Stress and Strain

Stress

The stress applied to a material is the force per unit area applied to the material. The maximum stress a material can stand before it breaks is called the breaking stress or ultimate tensile stress.

Tensile means the material is under tension. The forces acting on it are trying to stretch the material. Compression is when the forces acting on an object are trying to squash it.

The equation below is used to calculate the stress.

$$stress = \frac{force}{area}$$

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

where,

σ = stress measured in Nm^{-2} or Pascal (Pa),

F = force applied in Newtons (N), and

A = cross-sectional area in m^2

Strain

The ratio of extension to original length is called strain it has no units as it is a ratio of two lengths measured in meters.

$$strain = \frac{extension}{length}$$

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

$$\varepsilon = \frac{e}{l_o}$$

Where,

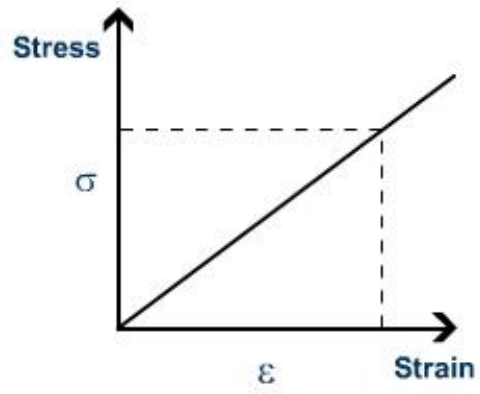
Strain = strain it has no units
ε = strain,

l_o = the original length measured in meters

e = extension = (l-l_o) measured in meters

Young Modulus

Instead of drawing a force - extension graph, if you plot stress against strain for an object showing (linear) elastic behaviour, you get a straight line.



This is because stress is proportional to strain. The gradient of the straight-line graph is the Young's modulus, **Y**

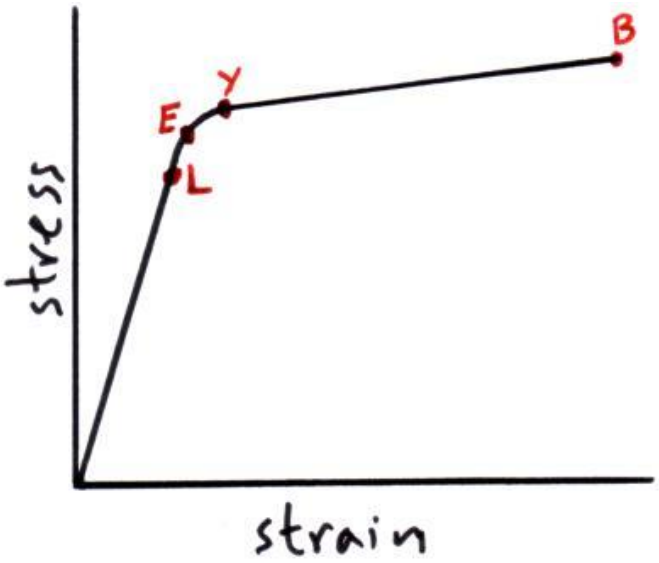
$$Y = tensile\ stress/tensile\ strain = \sigma/\varepsilon = (F/A)/(\Delta L/L_0) = F.L_0/A.\Delta L$$

Y is constant and does not change for a given material. It in fact represents 'stiffness' property of the material. Values of the young modulus of different materials are often listed in the form of a table in reference books so scientists and engineers can look them up.

Units of the Young modulus Y is Nm^{-2} or Pa.

Note: The value of **Y** in Pa can turn out to be a very large number. Therefore some times the value of **Y** may be given **MNm^{-2}**.

Stress-Strain graph for a ductile material (like copper)



- L = the limit of proportionality, Hooke's law applies up to this point.
- E = elastic limit, beyond this point the material is permanently stretch and it will not go back to its original length. Elastic behaviour is when a material returns to its original length, plastic behaviour is when the stretched material does not return to its original length.
- Y = yield point, beyond this point small increases in force give much big increases in length.
- B = breaking point / breaking stress, the material breaks at this point.

Stress-Strain graph for a brittle material (like glass)