Department of Mechanical Engineering
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MECHANICAL PROPERTIES OF MATERIALS

Workshop Technology

Mechanical properties

- Reaction of materials to the action of external stresses is indicated as **mechanical properties.**

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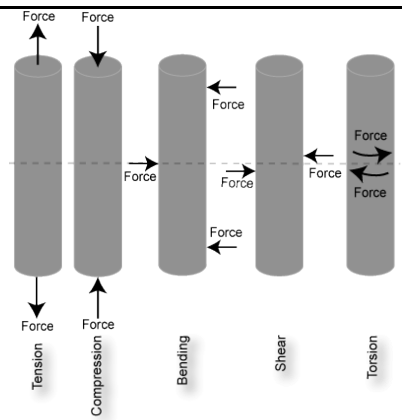

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Mechanical properties

1. Strength
2. Elasticity
3. Plasticity
4. Ductility
5. Brittleness
6. Malleability
7. Toughness
8. Fracture Toughness
9. Resilience
10. Hardness

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Deformation

- Application of a stress causes a material to change its size and shape.
- Change in size and shape is known as deformation.

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Elastic deformation

- Reversible: when the stress is removed, the material returns to the dimension it had before the loading.

Plastic deformation

- Irreversible: when the stress is removed, the material does not return to its previous dimension.

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Strength

- Ability of material to withstand the applied stresses or loads without failure is defined as strength.

1. Tensile strength

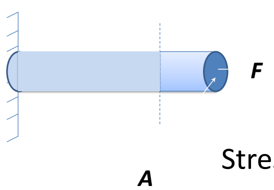
Ability to withstand for tension can define as tensile strength.

Tensile testing

- Tensile properties indicate how the material will react to forces being applied in tension.
- A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance.

Stress (δ)

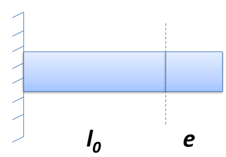
- Force when expressed per unit area is known as stress.



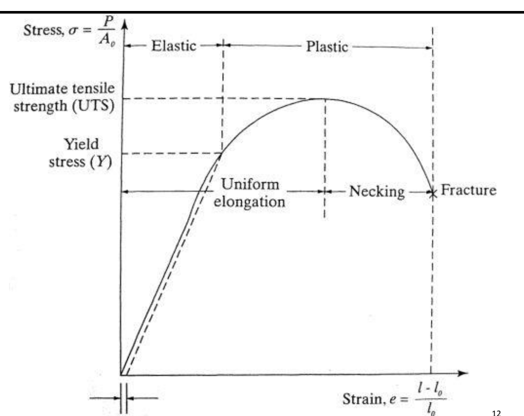
$$\text{Stress} = \frac{F}{A}$$

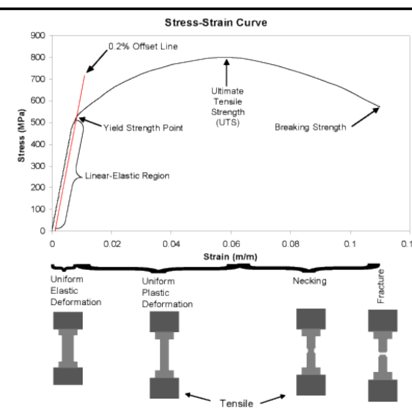
Strain (ε)

- Extension when expressed per unit length is known as strain.

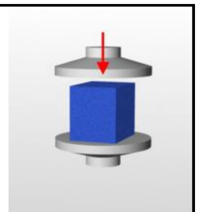


$$\text{Strain} = \frac{e}{l_o}$$

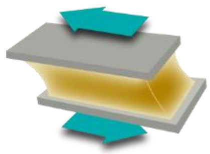




2. Compressive strength
   - Ability to withstand for compressive force can be defined as compressive strength.
   - Found by performing the compression test (for brittle materials)



3. Shear strength
   - Ability to withstand for shear forces can be defined as shear strength.



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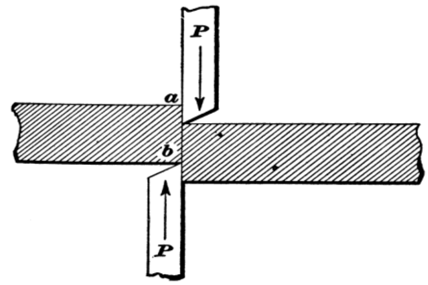
Shear strength



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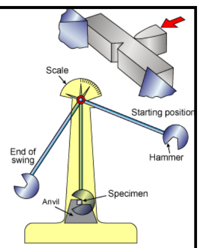
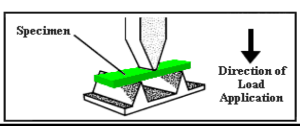
4. Impact strength
   - Ability to withstand for impact load can be defined as impact strength.

   (Charpy impact test)



5. Flexural Strength (Three point bending test)
   - Ability to withstand for bending force can define as flexural strength.



6. Torsional strength
   - Ability to absorb torsion
   - Can measure by performing Torsional test

Elastic deformation

- All material show temporary deformation to a certain extent called elastic deformation.
- Reversible: when the stress is removed, the material returns to the dimension it had before the loading.
- Usually strains are small (except for the case of plastics).
- The property of the materials gives a straight line in the **σ-ε** diagram.
- For linear elastic materials (Hooks Law)

  $\sigma = E\varepsilon$
- E is known as Elastic modulus or Young's modulus

  (E of the steel is 2×10^{11} pa)

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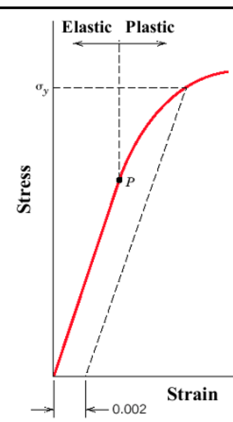

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Plastic deformation

- Irreversible: when the stress is removed, the material does not return to its previous dimension & the deformation become permanent beyond a certain stress level in metals.
- It is known as plastic deformation and the property is known as **plasticity.**
- Plastic deformation begins at the yield point.

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Plastic deformation

- Plastic deformation in metals occurs due to a phenomenon known as <u>Slip</u> (relative displacement of atomic planes)

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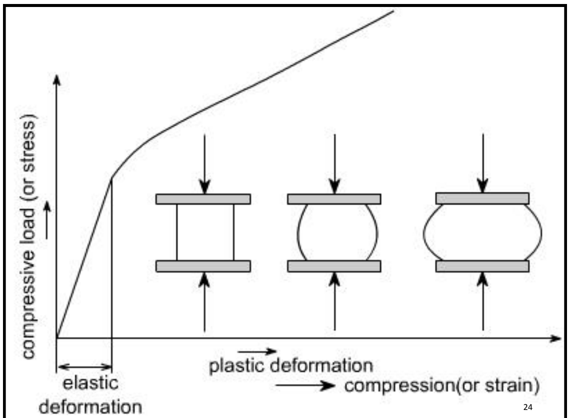

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Ductility

- Ability of a metal to undergo plastic deformation under tensile load is defined as ductility.
- Ductility of copper is greater than that of steel.
- Important property in wire drawing.

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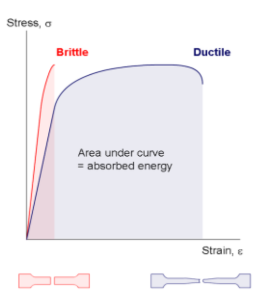
Brittleness

- Brittleness is opposite to ductility.
- Brittleness of steel is greater than that of copper.



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Ductile and Brittle materials

- Ductile materials

  Materials that exhibit plastic deformation.

  Eg: Cu, Al, Iron
- Brittle materials

  Materials that do not have plasticity.

  Eg: Glass, Cast iron

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Ductile – Brittle Transition Temperature

- Whether a material is ductile or brittle depends on the temperature.
- **Ductile** material show **Brittle** behavior as the temperature is lowered.
- This is known as Ductile-Brittle transition.

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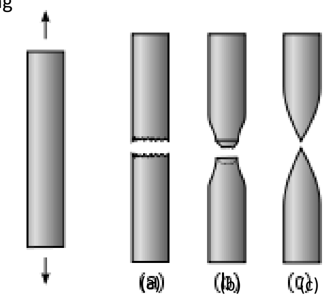
Schematic appearance of round metal bars after tensile testing



(a) Brittle fracture
(b) Ductile fracture
(c) Completely ductile fracture

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Malleability

- Ability of a material undergo plastic deformation in compression.
- A malleable material is preferred in process such as hammering, forging, rolling and rivet heading.

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Toughness

- Work done during the deformation of a material is stored in the form of strain energy.
- Strain energy (energy due to deformation) absorbed by a material up to fracture is defined as toughness.
- Also the toughness can be defined as the work done at fracture.
- Units: the energy per unit volume, e.g. J/m^3

Toughness = energy required to fracture
= area under true stress-strain curve

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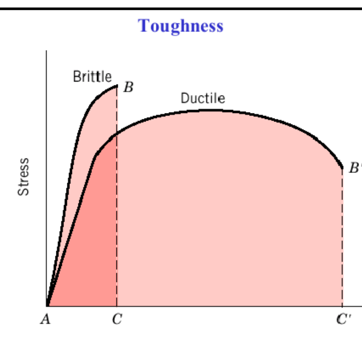

- Area under the **σ-ε** diagram is a measure of toughness

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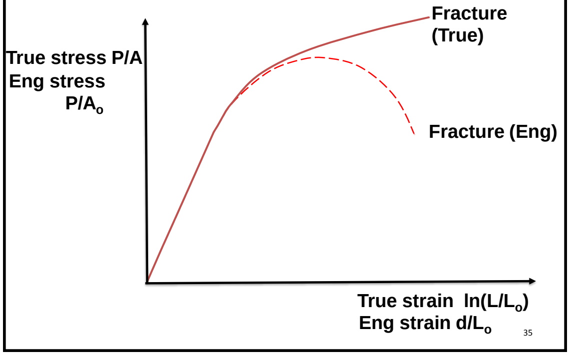
True Stress, True Strain, and Toughness



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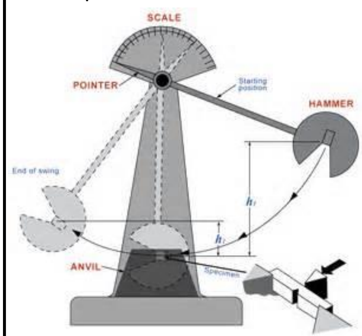
- Impact test is used to measure the toughness



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Fracture Toughness

- Resistance to fracture growth on applied tensile force.

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Resilience

- The capacity of a material to absorb energy when is deform Elastically.

  (It measure the ability of a material to absorb energy without plastic or permanent deformation.)

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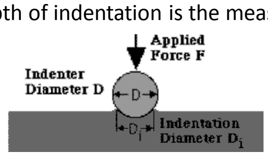
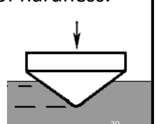
Hardness

- Hardness of metals is defined as the **resistance to indentation** [material's resistance to localized plastic deformation(e.g. dent or scratch)]
- Hardness of metals is measured by indentation test or a qualitative Moh's scale, determined by the ability of a material to scratch another material: from 1 (softest = talc) to 10 (hardest = diamond).
- Depth of indentation is the measure of hardness.





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Hardness

Test	Indenter	Shape of indentation: Side view	Shape of indentation: Top view	Load, P	Hardness number
Brinell	10-mm steel or tungsten carbide ball	D, d	d	500 kg 1500 kg 3000 kg	$HB = \dfrac{2P}{(\pi D)(D - \sqrt{D^2 - d^2})}$
Vickers	Diamond pyramid	136°	L	1–120 kg	$HV = \dfrac{1.854P}{L^2}$
Knoop	Diamond pyramid	$L/b = 7.11$ $b/t = 4.00$ t	b, L	25 g–5 kg	$HK = \dfrac{14.2P}{L^2}$
Rockwell A, C, D	Diamond cone	120° t = mm		60 kg 150 kg 100 kg	HRA, HRC, HRD $= 100 - 500t$
B, F, G	$\frac{1}{16}$- in. diameter steel ball	t = mm		100 kg 60 kg 150 kg	HRB, HRF, HRG $= 130 - 500t$
E	$\frac{1}{8}$- in. diameter steel ball			100 kg	HRE $= 130 - 500t$

[redacted]

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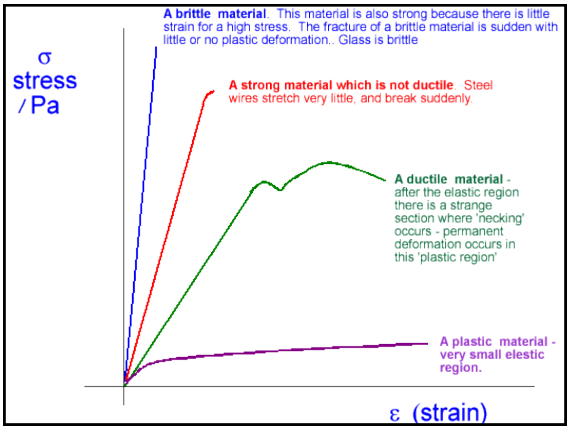

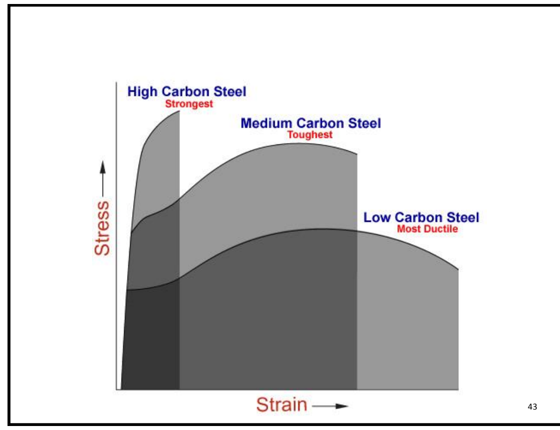

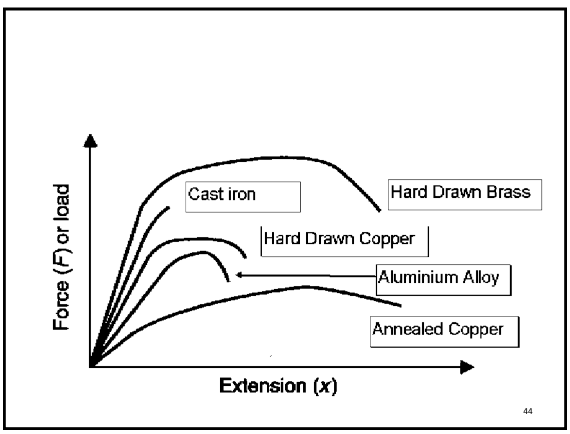

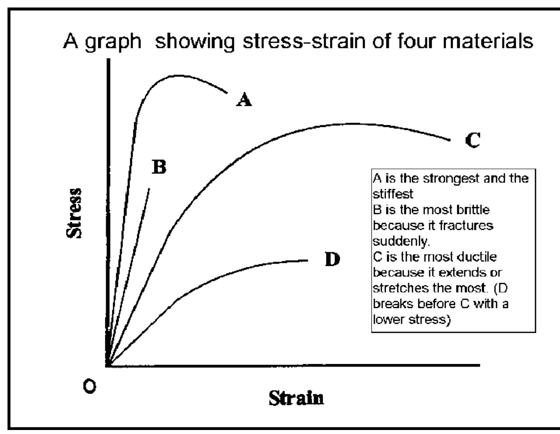

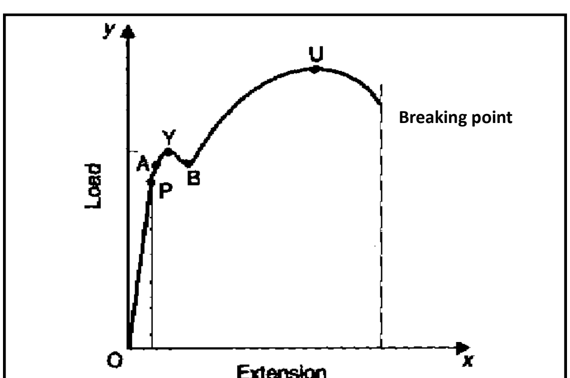

Typical load - extension graph for mild steel.

Important points and regions of stress strain curve for Mild Steel

- **O - P**
  Steel is stretching in direct proportion to the load.
- **O - A**
  Steel will return to its original size if the load is removed. (the elastic stage, A is the elastic limit)
- **A - Y**
  Steel is beginning to change internally.

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➢ **<u>Y</u>**

Y is the yield point. Extension occurs without increasing the load.

➢ **<u>B - U</u>**

Steel is in the plastic stage where extension is much more rapid.

➢ **<u>U</u>**

U is the point where necking occurs and fracture can be occur at any time after this. (Ultimate Tensile Strength)

➢ **<u>Breaking point</u>**

The point where the material breaks in to parts.

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Summary

- Materials have different physical, chemical, electrical & **mechanical** properties
- Knowledge of materials' properties is required to
  - Select appropriate material for design requirement
  - Select appropriate manufacturing process
  - Optimize processing conditions for economic manufacturing

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