Introduction to "Stress Analysis"

Chapter one
Basic concepts

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Contents

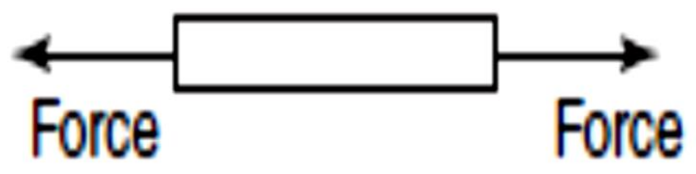
Introduction

- A force exerted on a body can cause a change in either the shape or the motion of the body. The unit of force is the newton, N. No solid body is perfectly rigid and when forces are applied to it, changes in dimensions occur. Such changes are not always perceptible to the human eye since they are so small. For example, the span of a bridge will sag under the weight of a vehicle and a spanner will bend slightly when tightening a nut. It is important for engineers and designers to appreciate the effects of forces on materials, together with their mechanical properties. The three main types of mechanical force that can act on a body are: (i) tensile, (ii) compressive, and (iii) shear.

Types of Forces

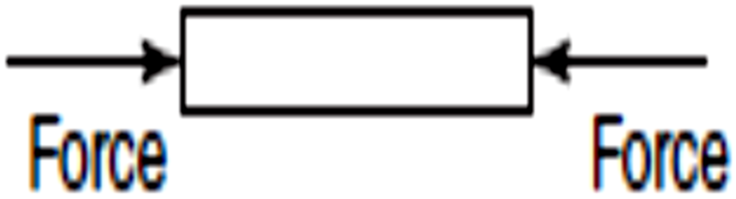
- **Tensile force**

Tension is a force that tends to stretch a material, as shown in Figure 1.1.
For example,
(i) the rope or cable of a crane carrying a load is in tension (ii) rubber bands, when stretched, are in tension. (iii) when a nut is tightened, a bolt is under tension A tensile force, i.e. one producing tension, increases the length of the material on which it acts.



Types of Forces

- Compressive force
- Compression is a force that tends to squeeze or crush a material, as shown in Figure.
- For example, (i) a pillar supporting a bridge is in compression (ii) the sole of a shoe is in compression (iii) the jib of a crane is in compression A compressive force.

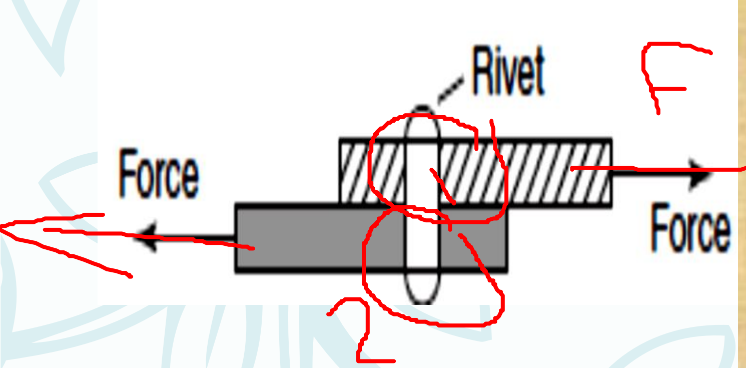


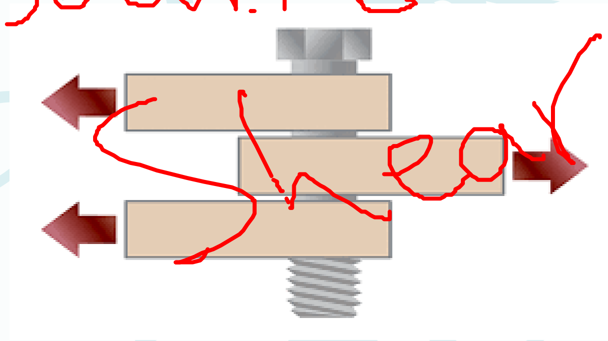
Types of Forces

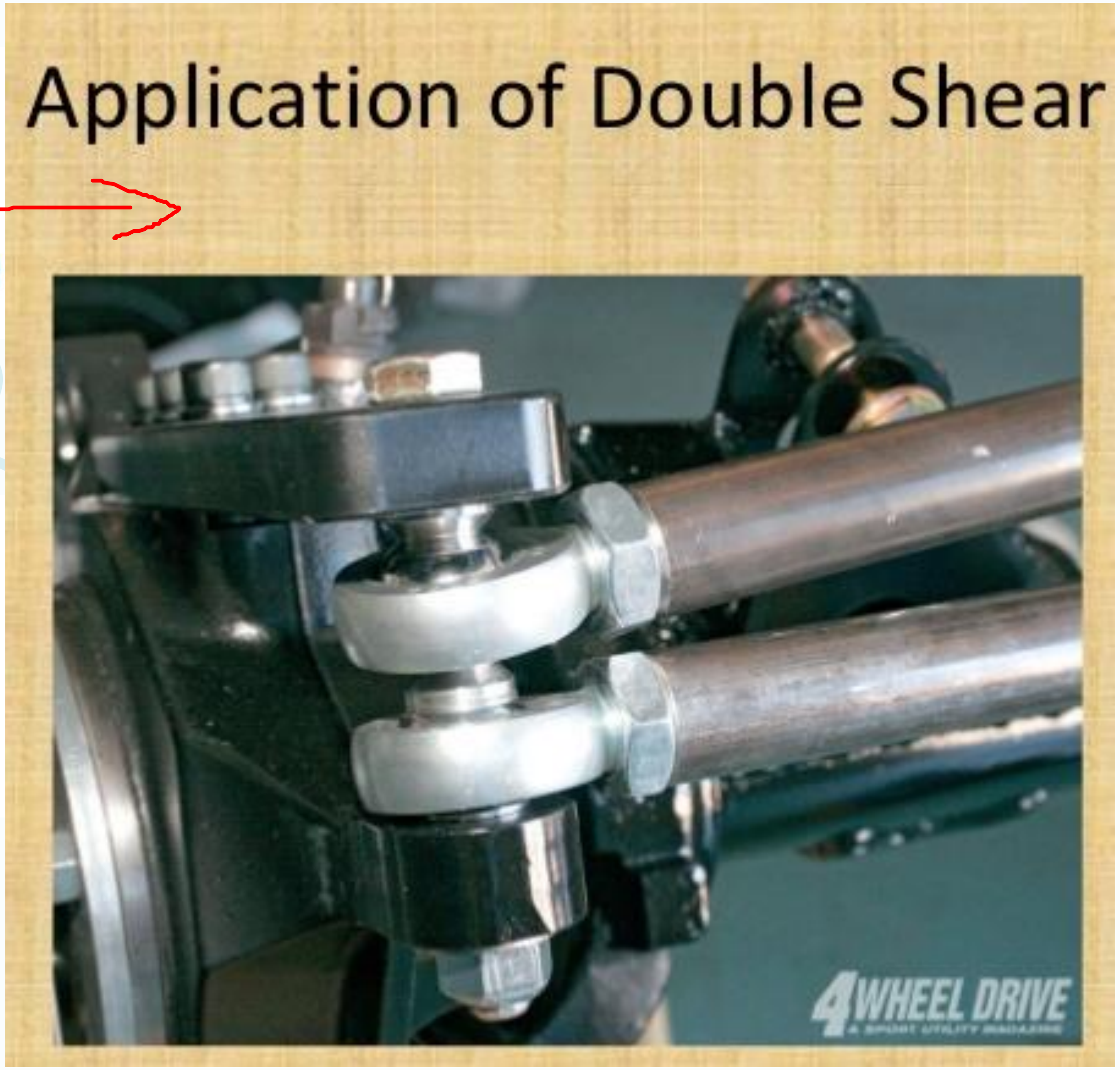
- **Shear force**
- Shear is a force that tends to slide one face of the material over an adjacent face. For example, (i) a rivet holding two plates together is in shear if a tensile force is applied between the plates—as shown in Figure. (ii) a guillotine cutting sheet metal, or garden shears, each provide a shear force (iii) a horizontal beam is subject to shear force (iv) transmission joints on cars are subject to shear forces A shear force can cause a material to bend, slide or twist.

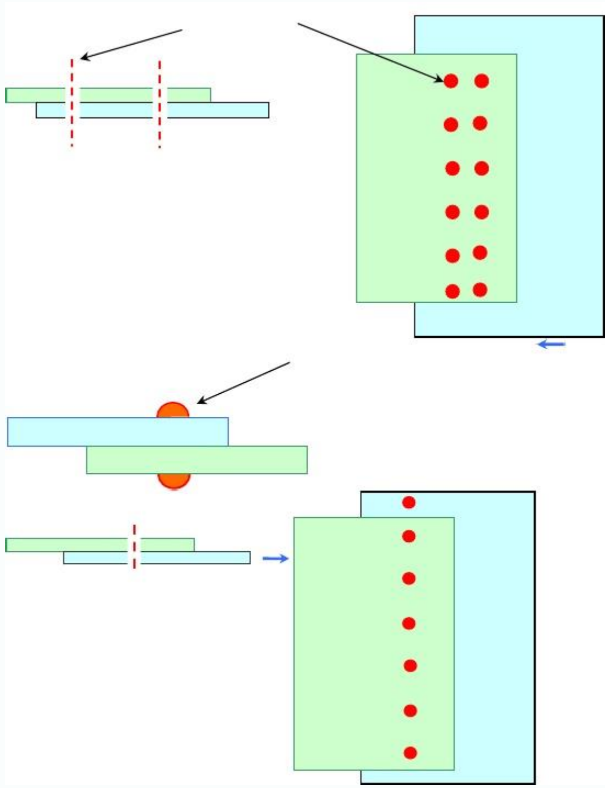
Types of Forces

- **Shear force**



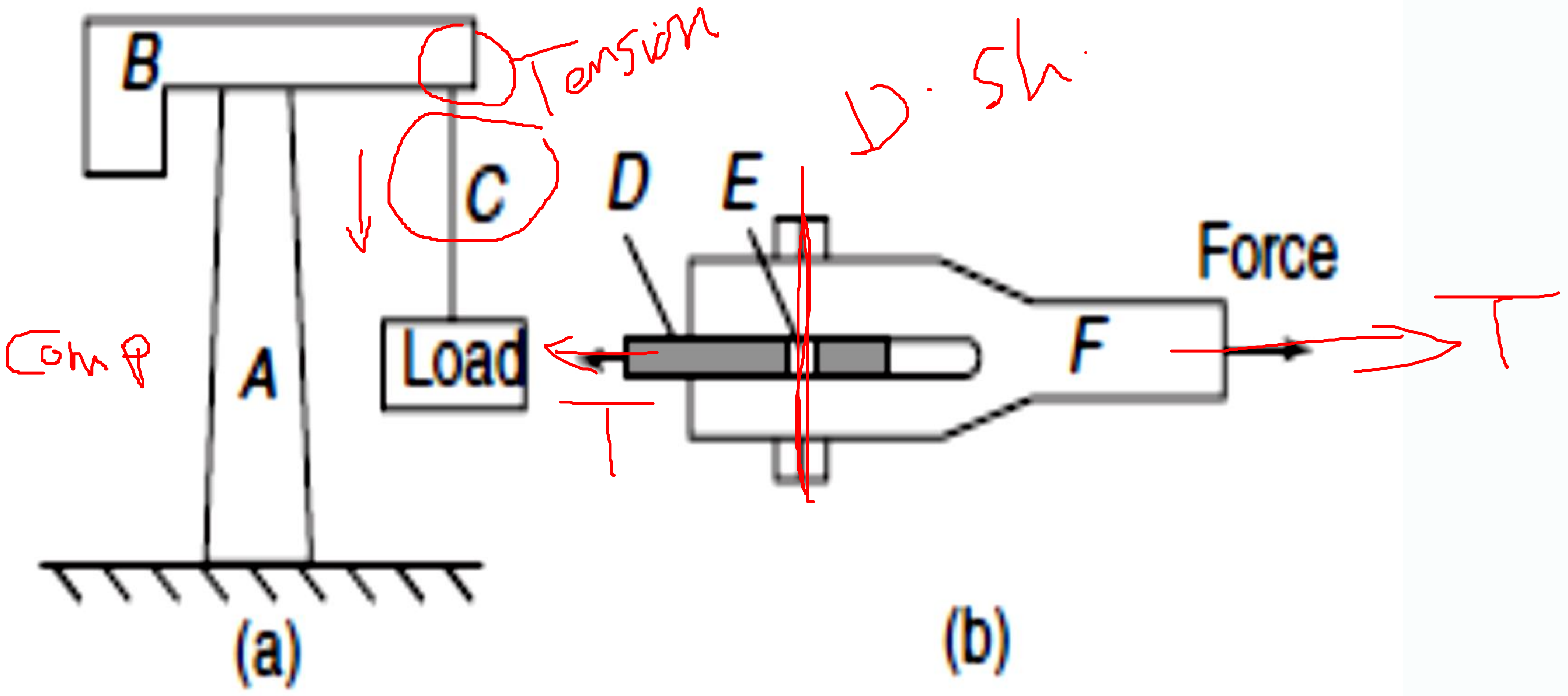






Types of Forces

- **Example**



Stress

- Stress
- Forces acting on a material cause a change in dimensions and the material is said to be in a state of stress. Stress is the ratio of the applied force F to cross-sectional area A of the material. The symbol used for tensile and compressive stress is σ (Greek letter sigma). The unit of stress is the Pascal, Pa, where 1 Pa = 1 N/m2. Hence: $\sigma = \frac{F}{A}$ Pa

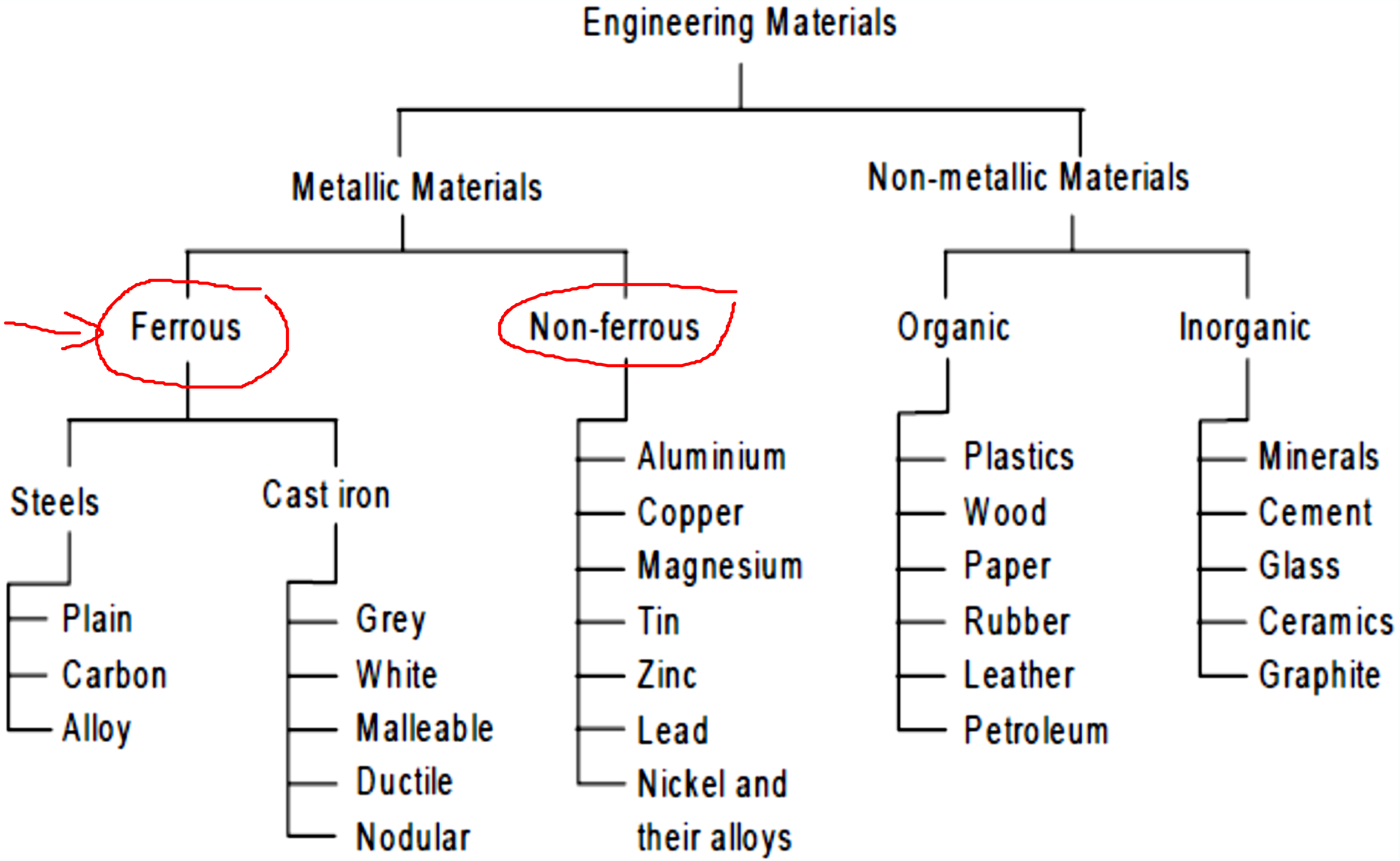
Strain

- **Strain**
- **The fractional change in a dimension of a material produced by a force is called the strain. For a tensile or compressive force, strain is the ratio of the change of length to the original length. The symbol used for strain is ε (Greek epsilon). For a material of length L metres which changes in length by an amount x metres when subjected to stress,**

$$\varepsilon = \frac{x}{L}$$

Metals and Alloys

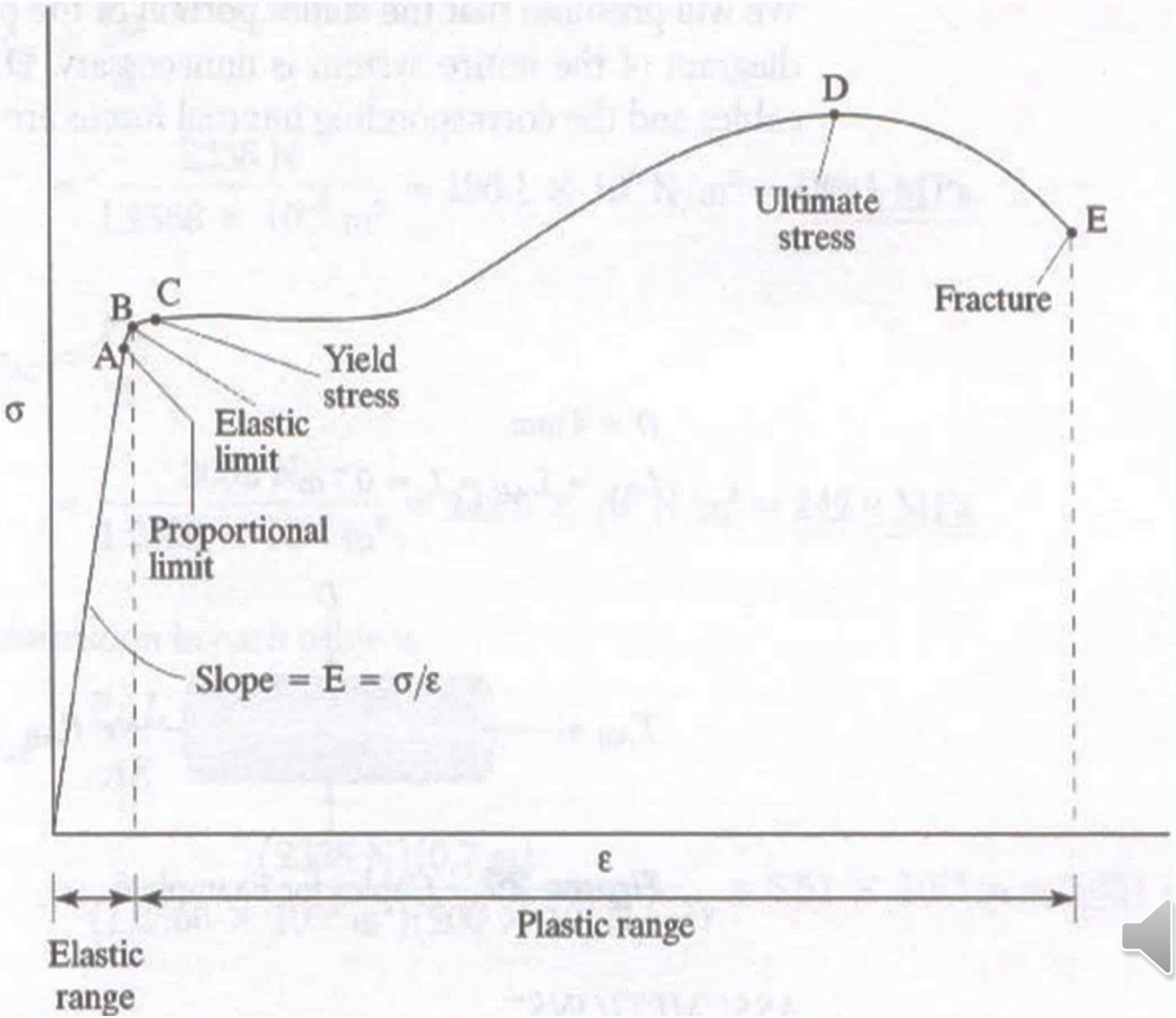
- **Engineering Materials**



Stress-Strain Diagrams

(a) Stress-Strain Curves for Ductile Materials

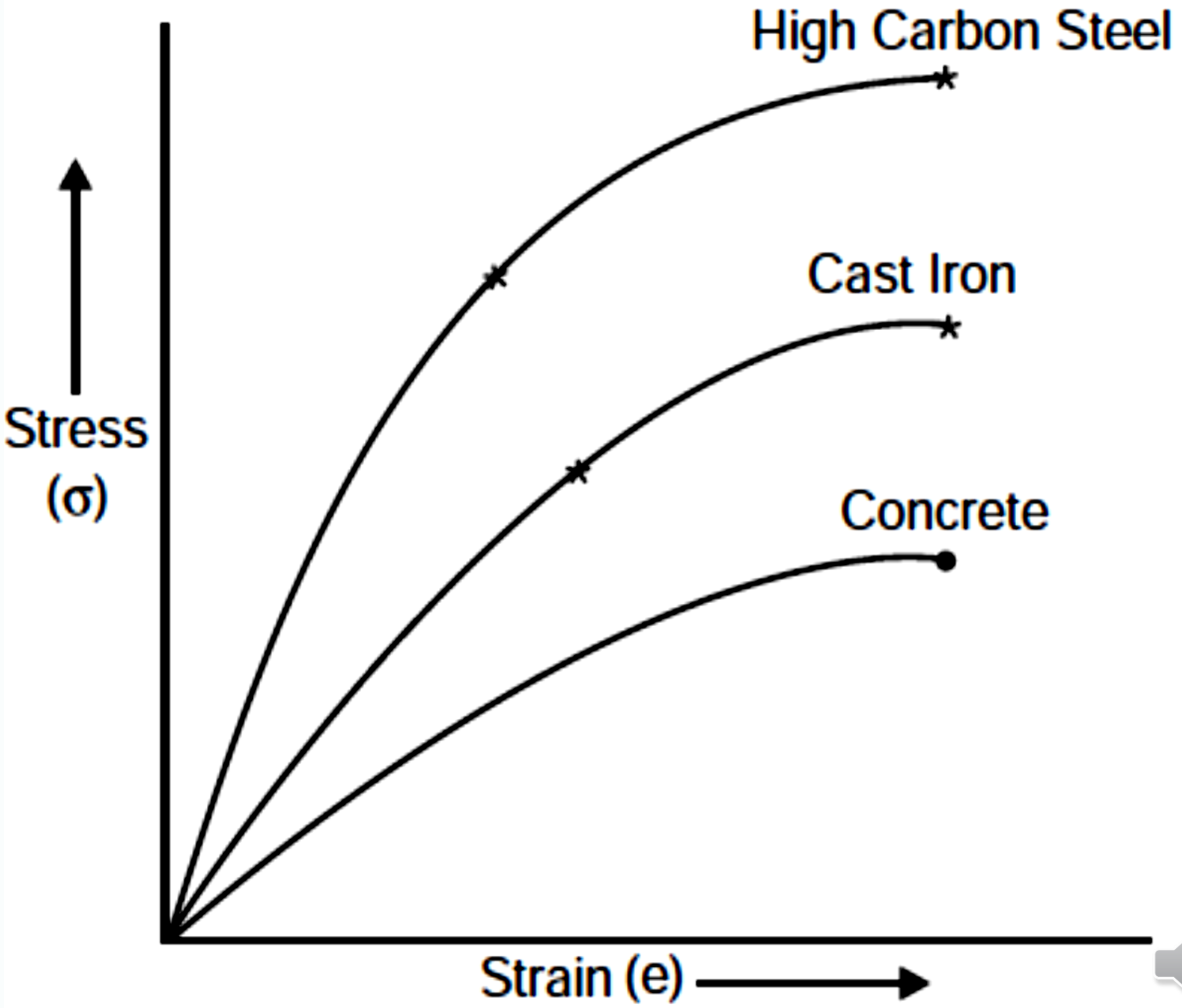
If a mild steel bar of uniform cross-sectional area is subjected to gradually increasing axial tensile force (generally is done in Universal Testing Machine) till failure of the bar occurs, and if we plot the graph for stress and strain, the following curve



Stress-Strain Diagrams

(b) Stress Strain Curves for Brittle Materials

Materials which show very small elongation before they fracture are called brittle materials. The shape of curve for high carbon steel is shown in Figure.



Stress-Strain Diagrams

(b) Stress Strain Curves for Brittle Materials

Materials which show very small elongation before they fracture are called brittle materials. The shape of curve for high carbon steel is shown in Figure. Brittle materials such as G.I., concrete and high strength light alloys. For most brittle materials the permanent elongation (i.e. increase in length) is less than 10%.

Main features on the stress–strain diagram.

Strain hardening

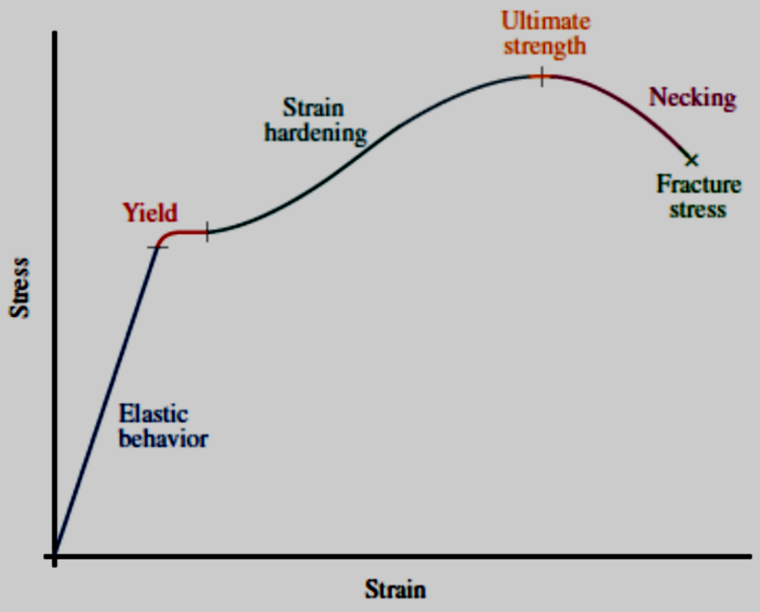
- As the material stretches, it can withstand increasing amounts of stress.

Ultimate strength

- According to the engineering definition of stress, the ultimate strength is the largest stress that the material can withstand.

Yield

- A slight increase in stress causes a marked increase in strain.
- Beginning at yield, the material is permanently altered. Only a portion of the strain will be recovered after the stress has been removed.
- Strains are termed inelastic since only a portion of the strain will be recovered upon removal of the stress.
- The yield strength is an important design parameter for the material.



Necking

- The cross-sectional area begins to decrease markedly in a localized region of the specimen.
- The tension force required to produce additional stretch in the specimen decreases as the area is reduced.
- Necking occurs in ductile materials, but not in brittle materials.

Elastic behavior

- In general, the initial relationship between stress and strain is linear.
- Elastic strain is temporary, meaning that all strain is fully recovered upon removal of the stress.
- The slope of this line is called the elastic modulus or the modulus of elasticity.

Fracture stress

- The fracture stress is the engineering stress at which the specimen breaks into two pieces.

Principal Mechanical Properties

- **Strength**

➢ It is the resistance offered by a material when subjected to external loading.

- **Elasticity**

➢ Elasticity of a material is its power of coming back to its original position after deformation when the stress or load is removed.

Principal Mechanical Properties

- **Stiffness (Rigidity)**

➢ The resistance of a material to deflection is called stiffness or rigidity

- **Plasticity**

➢ The plasticity of a material is its ability to undergo some degree of permanent deformation without failure. Plastic deformation will take place only after the elastic range has been exceeded, beyond point b.

Principal Mechanical Properties

- **Ductility**

➢ Ductility of a material enables it to draw out into thin wire on application of the load. Mild steel is a ductile material. The wires of gold, silver, copper, aluminum.

- **Malleability**

➢ Malleability of a material is its ability to be flattened into thin sheets without cracking by hot or cold working. Aluminum, copper, tin, lead, steel, etc. are malleable metals.

Principal Mechanical Properties

- Brittleness

➢ is the property of breaking without much permanent distortion. There are many materials, which break or fail before much deformation take place. Such materials are brittle e.g., glass, cast iron.

Principal Mechanical Properties

- **Toughness**
  - ➢ The toughness of a material is its ability to withstand both plastic and elastic deformations.
- **Hardness**
  - ➢ It is the ability of a material to resist scratching, abrasion, indentation, or penetration.

Principal Mechanical Properties

- **Impact Strength**
  - ➢ It can be defined as the resistance of the material to fracture under impact loading, i.e., **under quickly applied dynamic loads.**
- **Resilience**
  - ➢ is the capacity of material to absorb energy elastically.


THANK
YOU!