LECTURE PLAN

ENGINEERING PHYSICS

BECF181T30/CBSPH18T30

B.E. / B. Tech.

(ECE, EIE, Mechatronics, EEE, CSE&IT)

(2020 -21 / I SEMESTER)

UNIT III – Elasticity Elasticity – Types of stress and strain - Stress-strain diagram and its uses – Hooke's Law – Types of moduli of Elasticity - Factors affecting Elasticity	
Delivery Mode	• Black board / Powerpoint Presentation
Key Lecture Points	• Introduction to Stress , Strain and Elasticity • Types of Stress and Strain • Hooke's Law • Proportionality Co-efficients • Stress and Strain Curve
Conclusions	• An elastic body is one that returns to its original shape after a deformation whereas an inelastic body fails. • Stress refers to the cause of a deformation, and strain refers to the effect of the deformation. • The elastic limit is the maximum stress a body can experience without becoming permanently deformed • The ultimate strength is the greatest stress a body can experience without breaking or rupturing.
Questions	• Explain Bending Moment of a beam • Factors affecting the elasticity of a material • Inference from Stress - Strain curve • What is Poisson ratio?

Credits	Exam	Marks		Total
		UI	UE	
4	3Hrs	40	60	100

Objectives:

Student will learn

- Basic definitions (stress, strain, Hooke's law and Poisson's ratio) of elasticity
- Stress – Strain Types
- Stress – Strain Diagram
- Three types of modulus

Outcomes:

Student will be able to explain

- Definitions of elasticity
- Various stages of Stress Strain Curve
- Modulus types

Pre requisites:

Basic knowledge on

- Concept of properties of matters and various forces acting on it

Terms used :

- Elastic Limit
- Deformation
- Bending Moment
- Rigidity
- Tensile Strength and yield strength

Elasticity

Introduction

Elasticity is the property by which a body resists change in its size or shape when an external force is acting on it and returns to the original state after the removal of the deforming force.

Elastic materials are classified into two types:

- Perfectly elastic
- Plastic

Materials which recover their original state after the removal of the deforming force are called *perfectly elastic materials*. Materials which do not recover their original state even after the removal of deforming force are called as *plastic materials***.** A material which does not undergo any relative displacement of its parts when an external force acts on it, however large it may be, is called a *perfectly rigid material***.**

No substance is perfectly elastic or perfectly plastic, since every substance tends to regain its equilibrium condition at least partially.

Fundamental Definitions

Restoring Force

When an external force acts on a body to cause deformation, forces of reaction comes into play internally and tends to restore the body to its original condition. These internal forces are called *restoring forces*.

Stress

The restoring force or recovering force per unit area is called *stress*.

$$\text{Stress} = \frac{\text{Restoring force}}{\text{Area}} = \frac{F}{A}$$

Stress is expressed in Nm^{-2} or Pascal.

Types of Stress

(a) Longitudinal stress (or) Tensile stress

If the deforming force acting on a body is along its longitudinal axis and produces a change in its length, then the deforming force / unit area acting normal to the cross sectional surface is called longitudinal or normal or tensile stress.

(b) Volume or Bulk Stress

If equal deforming forces are applied on each face of a cube in outward direction, then the cube suffers an increase in its volume. Under equilibrium, the applied force per unit area is called volume or bulk stress.

(c) Shearing Stress (or) Tangential Stress

If the deforming forces are applied tangentially over the top surface of a cube and bottom surface being kept fixed then, the top face gets displaced towards the direction of applied force. The tangential force per unit area or the stress which tends to make one part of the body slide across the other part is termed as shearing stress or tangential stress.

Strain

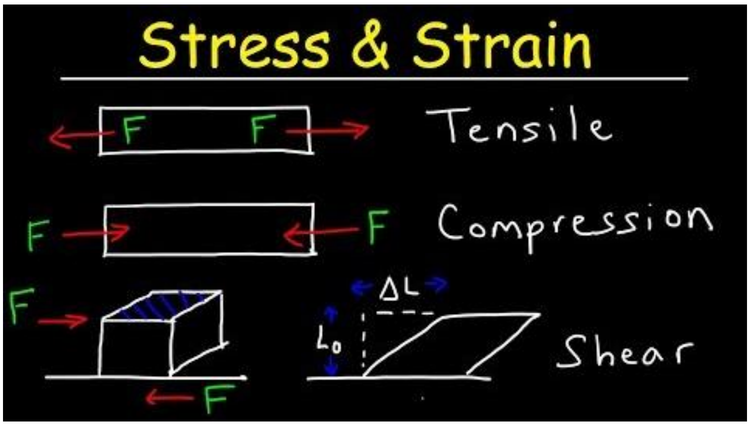
The ratio of the change in dimension produced by an external force to its original dimension is known as *strain*. The nature of the strain depends on the nature of the deforming forces. Strain has no unit and dimension.

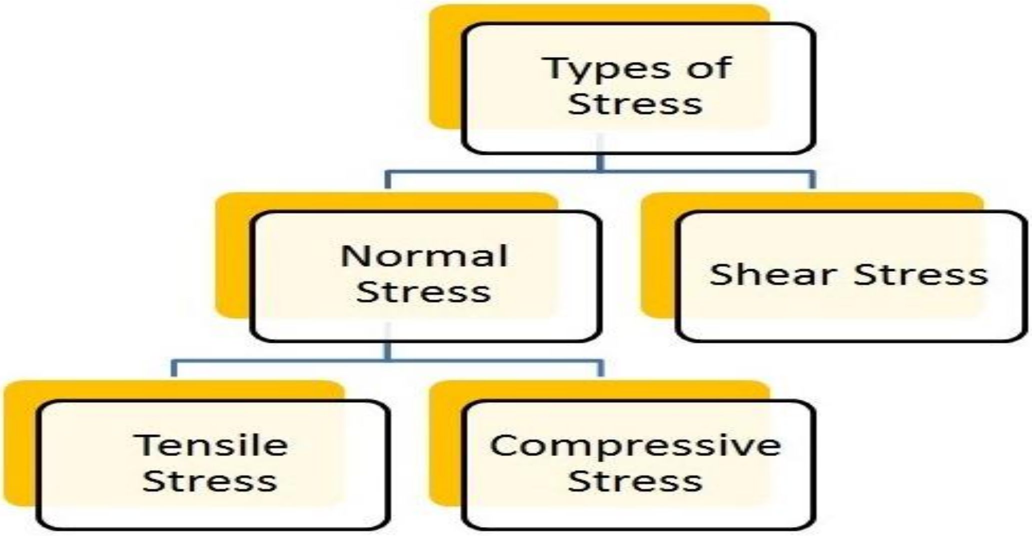
The ratio of change in length per unit length is known as *linear strain or longitudinal strain*. It is created by longitudinal stress.

When equal and opposite forces act tangentially along two opposite faces of a cube, a change in shape is produced. Such a strain is called *shearing strain*.

When an equal inward or outward force is applied normal to each face of a cube, a change in volume is produced. The ratio of the change in volume per unit volume is known as *volume strain*.

Types of Stress





a) Longitudinal strain or Tensile strain

If the deforming force is of the nature of pull or a tension and acting along the longitudinal axis of a wire of length L and produces a change in length L' without any change in shape, then this fractional change L/L' is called longitudinal strain.

Longitudinal strain = change in length / original length

If length increases from its natural length, then it is tensile strain. If in case there is decrease in length then it is compressive strain.

b) Volume strain

When the forces or pressure are applied uniformly and normally inwards (or outwards) over the whole surface of a body of volume V, then its volume gets decreased (or increased) by an amount V without any change in shape. The ratio of this change in volume to its original volume is called volume strain.

Volume strain = change in volume / original volume

c) Shear strain

When the deforming forces are applied tangentially over the top surface of the body, it suffers a change in shape without any change in volume or length and is said to be sheared. Shear is numerically equal to the ratio of the displacement of any layer in the direction of applied tangential force to its distance from the fixed surface.

Hooke's Law

Robert Hooke, in 1679, proposed a relation between stress and strain. The maximum value of the stress within which a body completely regains its original condition of shape and size when the deforming forces are removed is known as the *elastic limit*.

Hooke's law states that within the elastic limit, the ratio of the stress to the strain is constant. This constant is called the *modulus of elasticity* of the material.

Stress α strain

Stress = a constant x Strain

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

The constant is a proportionality constant which is known as *modulus of elasticity*.

Types of Moduli of Elasticity

There are three moduli of elasticity:

- Young' modulus (*Y*)
- Bulk modulus (*K*)
- Rigidity modulus (*n*)

Young's Modulus of Elasticity (Y)

It is the ratio of longitudinal (tensile) stress to longitudinal strain. It is denoted by *Y*.

$$\text{Young's modulus } Y = \frac{\text{Longitudinal or linear stress}}{\text{Longitudinal or linear strain}} = \frac{F.L}{A.dL}$$

Bulk Modulus(K)

Suppose equal forces act perpendicular to the six faces of a cube of volume V as shown in Due to the action of these forces, let the decrease in volume be dV.

Now, Bulk stress = Force / Area = F / A

Bulk Strain = change in volume / original volume = - dV/V

(The negative sign indicates that volume decreases.)

Bulk modulus of the material of the object is defined as the ratio bulk stress to bulk strain.

It is denoted by k

$$\text{Bulk modulus } K = \frac{\text{Bulk stress}}{\text{Bulk strain}} = \frac{-PV}{dV}$$

Rigidity Modulus

When a body is subjected to tangential deforming force, it suffers a change in shape but volume remains unchanged. Then body is said to be sheared. The stress developed in this case is called shearing stress, due to which a shearing strain is developed. Within the elastic limit, the ratio of shearing stress or tangential stress to shearing strain is called modulus of rigidity of the material. Its unit is N/m^2 and dimensional formula is $[ML^{-1} T^{-2}]$

modulus (symbols)	stress (symbol)	strain (symbol)	configuration change
Young's (E or Y)	normal to opposite faces (σ)	length $\varepsilon = \Delta\ell/\ell_0$	longer and thinner or shorter and fatter
shear (G or S)	tangential to opposite faces (τ)	tangent $\gamma = \Delta x/y$	rectangles become parallelograms
bulk (K or B)	normal to all faces, pressure (P)	volume $\theta = \Delta V/V_0$	volume changes but shape does not
Elastic moduli			

Poisson's Ratio (σ)

When a wire is pulled, it not only becomes longer but also thinner. If a force produces elongation or extension in its own direction, a contraction also occurs in a direction perpendicular to it, that is in lateral direction or vice versa. The fractional change in the direction of applied force is longitudinal strain, fractional change in perpendicular direction is lateral strain. Within elastic limit, ratio of lateral strain to longitudinal strain is constant for a given material and is called Poisson's ratio (σ). Poisson's ratio is related to the bulk modulus (K), the shear modulus (n) and Young's modulus (Y) by the following relation.

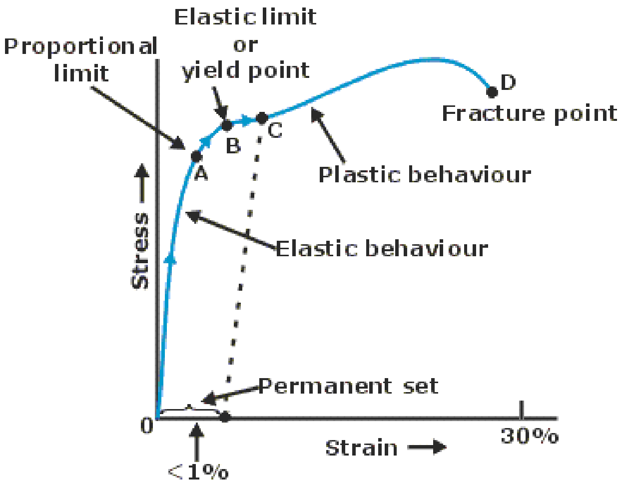
$$\boldsymbol{\sigma = (3K - 2n)/(6K + 2n)}$$

$$Y = 2n(1 + \sigma)$$

$$Y = 3K(1 - 2\sigma)$$

Stress-Strain Diagram

Consider a body subjected to a uniformly increasing stress which results in a change in its dimension. The elastic behavior of a material is studied from the graph plotted between different stresses applied to the material and the corre ponding strain produced in it. This graph, as shown in Figure is called stress-strain curve.



A typical stress-strain curve for a ductile metal

Stress strain curve has different regions and points. These regions and points are:

(i). Proportional limit

(ii). Elastic limit

(iii). Yield point

(iv). Ultimate stress point

(v). Fracture or breaking point.

(i) The part OA of the curve is a straight line, where Hooke's law is obeyed. (i.e.,) Stress is proportional to strain. A is called Elastic limit measured by the maximum stress that can be developed in the given material without causing a deviation from Hooke's law.

(ii) If wire is loaded beyond the elastic limit A, the wire gets stretched & attains a permanent set (ie) there is a permanent deformation in the body after the removal of deforming forces which is shown by OE.

(iii) On increasing the load still further a point B called yield point at which extension of the wire increases rapidly without an increase in the load. The value of stress at the yield point is called yield strength of that material. Elongation without addition in load is called creeping and this behaviour of the metal is called yielding.

(iv) If the wire is further loaded, a point represented by C is reached after which the wire begins to flow locally so that its cross sectional area gradually decreases. At point C the value of the developed stress is maximum and is called the ULTIMATE TENSILE STRENGTH or tensile strength of the given material.

(v) The stress corresponding to point D where the wire actually breaks down, is called Breaking stress.

Uses of stress – strain diagram

1. It is used to measure the elastic strength yield strength and tensile strength of metals
2. It is used to estimate the working stress and safety factor of an engineering material.
3. This diagram is also used to identify the ductile and brittle materials.
4. The area under the curve in the elastic region gives the energy required to deform it elastically.

The area under the curve upto Ultimate Tensile strength (UTS) gives the energy required to deform it plastically.

Factors Affecting Elasticity

The following are some of the important factors which affect the elastic properties of solids.

- Stress.
- Temperature withstand their elastic properties even at high temperatures.
- Impurities
- Crystalline nature
- Heat treatment and metal processing.

Course Teacher

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