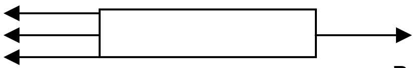
UNIT 1 STRESS, STRAIN AND DEFORMATION OF SOLIDS

1. What is stress?

The internal resistance offered by a body per unit area against deformation is known as stress. The unit of stress is N/mm^2 or N/m^2 When an external force acts on a body, the body tends to undergo deformation. Due to cohesion between molecules the body resist the force. This resistance offered by the body is known as strength of material.

Resistance  P

Mathematically stress or intensity of stress is written as

$\sigma = \frac{P}{A}$ where σ is stress and P is load and A is area ofcross section

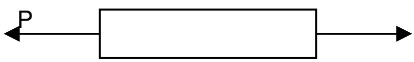
Note: $1\ N/m^2 = 1$ Pascal

$1\ N/mm^2 = 10^6 N/m^2$

$1\ bar = 1 \times 10^5 N/m^2$

2. What is tensile stress?

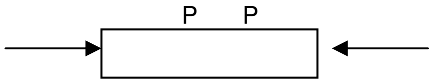
Tensile stress: The resistance offered by a body per unit area when it is subjected to a force which acts away from its point of application is called tensile stress.



P

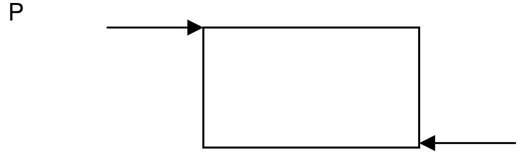
3. What is compressive stress?

Compressive stress: The resistance offered by a body per unit area when it is subjected to a force which acts towards its point of application is called compressive stress.



4. What is shear stress?

Shear Stress: The resistance offered by a body per unit area when the applied load on the body consists of two equal and opposite forces not in the same line is called shear stress.



$\tau = P/A$

where τ is shear stress, P is tangential force and A is area of shearing

5. What is strain?

when a body is subjected to some external force, there is some deformation of the body. The ratio of change of dimension of the body to the original dimension is known as strain. It has no unit.

$$\text{Strain} = \frac{\text{change in length } (\delta\ell)}{\text{original length } (\ell)}$$

6. What is Tensile strain?

The length of the bar increases by an amount under the action of external force P then tensile strain = $\dfrac{\text{increase in length}}{\text{original length}}$

7. What is compressive strain?

The length of the bar decreases by an amount under the action of external force P then compressive strain =

$$\frac{\text{decrease in length}}{\text{original length}}$$

8.What is Shear strain?

The distortion produced by shear stress on an element or rectangular block is known as shear strain. It can also be defined as the change in the right angle.

9.What is volumetric strain?

The ratio between the change in volume and the original volume is known as volumetric stain.

$$\text{Volumetric strain} = \frac{\text{change in volume}}{\text{original volume}}$$

10. Define True stress and True Strain

The true stress is defined as the ratio of the load to the cross section area at any instant.

$$(\varepsilon_T) = \int_{L_o}^{L} \frac{dl}{l} = \ln\left(\frac{L}{L_o}\right) = \ln(1+\varepsilon) = \ln\left(\frac{A_o}{A}\right) = 2\ln\left(\frac{d_o}{d}\right)$$

or engineering strain (ε) = e^{ε_T} -1

11. Define Hooke's law?

Within the elastic limit, when a body is loaded, then stress induced is proportional to the strain. This is called as Hook's law.

12. What is linear strain?

The ratio of increase or decrease in length to the original length is called as linear strain.

13. What is lateral strain?

The ratio of increase or decrease in lateral dimensions to the original lateral dimensions is called as lateral strain.

14.What are the types of elastic constants?

- Modulus of elasticity or Young's modulus
- Modulus of rigidity or shear modulus
- Bulk modulus

15. What is poison’s ratio?

When a member is stressed with in elastic limit, the ratio of lateral strain to its corresponding linear strain remains constant throughout the loading. This constant is called as poison’s ratio. It is the ratio of lateral strain to longitudinal or linear strain.

16. What is the inter relationship between the three constants?

$$E = 2G(1+\mu) = 3K(1-2\mu) = \frac{9KG}{3K+G}$$

Where, E = Young’s modulus in N/mm^2
K = Bulk modulus in N/mm^2
G = Modulus of rigidity in N/mm^2 μ Poisson’s ratio

17. Define bulk modulus?

When a body is stressed the ratio of direct stress to the corresponding volumetric strain is constant with in elastic limit. This constant is called as bulk modulus. Bulk modulus is the ratio of direct stress to volumetric strain.

18. Define modulus of elasticity?

Modulus of elasticity is the ratio of stress to strain.

19. Define factor of safety?

Factor of safety is defined as the ratio of ultimate stress to the working stress (permissible stress).

20.What is elasticity?

The deformation produced due to the application of external load disappears completely with the removal of the load. This property of the material is called as elasticity.

21.What is elastic limit?

Elastic limit is the limiting value of the load up to which the material returns back to its original position. Beyond this load, the material will not return back to its original position.

22What are thermal stresses and strain?

Whenever there is increase or decrease in the temperature of the body, the body tends to expand or contract. If this deformation is prevented, some stresses are induced in the body, these stresses are called as thermal stresses or temperature stresses. The corresponding strains are thermal strain or temperature strains. Thermal stress is $\sigma_t = \alpha\ T\ E$ where α is co-efficient of linear expansion, T is rise in temperature E is young's modulus

$$\text{Temperature stain or thermal strain} = \frac{\text{Extension prevented}}{\text{original length}}$$

Extension prevented $= \alpha\ T\ L$

So thermal strain is $e_t = \alpha\ T$

23.If the values of E and μ for an alloy body is 150 GPa and 0.25 respectively, find out the value of bulk modulus for the alloy?

Bulk modulus, $K = (mE) / [3(m-2)] = 100 \times 10^{3}\ N / mm^{2}$

24. Differentiate between Ultimate stress and working stress?

Ultimate stress is the maximum value of stress up to which the material withstand its failure. Working stress is the maximum stress allowed to setup in a material in actual practice.

25. What is a compound or composite bar?

A bar made of two or more different materials, joined together is called a compound or composite bar.

26. Write the Compatibility equation for solving compound bar problems

The extension or contraction in each bar is equal. Hence deformation per unit length i.e. strain in each bar is equal.

$$\delta\ell = \delta\ell_1 = \delta\ell_2 = \delta\ell_3$$

$$\delta\ell = \frac{P\ell}{AE}$$ Where P is load ℓ is length of the section

A is area of cross section, E is young's modulus

2. The total external load on the composite bar is equal to the sum of the loads carried by each different material

$P = P_1 + P_2 + P_3$

$P_1 = \sigma_1 A_1$ Where σ is stress induced and A_1 is area of cross section

27. Write Thermal stresses in composite bars(Procedure for finding thermal stresses in composite bar)

1. If a compound bar made up of different materials is subjected to a change in temperature there will be a tendency for the compound parts to expand different amounts due to the unequal coefficients of thermal expansion. If the parts are constrained to remain together then **the actual change in length must be the same for each**. This change is the resultant of the effects due to temperature and stress conditions.

$$\alpha_1 T\,L + \frac{\sigma_1}{E_1} L = \alpha_2 T\,L - \frac{\sigma_2}{E2} L$$

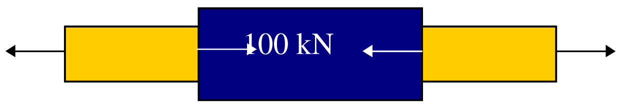
1. For equilibrium the resultant force acting over any cross section must be equal.

$$\sigma_1 A_1 = \sigma_2 A_2$$

28 .What is principle of super position?

When a body is subjected to number of forces acting on different sections along the length of body, then the resulting deformation of the body is equal to the algebraic sum of the deformations of the individual sections. This is called principle of super position.

29.Find the magnitude of 'P' of a compound bar?



100

Sum of all the forces acting in left direction = Sum of all the forces acting in right direction.

Therefore, 100 + P = 100 + 50

P = 50 kN.

30. How will you calculate the total elongation of a compound bar which is connected in series?

The total elongation of a compound bar connected in series can be computed by the relation

$$= \delta l_1 + \delta l_2 + \delta l_3 + \ldots + \delta l_n$$

$$\delta l = \frac{P_1 L_1}{A_1 E_1} + \frac{P_2 L_2}{A_2 E_2} + \ldots + \frac{P_n L_n}{A_n E_n}$$

where, □l_i is the deformation on individual bar in the system.

31.what do you mean by a bar of uniform strength:
A bar having uniform stress when it is subjected to its own weight is known as a bar of uniform strength.

32. Expression for the total elongation of uniformly tapering rectangular bar when it is subjected to an axial load P

$$\delta \ell = \frac{PL}{Et(a-b)} \log_e \frac{a}{b}$$

where L- Total length of the bar t- thickness of the bar a – width at bigger bar b- width at smaller end **E-** Young's modulus

33.What is meant by free body diagram?

A free body diagram is a complete diagram or a simplified sketch that shows all the external forces with the direction and the point of application of external load. This includes all the reactive forces by the supports and the weight of the body due to its mass.

34.Define elastic strain energy?

If the material is loaded within the elastic limit and then unloaded to zero stress, the strain also becomes zero and the strain energy stored in the body in straining the material is recoverable. However, when the material is loaded beyond the elastic limit and then unloaded, some permanent deformations will be setup in the body even after unloading. Therefore, only the partial strain energy will be recoverable and is called elastic strain energy.

36.What do you mean by strain energy density?

Strain energy density is defined as the strain energy per unit volume of the material. It is actually the area under the stress-strain curve.

37.Define Proof load.

The maximum load which can be applied to a body without permanent deformation is called proof load.

38.Define resilience.

Resilience is defined as the capacity of a material to absorb energy upon loading.

39.Define modulus of resilience.

Modulus of resilience is defined as the energy per unit volume that the material can absorb without yielding.

40.Define toughness of a material.

Toughness is defined as the maximum strain energy that can be absorbed per unit volume till rupture.
The modulus of toughness is a measure of the resistance of the structure to impact loading and is dependent on the ductility of the material.

41.What are the major types of deformation?

Elastic deformation (deformation due to loads)
Thermal deformation (deformation due to temperature variation)

42.What is meant by residual stresses?

In reality, when materials are being manufactured, they are often rolled, extruded, forged, welded and hammered. In castings, materials may cool unevenly.
These processes can setup high internal stresses called residual stresses. Note:
This process causes the development of larger normal stresses

near the outer surface than in the middle.
These residual stresses are self-equilibrating. i.e. they are in equilibrium without any externally applied forces.
In real world problems, such residual stresses may be large and should be carefully investigated and then added to the calculated stresses for the initially stress-free material.

43.Strain Energy

The energy required to deform an elastic body is known as strain energy.

U = $\frac{1}{2}$ P x

U = $\frac{\sigma^2}{2E} AL$ Where AL is the volume of the bar

44. Resilience: The strain energy stored per unit Volume is usually known as Resilience

45. Proof Resilience: The strain energy stored per unit volume upto elastic limit is known as proof resilience.

46. Expression for strain energy stored in a body when the load is applied gradually

U = $\frac{\sigma_1^2}{2E} AL$

47. Expression for strain energy stored in a body when the load is applied suddenly

U = $\frac{\sigma^2}{2E} AL$ where $\sigma = 2\sigma_1$ i.e., the maximum stress induced due to suddenly applied load is two times gradually applied load.

48. Expression for strain energy stored in a body when the load is applied with impact

U = $\frac{\sigma^2}{2E} AL$ where

σ = $\frac{P}{A}\left(1+\sqrt{1+\frac{2AEh}{PL}}\right)$ Where P – load dropped or impact load, L- Length of the rod A area of cross section, h- height through which load is dropped

49. Expression for strain energy stored in a body due to shear.

U = $\frac{\tau^2}{2C} AL$ Where τ is shear stress,C is rigidity modulus

50. How will you calculate major principal stress on member subjected to like principal stresses and shear stress?

Major normal principal stresses

$$,\sigma_{n_1} = \frac{\sigma_1 + \sigma_2}{2} + \sqrt{\left(\frac{\sigma_1 - \sigma_2}{2}\right)^2 + \tau^2}$$

51. How will you calculate minor principal stress on member subjected to like principal stresses and shear stress?

Minor normal principal stresses

$$,\sigma_{n2} = \frac{\sigma_1 + \sigma_2}{2} - \sqrt{\left(\frac{\sigma_1 - \sigma_2}{2}\right)^2 + \tau^2}$$

52. What is the use of Mohr's circle?

This is a graphical method which is frequently used to find out the normal, tangential, resultant stresses, and principal planes for the given stresses on oblique plane.

53.What do you mean by limit of proportionality or elastic limit?

Limit of proportionality or elastic limit is a point in the stress-strain curve at which the linear relation between them ceases. (i.e. the point at which the straight line changes to a curve). Thereafter the stress is not directly proportional to strain and therefore *Hooke's law is not valid after the elastic limit*. Also this is the point at which material undergoes rearrangement of molecular structure, in which atoms are being shifted to some other stable configuration.

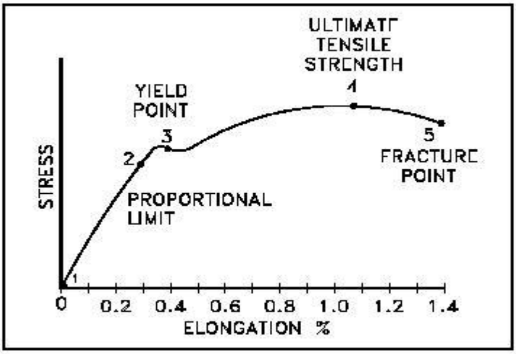


Figure 1.1 Stress-Strain Curves

54. What do you mean by the term “necking”?

When a material is being loaded to its yield point, the specimen begins to “neck” (i.e. the cross sectional area of the material start decreasing) due to plastic flow. Therefore Necking can be defined as the mode of ductile flow of material in tension. Necking usually occurs where the surface imperfections are predominant.

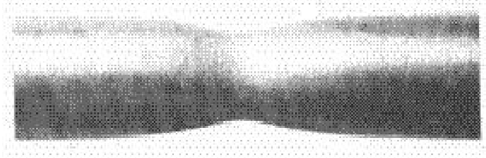


Figure 1.2 Necking