BMM1523/BHA1113 ENGINEERING MATERIALS

MECHANICAL PROPERTIES OF MATERIALS

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Chapter Description

- **Aims**

  Students are expected to understand the behaviour of materials based on their stress-strain curve including their elastic and plastic deformation during loading as well as to identify the characteristics of different types of mechanical testing.

- **Expected Outcomes**
  - Students should be able to define and differentiate between engineering stress and true stress as well as engineering strain and true strain.
  - Determine the modulus of elasticity, yield strength (0.002 strain offset), ultimate tensile strength and percent of elongation or ductility of materials.
  - Explain the characteristics of materials based on their stress-strain curve.

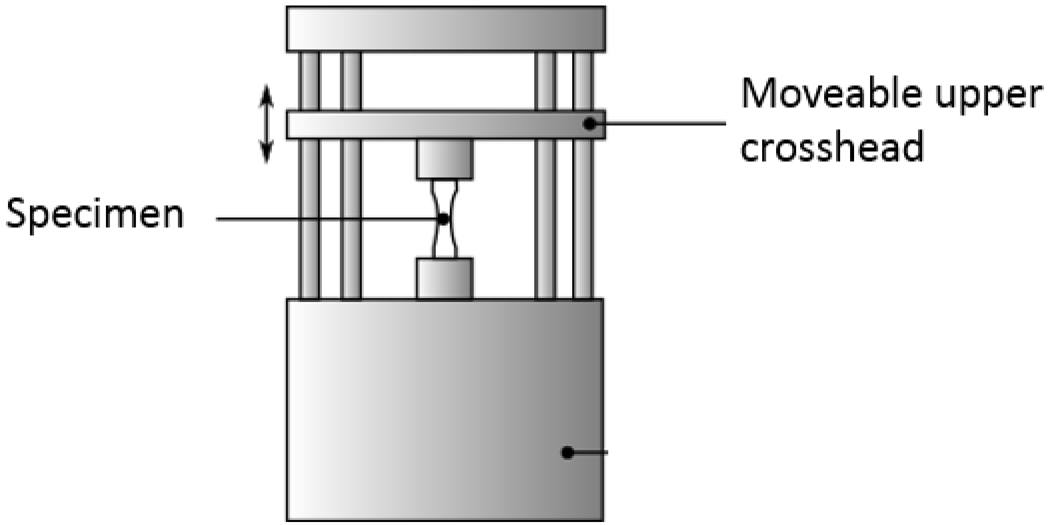
- **References**

1. William D. Callister and David G. Rethwisch. Materials science and engineering: An Introduction, 9th Ed. Wiley, 2014

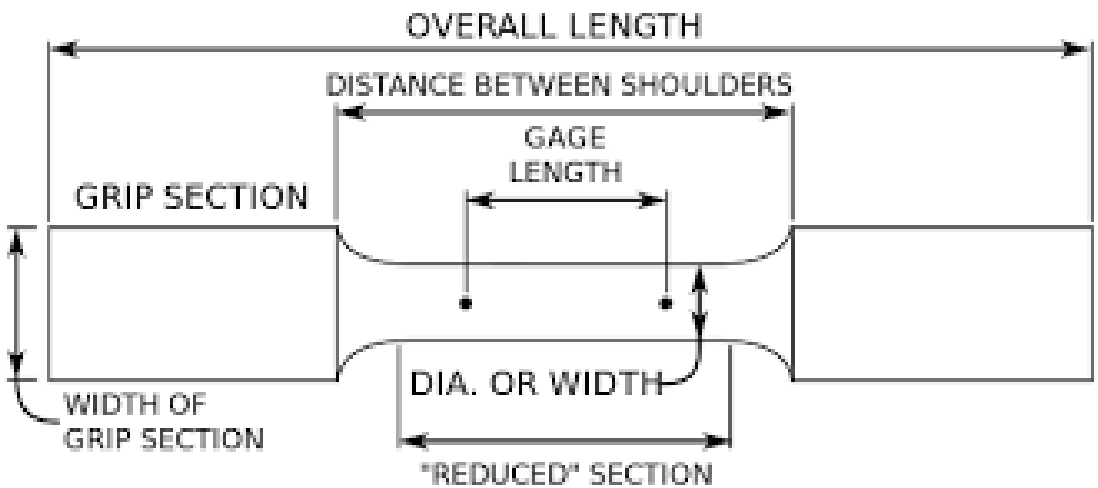
Mechanical Testing

- Tensile
- Compression
- Hardness
- Impact
- Bending

Tensile Test Machine



Tensile Test Specimen



Engineering Stress, Engineering Strain and Young Modulus

- Engineering stress (σ) is defined as tensile force (F) divided by original cross sectional area before any load is applied.

$$\sigma = \frac{F}{A_0}$$

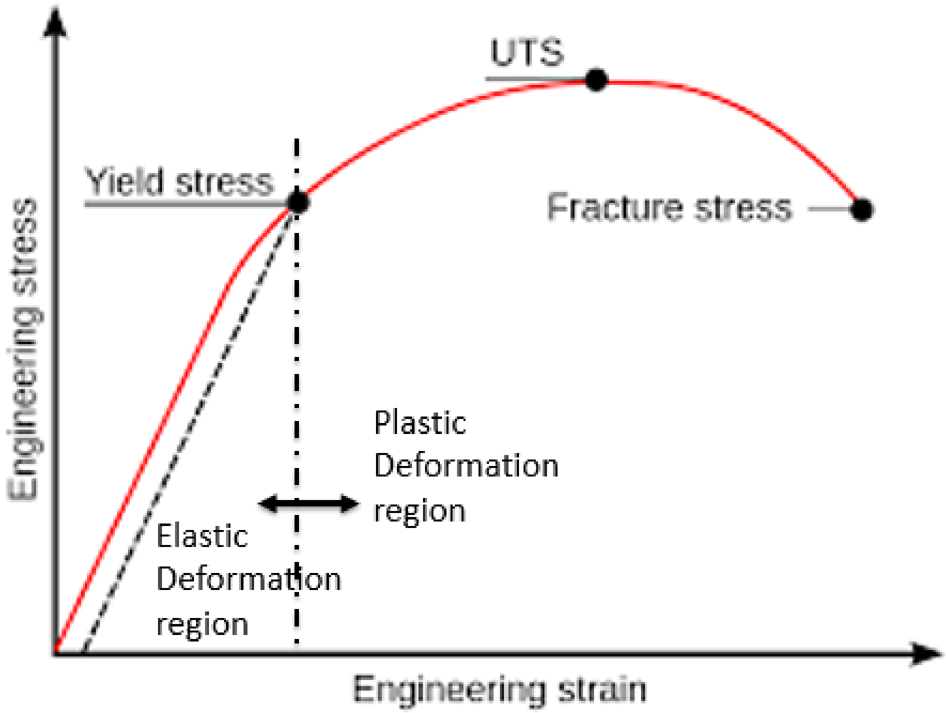
- Engineering strain (ε) is defined as change of specimen length (ΔL) or elongation divided by original length (l_0)

$$\varepsilon = \frac{l_i - l_0}{l_0} = \frac{\Delta L}{l_0}$$

- Young Modulus (E) is defined as the ratio of stress to strain

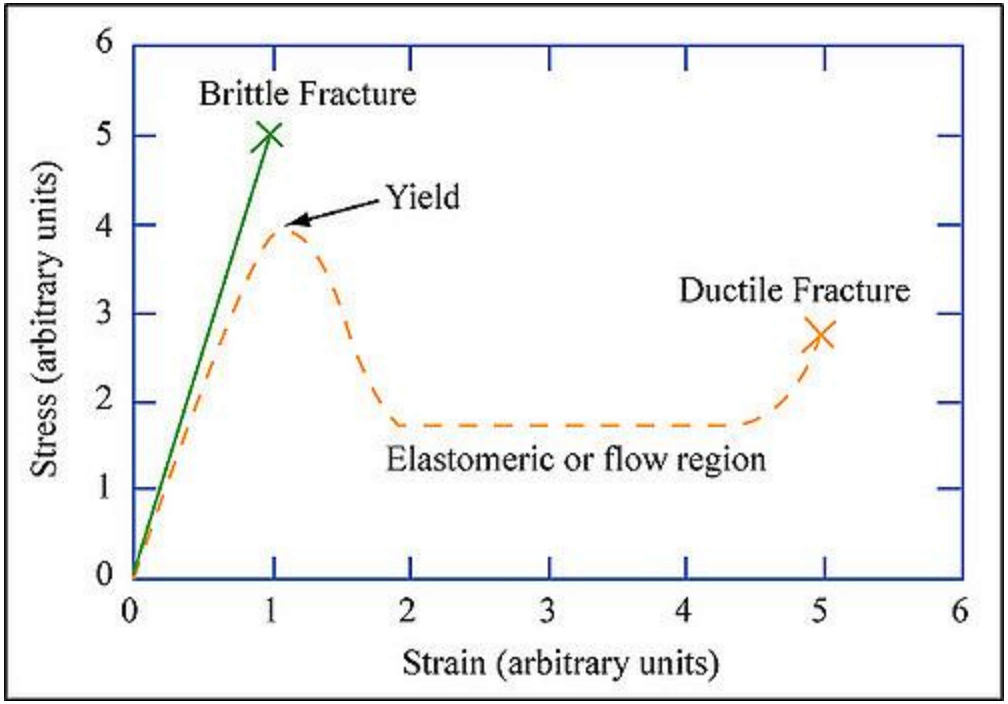
$$E = \frac{\sigma}{\varepsilon} = \frac{F / A_o}{\Delta L / l_o}$$

Engineering Stress-Strain Curve



- Yield stress or strength: Stress at which the material surpassed elastic deformation and undergo plastic deformation region.
- Ultimate Tensile Strength (UTS): Maximum stress the material can experience during loading
- Fracture stress: Stress at which the sample break

Ductility of Material



- Plastic deformation behavior allow the measurement of ductility of a material. Material with very little or without plastic deformation behavior exhibits brittle failure mode.

- Ductility maybe defined as:

1. $\% \text{ Elongation} = \frac{l_f - l_o}{l_o} x\ 100$

   Where l_f is the fracture length and l_o is the original length

   Or

2. $\% \text{ Elongation} = \frac{A_o - A_f}{A_o} x\ 100$

   Where A_f is the cross-sectional area at fracture and A_o is the original cross-sectional area

True Stress and True Strain

- True stress (σ_T) is defined as the load F divided by the instantaneous cross-sectional area A_i

$$\sigma_T = \frac{F}{A_i}$$

- True strain (ε_T) is defined by

$$\varepsilon_T = \ln\frac{l_i}{l_o}$$

- Relation of true and engineering stress and strain is given by

$$\sigma_T = \sigma(1 + \varepsilon)$$
$$\varepsilon_T = \ln(1 + \varepsilon)$$

Effects of Temperature on Stress-Strain Curve

Higher temperature will give:

- Higher ductility and toughness
- Lower yield strength and modulus of elasticity of materials
- Lower in ultimate tensile strength (UTS) of materials
- Lower the toughness of materials (reduction in area under graph of stress-strain curve)

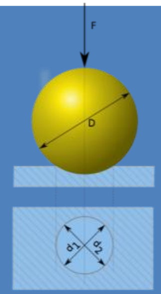
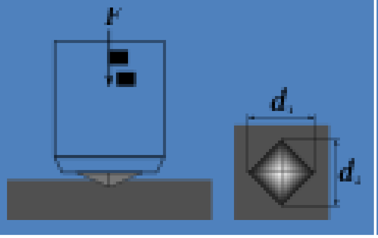
Compression Test

- Compression is performed in a similar fashion as tensile test except the applied force is compressive instead of tension.
- Compressive stress and strain is calculated using the same equation as in tensile test as discussed previously.
- Compressive stress will be negative due to the direction of the force is in compression.
- Compressive strain also will be negative as the original length (l_o) is greater than instantaneous (l_i) length.

Hardness Test

- Hardness test is performed to measure the material's resistance against plastic deformation like scratch or dent.
- Hardness test is frequently chosen compare to other type of mechanical testing since it is easy, inexpensive and is a nondestructive method of testing.
- Good hardness of a material reflects their ability resist scratch or wear.
- Typically, this test is performed either by Rockwell or Brinell hardness test.

Hardness Test

Test	Indenter	Shape of Indenter	Load	Hardness Formula
Brinell	10mm sphere of steel or tungsten carbine		F	$HB = \frac{2F}{A = \pi D[D - \sqrt{D^2 - d^2}]}$
Rockwell	Diamond cone (few diameters are available)		60kg 100kg 150kg	
Vickers	Diamond pyramid		F	$HV = 1.854F/d_1^2$

Source: Materials science and engineering and introduction, William D Callister, 6th Edition

Impact Test

- Impact test is performed to determine the amount of energy absorbed by a material upon impact to fracture.
- The quantitative data of the energy absorbed is typically termed as toughness of the material.
- Qualitatively, material characteristic either ductile or brittle can be determined according to the fracture behavior.
- Most commonly used impact test procedures are Izod and Charpy

Izod and Charpy Impact Test

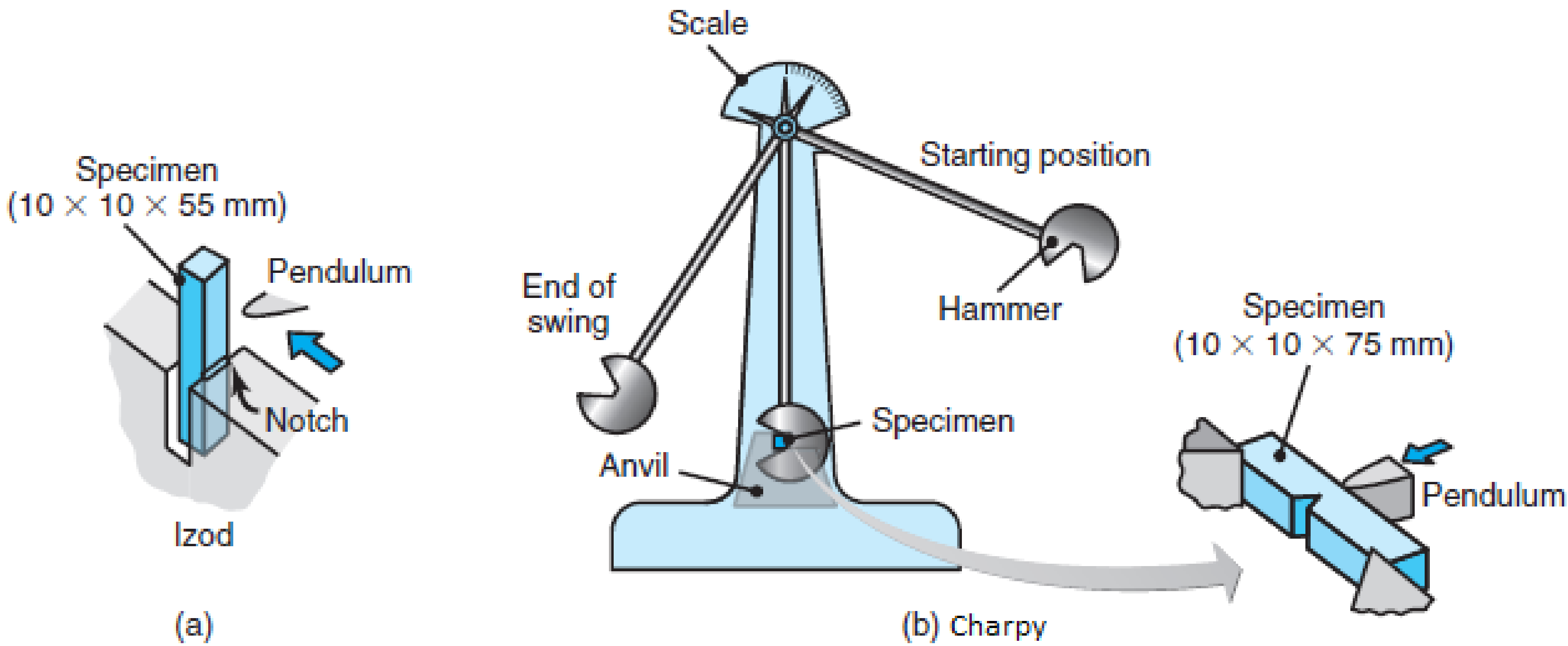
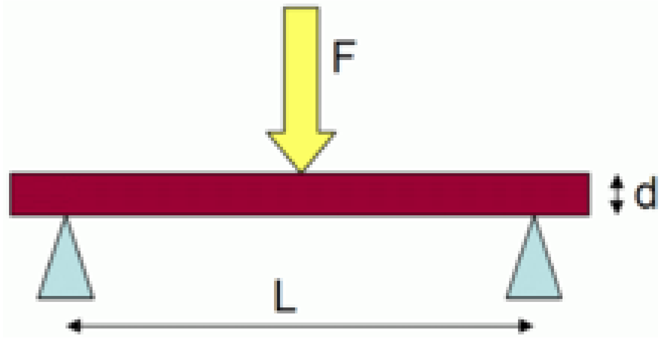
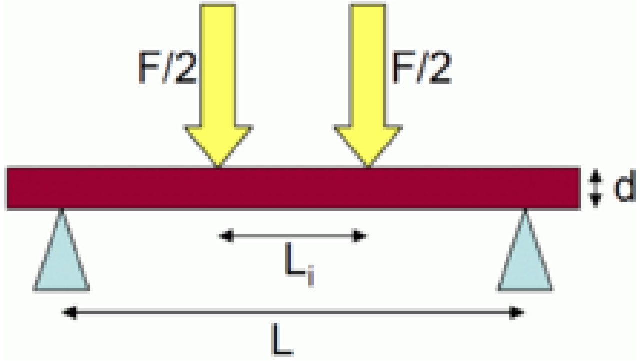


Figure shows the different in the position of specimen for both Izod and Charpy impact test

Bending or Flexural Test

- Flexural testing can provide flexural strength and flexural modulus of a material.
- It can be performed either by 3 point bending or 4 point bending.
- Similar to tensile and compression testing, flexural testing also can performed using Universal Testing Machine (UTM)





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Research Interest:

- ❑High Temperature Physical Chemistry
- ❑Thin Films Technology
- ❑Metals and Alloys.

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