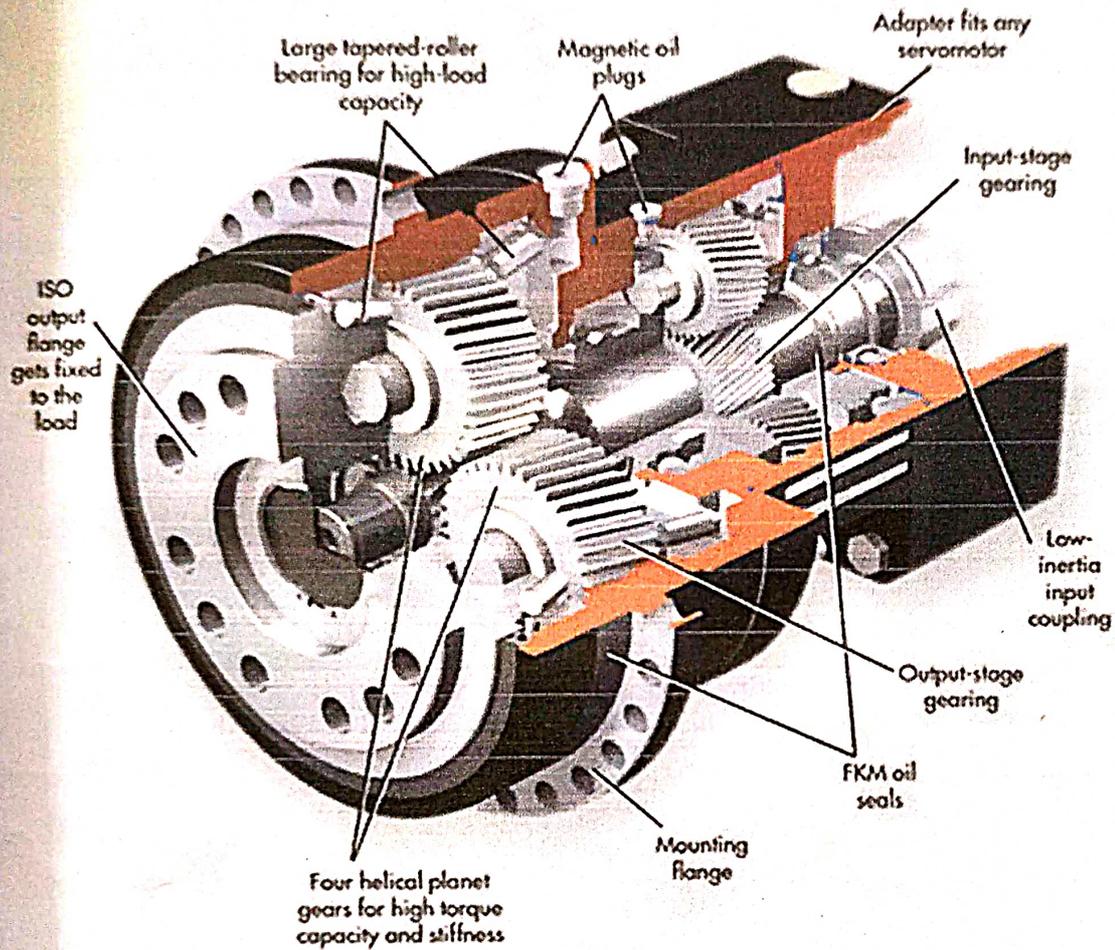


# MACHINE DESIGN

## NOTE



BY...

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## MACHINE DESIGN

Course code:	MET-501	Semester :	5th
Total Period:	60	Examination :	3 hrs (Design data book allowed)
Theory periods:	4 P/W	Class Test:	20
Maximum marks:	100	Teacher's Assessment:	10
		End Sem Examination:	70

### Rationale:

Machine design is the art of planning or devising new or improved machines to accomplish specific purposes. Idea of design is helpful in visualizing, specifying and selection of parts and components which constitute a machine. Hence all mechanical engineers should be conversant with the subject.

### Course Objectives:

1. Understanding the behaviours of material and their uses.
2. Understanding the design of various fastening elements and their industrial uses.
3. Understanding the different failures of design elements.
4. Understanding the change of design to accomplish the different field of applications.

<b>1.0</b>	<b>Introduction:</b>	<b>Periods</b>
1.1	Introduction to Machine Design and Classify it.	8
1.2	State the types of loads.	
1.3	Define working stress, yield stress, ultimate stress & factor of safety.	
1.4	State mechanical properties of the material.	
1.5	State the factors governing the design of machine elements.	
1.6	Describe design procedure.	
<b>2.0</b>	<b>Design of fastening elements:</b>	<b>14</b>
2.1	State nomenclatures, form of threads & specifications.	
2.2	Design of Screw thread (Nut and Bolt)	
2.3	State types of welded joints.	
2.4	State advantages of welded joints over other joints.	
2.5	Determine strength of welded joints for eccentric loads.	
2.6	State types of riveted joints.	
2.7	Describe failure of riveted joints.	
2.8	Determine strength & efficiency of riveted joints.	
2.9	Design riveted joints for pressure vessel.	
2.10	Solve numerical on Screw thread, Welded Joint and Riveted Joints.	
<b>3.0</b>	<b>Design of shafts and Keys:</b>	<b>12</b>
3.1	State function of shafts.	
3.2	State materials for shafts.	
3.3	Design solid & hollow shafts to transmit a given power at given rpm based on	
	a) Strength: (i) Shear stress, (ii) Combined bending & tension;	
	b) Rigidity: (i) Angle of twist, (ii) Deflection, (iii) Modulus of rigidity	
3.4	State standard size of shaft as per I.S.	
3.5	State function of keys, types of keys & material of keys.	

- 3.6 Describe failure of key, effect of key way.
- 3.7 Design rectangular sunk key considering its failure against shear & crushing.
- 3.8 Design rectangular sunk key by using empirical relation for given diameter of shaft.
- 3.9 State specification of parallel key, gib-head key, taper key as per I.S.
- 3.10 Solve numerical on Design of Shaft and keys.
- 0 Design of belt drivers and pulleys: 14**
- 4.1 State types of belt drives & pulleys.
- 4.2 State formula for length of open and crossed belt, ratio of driving and driven side tension, centrifugal tension, relation between centrifugal tension and tension on tight side for maximum power transmission.
- 4.3 Determine belt thickness and width for given permissible stress for open and crossed belt considering centrifugal tension.
- 4.4 Design a cast iron (C.I) pulley using empirical formula only.
- 4.5 Solve numerical on design of belt and design of C.I pulley.
- 0 Design a closed coil helical spring: 12**
- 5.1 Materials used for helical spring.
- 5.2 Standard size spring wire. (SWG).
- 5.3 Terms used in compression spring.
- 5.4 Stress in helical spring of a circular wire.
- 5.5 End connection for helical tension spring.
- 5.6 Deflection of helical spring of circular wire.
- 5.7 Eccentric loading of spring.
- 5.8 Surge in spring.
- 5.9 Solve numerical on design of spring.

#### Learning Resources:

<i>Sl No.</i>	<i>Name of Authors</i>	<i>Title of the Book</i>	<i>Name of the Publisher</i>
1	R.S. Khurmi & J.K. Gupta	A text book of Machine Design	S.Chand
2	P.C. Sharma & D.K. Aggarwal	A text book of Machine Design	S.K Kataria & Sons
3	V.B. Bhandari	Design of machine element	TMH
4	S. Md. Jalaludeen	Design data handbook	Anuradha Publication

# Introduction

1

## Machine Design

It is the creation of better & new machines & improving the existing ones.

In designing a machine component, it is necessary to have a good knowledge of many subjects such as mathematics, Engg. mechanics, Strength of material, Theory of machine, Workshop processes & Engineering drawing.

## Classification

1) Adoptive design :- In most cases, the designer's work is concerned with adoption of existing designs. This type of design needs no special knowledge or skill & can be attempted by designers of ordinary technical training. The designer only makes minor alternation or modification in the existing designs of the product.

2) Development design :- This type of design needs scientific training & design ability in order to modify the existing designs into new idea. In this case, though the designer start from the existing design, but the final product may differ from the original product.

3) New Design :- This type of designs needs lot of research, technical ability & creative thinking

\* Rational design :- This type of design depends upon mathematical formulae of principle of mechanics.

\* Empirical design :- This type of design depends upon empirical formulae based on the practice & past experience.

\* Industrial design :- This type of design depends upon the production aspects to manufacture any machine component in the industry.

\* Optimum design :- It is the best design for the given objective function under the specified constraints. It may be achieved by minimising the undesirable effects.

\* System design: - It is the design of any mechanical system like a motor car.

\* Element design: - It is the design of any of the mechanical system like piston, crank connecting rod etc.

\* Computer aided design: - This type of design is based upon the use of computer systems to assist in the creation, modification, analysis & optimisation of design.

## Factors governing the design of Machine or General consideration in Machine

\* Type of load & stresses caused by the

The load on a machine component, material & several ways due to which the internal stress is set up.

\* Motion of the parts / kinematics of the

The successful operation of any machine largely depends upon the simplest arrangement of parts which will give the motion required.

The motion of the parts may be:-

(i) Rectilinear motion  
↳ It includes unidirectional reciprocating motions.

(ii) Curvilinear motion  
↳ It includes rotary, oscillatory & simple harmonic.

(iii) constant velocity

(iv) constant or variable acceleration.

\* Selection of material

It is essential that a designer should have thorough knowledge of the properties of the materials & their behaviour under working conditions.

Some of the important characteristics of materials are:- Strength, durability, resistance to heat & corrosion, welded & machinability, electrical conductivity etc.

## Form & Size of the parts :-

The form & size are based on judgment. In order to design any machine parts for form & size, it is necessary to know the forces which the part must sustain. It is also anticipate any suddenly applied or impact load which may cause failure.

## Frictional resistance & Lubrication :-

There is always a loss of power due to frictional resistance & it should be noted that the friction of starting is higher than that of running friction. There fore it is essential that a careful attention must be given to the matter of lubrication of all surfaces which move in contact with others whether in rotating, sliding or rolling bearing.

## Convenient & Economical Features

In designing, the operating features of the machine should be carefully studied. The starting, controlling, & stopping levers should be located on the basis of convenient handling.

The economical operation of a machine which is to be used for production or for the processing of material should be studied, in order to learn whether it has the max<sup>m</sup> capacity with the production of good work.

## Use of Standard parts

It is closely related to cost, because the cost of standard parts is only a fraction of the cost of similar parts made to order.

The standard parts should be used whenever possible, parts for which patterns are already in existence such as gears, pulleys, bearings & parts which may be selected from regular stock such as screws, nuts & pins.

## \* Safety operation

Some machines are dangerous to operate those which are speeded up to insure production at a max<sup>m</sup> rate. Therefore, any moving part of a machine which is within the zone of consideration is considered an accident hazard & may cause an injury.

Therefore it is necessary that machines should always provide safety devices for the safety of the operator.

## \* Workshop Facilities

A design engineer should be familiar with the limitations of his employer's workshop, to avoid the necessity of having work done in another workshop.

It is sometimes necessary to plan the workshop operations & to draft manufacturing, handling & machine special parts.

## \* Number of machines to be manufactured.

The engineering & shop costs which are fixed charges or ~~overhead~~ overhead expenses distributed over the number of machines manufactured.

If only a few machines are to be made, extra expenses are not justified unless the machine is large or of some special design.

## \* Cost of Construction

The cost of construction of a machine is the most important consideration involved in design.

If a machine has been invented & if handmade samples have shown that it has commercial value.

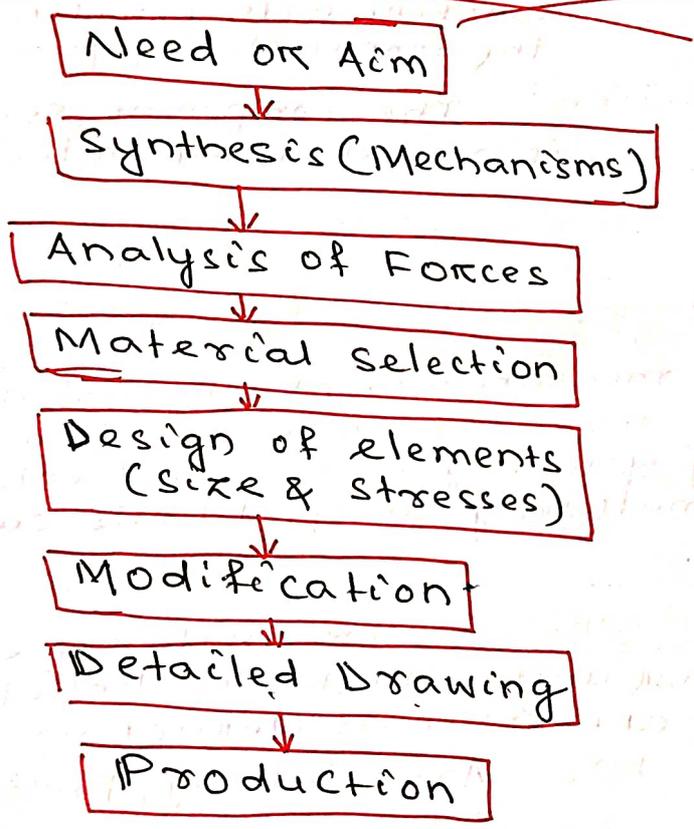
The aim of design engineer under these conditions should be to reduce the manufacturing cost to the minimum.

### Assembling :-

Every machine must be assembled as a unit before it can function. The large units must often be assembled in the shop, tested & then taken to be transported to their place of service.

The final location of any machine is important & the design engineer must anticipate the exact location.

### General Procedure in Machine Design



Need or Aim :- First of all, make a complete statement of the problem, indicating the need, aim, purpose for which the machine is to be designed.

Synthesis (mechanism) :- Select the possible mechanisms which will give the desired motion.

Analysis of Forces :- Find the forces acting on each member of the machine & the energy transmitted by each member.

Material selection: - Select the material for each member of machine

Design of elements: - Find the size of each of the machine by considering force acting on the member permissible stresses for the material

Modification: - Modify the size of the machine with the past experience & the modification may also be considered for reducing or

Detailed Drawing: - Draw the detailed of each component & assemble machine with complete specify the manufacturing processes

Production: - The component, as per the drawing is manufactured in the works

## Fundamental units

The measurement of physical quantities of the most important operation in engineering. Every quantity is measured in terms of internationally accepted units called fundamental units.

Derived units: - Some units are expressed in terms of other units, which are derived from the fundamental units, are known as derived units.

Exp: - Area, Velocity, Pressure, etc.

## System of units

There are four systems of units commonly used: C.G.S, F.P.S, M.K.S, S.I

## S.I units

It is a scientific method of expressing magnitudes or quantities of important phenomena. There are seven base units.

Length (L) - metre (m)

Mass (m) - Kg

Time (t) - second (s)

Temp (T) - Kelvin (K)

Elect. current (I) - Ampere (A)

Luminous intensity (I<sub>v</sub>) - Candela (Cd)

Amount of substance (n) - mole (mol)

Angles

plane angle - (α, β, θ, φ)

Solid angle - (Ω)

Derived units

Linear velocity (v) - m/s

Linear Acceleration (a) - m/s<sup>2</sup>

Angular Velocity (ω) - rad/s

Angular Acceleration (α) - rad/s<sup>2</sup>Mass density (ρ) - kg/m<sup>3</sup>

Force, weight (F) - Newton (N)

Pressure (P) - N/m<sup>2</sup>

Work (W)

Energy (E)

Enthalpy (H)

Power (P) - Watt (W), J/s

Absolute or dynamic

viscosity (μ) - N-s/m<sup>2</sup>Kinematic viscosity (ν) - m<sup>2</sup>/s

Frequency (f) - Hz

Thermal conductivity (k) - W/mK

Specific heat (c) - J/kg-K

Molecular mass (M) - kg/mol

Mass: - \* It is the amount of matter contained in a given body & does not vary with the change in its position on the earth's surface.

$$m = \frac{W}{g}$$

\* It is measured with the help of lever balance.

Weight: - \* It is the amount of pull, which the earth exerts upon a given body.

$$W = m \cdot g$$

\* The weight of the body varies with its position on the earth's surface.

Inertia: - It is that property of matter, by virtue of which a body can not move of itself.

Laws of motion

Newton's First Law: - Every body continues in its state of rest, unless any external force act on it.

Newton's 2nd Law: - The rate of change of momentum is directly proportional to the impressed force & takes place in the same direction in which the force acts.

Newton's 3rd Law: - To every action, there is always an equal & opposite reaction.

Force: -

It is defined as an agent which produces or tends to produce, destroy or tends to destroy motion.

$$F = m \cdot a$$

m = mass

a = Acceleration

Unit: - Newton (N)

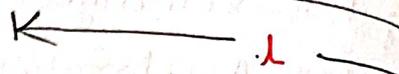
## Moment of Force

It is equal to the product of the force & the perp distance of the point.

Mathematically

$$\text{Moment of force} = F \times l$$

F = Force acting on the body  
l = perp distance of the point

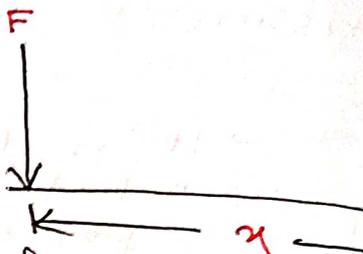


Couple: - The two equal & opposite par forces whose line of action are diff. from a couple.

The moment of couple is the product of one of the force & the arm of the couple. (x)

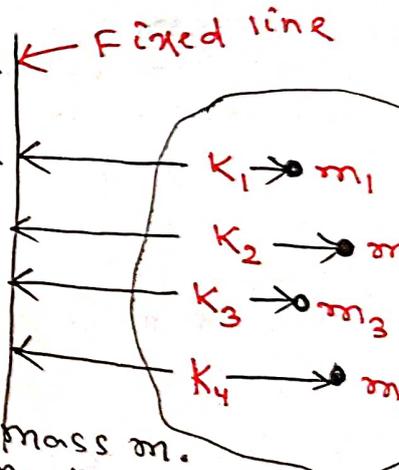
Mathematically

$$\text{Moment of couple} = F \times x$$



## Mass moment of Inertia

If the mass of every particle of a body is multiplied by the square of its perp distance from a fixed line, then the sum of these quantities is known as mass moment of inertia.



Consider a body of total mass m. the various masses are  $m_1, m_2, m_3, m_4$  etc. if  $K_1, K_2, K_3, K_4$  etc. are the distances from a

Then,  $I = m_1 K_1^2 + m_2 K_2^2 + m_3 K_3^2 + m_4 K_4^2 + \dots$   
If the distance K is considered then

$$I = m K^2$$

Unit -  $\text{kg} \cdot \text{m}^2$

## Angular momentum

It is the product of mass moment of inertia & the angular velocity of the body.

Mathematically,

$$\text{Angular momentum} = I \cdot \omega$$

## Torque (T)

It may be defined as the product of force & the perpendicular distance of its line of action from the given point or axis.

$$T = I \cdot \alpha$$

$$\text{Unit} \rightarrow \begin{matrix} \text{N-m} \\ \text{N-mm} \end{matrix}$$

## Work (W)

Whenever a force acts on a body undergoes a displacement in the direction of the force, then work is said to be done.

$$\text{Work done} = \text{Force} \times \text{displacement}$$

$$W = F \times x$$

$$\text{unit} - \text{N-m}$$

When, torque acting on a body, causing angular displacement ( $\theta$ ), then

$$\text{Work done} = W = T \cdot \theta$$

## Power (P)

It may be defined as the rate of doing work or work done per unit time.

Mathematically

$$P = \frac{\text{Work done}}{\text{Time taken}}$$

## Energy

It may be defined as the capacity to do work. The various types of energies are:- Mechanical, Electrical, chemical, heat, light etc.

### Types of Mechanical energy

#### Potential energy

The energy possessed by the body by virtue of its position, is known as potential energy.

$$P.E = m \cdot g \cdot h$$

$$\begin{aligned} h &= \text{height of the body} \\ W &= \text{Weight} \quad " \quad " \\ &= mg \end{aligned}$$

## Strain energy

It is the potential energy stored by an el when deformed.

Exp. - Spring

$$\text{Strain energy} = \frac{1}{2} S \cdot x^2$$

S = Stiffness of spring

x = distance

## Kinetic energy

The energy posses by the body by vicitu is known as kinetic energy.

$$K.E = \frac{1}{2} \cdot m \cdot v^2$$

m = mass of the  
v = Velocity of

## Mechanical properties of Metal

The mechanical properties of the metals which are associated with the ability of to resist mechanical forces & load.

The various properties are: →

Strength: - It is the ability of a mater the externally applied forces without ~~breaking~~ yielding.

Stiffness: - It is the ability of a mate resist deformation under stress.

Elasticity: - It is the property of a ma regain its original shape after deforma the external forces are removed. (steel elastic)

Plasticity: → It is the property of a ma does not regain its original shape after when external forces are removed.

(Exp: - Necessary in Forging, stamping & ornamental work)

## Ductility

It is the property of a material allow be drawn into wire with the application of force. It is measured in terms of percentage & percentage of reduction in area.

Exp: mild steel

Copper, Aluminium

Nickel, Zinc, Tin, Lead

## Brittleness

It is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion.

Exp: - Cast iron

## Malleability:-

It is a special case of ductility which permits material to be rolled or hammered into thin sheets.

Exp: - Lead, soft steel, wrought iron, copper, Aluminium.

Toughness:- It is the property of a material to resist fracture due to high impact loads like hammer blows.

Machinability:- It is the property of a material which refers to a relative ease with which a material can be cut.

(Brass can be easily machined than steel)

Resilience:- It is the property of a material to absorb energy & to resist shock & impact loads. This property is essential for spring material.

## Creep

When a part is subjected to a constant stress at high temp. for a long period of time, it will undergo a slow & permanent deformation called creep.

This property is considered in designing of I.C engines, Boilers, turbines,

## Fatigue

When a material is subjected to repeated stresses, it fails at the stresses below the yield point stresses. Such type of failure of a material is known as fatigue.

This property is considered in designing of shaft, connecting rod, spring, gear, etc.

## Hardness:-

It is the ability of a metal to cut another metal. The hardness is usually expressed in numbers which are depend upon the method of marking test. The hardness may be determined by various tests, that are:-

Brinell hardness test  
Rockwell hardness test  
Vickers " "

# Load

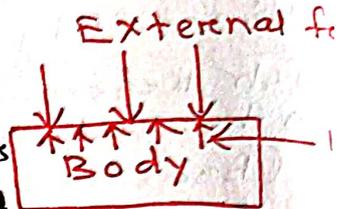
It is defined as the <sup>any</sup> external force acting upon machine parts.

## Types

- \* Dead or steady load: - does not change in &.
- \* Live or variable load: - ~~is~~ change contin
- \* Suddenly applied or shock load: - Suddenly removed
- \* Impact load: - Applied with some initial

## Stress ( $\sigma$ )

When some external force is applied on the body, the internal force of the body opposes the external force. This ~~external~~ internal force per unit area is known as stress.



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

Unit -  $N/m^2$  (Pa)  
 $N/mm^2$  (mpa)

## Strain ( $\epsilon$ )

When a load act on a body, it undergoes deformation. This deformation per unit length is strain.

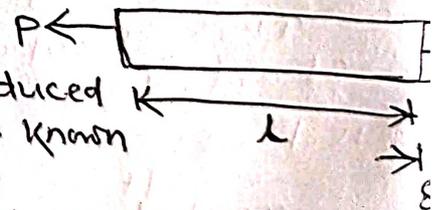
$$\epsilon = \frac{\Delta l}{l}$$

$l$  = original length  
 $\Delta l$  = change in length

Unit Less

## Tensile Stress & Strain

When a body is subjected to two equal & opposite axial pulls ( $P$ ), then the stress induced at any section of the body is known as tensile stress.



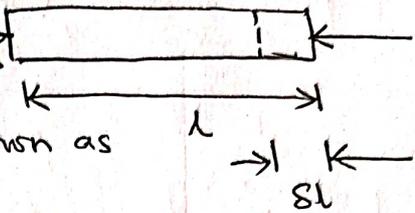
$$\sigma_t = \frac{P}{A}$$

Due to the tensile load, there will be decrease in cross-sectional area & increase in length. The ratio of the increase in length to its original length is known as tensile strain.

$$\epsilon_t = \frac{\Delta l}{l}$$

## Compressive Stress & Strain

When a body is subjected to two equal & opposite axial pushes (P), then the stress induced at any section of the body is known as Compressive stress.



$$\sigma_c = \frac{P}{A}$$

Due to the compressive load, there will be an increase in cross-sectional area & decrease in length. This decrease in length to its original length is known as compressive strain.

$$\epsilon_c = \frac{\delta L}{L}$$

## Young's modulus of Elasticity

Hooke's law states that, when a material is loaded within elastic limit, the stress is directly proportional to strain.

$$\sigma \propto \epsilon$$

$$\Rightarrow \sigma = E \cdot \epsilon$$

$$\Rightarrow E = \frac{\sigma}{\epsilon}$$

E = Young's modulus of elasticity  
Unit - GPa  
GN/m<sup>2</sup>

## Shear Stress & Strain



When a body is subjected to two equal & opposite forces acting tangentially across the resisting section, as a result the body tends to shear off the section, then the stress induced is called Shear stress ( $\tau$ ). The corresponding strain is known as Shear strain.

## Shear modulus or modulus of Rigidity (C, G) ( $\phi$ )

It has been experimentally found that within the elastic limit, the shear stress is directly proportional to shear strain.

Mathematically,  $\tau \propto \phi$

$$\Rightarrow \tau = C \cdot \phi$$

$$\Rightarrow C = \frac{\tau}{\phi}$$

C = Modulus of rigidity