

## Elasticity - Elastic, plastic materials, stress, strain and their units and young's modulus

### Elastic material

The Elastic materials are those materials that have the ability to resist a distorting or deforming influence or force, and then return to their original shape and size when the same force is removed.

Linear elasticity is widely used in the design and analysis of structures such as beams, plates and sheets.

Elastic materials are of great importance to society since many of them are used to make clothes, tires, automotive spare parts, etc.

### Characteristics of elastic materials

When an elastic material is deformed with an external force, it experiences an internal resistance to the deformation and restores it to its original state if the external force is no longer applied.

To a certain extent, most solid materials exhibit elastic behavior, but there is a limit of the magnitude of the force and the accompanying deformation within this elastic recovery.

A material is considered as elastic if it can be stretched up to 3 times of its original length.

For this reason there is an elastic limit, which is the greatest force or tension per unit area of a solid material that can withstand permanent deformation.

For these materials, the elasticity limit marks the end of their elastic behavior and the beginning of their plastic behavior. For weaker materials, the stress or stress on its elasticity limit results in its fracture.

The elasticity limit depends on the type of solid considered. For example, a metal bar can be extended elastically up to 1% of its original length.

However, fragments of certain gummy materials may undergo extensions up to 10 times. The elastic properties of most solid intentions tend to fall between these two extremes.

Maybe you might be interested How to Synthesize an Elastolic Material?

### Examples of elastic materials

- 1 Natural gum
- 2 Spandex or lycra
- 3 Butyl Rubber (GDP)
- 4 Fluoroelastomer
- 5 Elastomers
- 6 Ethylene-propylene rubber (EPR)
- 7 Resilin
- 8 Styrene-butadiene rubber (SBR)
- 9 Chloroprene

- 10 Elastin
- 11 Rubber Epichlorohydrin
- 12 Nylon
- 13 Terpene
- 14 Isoprene Rubber
- 15 Poilbutadiene
- 16 Nitrile Rubber
- 17 Vinyl stretch
- 18 Thermoplastic elastomer
- 19 Silicone rubber
- 20 Ethylene-propylene-diene rubber (EPDM)
- 21 Ethylvinylacetate (EVA or foamy gum)
- 22 Halogenated butyl rubbers (CIIR, BIIR)
- 23 Neoprene

### Plastic Material

#### Plastic Material Classification

“Plastic material” is a term that refers to a large class of polymers, separated into various groups and sub-groups. Before starting the chapter on the uses and subsequent recycling of plastic, let us establish a general classification of these thermosetting resins or thermo-plastics (the two big groups into which we include elastomers) by detailing their properties, their make-up, their aspect, and their final uses, while explaining which ones are recyclable.

#### Thermoplastics

Remember that thermoplastic is a material whose structure and viscosity can be modified both ways through heating or cooling. This large family of materials is commonly used by many industries and is easily integrated into France's recycling cycles.

The following polymers are some examples of plastic material:

- 1 Polyolefins
- 2 Vinyl polymers
- 3 Polystyrenes
- 4 Acrylate and methacrylate polymers
- 5 Polyamide
- 6 Polycarbonates
- 7 Celluloid
- 8 Linear polyesters
- 9 Polyfluorethane
- 10 Polyacetal
- 11 Polysulfone

12 Polyphenylene sulfide

13 Modified polyphenylene oxide (PPO)

### Thermosetting plastic

Thermosetting plastic is a compound that, during condensation polymerisation and/or implementation, when submitted to a catalyst or a temperature increase, irreversibly cures. the structure, shape, or rigidity of the manufactured plastic object can not be modified again, and the material is rarely recycled.

This type of plastic includes the following types of compounds:

- 1 Unsaturated polyester
- 2 Phenol formaldehyde resins
- 3 Melamine resins
- 4 Polyepoxides
- 5 Polyimide
- 6 Polyurethane
- 7 Polyorganosiloxanes

Generally in any industry the material used are elastic in nature. Hence if a material is subjected to an external load, it undergoes deformation. During the deformation process the material will offer a resistance against the deformation. In case if the material fails to put up full resistance to the external load, the deformation continues until rupture takes place. Hence it is important to have a considerable knowledge about the materials and their properties for designing and fabricating.

### Force

Force is defined as an external source which changes or tends to change the state of rest or of uniform motion of an object. In other words everybody preserves in its state of rest or of uniform motion unless it is forced by an external source to change that state. That external source is called as Force. It has both magnitude and direction. So it is a vector quantity. In SI system, its unit is Newton.

Unit in MKS - kgf

1 kgf = 9.81 Newton

Force is defined as the product of mass of the object and the acceleration.

Force = mass x acceleration

$$\begin{aligned} F &= m \times a \\ &= \text{Kg} \times \text{m}/\text{sec}^2 \\ &= 1 \text{ Newton} \end{aligned}$$

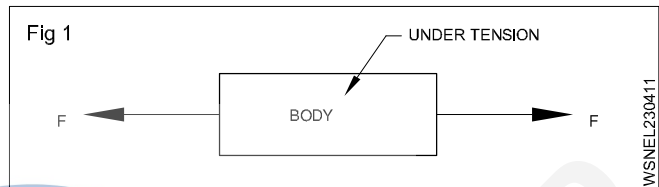
### Causes of force

- Change in speed
- Change in direction
- Change in shape
- Change in dimension
- Change in condition (Rest to uniform motion and vice versa)

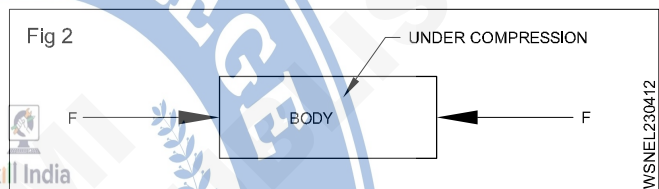
### Types of forces

- tensile force
- compressive force
- shear force.

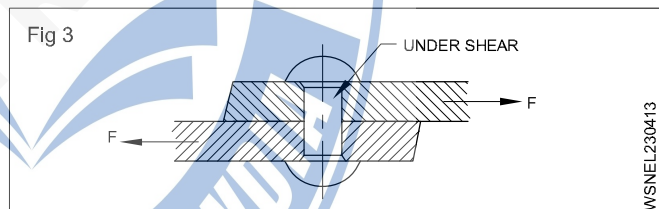
**Tensile force:** When two equal and opposite forces act on a body and have the same line of action, and if they tend to increase the length of the body, the applied forces are called tensile forces. (Fig 1)



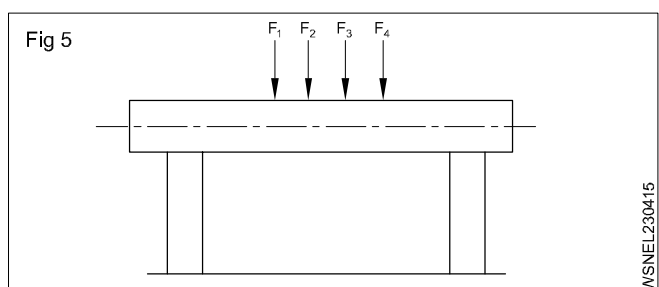
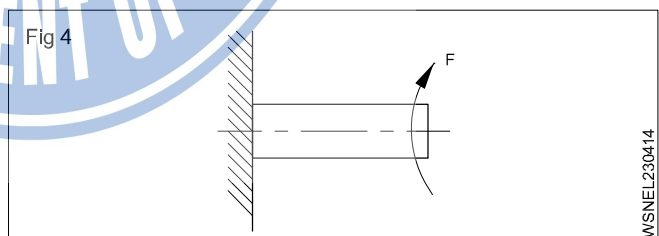
**Compressive force:** When two equal and opposite forces act on a body having the same line of action and if they tend to compress the body and try to reduce the length of the body, the forces applied are called compressive forces. (Fig 2)



**Shear force:** When two equal and opposite forces having different lines of action act on a body such that one section of the body tends to slide over another section which results in a shearing action then the forces are referred to as shear forces. (Fig 3)



**Direct effect of forces:** Forces acting on a body can cause in the material. (Fig 4 & Fig 5)



- Tension
- Compression
- Shearing effect
- Twisting effect
- Bending effect.

**Force is mainly classified as tensile force, compressive force and shear force.**

### Stress

The internal opposite force to the external load per unit area is known as stress. The unit of stress depends upon the force applied and area of original cross-section of material.

$$\therefore \text{Stress} = \frac{\text{Force applied}}{\text{Area of original cross section}}$$

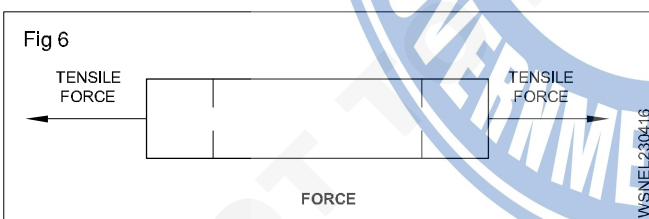
$$= \frac{\text{Load(or)Force}}{\text{Area}} \left( \frac{\text{N}}{\text{mm}^2} \text{ or } \frac{\text{Kg}}{\text{cm}^2} \right)$$

$$\text{Shear stress} = \frac{F}{A} \left( \frac{\text{N}}{\text{cm}^2} \text{ or } \frac{\text{Kg}}{\text{cm}^2} \right)$$

### Types of Stress

- 1 Tensile stress
- 2 Compressive stress
- 3 Shear stress
- 4 Torsional Stress

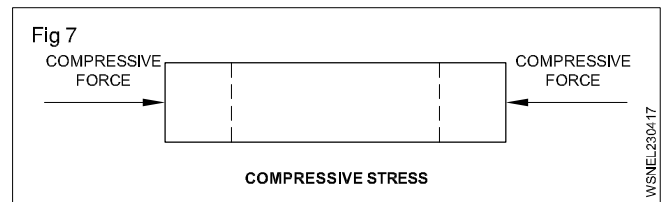
1 **Tensile stress:** When a material is subjected to two equal and opposite axial pulls, the material tends to increase in length. The resistance offered against this increase in length is called tensile stress. The corresponding strain is called tensile strain. (Fig 6)



#### E.g.:

- 1 When brake is applied the brake rod is under tensile stress.
  - 2 During tightening of bolt or nut.
  - 3 Belt driving motor.
  - 4 Crane rope (When rope is pulling)
- 2 **Compressive stress:** When a material is subjected to two equal and opposite axial pushes, the material tends to decrease in length. The resistance offered against

the decrease in length is called compressive stress. The corresponding strain is called compressive strain. (Fig 7)

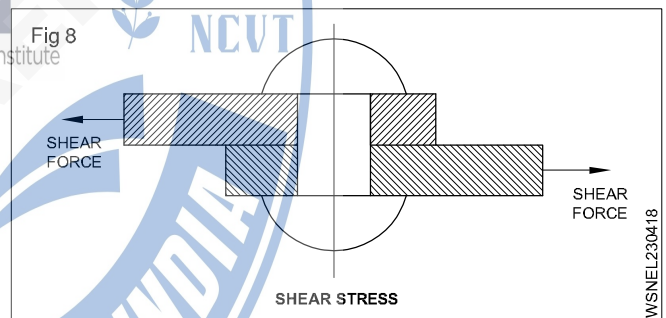


$$\text{Compressive stress} = \frac{\text{Axial push}}{\text{Area of cross section}}$$

$$\text{Compressive stress} = \frac{\text{Decrease in length}}{\text{Original length}}$$

#### Eg.

- 1 Compressive stress on connecting rod on the first part of power stroke
  - 2 Compressive stress on push rod during valve opening
  - 3 Clutch lining when the clutch is engaged
- 3 **Shear stress:** When a material is subjected to two equal and opposite forces acting tangentially across the resisting section, the body tends to be sheared off across the cross section. The stress included is called shear stress. It is represented by  $\tau$ . The corresponding strain is called shear strain. (Fig 8)



$$\text{Shear stress} = \frac{F}{A} \left( \frac{\text{N}}{\text{cm}^2} \text{ or } \frac{\text{Kg}}{\text{cm}^2} \right)$$

#### Eg.

- 1 Rivets
- 2 Gudgeon Pin
- 3 Spring shackle pin
- 4 Brake rod rivets
- 5 Chassis rivets
- 6 Fly wheel holding bolts
- 7 Swivel pins
- 8 Gear box shaft
- 9 Axle shaft

**4 Torsional stress:** When a shaft is subjected to the action of two equal and opposite couples acting in parallel planes, then the shaft is said to be in torsion. The stress set up by the torsion is known as torsional shear stress.

Eg.

- 1 Rear axle
- 2 Crank shaft
- 3 Coil springs
- 4 Propeller shaft
- 5 Starter motor armature shaft

**Examples**

**1 A steel wire 3 mm dia. is loaded in tension with a weight of 50 kg. Find out the stress developed.**

Diameter of the steel wire = 3 mm

Radius = 1.5 mm

Weight = 50 kg

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

Area of circular wire (A) =  $\pi r^2$  unit<sup>2</sup>

$$= \frac{22}{7} \times 1.5 \times 1.5$$

$$= \frac{49.5}{7} = 7.07 \text{ mm}^2$$

$$\text{Stress} = \frac{50}{7.07}$$

$$= 7.072 \text{ Kg/mm}^2$$

**2 A force of 500 N is applied on a metallic wire of 5mm diameter. Find the stress.**

Diameter of the wire = 5 mm

Radius = 2.5 mm

Force = 500 Newton

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

Area of circular wire (A) =  $\pi r^2$  unit<sup>2</sup>

$$= \frac{22}{7} \times 2.5 \times 2.5$$

$$= \frac{137.5}{7} = 19.64 \text{ mm}^2$$

$$\text{Stress} = \frac{500}{19.64}$$

$$= 25.46 \text{ N/mm}^2$$

**3 A load of 600 kg is placed on a hollow cast iron cylinder of 200 mm outer diameter and 100 mm internal diameter. Find the stress on the cylinder.**

**Hollow cylinder**

Outer diameter (D) = 200 mm = 20 cm

Outer radius (R) = 10 cm

Internal diameter (d) = 100 mm = 10 cm

Inner radius (r) = 5 cm

Weight = 600 kg

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

Area =  $\pi (R+r)(R-r)$

$$= \frac{22}{7} \times (10+5) \times (10-5)$$

$$= \frac{22}{7} \times 15 \times 5$$

$$= \frac{1650}{7} = 235.7 \text{ cm}^2$$

$$\text{Stress} = \frac{600}{235.7} \text{ kg/cm}^2$$

$$= 2.546 \text{ kg/cm}^2$$

**4 Calculate the minimum cross section area of a M.S. bar to withstand a load 6720 kg. Take the maximum stress of the material as 698.2 kg/cm<sup>2</sup>.**

Weight = 6720 kg

Maximum stress = 698.2 kg/cm<sup>2</sup>

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

$$\text{Area}(A) = \frac{6720}{698.2}$$

$$= 9.625 \text{ cm}^2$$

To calculate diameter

$$\text{Area} = \frac{\pi d^2}{4} \text{ unit}^2$$

$$d^2 = 4 \times 9.625 \times \frac{7}{22}$$

$$= \frac{134.75}{11}$$

$$d^2 = 12.25$$

$$d = 3.5 \text{ cm}$$

**5 A load of 300 kg hanging from a rod of 3 metre length and 5 mm diameter extends it by 4 mm. Find the stress in the material and the strain it causes.**

Length of the rod = 3 m = 3000 mm

Increased length = 4 mm

Diameter = 5 mm;

Radius = 2.5 mm

Weight = 300 kg

Strain =  $\frac{\text{Change in length}}{\text{Original length}}$

$$= \frac{4}{3000} = 0.00133$$

Stress =  $\frac{\text{Force}(F)}{\text{Area}(A)}$

Area of circular rod (A) =  $\pi r^2$  unit<sup>2</sup>

$$= \frac{22}{7} \times 2.5 \times 2.5$$

$$= \frac{137.5}{7}$$

$$= 19.643 \text{ mm}^2$$

Stress =  $\frac{300}{19.643}$

$$= 15.273 \text{ kg/mm}^2$$

**6 Find the force required to punch a hole of 10 mm dia. in a 1 mm thick plate, if the allowable shear stress is 50 N/mm<sup>2</sup>.**

Thickness of the plate = 1 mm

Dia. of the punch = 10 mm

Shear stress = 50 Newton/mm<sup>2</sup>

Force = Shear stress x area

Shear area = Circumference x thickness

$$= \pi dt$$

$$= \frac{22}{7} \times 10 \times 1$$

$$= \frac{220}{7} = 31.43 \text{ mm}^2$$

Force = 50 x 31.43

$$= 1571.5 \text{ Newtons}$$

**7 A hole of 30 mm diameter is punched in a plate of 5 mm thickness. If the shear stress is 400 kg/cm<sup>2</sup>. Find the force required to punch the hole.**

Thickness of the plate = 5 mm = 0.5 cm

Diameter of the punch = 30 mm = 3 cm

Shear stress = 400 kg/cm<sup>2</sup>

Force = Shear stress x area

Shear area = Circumference x thickness

$$= \pi dt$$

$$= \frac{22}{7} \times 3 \times 0.5$$

$$= \frac{33}{7} = 4.71 \text{ mm}^2$$

Required force = 400 x 4.71

$$= 1885.71 \text{ kg}$$

**8 What force will be required to shear off a bar of 30 mm dia. if the ultimate shear stress of the material is 35 kg/mm<sup>2</sup>.**

Diameter of the bar = 30 mm

Shear stress = 35 kg/mm<sup>2</sup>

Stress =  $\frac{\text{Force}(F)}{\text{Area}(A)}$

$$= \frac{\text{Force}(F)}{\text{Area}(A)}$$

$$= \frac{F}{\pi \times 15 \times 15}$$

$$= 35 \times \pi \times 15 \times 15 \text{ kg}$$

Required Force = 24750 kg

**9 A Hole of 2 cm dia is to be punched out of a plate of 1.4 cm thick. If the force applied to the punching die is 12 KN. Calculate the shear stress.**

Dia. of the hole = 2 cm

Thickness = 1.4 cm

Force = 12 KN

Shear stress = ?

Punched out area = Circumference of the hole x Thickness

$$= 2 \pi \times t \text{ unit}^2$$

$$= 2 \times \pi \times 1 \times 1.4$$

$$= 2.8 \pi \text{ cm}^2$$

Shear stress =  $\frac{F}{A}$

$$= \frac{12 \text{ KN}}{2.8 \pi \text{ cm}^2}$$

Shear stress = 1.364 KN/cm<sup>2</sup>

**10 A square rod of 10 mm side is tested for a tensile load of 1016 kg. Calculate the tensile stress?**

Side of square rod (a) = 10 mm  
 Tensile force (F) = 1016 kg  
 Tensile stress ( $\sigma$ ) = ?

$$\begin{aligned} \text{Stress} &= \frac{\text{Force}(F)}{\text{Area}(A)} \\ &= \frac{\text{Force}}{a^2} \\ &= \frac{1016}{10 \times 10} \end{aligned}$$

**Tensile stress = 10.16 Kg/mm<sup>2</sup>**

**11 A M.S. tie bar 3.5 cm dia. is under a state of stress which carries a load of 6720 kg. Find the intensity of stress in the material.**

d = 3.5 cm  
 r = 1.75 cm  
 F = 6720 kg

$$\begin{aligned} \text{Stress} &= \frac{\text{Force}(F)}{\text{Area}(A)} \\ &= \frac{\text{Force}}{\pi r^2} \\ &= \frac{6720}{3.14 \times 1.75 \times 1.75} \\ &= \frac{6720}{9.616} \end{aligned}$$

**Intensity of stress = 698.8 Kg/cm<sup>2</sup>**

**12 A rivet of 10 mm dia. is subjected to a double shear force of 1.5 KN. Find the shear stress in the rivet.**

dia. of the rivet = 10 mm  
 r = 5 mm  
 Shear stress = ?

Double shear force is acting on the rivet, consider the area as double.

$$\begin{aligned} \text{Stress} &= \frac{F}{2 \text{Area}} \\ &= \frac{1.5}{2 \times 3.14 \times 5 \times 5} \end{aligned}$$

**Shear stress = 0.00955 KN/mm<sup>2</sup>**

## Strain

When an external forces acting on a material, there is a change in its dimension and shape. The deformation is called strain. Thus, strain is the ratio between the change in dimension of a material to its original dimension. It has no unit. It is represented by E (Epsilon)

$$\text{Strain} = \frac{\text{Change in dimension } (\delta \ell)}{\text{Original dimension } (\ell)}$$

## Linear or Longitudinal strain

It is the ratio between the change in length of the material to its original length.

$$\text{Linear Strain} = \frac{\text{Change in length } (\delta \ell)}{\text{Original length } (\ell)}$$

## Lateral Strain

It is the ratio between change in cross sectional area of material to its original area.

$$\text{Lateral Strain} = \frac{\text{Change in area}}{\text{Original Area}}$$

## Volumetric Strain

It is the ratio between change in volume of material to its original volume.

$$\text{Volumetric Strain} = \frac{\text{Change in volume}}{\text{Original Volume}}$$

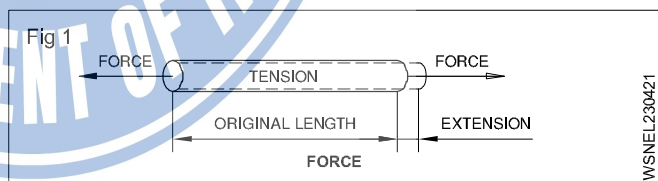
## Poisson's ratio

It is a ratio between lateral strain and linear strain.

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Linear strain}} = \frac{1}{m}$$

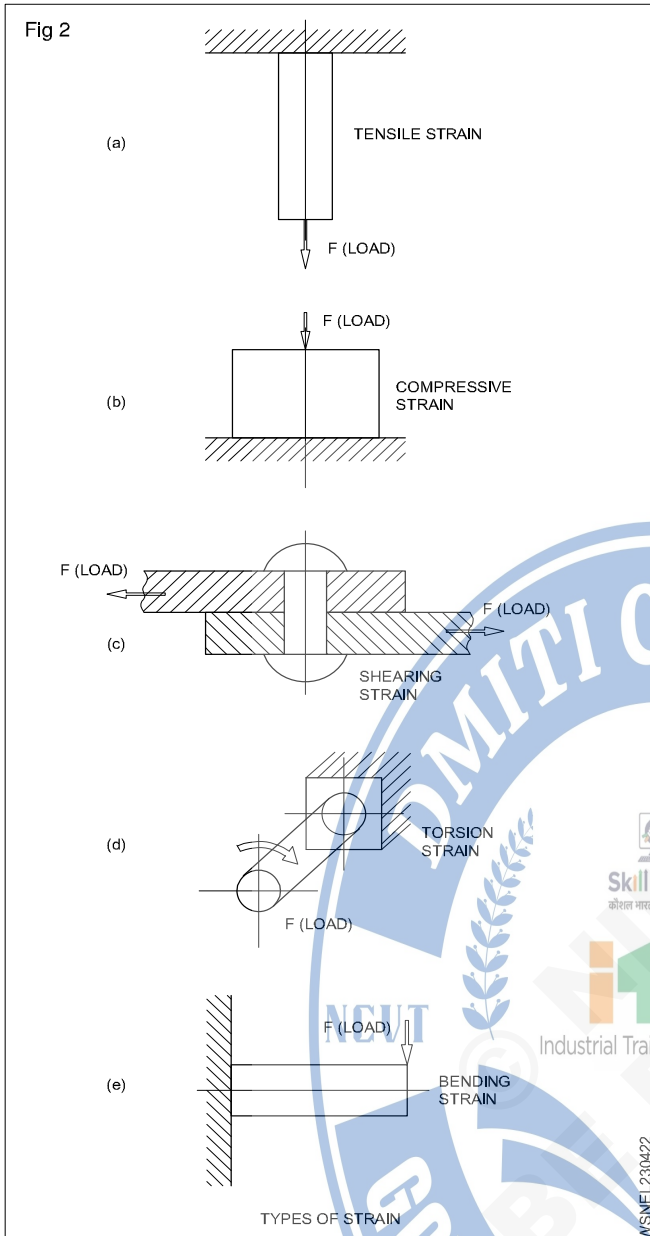
## Examples

1 Calculate the tensile strain when a force of 3.2 kN is applied to a bar of original length 280 cm extends the bar by 0.5 mm (Fig 1 & Fig 2)



$$\begin{aligned} \text{Force} &= 3.2 \text{ kN} \\ \text{Original length (L)} &= 280 \text{ cm} \\ \text{Increased length } (\Delta \ell) &= 0.5 \text{ mm} = 0.05 \text{ cm} \\ \text{Tensile Strain} &= \frac{\text{Increased length}}{\text{Original Length}} \\ &= \frac{0.05}{280} \end{aligned}$$

**Tensile strain = 0.0001786**



2 A steel rod used for brake operation is 1.50 m long. When it is subjected to a tensile force the extension produced is 0.5 mm. Find the strain in the rod.

$$\begin{aligned} \text{Tensile strain} &= \frac{\text{Extension}}{\text{Original length}} \\ &= \frac{0.5}{1.5 \times 1000} \left( \frac{\text{mm}}{\text{mm}} \right) \end{aligned}$$

Strain in the brake rod = 0.0003

3 A helical spring is loaded with a force of 600 Newton and is compressed by 30mm. What would be the load required to compress it to 10 mm. (Fig 3)

Solution

$$\text{Spring stiffness} = \frac{\text{Applied load}}{\text{Compression}}$$

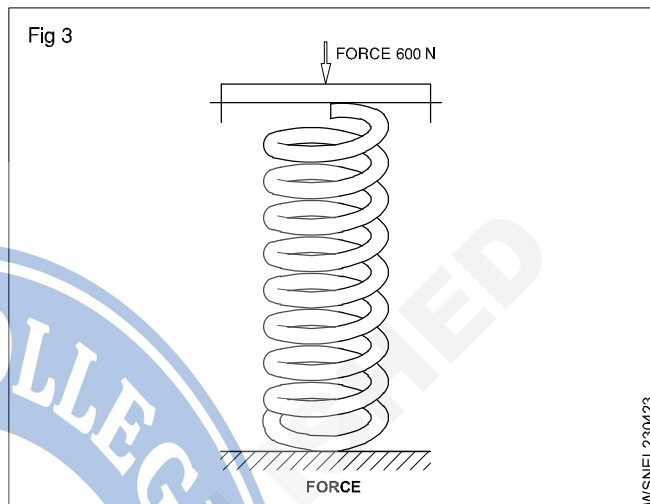
$$= \frac{600 \left( \frac{\text{N}}{\text{mm}} \right)}{30} = 20 \left( \frac{\text{N}}{\text{mm}} \right)$$

Load required to compress the spring by 10 mm

$$= \text{spring stiffness} \times \text{compression}$$

$$= 20 \text{ (N/mm)} \times 10 \text{ (mm)}$$

$$\text{Load required} = 200 \text{ N}$$



4 Helical spring is loaded with a force of 400 Newton and it is compressed by 18 mm. What would be the load required to compress it to 6 mm?

$$\text{Given force} = 400 \text{ Newton}$$

$$\text{Deflection} = 18 \text{ mm}$$

$$\text{Spring Stiffness} = \text{Force} / \text{Compressed length}$$

$$= 400 / 18$$

$$= 22.22 \text{ Newton / mm}$$

$$\begin{aligned} \text{Force required to} & \\ \text{compress the} & \\ \text{spring into 6 mm} & \\ \text{Load required} & = \text{Spring stiffness} \times \text{Compression} \end{aligned}$$

$$= 22.22 \times 6$$

$$= 133.32 \text{ N}$$

5 Calculate the tensile strain when a force of 3.2 KN is applied to a bar of original length 2.8 m extends the bar by 0.5 mm.

$$\text{Force F} = 3.2 \text{ KN}$$

$$\text{Original length L} = 280 \text{ cm}$$

$$\text{Increased length } (\Delta l) = 0.5 \text{ mm} = 0.05 \text{ cm}$$

$$\text{Tensile strain} = ?$$

$$\text{Strain} = \frac{\Delta l}{L}$$

$$= \frac{0.05}{280}$$

$$\text{Tensile strain} = 0.0001786$$

- 6 A metal bar is 2m long. When 5.5 tonne is applied its length becomes 1.995 m. Find the compressive strain?

$$\begin{aligned} \text{Force } F &= 5.5 \text{ KN} \\ \text{Original length } L_1 &= 2 \text{ m} \\ \text{Final length } L_2 &= 1.995 \text{ m} \\ \text{Increased length } (\Delta l) &= 2 - 1.995 = 0.005 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Compressive strain} &= \frac{\Delta l}{L} \\ &= \frac{0.005}{2} \end{aligned}$$

$$\text{Compressive strain} = 0.0025$$

- 7 When a steel rod of 4mm diameter experienced the load of 200 Kg. It is found to be elongated by 1.5 mm from the original length of 1500 mm. Calculate the strain.

$$\begin{aligned} \text{Force } F &= 200 \text{ Kg.} \\ \text{Original length } L_1 &= 1500 \text{ mm} \\ \Delta l &= 1.5 \text{ mm} \end{aligned}$$

$$\text{Strain} = ?$$

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

$$= \frac{1.5}{1500}$$

$$\text{strain} = 0.001$$

- 8 An iron rod of length 1 metre and 1 cm diameter gets elongated by 1 cm. When a force of 100 Kg is applied at one end. Calculate the strain developed in the rod.

$$\begin{aligned} \text{Force } F &= 100 \text{ Kg.} \\ \text{Original length } L_1 &= 1 \text{ m} = 100 \text{ cm} \\ \Delta l &= 1 \text{ cm} \end{aligned}$$

$$\text{Strain} = ?$$

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

$$= \frac{1}{100}$$

$$\text{Compressive strain} = 0.01$$

### Elasticity and Elastic limit

When an external force acts on a body, the body tends to undergo some deformation. If the external force is removed and the body comes back to its original shape and size (Which means the deformation disappears completely). The body is known as elastic body. This property by virtue

of which certain materials return back to their original position after the removal of the external force is called elasticity.

The body will regain its previous shape and size only when the deformation caused by the external force is within a certain limit. Thus there is a limiting value of force up to and within which the deformation completely disappears on the removal of the force. The value of stress corresponding to this limiting force is known as elastic limit of the material.

If the external force is so large that the stress exceeds the limit, the material loses to some extent its property of elasticity. If now the force is removed, the material will not return to its original shape and size and there will be a residual deformation in material.

### Yield point

The yield point of a material is the point at which there is a marked increase in elongation without increase in load.

### Hooke's law

Robert Hooke discovered a relationship between stress and strain. According to Hooke's law stress is proportional to strain within elastic limit.

### Young's Modulus or Modulus of Elasticity

The ratio of stress to strain within elastic limit is known as young's modulus or modulus of elasticity. This is expressed by a symbol "E". The unit of Young's modulus is same that of stress.

$$\text{Young's modulus (E)} = \frac{\text{Stress}}{\text{Strain}}$$

### Modulus of Rigidity

The ratio of shear stress to shear strain is known as "modulus of rigidity" represented by symbol "N".

$$\therefore \text{Modulus of Rigidity (N)} = \frac{\text{Shear stress}}{\text{Shear strain}}$$

### Bulk Modulus

When a body is subjected to three mutually perpendicular forces of the same intensity, the ratio of volumetric stress to the volumetric strain is known as Bulk Modulus. It is usually represented by the letter K.

$$\therefore \text{Bulk Modulus (K)} = \frac{\text{Volumetric stress}}{\text{Volumetric strain}}$$

### Relationship between three moduli for a given material

The relationship between three moduli for a given material is as follows :

$$E = 2N \left( 1 + \frac{1}{m} \right) = 3K \left( 1 - \frac{2}{m} \right)$$

Where

E = Young's modulus of elasticity

N = Modulus of rigidity

K = Bulk modulus

$\frac{1}{m}$  = Poisson's ratio

$$= \frac{4500}{\pi \times 6.25}$$

$$= \frac{4500 \times 4}{\pi \times 6.25}$$

$$= \frac{2880}{\pi}$$

$$= \frac{2880}{\pi}$$

**Example**

**1 A steel rod of 10 mm diameter and 175 mm long is subjected to a tensile load of 15 kN. If E = 2 x 10<sup>5</sup> N/mm<sup>2</sup>, calculate the change in length.**

Tensile load = 15 kN = 15000 N

Area of cross section =  $(\pi r^2) = \frac{22}{7} \times 5 \times 5 \text{ mm}^2 = 78.57$

$$\therefore \text{Stress} = \frac{15000 \text{ N}}{0.785 \times 100 \text{ mm}^2} = 191 \text{ N/mm}^2$$

$$\text{Young's modulus } E = \frac{\text{Stress}}{\text{Strain}}$$

$$E = 2 \times 10^5 \text{ N/mm}^2 = \frac{191 \text{ N/mm}^2}{\text{Strain}}$$

$$\therefore \text{Strain} = \frac{191}{2 \times 10^5}$$

$$\text{Change in length} = \frac{175 \times 191}{2 \times 10^5} \text{ mm}$$

$$= 0.167 \text{ mm.}$$

**2 A bar of steel 2.5 cm diameter was subjected to compressive load of 4500 kg. The compression in a length of 20 cm was found to be 0.008 cm. Find the Young's modulus of elasticity of bar.**

**Solution**

Diameter of bar (d) = 2.5 cm

Force applied i.e. compressive load = 4500 kg

Original length of bar = 20 cm

Change in length = 0.008 cm

$$\therefore \text{Area of original cross-section} = \frac{\pi}{4} d^2$$

$$= \frac{\pi}{4} \times 2.5^2$$

$$= \frac{\pi \times 6.25}{4} \text{ cm}^2$$

$$\therefore \text{Stress} = \frac{\text{Force applied}}{\text{Area of original cross section}}$$

$$\therefore \text{Stress} = \frac{2880}{\pi} \text{ Kg/cm}^2$$

$$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}}$$

$$= \frac{0.008}{20} = \frac{8/1000}{20}$$

$$= \frac{8}{20 \times 1000} = \frac{4}{10000}$$

$$\therefore \text{Strain} = \frac{4}{10000}$$

$$\therefore \text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$= \frac{2880}{\pi} \div \frac{4}{10000}$$

$$= \frac{2880}{\pi} \times \frac{10000}{4}$$

$$= \frac{7200000}{\pi}$$

$$= 2292000 \text{ Kg/cm}^2$$

$$= 2.292 \times 10^6 \text{ Kg/cm}^2$$

**3 A force of 10 tonnes is applied axially on a rod of 1.2 cm dia. the original length is 100 mm. If modulus of elasticity is 2 x 10<sup>12</sup> kg/cm<sup>2</sup>. Calculate stress and strain developed in the rod.**

**Solution**

Force applied = 10 tonnes = 10 x 1000 kg  
= 10<sup>4</sup> kg

Diameter (d) = 1.2 cm

Young's modulus (E) = 2 x 10<sup>12</sup> kg/cm<sup>2</sup>

$$\text{Stress} = \frac{\text{Force applied}}{\text{Area of original cross section}}$$

$$= \frac{4 \times 10^4}{\pi \times 1.2 \times 1.2}$$

$$= \frac{10^4 \times 4}{1.2 \times 1.2 \times 3.142}$$

$$= \frac{40000}{4.52448}$$

$$= 8841 \text{ kg/cm}^2$$

$$\therefore \text{Stress} = 8841 \text{ kg/cm}^2$$

We know

$$\frac{\text{Stress}}{\text{Strain}} = \text{Young's modulus}$$

$$\text{Strain} \times \text{Young's modulus} = \text{Stress}$$

$$\text{Strain} = \frac{\text{Stress}}{\text{Young's Modulus}}$$

$$= \frac{8841}{2 \times 10^{12}}$$

$$= \frac{4420.5}{10^{12}}$$

$$= 4420.5 \times 10^{-12}$$

$$\text{Stress} = 8841 \text{ kg/cm}^2$$

$$\text{Strain} = 4420.5 \times 10^{-12}$$

- 4 A bar of 100 cm elongates to 101.36 cm when a load of 15000 kg is applied to it. Take the area of cross section of bar as 10 cm<sup>2</sup>. Find the stress, strain and young's modulus.

$$L_1 = 100 \text{ cm}$$

$$L_2 = 101.36 \text{ cm}$$

$$\Delta l = L_2 - L_1 = 101.36 - 100 = 1.36 \text{ cm}$$

$$F = 15000 \text{ kg}$$

$$A = 10 \text{ cm}^2$$

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

$$= \frac{15000}{10}$$

$$= 1500 \text{ kg/cm}^2$$

$$\text{Strain} = \frac{\Delta l}{L}$$

$$= \frac{1.36}{100}$$

$$= 0.0136$$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$E = \frac{1500}{0.0136}$$

$$= 110300 \text{ kg/cm}^2$$

- 5 What force is required to stretch a steel wire of 10 mm long and 10 mm dia. to double its length. E of steel is 205 KN/cm<sup>2</sup>.

$$d = 10 \text{ mm} = 1 \text{ cm}$$

$$r = 0.5 \text{ cm}$$

$$L_1 = 1 \text{ cm}$$

$$L_2 = 2 \text{ cm}$$

$$\Delta l = L_2 - L_1 = 2 - 1 = 1 \text{ cm}$$

$$E = 205 \text{ KN/cm}^2$$

$$\text{Strain} = \frac{\Delta l}{L} = \frac{1}{1} = 1$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$205 = \frac{\text{Stress}}{1}$$

$$\text{Stress} = 1 \times 205 = 205 \text{ KN/cm}^2$$

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

$$205 = \frac{\text{Force}}{3.14 \times 0.5 \times 0.5}$$

$$\text{Force} = 205 \times 3.14 \times 0.5 \times 0.5 = 161 \text{ KN}$$

- 6 A wire of 1.6 cm diameter is subjected to a tensile load of 2000 Kg. Find the stress and strain if young's modulus = 2 x 10<sup>6</sup> kg/cm<sup>2</sup>.

$$F = 2000 \text{ kg}$$

$$d = 1.6 \text{ cm}$$

$$r = 0.8 \text{ cm}$$

$$E = 2 \times 10^6 \text{ Kg/cm}^2$$

$$\text{Stress} = \frac{F}{A}$$

$$= \frac{2000}{\pi r^2}$$

$$= \frac{2000}{3.14 \times 0.8 \times 0.8}$$

$$= \frac{2000}{2.0096}$$

$$= 995.2 \text{ kg/cm}^2$$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$2 \times 10^6 = \frac{995.2}{\text{Strain}}$$

$$\text{Strain} = \frac{995.2}{2 \times 10^6}$$

$$= 0.0005$$

$$\text{Stress}(\sigma) = \frac{\text{Force}(F)}{\text{Area}(A)} = \frac{\text{Force}}{l \times b}$$

$$= \frac{2000}{2 \times 1}$$

$$= 1000 \text{ kg/cm}^2$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$2 \times 10^6 = \frac{1000}{\text{Strain}}$$

$$\text{Strain} = \frac{1000}{2 \times 10^6}$$

$$= 0.0005$$

$$\frac{\Delta l}{L_1} = \text{Strain}$$

$$\frac{\Delta l}{200} = 0.0005$$

$$\Delta l = 200 \times 0.0005$$

$$= 0.1 \text{ cm}$$

$$\therefore \text{Elongated length} = 0.1 \text{ cm}$$

**7 A tensile load of 2000 kg is applied on a rectangular rod of 2 cm x 1 cm whose length is 2 metres. Calculate the elongation in length as E = 2 x 10<sup>6</sup> Kg/cm<sup>2</sup>.**

$$F = 2000 \text{ Kg.}$$

$$L_1 = 2 \text{ m} = 200 \text{ cm}$$

$$E = 2 \times 10^6 \text{ kg/cm}^2$$

$$\text{Rectangular rod length} = 2 \text{ cm}$$

$$\text{Breadth} = 1 \text{ cm}$$

Skill India  
कौशल भारत - सुरल भारत

Industrial Training Institute

## Assignment

### Stress

- 1 Calculate the intensity of stress in the material if a copper rod of 40 mm diameter is subjected by tensile load of 4000 Newton's.
- 2 Calculate the intensity of stress if a mild steel rod having a cross sectional area of 40 mm<sup>2</sup> is subjected to the load of 1000 kg.
- 3 Calculate the tensile stress if a square rod of 10 mm side is tested for a tensile load of 1000 kg.
- 4 Calculate the maximum stress if a bar of 9 cm<sup>2</sup> cross sectional area and 300 cm long carries a tensile load of 3500 kg.
- 5 Find out the stress on the rod. if a load of 500 kg is placed on a M.S.rod of dia. 35 mm.
- 6 A metallic bar of 8 cm diameter is under stress carrying a load of 8620 N. Calculate the intensity of stress.
- 7 A steel wire 2 mm diameter is loaded in tension with a weight of 20 kg. Find out the stress developed.

- 8 A rod having a cross sectional area of 25 mm<sup>2</sup> is subjected to a load of 1500 kg. Find out stress on the rod.
- 9 A square rod of 10 mm side is tested for a tensile load of 2500 kg. Calculate the tensile stress of the rod.

### Strain

- 1 Find the compressive strain if a metal bar is 150 cm long. When 2.5 KN is applied, its length becomes 148.6 cm.
- 2 Calculate the strain if a metallic bar is 150 cm long. When 2500 kg is applied its length becomes 150.5 cm.
- 3 Find the strain it causes if a load of 300 kg hanging from a rod of 3 metres length and 5 mm diameter extends it by 4 mm.
- 4 A tensile force of 10 kg is applied on a copper wire of diameter 1 cm. So that the length of wire increases by 5 mm. If the original length of wire was 2 metres, find out the strain.

- 5 A steel rod whose diameter is 1 cm and 60 cm in length. This rod is pulled at both ends by a force of 700 kg. If modulus of elasticity of steel is  $2.1 \times 10^6 \text{ kg/cm}^2$ , find out increase in length of rod and strain produced in it.
- 6 A steel rod 1.5 metres long and of 30 mm diameter is pulled at both ends by a force of 1500 kg. If modulus of elasticity of steel is  $2.4 \times 10^6 \text{ kg/cm}^2$ , determine increase in length of rod and strain produced in it.
- 7 Calculate the change in length of a rod of dia 16 mm and 160 mm long when it carries a load of 40KN. Take  $E = 200000 \text{ N/mm}^2$ .
- 8 A hollow C.I. column with a wall thickness of 2 cm is subjected to an axial compressive load of 80 tonnes. If the maximum stress is not to be exceeded 1 tonne per  $\text{cm}^2$ , determine the internal diameter of column. Calculate compressive strain, if  $E = 950 \text{ tonnes per cm}^2$ .
- 4 A wire 2800 mm long is stretched by 0.5 mm, when a weight of 9 kg is hung on it, its diameter is 2 mm. Calculate stress and young's modulus for the substance of the wire.
- 5 A force of 1000 kg is applied axially on rod of 12 mm diameter the original length is 100 mm. If modulus of elasticity is  $2 \times 10^{12} \text{ kg/cm}^2$ . Calculate the stress and strain developed in the rod.
- 6 A steel wire 3.2 mm diameter and 3.65 metre long stretches by 2.03 mm under the load of 115 kg. Calculate the stress and young's modulus of elasticity.
- 7 A mass of 10 kg is hung from a vertical wire 300.25 cm long and 0.0005 sq. cm cross section. When the load is removed the wire is found to be 300 cm long. Find the modulus of elasticity for the wire material.

### Young's modulus

- 1 A piece of wire 2 m long,  $0.8 \text{ mm}^2$  in cross section increases its length by 1.6 mm on suspension of 8 kg weight from it. Calculate the stress, strain and young's modulus.
- 2 A wire of 16 mm dia. is subjected to a tensile load of 2000 kg. Find the stress and strain if young's modulus  $E = 2 \times 10^{16} \text{ kg/cm}^2$ .
- 3 A wire of 2 metres long and its area of cross section is  $0.78 \text{ mm}^2$ . If 78 kg weight is suspended on this wire, then the length of the wire is increased by 1.4 mm. Find out stress, strain and young's modulus of elasticity.
- 8 A steel rod of 1.5 cm diameter and 8 metres long pulled by a forced of 80 kg at both ends. Find out the expansion and strain on the rod. The coefficient of elasticity  $E = 2.10 \times 10^6 \text{ kg/cm}^2$ .
- 9 A wire of length 3.5 m and diameter 0.35 mm is stretched by a force of 2kg weight. If the elongation is 4 mm. Calculate the young's modulus of the material of wire.
- 10 A mass of 1kg is suspended from a metal wire 100 cm long and 0.5 mm diameter. An increase in length of wire equal to 2 mm is observed. Calculate the young's modulus of wire.
- 11 A 4 metre long copper wire of diameter 3 mm is used to support a mass of 50kg. What will be the elongation of the wire. Young's modulus of elasticity for copper is  $7 \times 10^{10} \text{ N/mm}^2$ .