least over part of their load range, produces deformations which are proportional to the loads producing them. Since loads are proportional to the stresses they produce and deformations are proportional to the strains, this also implies that, whilst materials are elastic, stress is proportional to strain. Hooke's law, in its simplest form, therefore states that:

$$\text{Stress}\,(\sigma) \;\alpha\; \text{Strain}\,(\varepsilon)$$

$$\frac{Stress}{Strain} = Constant$$

This constant is called Modulus of elasticity or Young's Modulus

Modulus of elasticity - Young's Modulus:

Within the elastic limits of materials, i.e. within the limits in which Hooke's law applies, it has been shown that

$$\frac{Stress}{Strain} = Constant$$

This constant is given the symbol E and termed the ***modulus of elasticity*** or ***Young's modulus***

Thus

$$E = \frac{Stress}{Strain} = \frac{\sigma}{\varepsilon} = \frac{P/A}{\text{delta L / L}}$$

E= P / A . L / delta L

delta L = P .L / A . E

Deformation of a body due to force acting on it.
Where, P: the loador force acting on a body.

L: Origonal length of the body.
A: Cross section area of the body.
Б : stress induced in the body.
E: Modulus of Elasticity for the material of the body

Ɛ :strainType your text

Delta L ( ):Deformation of the body

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Units:

In Si units , force is generally expressed in newton. The kilo Newton (KN) means 1000 Newton. Stress is expressed in various forms like Newton / meter2 (N / m2) or pascal (Pa), Kilo Newton / millimeter 2 (K N / mm2) or Mega pascal (MPa), Kilo Newton /meter2 (K N / m2) or kilo Pascal (KPa) Gega Pascal (GPa)

1 N / mm2 = 1 MPa = 10 6 n/ m2= 10 6 Pa.
1 N / m2 = 1Pa = 10-6 N / mm2
1GPa = 109 Pa = 109 N /mm2

Example 1: An elastic rod 25 mm in diameter, 200 mm long, extends by 0.25 mm under a tensile load of 40 K N. Finf the stress, strain and elastic modulus for the material of the rod.

Solution

Diameter of rod = d=25 mm

Length of rod= 200mm

Tension P= 40 K N

Area of the section A = $\pi d^2 / 4 = \pi . (25)^2 / 4 = 490.87\ mm^2$

Stress (6) Load /A = $40 \times 10^3 / 490.87 = 81.49\ N / mm^2$

strain (?) = delta L / L =0,25 / 200 = 0.00125 = 0.125 %

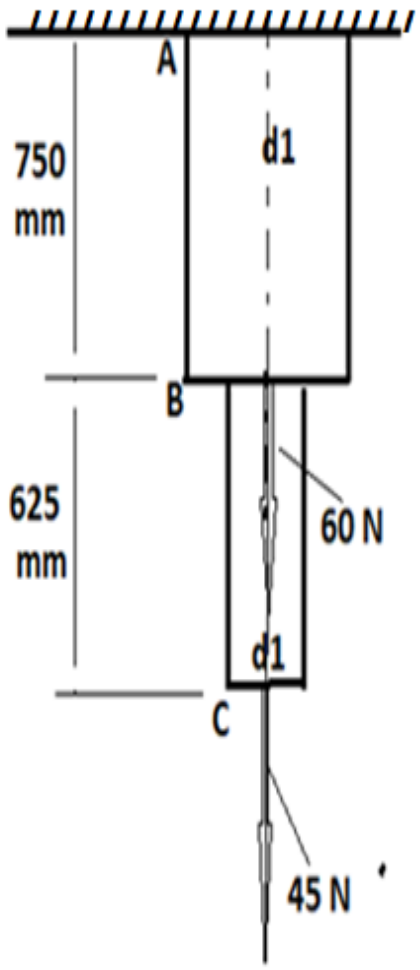
Elastic Modulus (E) = stress ?/ strain ? =81.49 / 0.00125

$= 0.625 \times 10^5\ N / mm^2$

Example 2

Two solid cylindrical rods AB and BC are welded at B as shown below. Determine the smallest allowable diameters d1 and d2 of AB and BC for an allowable tensile stress of 150N/mm2.

Solution



Rod AB

Tension in the rod= P1= 60+45=105 KN

Stress (6) = P/A

$150 = 105 \times 10^3 / A = 105 \times 10^3 / 150 = 700 mm^2$

$A = 700 = \pi d_1^2 / 4$ then d1 = 29.85 mm

Rod BC

Tension in the rod = P2 = 45 KN

$150 = 45 \times 10^3 / A = 45 \times 10^3 / 150 = 300 mm^2$

$A = 300 = \pi d_1^2 / 4$ then d1 = 19.54 mm