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FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

MEPS102:Strength of Material

Lecture 2

Topic: Stress-Strain Diagram

Instructor:

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Stress-Strain Diagram

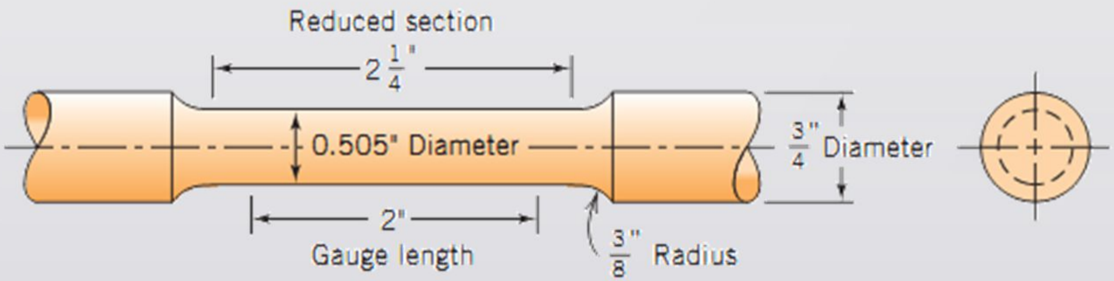
- ✓ If a load is static or changes relatively slowly with time and is applied uniformly over a cross section or surface of a member, the mechanical behaviour can be found out by a simple stress–strain test

- ✓ There are three principal ways in which a load may be applied
  - ✓ Tension
  - ✓ Compression
  - ✓ Shear

- ✓ We will be looking primarily be studying the tension test

Stress-Strain Diagram

- ✓ **Tension Test**
  - ✓ One of the most common mechanical stress–strain tests
  - ✓ A specimen is deformed, usually to fracture, with a gradually increasing tensile load that is applied uniaxially along the long axis of a specimen.
  - ✓ Normally, the cross section is circular, but rectangular specimens are also used.
  - ✓ This "dogbone" specimen configuration was chosen so that, during testing, deformation is confined to the narrow centre region (which has a uniform cross section along its length), and, also, to reduce the likelihood of fracture at the ends of the specimen.



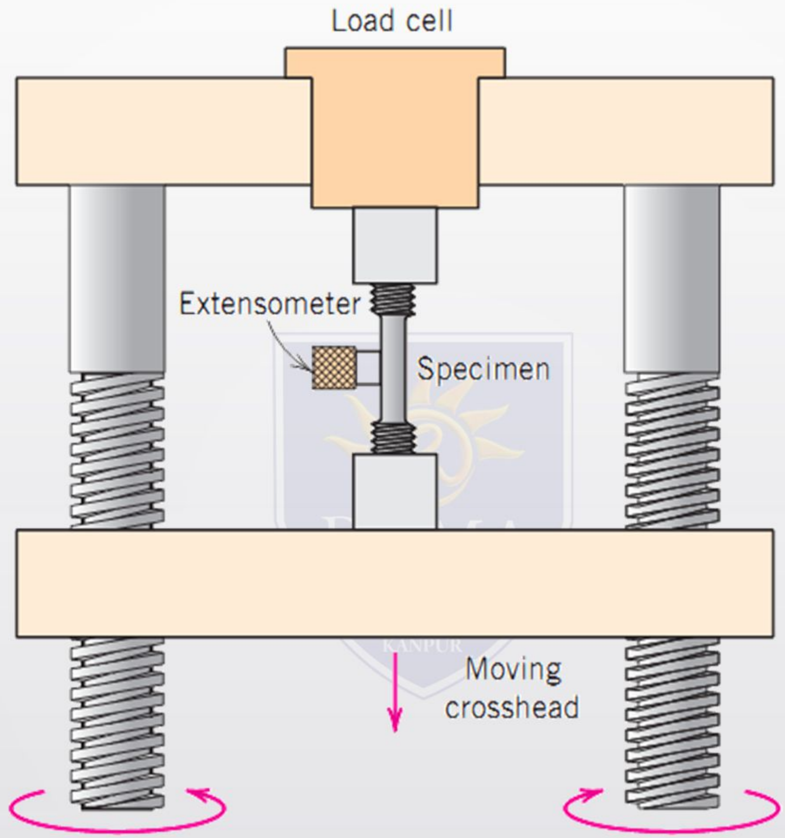
Stress-Strain Diagram

- ✓ The specimen is mounted by its ends into the holding grips of the testing apparatus (Figure 6.3).
- ✓ The tensile testing machine is designed to elongate the specimen at a constant rate, and to continuously and simultaneously measure the instantaneous **applied load** (with a load cell) and the resulting **elongations** (using an extensometer).
- ✓ The output of such a tensile test is recorded as load or force versus elongation.
  - ✓ These load–deformation characteristics are dependent on the specimen size.
  - ✓ To minimize these geometrical factors, load and elongation are normalized to the respective parameters of
    - ✓ Engineering (conventional) stress $\sigma = P/A_0$
    - ✓ Engineering (nominal) strain $\epsilon = \frac{l_i - l_0}{l_0}$

$P = Load\ applied\ ,\qquad A_0 = Cross\ sectional\ area\ before\ load\ is\ applied$

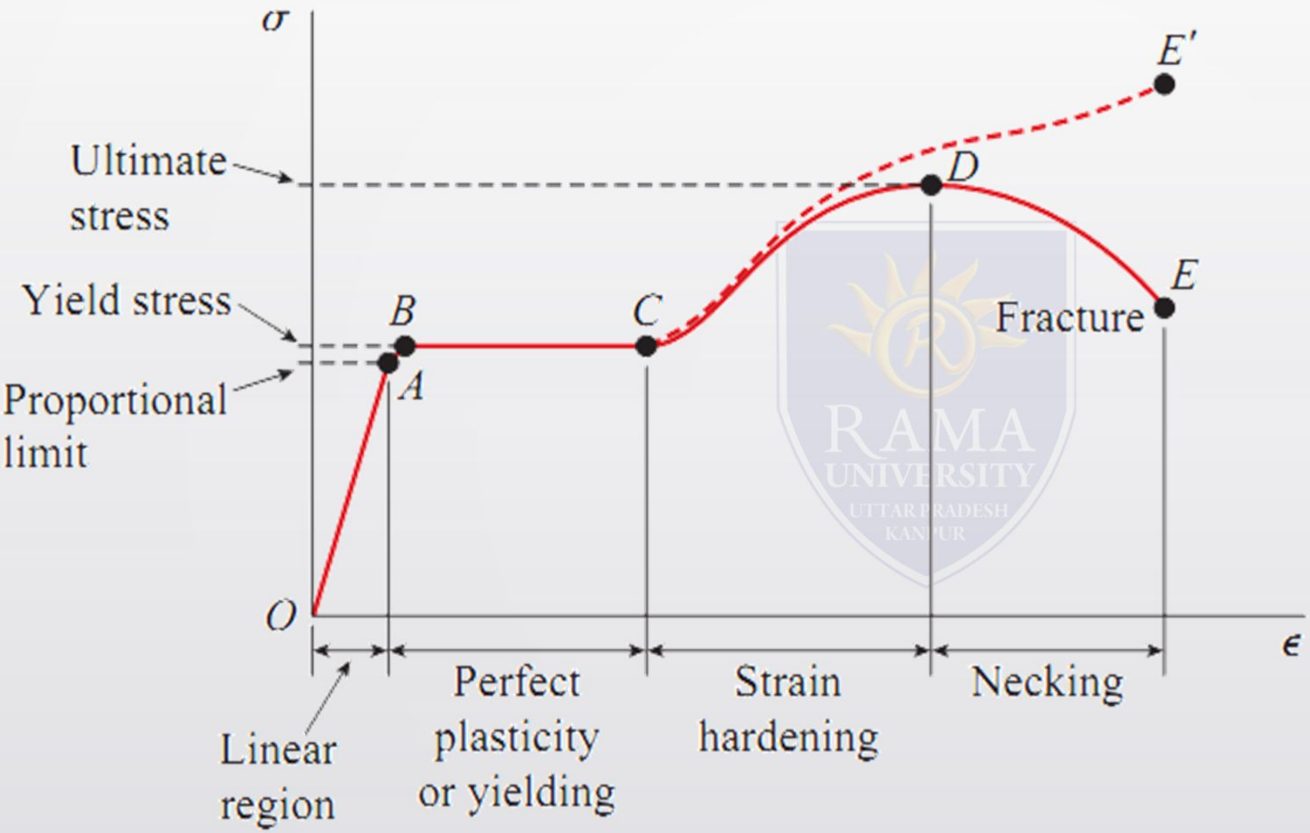
$l_i = instantaneous\ length\ ,\qquad l_0 = length before\ load\ is\ applied$

Stress-Strain Diagram



Schematic representation of the apparatus used to conduct tensile stress–strain tests. The specimen is elongated by the moving crosshead; load cell and extensometer measure, respectively, the magnitude of the applied load and the elongation.

Stress-Strain Diagram



- Proportional Limit & Modulus of Elasticity
- Yielding
- Plastic Deformation & Strain Hardening
- Ultimate Stress , Necking & Fracture

Stress-Strain Diagram: Proportional Limit & Modulus of Elasticity

- ✓ The diagram begins with a straight line from the origin O to point A, which means that the relationship between stress and strain in this initial region is not only linear but also proportional.
- ✓ Beyond point A, the proportionality between stress and strain no longer exists; hence the stress at A is called the **proportional limit**.
- ✓ The slope of the straight line from O to A is called the **modulus of elasticity E** it has the same units as stress.

✍ *Two variables are said to be proportional if their ratio remains constant. Therefore, a proportional relationship may be represented by a straight line through the origin. However, a proportional relationship is not the same as a linear relationship. Although a proportional relationship is linear, the converse is not necessarily true, because a relationship represented by a straight line that does not pass through the origin is linear but not proportional. The often-used expression "directly proportional" is synonymous with "proportional*

Stress-Strain Diagram: Yielding

- ✓ With an increase in stress beyond the proportional limit, the strain begins to increase more rapidly for each increment in stress. Consequently, the stress-strain curve has a smaller and smaller slope, until, at point B, the curve becomes horizontal
- ✓ Beginning at this point, considerable elongation of the test specimen occurs with no noticeable increase in the tensile force (from B to C).
- ✓ This phenomenon is known as **yielding** of the material, and point **B** is called the **yield point**.
- ✓ The corresponding stress is known as the **yield stress**

Stress-Strain Diagram: Plastic Deformation and Strain hardening

- ✓ In the region from B to C the material becomes **perfectly plastic**, which means that it deforms without an increase in the applied load.
- ✓ The presence of very large strains in the plastic region (and beyond) is the reason for not plotting this diagram to scale.
- ✓ After undergoing the large strains that occur during yielding in the region BC, the steel begins to strain harden. During **strain hardening**, the material undergoes changes in its crystalline structure, resulting in increased resistance of the material to further deformation.
- ✓ Elongation of the test specimen in this region requires an increase in the tensile load, and therefore the stress-strain diagram has a positive slope from C to D.

Stress-Strain Diagram: Ultimate Stress , Necking and Fracture

- ✓ The load eventually reaches its maximum value, and the corresponding stress (at point D) is called the ultimate stress.
- ✓ Further stretching of the bar is actually accompanied by a reduction in the load, and **fracture** finally occurs at a point such as E
- ✓ When a test specimen is stretched, lateral contraction occurs the resulting decrease in cross-sectional area is too small to have a noticeable effect on the calculated values of the stresses up to about point C
- ✓ But beyond C reduction in area begins to alter the shape of the curve. In the vicinity of the ultimate stress, the reduction in area of the bar becomes clearly visible and a pronounced **necking** of the bar occurs

Review Questions

Q1 Imagine that a long wire of tungsten hangs vertically from a high-altitude balloon.

(a) What is the greatest length (meters) it can have without breaking if the ultimate strength (or breaking strength) is 1500 MPa?

(b) If the same wire hangs from a ship at sea, what is the greatest length? (Obtain the weight densities of tungsten and sea water from, available online)

Review Questions

Q2 The strength-to-weight ratio of a structural material is defined as its load-carrying capacity divided by its weight. For materials in tension, we may use a characteristic tensile stress (as obtained from a stress-strain curve) as a measure of strength. For instance, either the yield stress or the ultimate stress could be used, depending upon the particular application. Thus, the strength-to-weight ratio $R_{S/W}$ for a material in tension is defined as

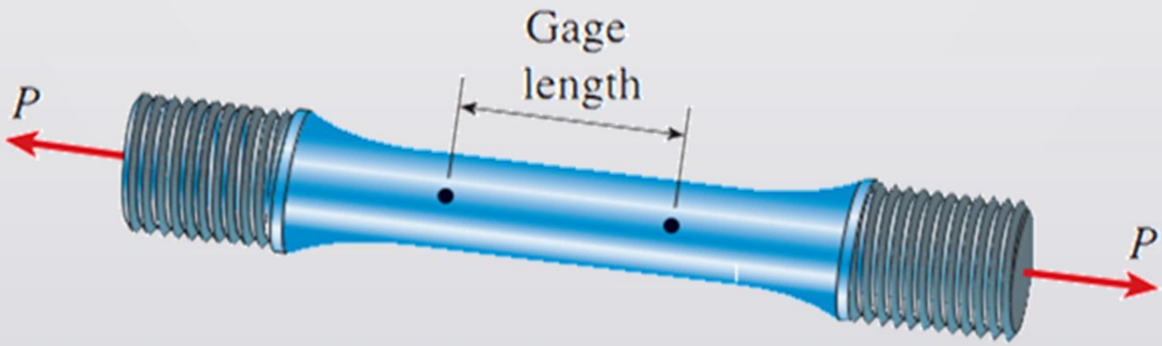
$$R_{s/w} = \sigma/\gamma$$

in which σ is the characteristic stress and γ is the weight density. Note that the ratio has units of length. Using the ultimate stress σ_U as the strength parameter, calculate the strength-to-weight ratio (in units of meters) for each of the following materials: aluminum alloy 6061-T6, Douglas fir (in bending), nylon, structural steel ASTM-A572, and a titanium alloy. (Obtain the material properties online. When a range of values is given in a table, use the average value.)

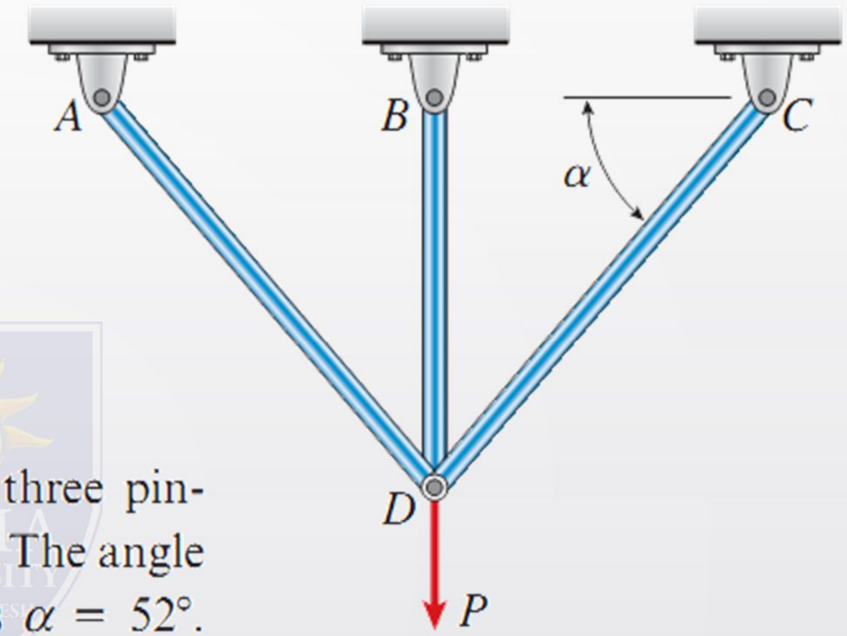
Review Questions

1.4-3 Three different materials, designated *A*, *B*, and *C*, are tested in tension using test specimens having diameters of 12 mm and gage lengths of 50 mm (see figure). At failure, the distances between the gage marks are found to be 54.5 mm, 63.2 mm, and 69.4 mm, respectively. Also, at the failure cross sections the diameters are found to be 11.46, 9.48, and 6.06 mm, respectively.

Determine the percent elongation and percent reduction in area of each specimen, and then, using your own judgment, classify each material as brittle or ductile.



Review Questions



1.4-5 A symmetrical framework consisting of three pin-connected bars is loaded by a force P (see figure). The angle between the inclined bars and the horizontal is $\alpha = 52°$. The axial strain in the middle bar is measured as 0.027.

Determine the tensile stress in the outer bars if they are constructed of a copper alloy having the following stress-strain relationship:

$$\sigma = \frac{124{,}020\varepsilon}{1 + 300\varepsilon} \qquad 0 \leq \varepsilon \leq 0.03 \qquad (\sigma = \text{MPa})$$

Review Questions

1.4-6 A specimen of a methacrylate plastic is tested in tension at room temperature (see figure), producing the stress-strain data listed in the accompanying table (see table below).

Plot the stress-strain curve and determine the proportional limit, modulus of elasticity (i.e., the slope of the initial part of the stress-strain curve), and yield stress at 0.2% offset. Is the material ductile or brittle?

STRESS-STRAIN DATA FOR PROB. 1.4-6

Stress (MPa)	Strain
8.0	0.0032
17.5	0.0073
25.6	0.0111
31.1	0.0129
39.8	0.0163
44.0	0.0184
48.2	0.0209
53.9	0.0260
58.1	0.0331
62.0	0.0429
62.1	Fracture