



University of Tabuk
College of Engineering
Mechanical Engineering Department

Course Title: Manufacturing Processes

Code/ No MCEN 1308

Chapter 2: Materials and testing In Manufacturing

Contents

Engineering Materials

Mechanical Properties Of Materials

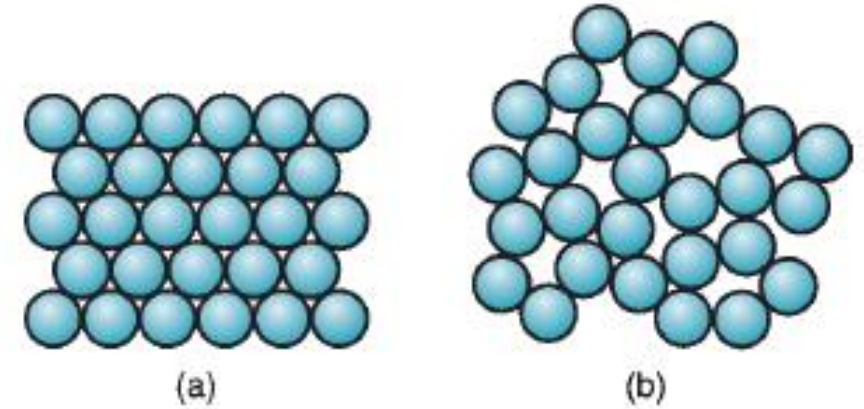
1. Classification of Loads on Materials
2. Stress and Strain
3. Stress-Strain Diagram
4. Material Properties

Non-Destructive Testing (NDT)

Engineering Materials

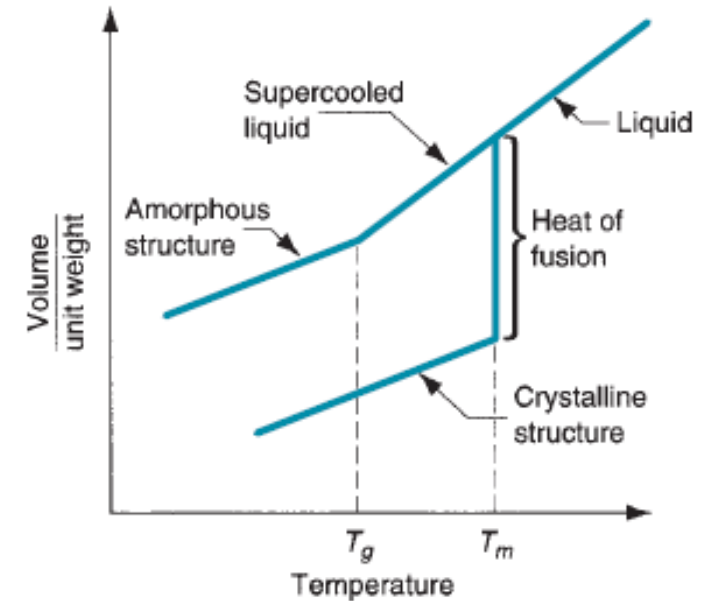
Illustration of difference in structure between:
(a) crystalline and (b) noncrystalline materials.

The crystal structure is regular, repeating, and denser, whereas the noncrystalline structure is more loosely packed and random.



Characteristic change in volume for a pure metal (a crystalline structure), compared to the same volumetric changes in glass (a noncrystalline structure).

Specific volume



The melting temperature T_m

The glass-transition temperature T_g

Types Of Crystal Structures

In metals, three lattice structures are common:

- (1) body-centered cubic (BCC),
- (2) Face centered cubic (FCC), and
- (3) hexagonal close-packed (HCP), illustrated in Figure below

Crystal structures for the common metals are presented in Table 2.1.

Note that some metals undergo a change of structure at different temperatures. **Iron**, for example, is **BCC** at room temperature; it changes to **FCC** **above 912°C** (1674F) and **back** to **BCC** at temperatures **above 1400°C** (2550F).

When a metal (or other material) changes structure like this, it is referred to as being **allotropic**.

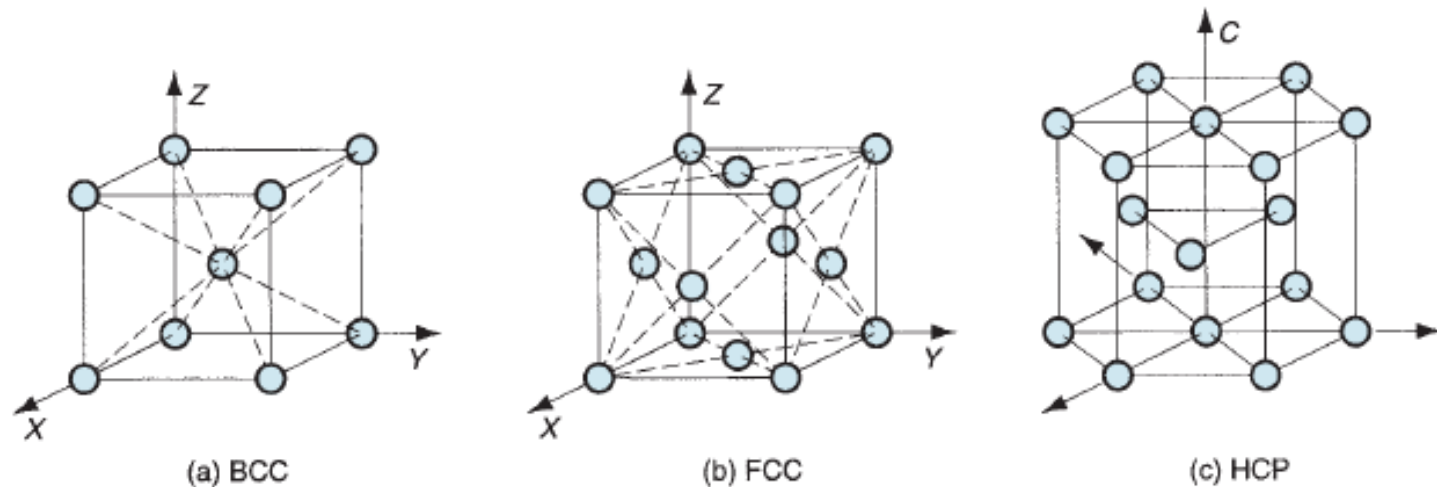


TABLE 2.1 Crystal structures for the common metals (at room temperature).

Body-Centered Cubic (BCC)	Face-Centered Cubic (FCC)	Hexagonal Close-Packed (HCP)
Chromium (Cr) Iron (Fe) Molybdenum (Mo) Tantalum (Ta) Tungsten (W)	Aluminum (Al) Copper (Cu) Gold (Au) Lead (Pb) Silver (Ag) Nickel (Ni)	Magnesium (Mg) Titanium (Ti) Zinc (Zn)

Imperfections In Crystals

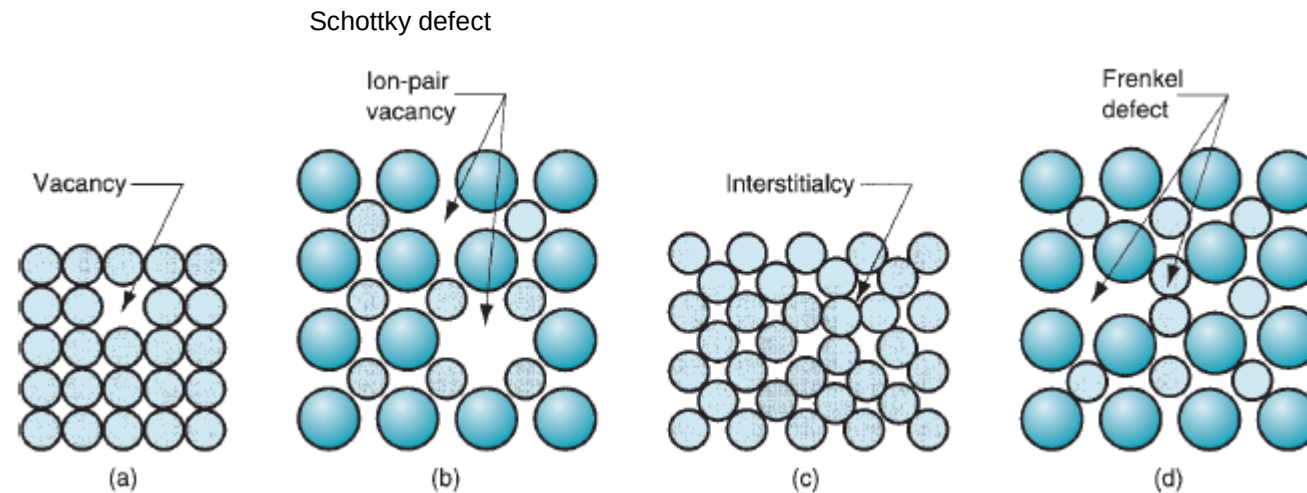


Figure: **Point** defects

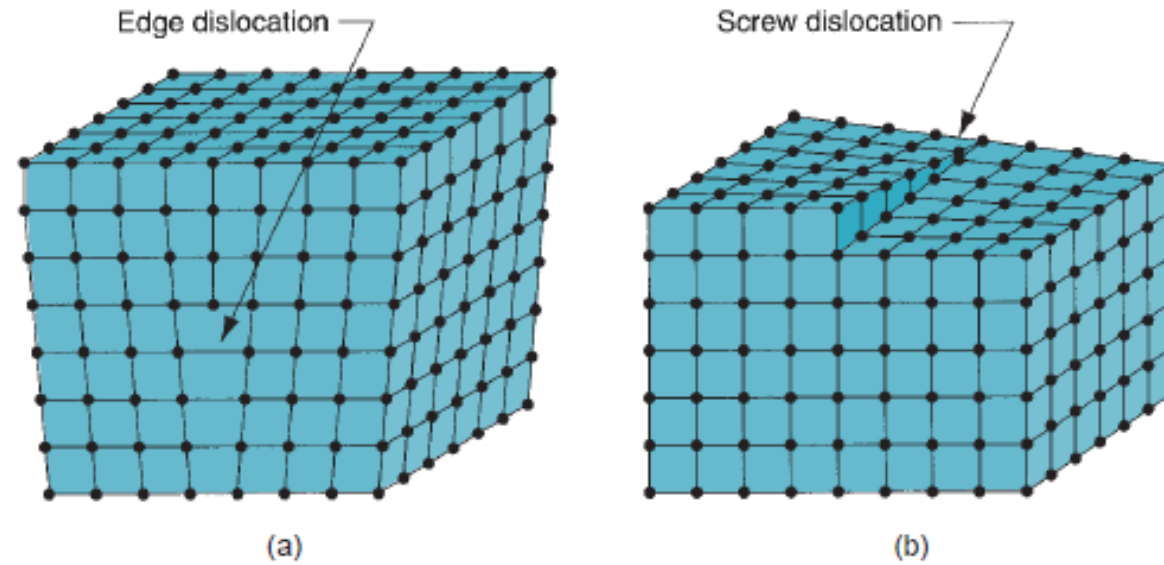
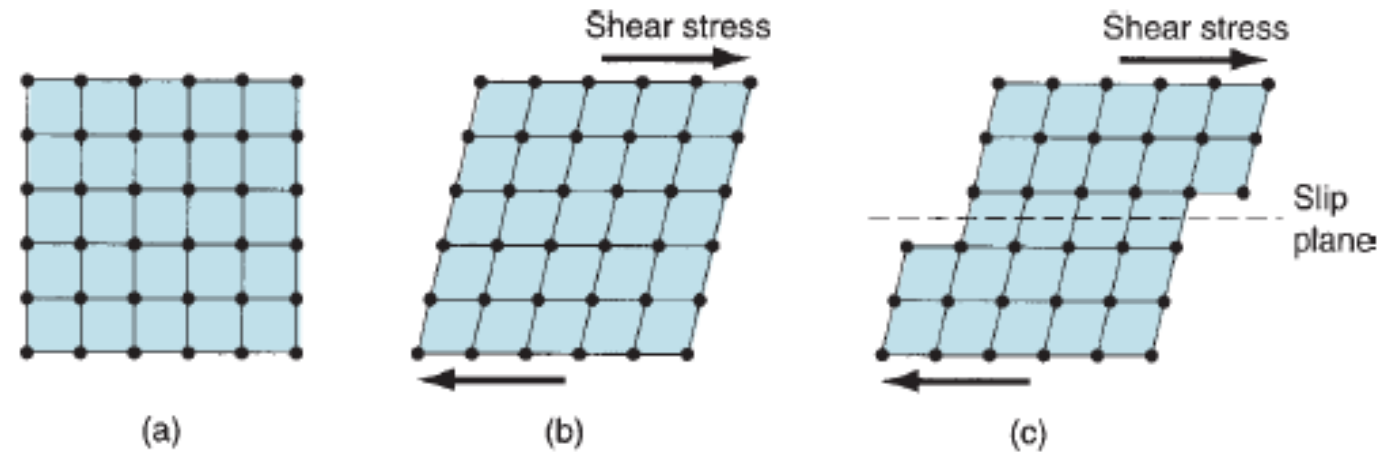


Figure : **Line defects:** (a) edge dislocation and (b) screw dislocation.

Deformation In Metallic Crystals

Figure : Deformation of a crystal structure:

- (a) original lattice;
- (b) elastic deformation, with no permanent change in positions of atoms; And
- (c) plastic deformation, in which atoms in the lattice are forced to move to new “homes.”



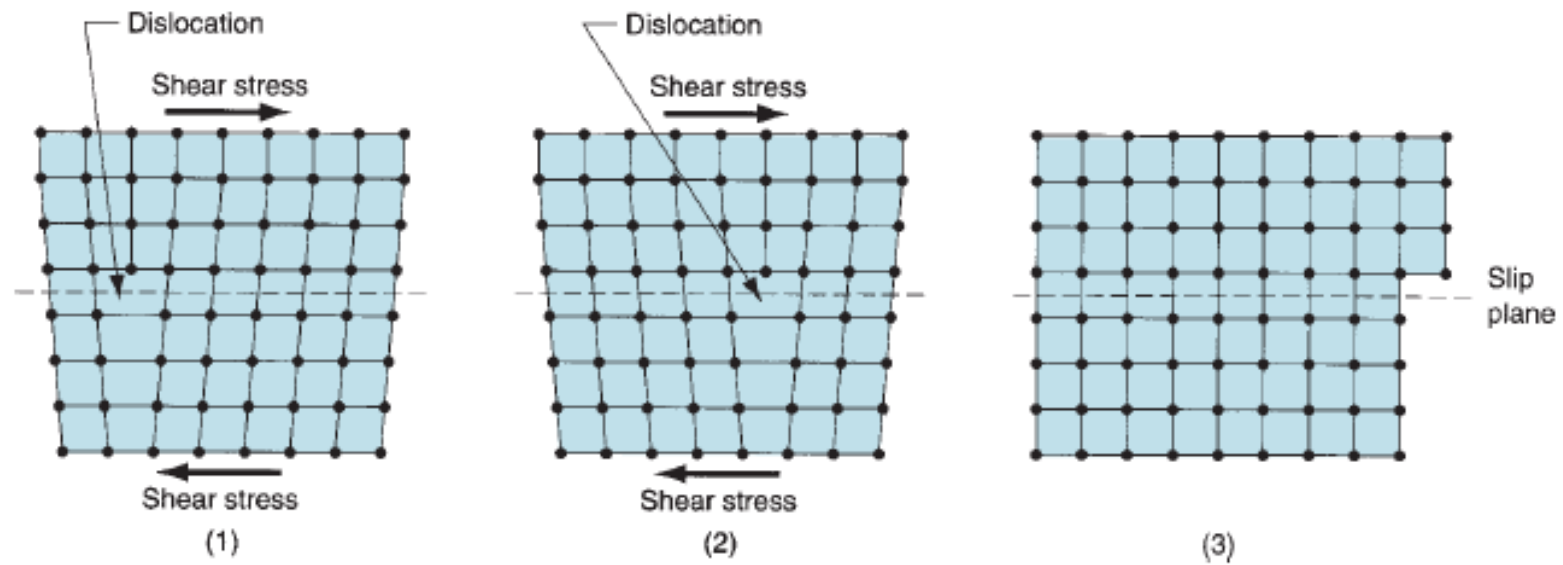
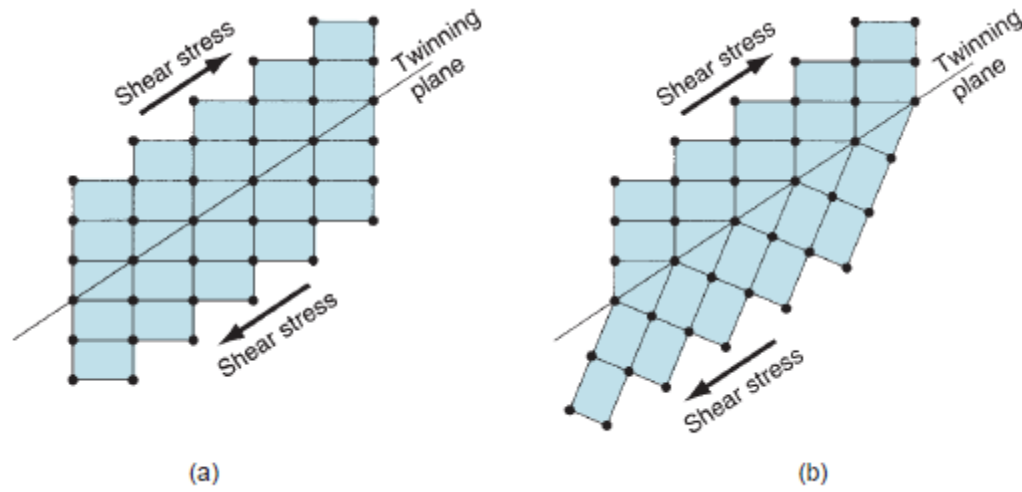


Figure: Effect of dislocations in the lattice structure under stress. In the series of diagrams, the movement of the dislocation allows deformation to occur under a lower stress than in a perfect lattice.



Twinning is a Mechanism of plastic deformation,
Occurs at high deformation rates,
Occurs more likely in metals with HCP structure

Figure :Twining involves the formation of an **atomic mirror** image (i.e., a “twin”) on the opposite side of the twinning plane: (a) before, and (b) after twinning.

Questions in Engineering Materials

1- The basic structural unit of matter is which one of the following:

(a) atom, (b) electron, (c) element,
(d) molecule, or (e) nucleus?

2- In the Periodic Table, the elements can be divided into which of the following categories (three best answers):

(a) ceramics, (b) gases, (c) liquids,
(d) metals, (e) non-metals, (f) polymers, (g) semimetals,
and (h) solids?

3- The element with the lowest density and smallest atomic weight is which one of the following:

(a) aluminum, (b) argon, (c) helium, (d) hydrogen, or (e) magnesium?

4- Which of the following bond types are classified as primary bonds (three correct answers):

(a) Covalent bonding, (b) hydrogen bonding, (c) ionic bonding,
(d) metallic bonding, and (e) van der Waals forces?

5- How many atoms are there in the face-centered cubic (FCC) unit cell (one correct answer):

(a) 8, (b) 9, (c) 10, (d) 2, or (e) 4?

6- Which of the following **are not point defects** in a crystal lattice structure (three correct answers):

(a) edge dislocation, (b) grain boundaries, (c) interstitialcy,
(d) Schottky defect, (e) screw dislocation, or (f) vacancy?

7- Which one of the following crystal structures has the fewest slip directions, thus making the metals with this structure generally more difficult to deform at room temperature:

(a) BCC, (b) FCC, or (c) HCP?

8- Grain boundaries are an example of which one of the following types of crystal structure defects:

(a) dislocation, (b) Frenkel defect, (c) line defects, (d) point defects, or (e) surface defects?

9- Twinning is which of the following (three best answers):

(a) elastic deformation, (b) mechanism of plastic deformation, (c) more likely at high deformation rates, (d) more likely in metals with HCP structure, (e) slip mechanism, and (f) type of dislocation?

10- Polymers are characterized by which of the following bonding types (two correct answers):

(a) adhesive, (b) covalent, (c) hydrogen, (d) ionic, (e) metallic, and (f) van der Waals?

11- How do grain boundaries contribute to the strain hardening phenomenon in metals?

12- Identify some materials that have a crystalline structure?

13- Identify some materials that have a noncrystalline structure?

14- What is the basic difference in the solidification (or melting) process between crystalline and noncrystalline structures?

11- How do grain boundaries contribute to the strain hardening phenomenon in metals?

Grain boundaries block the continued movement of dislocations in the metal during straining. As more dislocations become blocked, the metal becomes more difficult to deform; in effect it becomes stronger.

12- Identify some materials (three) that have a crystalline structure.

Chromium, Aluminum, Titanium

BCC: Iron, Chromium, Molybdenum, Tantalum, Tungsten

FCC: Aluminum, Copper, Gold, Lead, Silver, Nickel

HCP: Magnesium, Titanium, Zinc

13- Identify some materials (three) that have a noncrystalline structure.

Glass, rubber and certain plastics (PP, PE, PTE, PVC...)

14- What is the basic difference in the solidification (or melting) process between crystalline and non-crystalline structures?

crystalline materials melt at a definite temperature and have a fixed heat of fusion because of its regular pattern of structure, non-crystalline materials, on the other hand, do not have a fixed melting temperature and heat of fusion since their structure composed of non-regular pattern

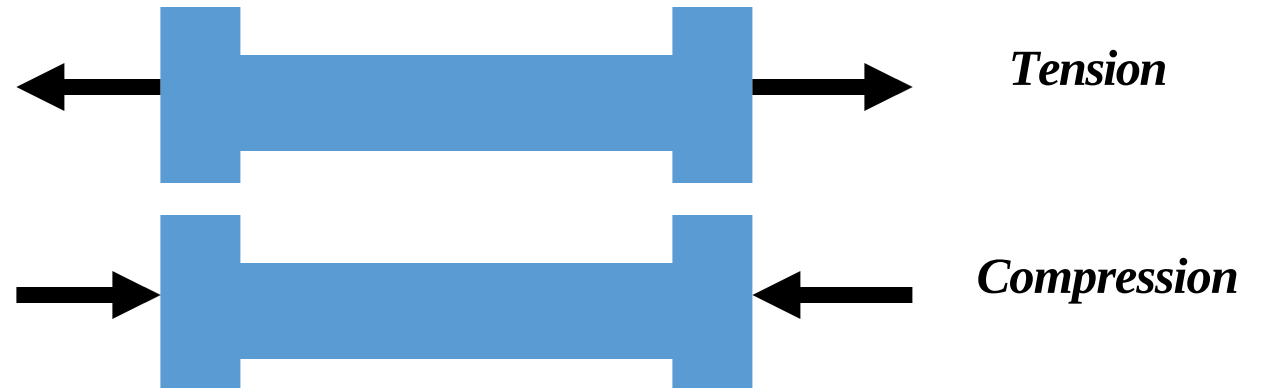
Mechanical Properties Of Materials

1. Classifying Loads on Materials

- **Tension Load:** As the ends of material are pulled apart to make the material longer, the load is called a tension load.

- **Compression Load:** As the ends of material are pushed in to make the material smaller, the load is called a compression load.

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



The *engineering strain* at any point in the test is given by

$$e = \frac{L - L_o}{L_o}$$

$$EL = \frac{L_f - L_o}{L_o}$$

where EL = elongation, often expressed as a percent; L_f = specimen length at fracture,

$$AR = \frac{A_o - A_f}{A_o}$$

where AR = area reduction, often expressed as a percent; A_f = area of the cross section at the point of fracture, mm²(in²); and A_o = original area, mm² (in²).

As strain becomes significant in the plastic region, the values of true strain and engineering strain diverge. True strain can be related to the corresponding engineering strain by

$$\epsilon = \ln(1 + e)$$

Similarly, true stress and engineering stress can be related by the expression

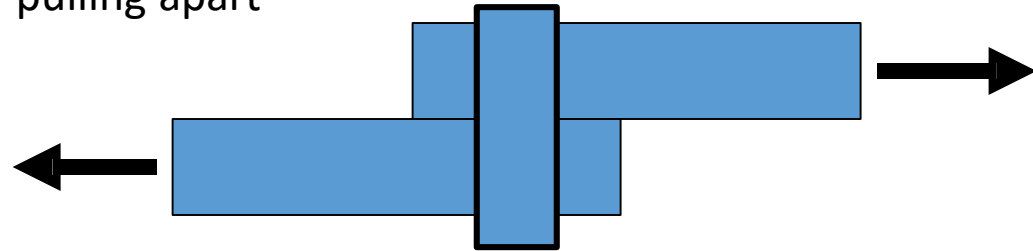
$$\sigma = s(1 + e) \qquad e = \frac{L - L_o}{L_o}$$

P = load	P = load
A_o = initial cross-sectional area	A_i = instantaneous cross-sectional area
Engineering Stress = $s = P/A_o$	True Stress = $\sigma = P/A_i$
l_o = initial length of gauge section	l_i = instantaneous gauge length
l = length of deformed gauge section	l_o = initial length of gauge section
$\Delta l = l - l_o$ = change of length of gauge section	
Engineering Strain = $e = (l - l_o)/l_o = \Delta l/l_o$	True Strain = $\epsilon = \ln (A_o/A_i) = \ln (l_i/l_o)$
Converting Engineering Stress to True Stress:	$\sigma = s (1+e)$
Converting Engineering Strain to True Strain:	$\epsilon = \ln (1+e)$

Classifying Loads on Materials

- **Shear Load : Tangential load**

pulling apart

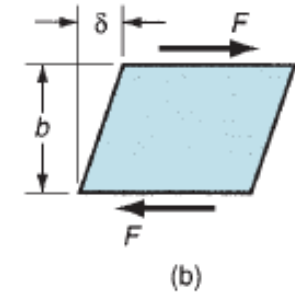
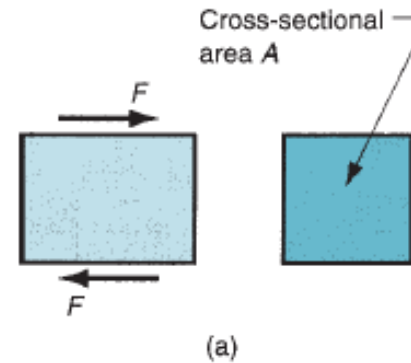
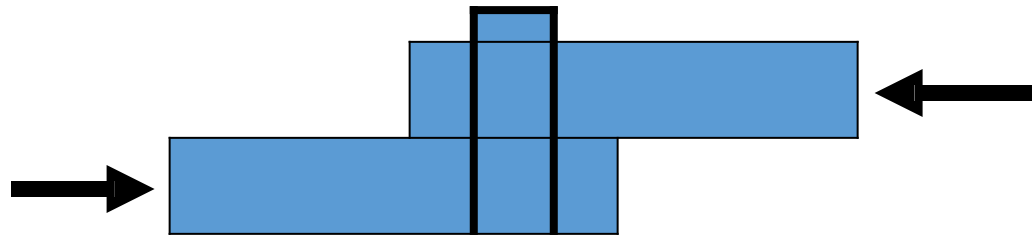


The shear stress is defined as

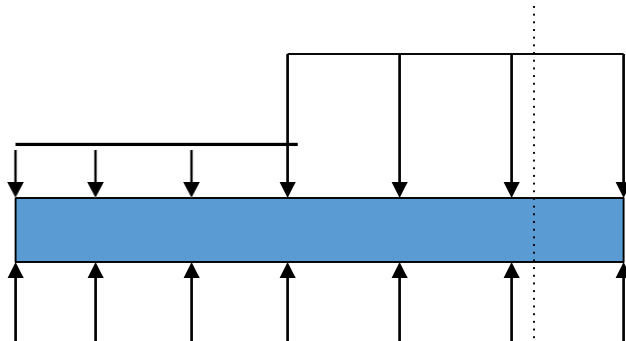
$$\tau = \frac{F}{A}$$

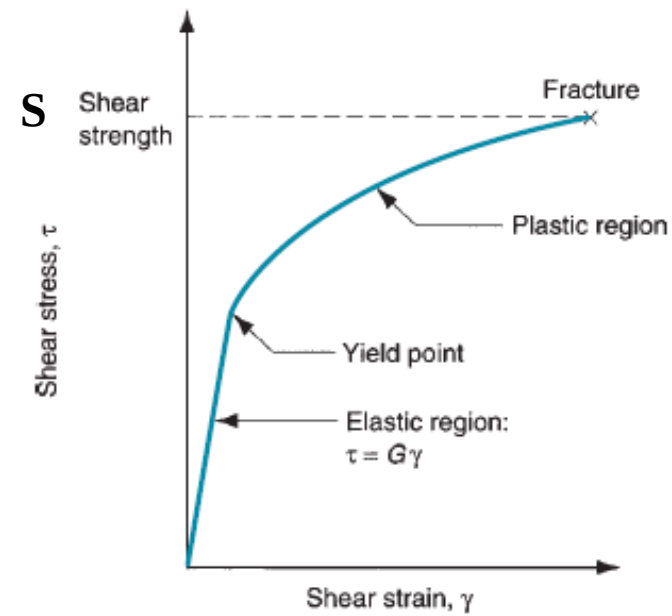
Shear strain can be defined as

$$\gamma = \frac{\delta}{b}$$



Pressure





Typical shear stress– strain curve from a torsion test.

$$\tau = G\gamma$$

Where G : the shear modulus, or **shear modulus of elasticity**, MPa (lb/in²).
 For most materials, the shear modulus can be approximated by: $G = 0.4 \cdot E$
 where E is the conventional elastic modulus.

The shear strength S of the material

Shear strength can be estimated from tensile strength data by the approximation: $S = 0.7(TS)$

Bending Loads:

Beam Bending Stress Formula

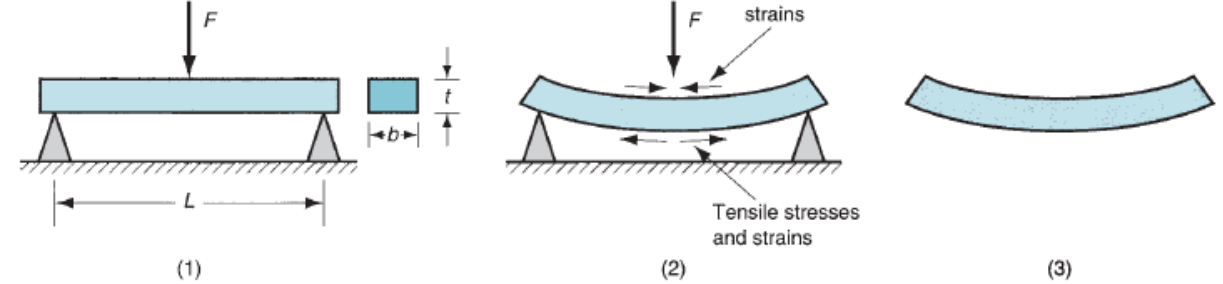
$$\sigma = \frac{My}{I_x}$$

σ – bending stress in N/m^2

M – moment of neutral axis Nm

y – perpendicular distance to neutral axis in m

I_x – second moment area of neutral axis in m^4



The shear stress is defined as

$$\tau = \frac{F}{A}$$

Shear strain can be defined as

$$\gamma = \frac{\delta}{b}$$

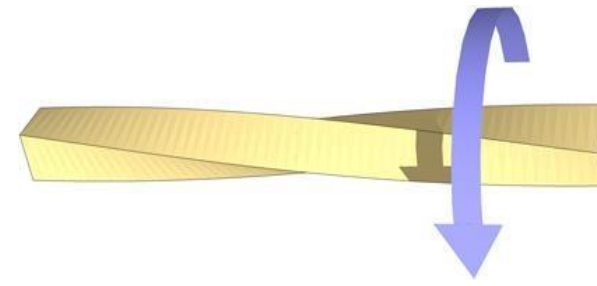
where γ = shear strain, mm/mm (in/in); δ = the deflection of the element, mm (in); and b = the orthogonal distance over which deflection occurs, mm (in).

The transverse rupture strength, calculated from the formula

$$TRS = \frac{1.5 FL}{bt^2}$$

where TRS = transverse rupture strength, MPa (lb/in²); F = applied load at fracture, N (lb); L = length of the specimen between supports, mm (in); and b and t are the dimensions of the cross section of the specimen as shown in the figure, mm (in).

- **Torsion Loads:** Angular distortion on a component, such as a shaft, when a moment is applied. (Twisting)



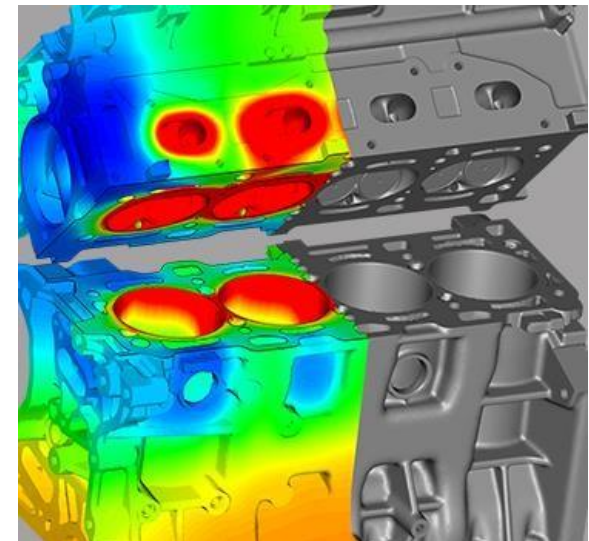
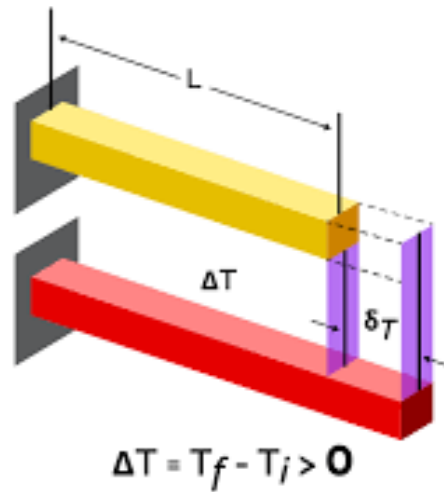
The shear stress can be determined in the in a torsion test by the equation

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G \times \theta}{L}$$

where:

- T = torque or twisting moment, [N×m, lb×in]
- J = polar moment of inertia or polar second moment of area about shaft axis, [m⁴, in⁴]
- τ = shear stress at outer fibre, [Pa, psi]
- r = radius of the shaft, [m, in]
- G = modulus of rigidity
- θ = angle of twist, [rad]
- L = length of the shaft, [m, in]

- **Thermal Loads:** Distortion caused by heating or cooling a material. A normal load is created when the material is constrained in any direction in the plane that is constrained.



2. Stress and Strain

In order to compare materials, we must have measures.

- Stress : load per unit Area

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

F : load applied in Newton
A : cross sectional area in m²

σ : stress in Pa

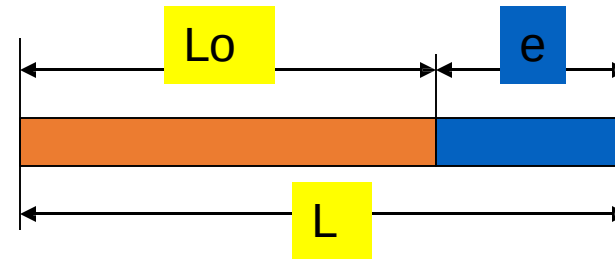


Stress and Strain

- **Strain:**

- Ratio of elongation of a material to the original length
- unit deformation

$$\epsilon = \frac{e}{L_o}$$



e : elongation (mm)

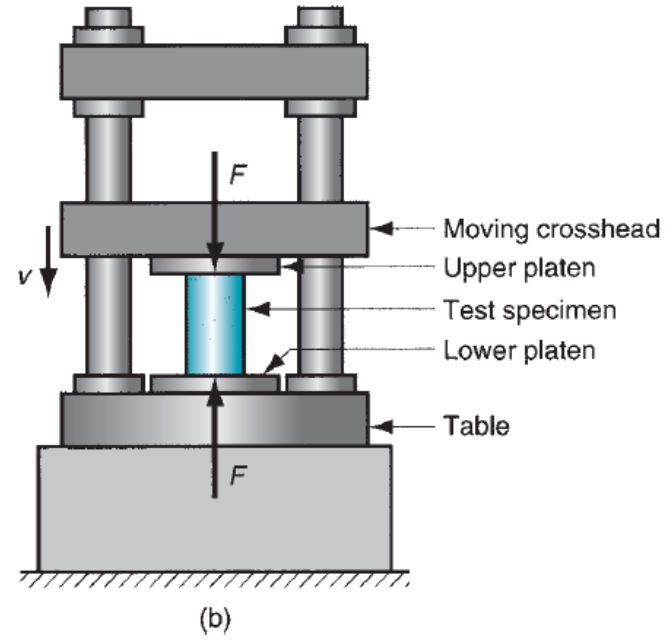
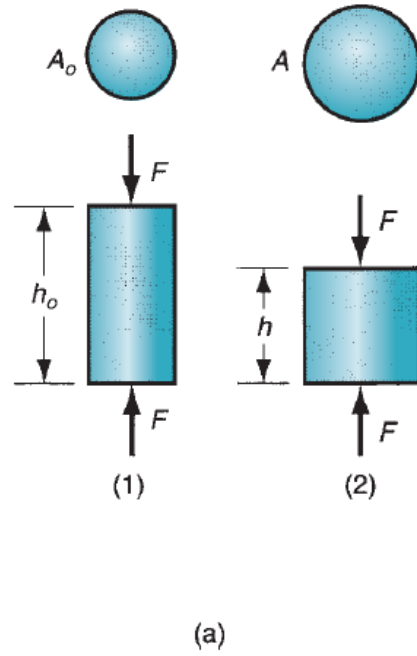
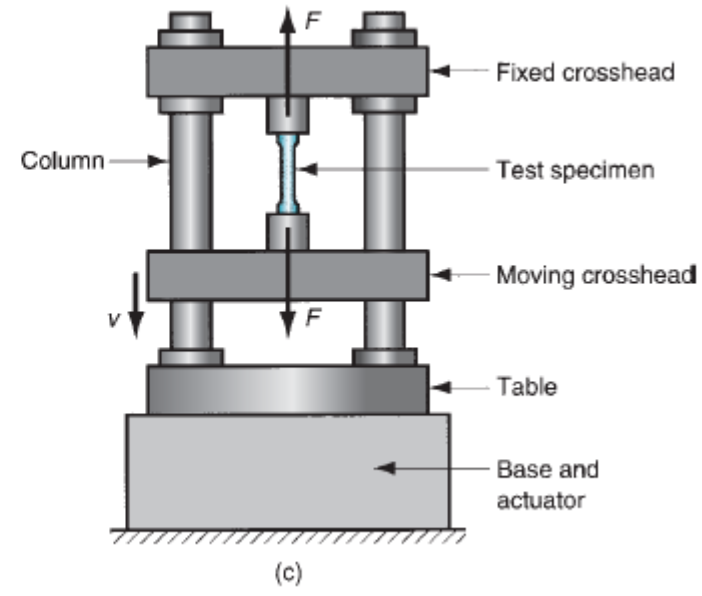
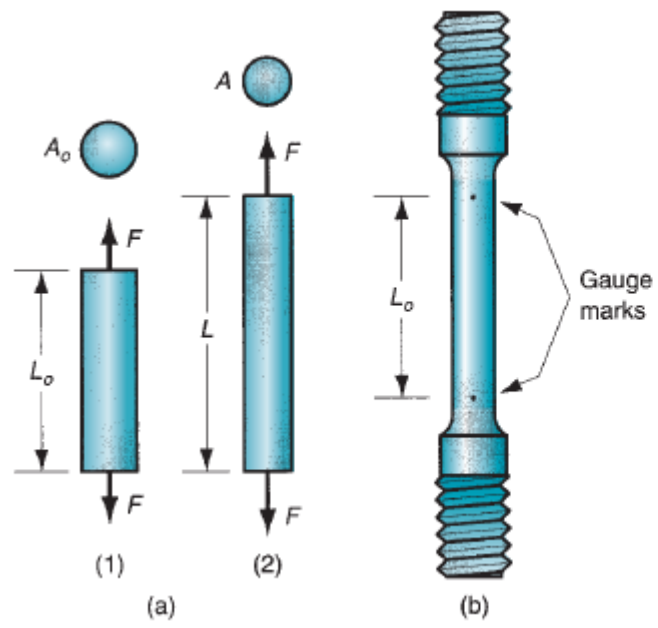
L_o : unloaded(original) length of a material (mm)

ϵ : strain (mm/mm) or (in/in)

Elongation:

$$e = L - L_o$$

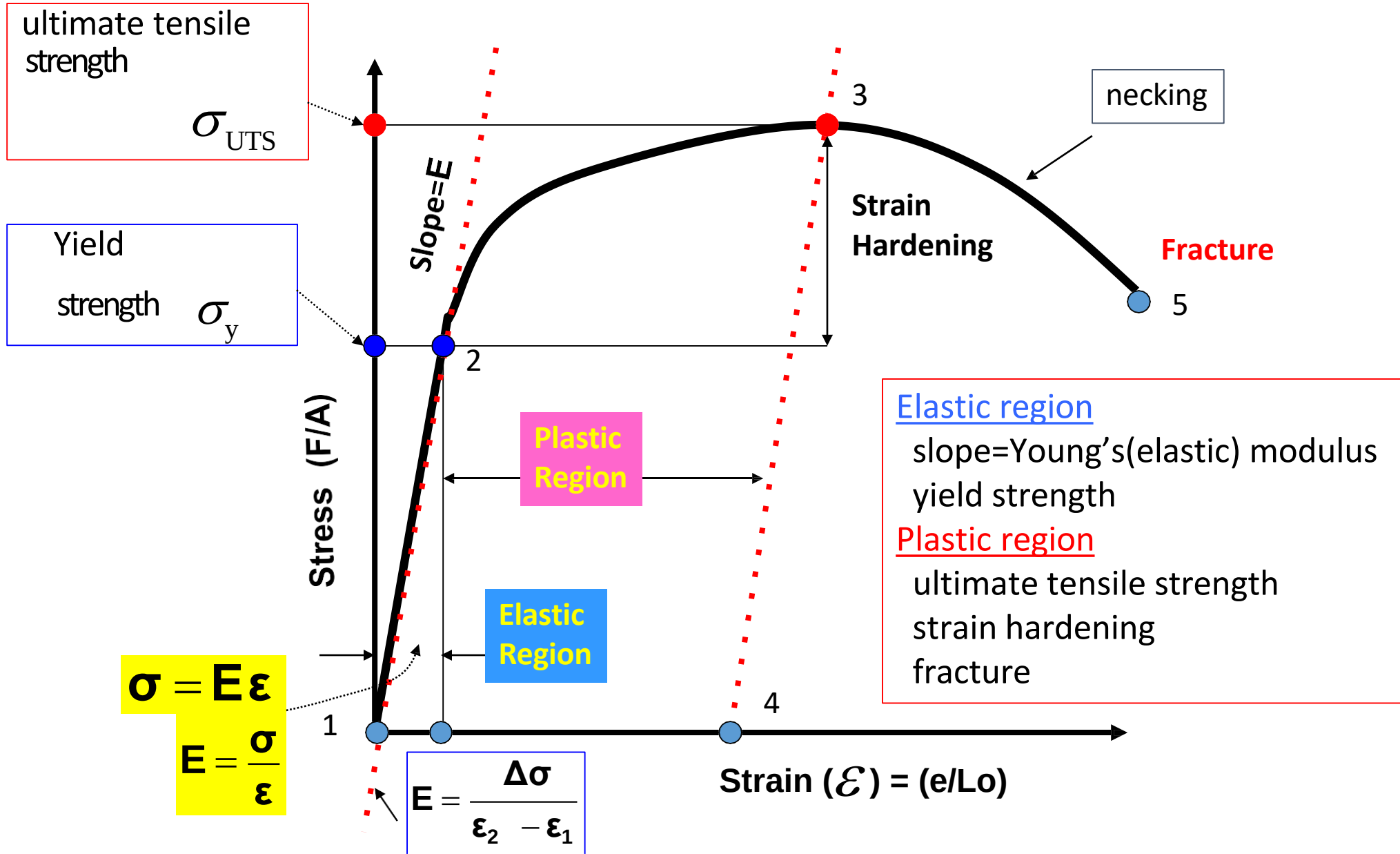
L : loaded length of a material (mm)



3. Stress-Strain Diagram

- A plot of Strain vs. Stress.
- The diagram gives us the behavior of the material and material properties.
- Each material produces a different stress-strain diagram.

Stress-Strain Diagram

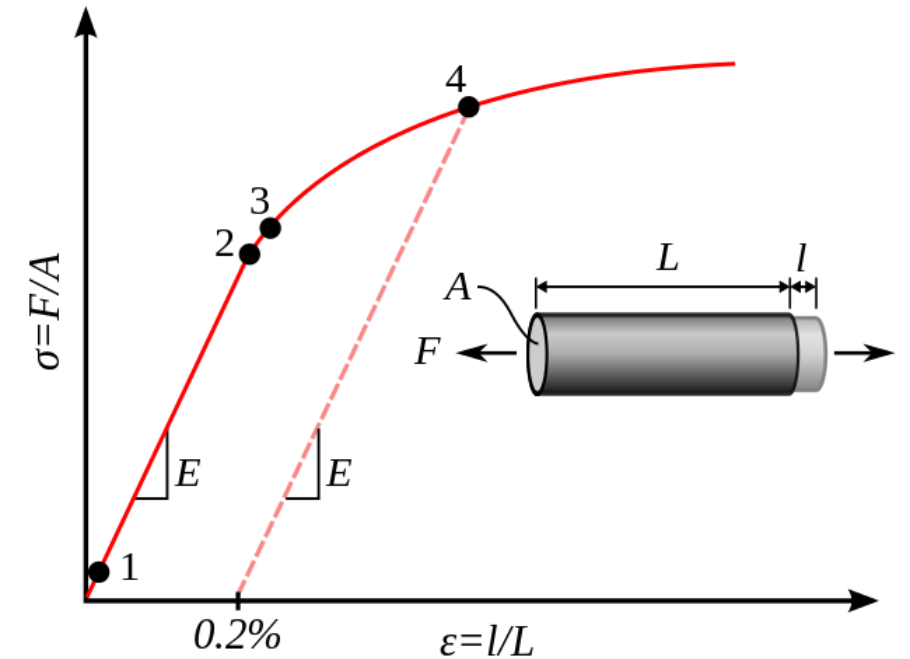
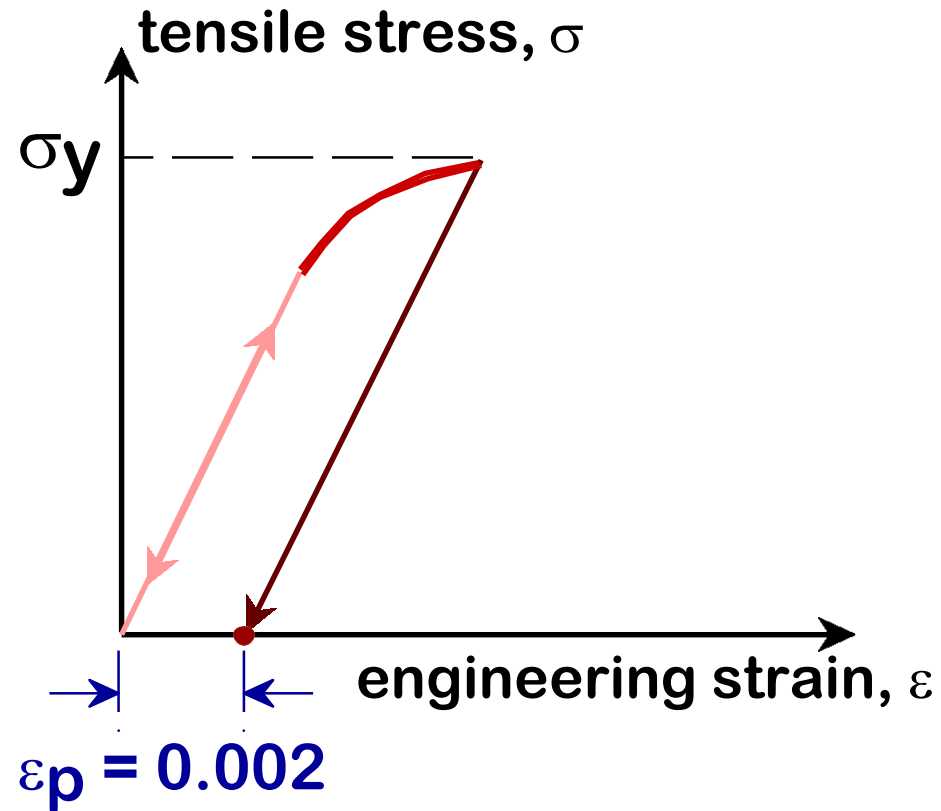


Yield strength, σ_y

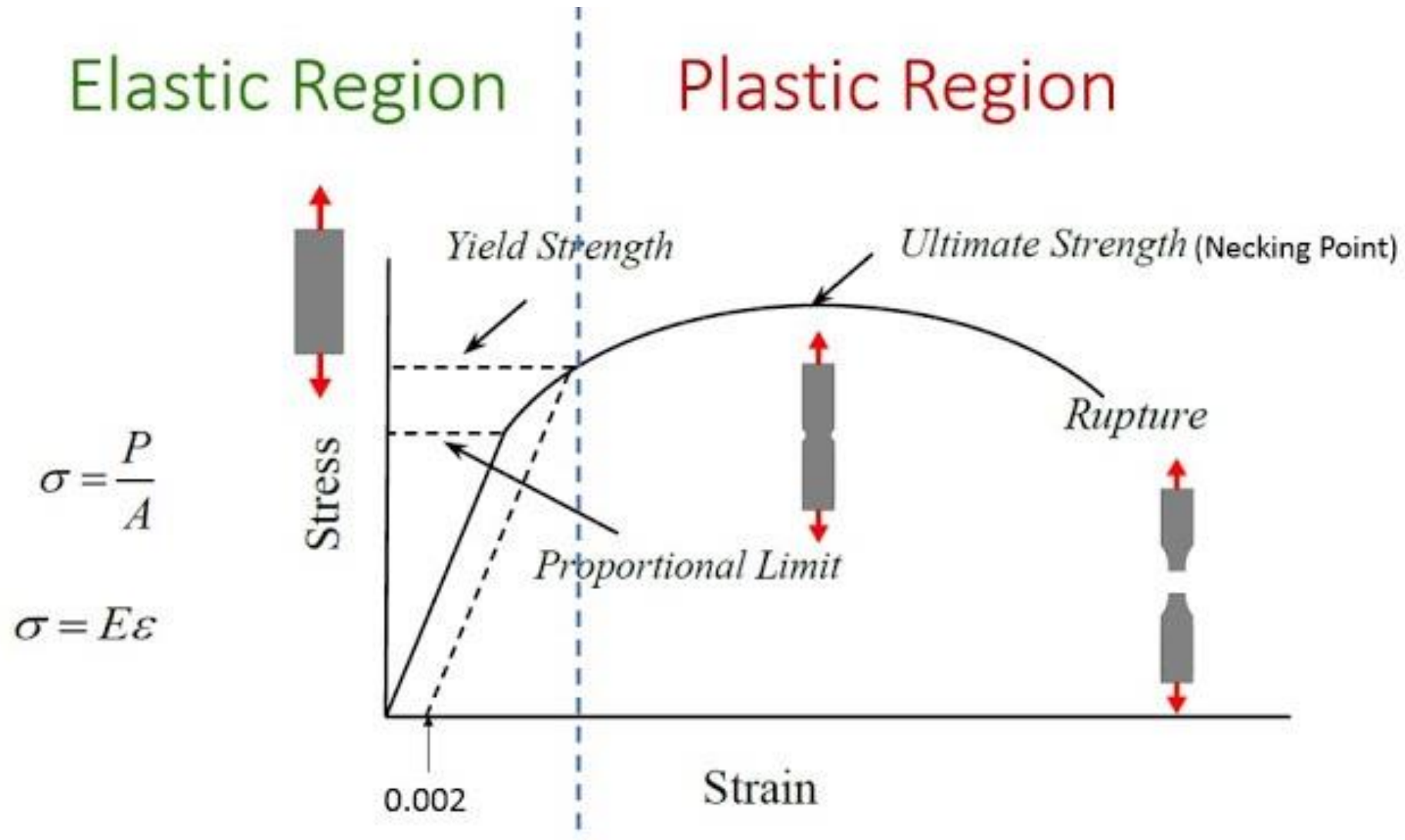
when $\varepsilon_p = 0.002$

- Stress at which *noticeable* plastic deformation has occurred.

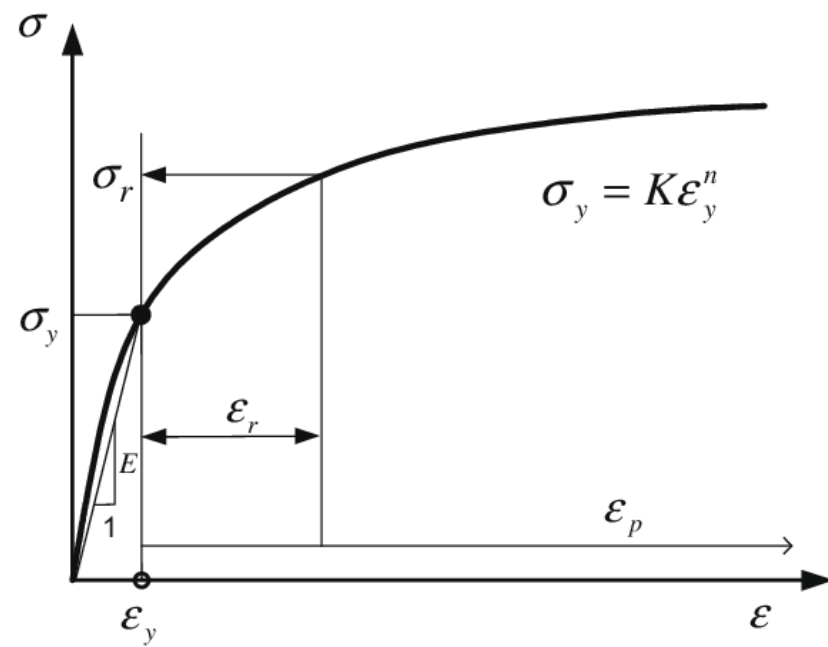
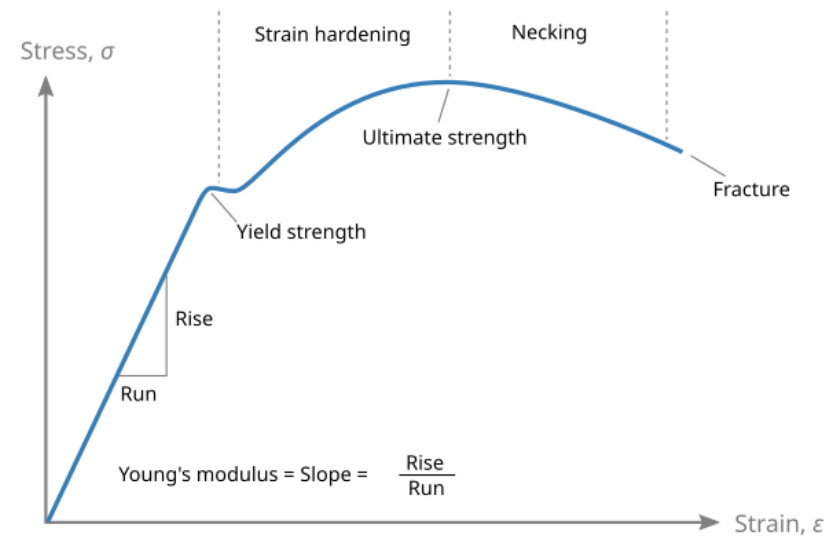
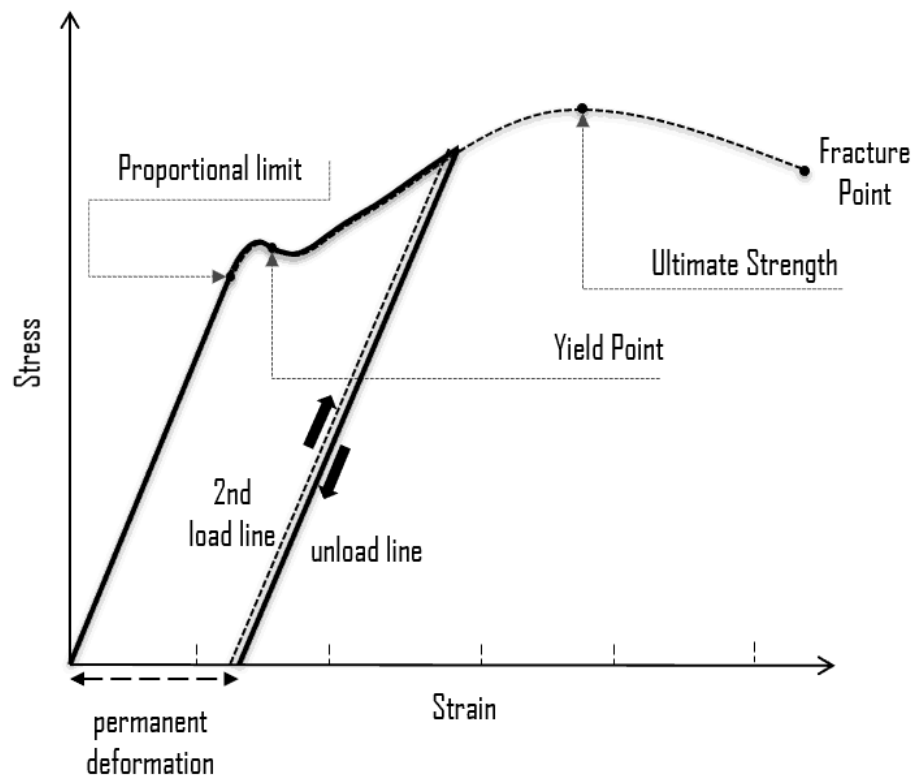
when $\varepsilon_p = 0.002$



Stress-Strain Diagram



Ductile Material Stress-Strain Curve
low carbon steel



Material	Young's Modulus (GPa)
Aluminum	69
Cobalt	207
Concrete	17
Copper	117
Diamond	1220
Glass	50-90
Gold	74
Iron	210
Lead	14
Magnesium	45
Molybdenum	329
Nickel	170
Niobium	103
Platinum	147
Low-density Polyethylene (LDPE)	0.1 – 0.45
Polyvinyl chloride (PVC)	2.4 – 4.1
Rubber	0.01-0.1
Silicon carbide (SiC)	450
Silver	72
Tin	47
Tungsten	400
Titanium Alloy	105 - 120
Steel, Structural ASTM-A36	200

Example

Question: The stress-strain diagram for the aluminum ($E = 70 \text{ GPa}$) rod of top figure is shown in the bottom figure. Determine the following quantities:

- (a) The yield stress of the material. Use the 0.2% offset method and show your work in the figure.

$$\sigma_Y \approx 280 \text{ MPa}$$

- (b) The stresses in segments AB and BC of the rod.

$$\sigma_{AB} = \frac{P}{\pi * r_{AB}^2} = 122 \text{ MPa}$$

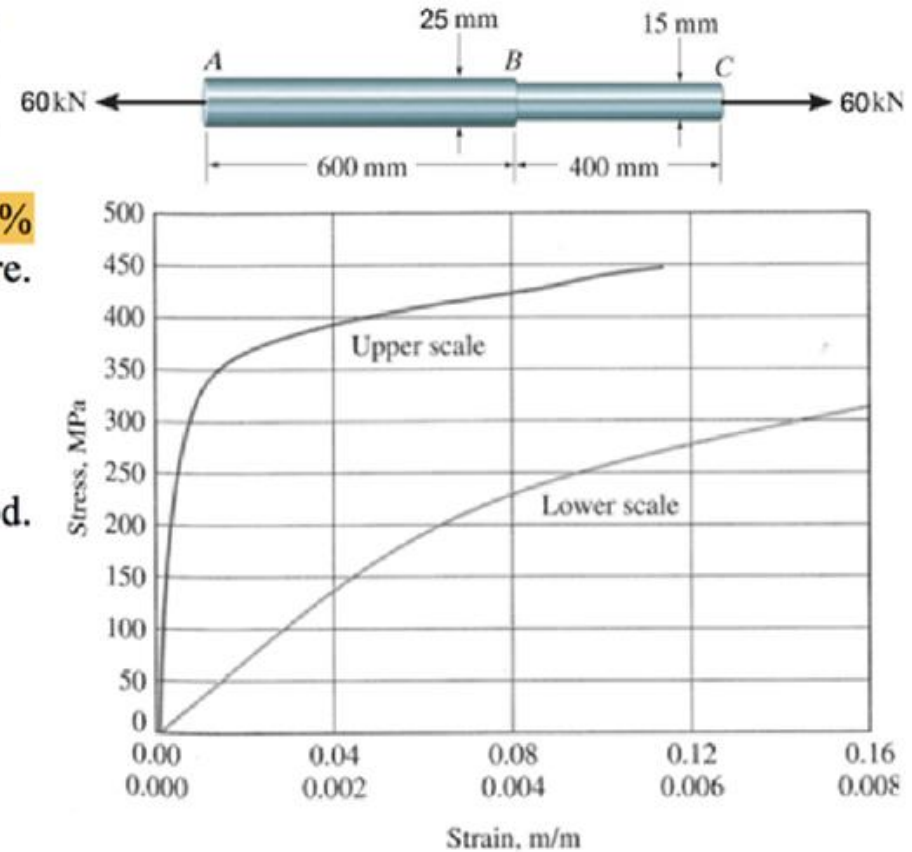
$$\sigma_{BC} = \frac{P}{\pi * r_{BC}^2} = 340 \text{ MPa}$$

- (c) The strains in segments AB and BC of the rod.

$$\epsilon_{AB} = \frac{\sigma_{AB}}{E} = 0.00175$$

stress over elastic

(Reading from the graph) $\epsilon_{BC} \approx 0.015$



4. Material Properties

Characteristics of Material are described as

- Strength**
- Hardness**
- Ductility**
- Brittleness**
- Toughness**

Strength:

- **Measure of the material property to resist deformation and to maintain its shape**
- **It is quantified in terms of yield stress σ_y or ultimate tensile strength σ_{ult} .**
- **High carbon steels and metal alloys have higher strength than pure metals.**
- **Ceramic also exhibit high strength characteristics.**

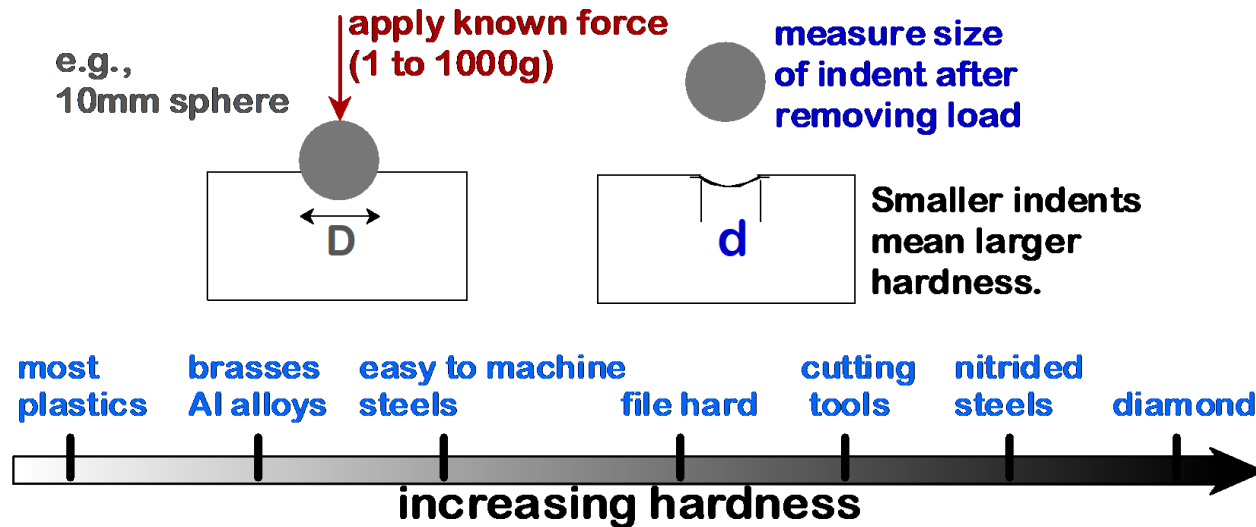
Material Properties

Hardness:

- Measure of the material property to resist indentation, abrasion and wear.
 - It is quantified by hardness scale such as Rockwell, Vickers and Brinell hardness scale that measure indentation / penetration under a load.
 - Hardness and Strength correlate well because both properties are related to inter-molecular bonding.
- A high-strength material is typically resistant to wear and abrasion.

Hardness

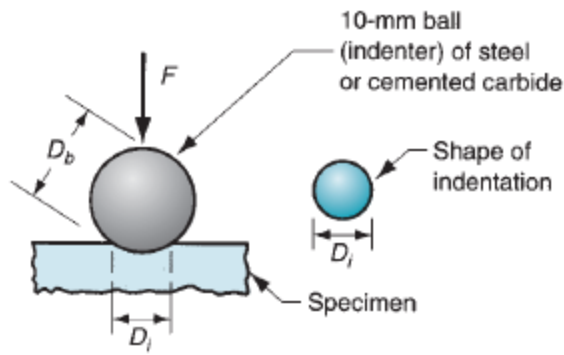
- Resistance to permanently indenting the surface.
- Large hardness means:
 - resistance to plastic deformation or cracking in compression.
 - better wear properties.



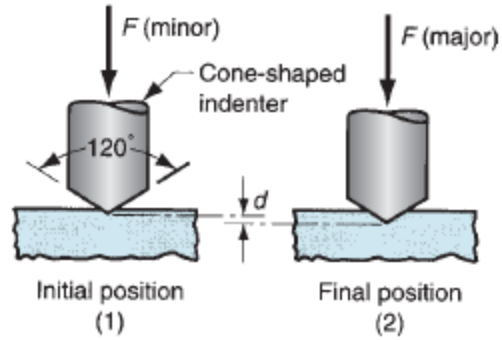
$$HB = \frac{2F}{\pi D_b \left(D_b - \sqrt{D_b^2 - D_i^2} \right)}$$

where HB : Brinell Hardness Number (BHN); F : indentation load, kg;
D_b : diameter of the ball, mm;
and D_i : diameter of the indentation on the surface, mm.

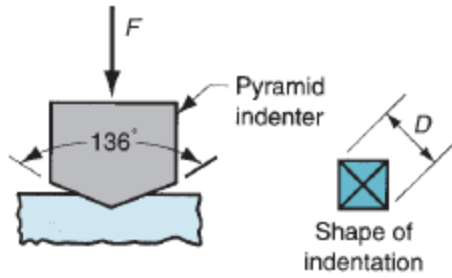
Adapted from Fig. 6.18, *Callister 6e*. (Fig. 6.18 is adapted from G.F. Kinney, *Engineering Properties and Applications of Plastics*, p. 202, John Wiley and Sons, 1957.)



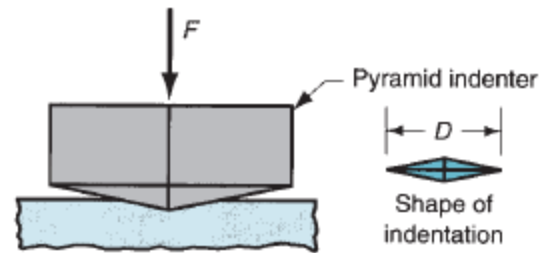
(a) Brinell



(b) Rockwell



(c) Vickers



(d) Knoop

TABLE 3.5 Common Rockwell hardness scales.

Rockwell Scale	Hardness Symbol	Indenter	Load (kg)	Typical Materials Tested
A	HRA	Cone	60	Carbides, ceramics
B	HRB	1.6 mm ball	100	Nonferrous metals
C	HRC	Cone	150	Ferrous metals, tool steels

$$TS = K_h(HB)$$

where K_h is a constant of proportionality. If TS is expressed in MPa, then $K_h = 3.45$; and if TS is in lb/in^2 , then $K_h = 500$.

$$HV = \frac{1.854 F}{D^2}$$

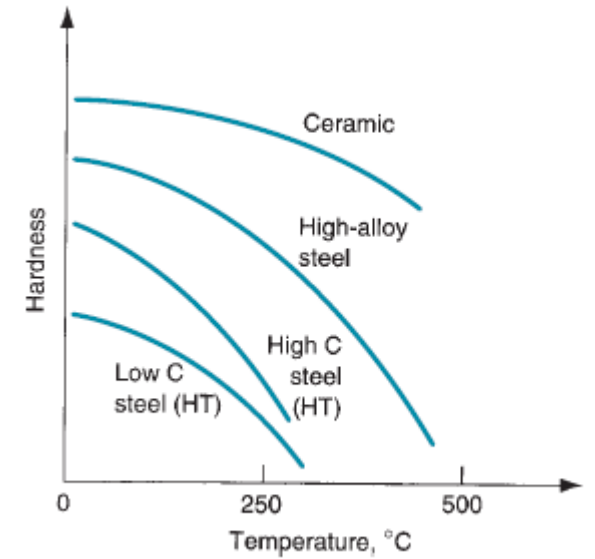
$$HK = 14.2 \frac{F}{D^2}$$

TABLE 3.6 Typical hardness of selected metals.

Metal	Brinell Hardness, HB	Rockwell Hardness, HR ^a	Metal	Brinell Hardness, HB	Rockwell Hardness, HR ^a
Aluminum, annealed	20		Magnesium alloys, hardened ^b	70	35B
Aluminum, cold worked	35		Nickel, annealed	75	40B
Aluminum alloys, annealed ^b	40		Steel, low C, hot rolled ^b	100	60B
Aluminum alloys, hardened ^b	90	52B	Steel, high C, hot rolled ^b	200	95B, 15C
Aluminum alloys, cast ^b	80	44B	Steel, alloy, annealed ^b	175	90B, 10C
Cast iron, gray, as cast ^b	175	10C	Steel, alloy, heat treated ^b	300	33C
Copper, annealed	45		Steel, stainless, austenitic ^b	150	85B
Copper alloy: brass, annealed	100	60B	Titanium, nearly pure	200	95B
Lead	4		Zinc	30	

TABLE 3.7 Hardness of selected ceramics and other hard materials, arranged in ascending order of hardness.

Material	Vickers Hardness, HV	Knoop Hardness, HK	Material	Vickers Hardness, HV	Knoop Hardness, HK
Hardened tool steel ^a	800	850	Titanium nitride, TiN	3000	2300
Cemented carbide (WC – Co) ^a	2000	1400	Titanium carbide, TiC	3200	2500
Alumina, Al ₂ O ₃	2200	1500	Cubic boron nitride, BN	6000	4000
Tungsten carbide, WC	2600	1900	Diamond, sintered polycrystal	7000	5000
Silicon carbide, SiC	2600	1900	Diamond, natural	10,000	8000



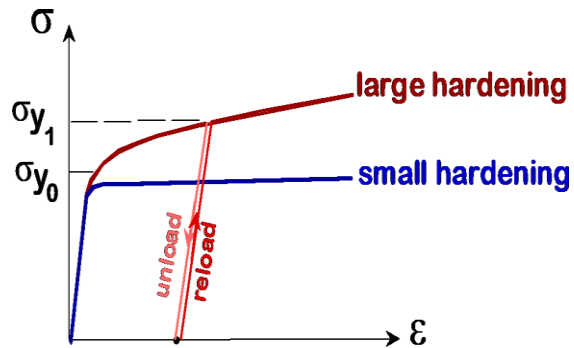
Hot hardness—typical hardness as a function of temperature for several materials.

TABLE 3.8 Hardness of selected polymers.

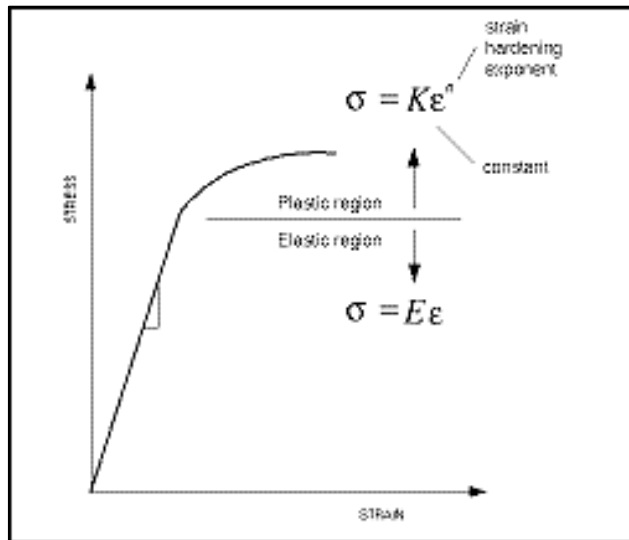
Polymer	Brinell Hardness, HB	Polymer	Brinell Hardness, HB
Nylon	12	Polypropylene	7
Phenol formaldehyde	50	Polystyrene	20
Polyethylene, low density	2	Polyvinyl-chloride	10
Polyethylene, high density	4		

Hardening

- An increase in σ_y due to plastic deformation.



- Curve fit to the stress-strain response:



Where: K and n are constants that differs between alloys.
The parameter n : is termed as the strain hardening exponent.

TABLE 3.4 Typical values of strength coefficient K and strain hardening exponent n for selected metals.

Material	Strength Coefficient, K		Strain Hardening Exponent, n
	MPa	lb/in ²	
Aluminum, pure, annealed	175	25,000	0.20
Aluminum alloy, annealed ^a	240	35,000	0.15
Aluminum alloy, heat treated	400	60,000	0.10
Copper, pure, annealed	300	45,000	0.50
Copper alloy: brass ^a	700	100,000	0.35
Steel, low C, annealed ^a	500	75,000	0.25
Steel, high C, annealed ^a	850	125,000	0.15
Steel, alloy, annealed ^a	700	100,000	0.15
Steel, stainless, austenitic, annealed	1200	175,000	0.40

Example:

Based on results of a tensile test, the flow curve strain hardening exponent = 0.40 and strength coefficient = 551.6 MPa.

Based on this information, calculate the (engineering) tensile strength for the metal. ($\epsilon = 0.18$)

Material Properties

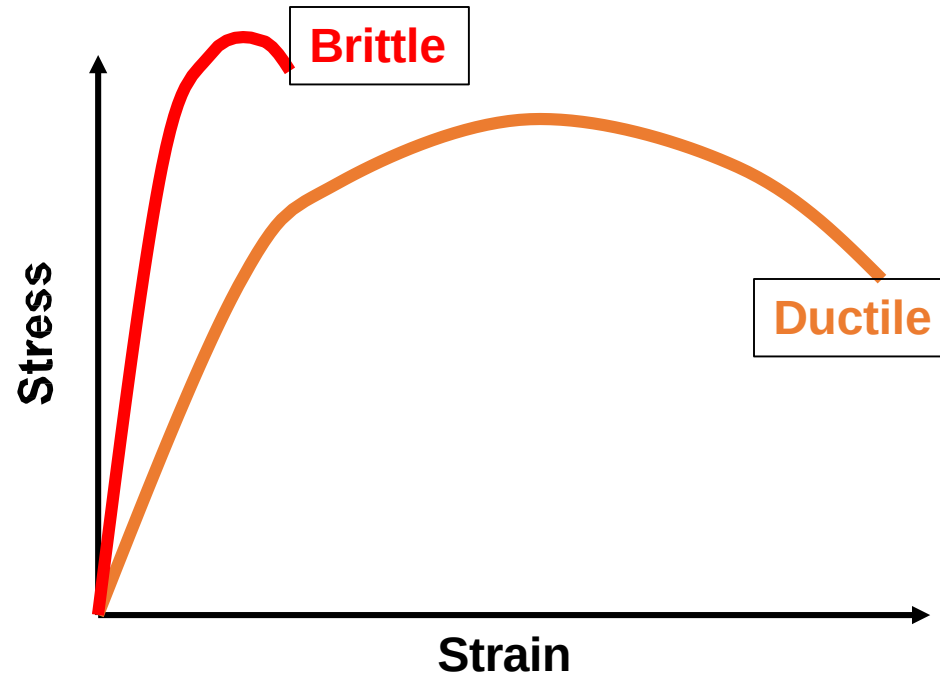
Ductility:

- Measure of the material property to deform before failure.
- It is quantified by reading the value of strain at the fracture point on the stress strain curve.
- Ductile materials can be pulled or drawn into pipes, wire, and other structural shapes
- Examples of ductile material :
 - low carbon steel
 - aluminum
 - copper
 - brass

Material Properties

Brittleness:

- Measure of the material's inability to deform before failure.
- The opposite of ductility.
- Example of ductile material : glass, high carbon steel, cast iron ceramics



Material Properties

Toughness:

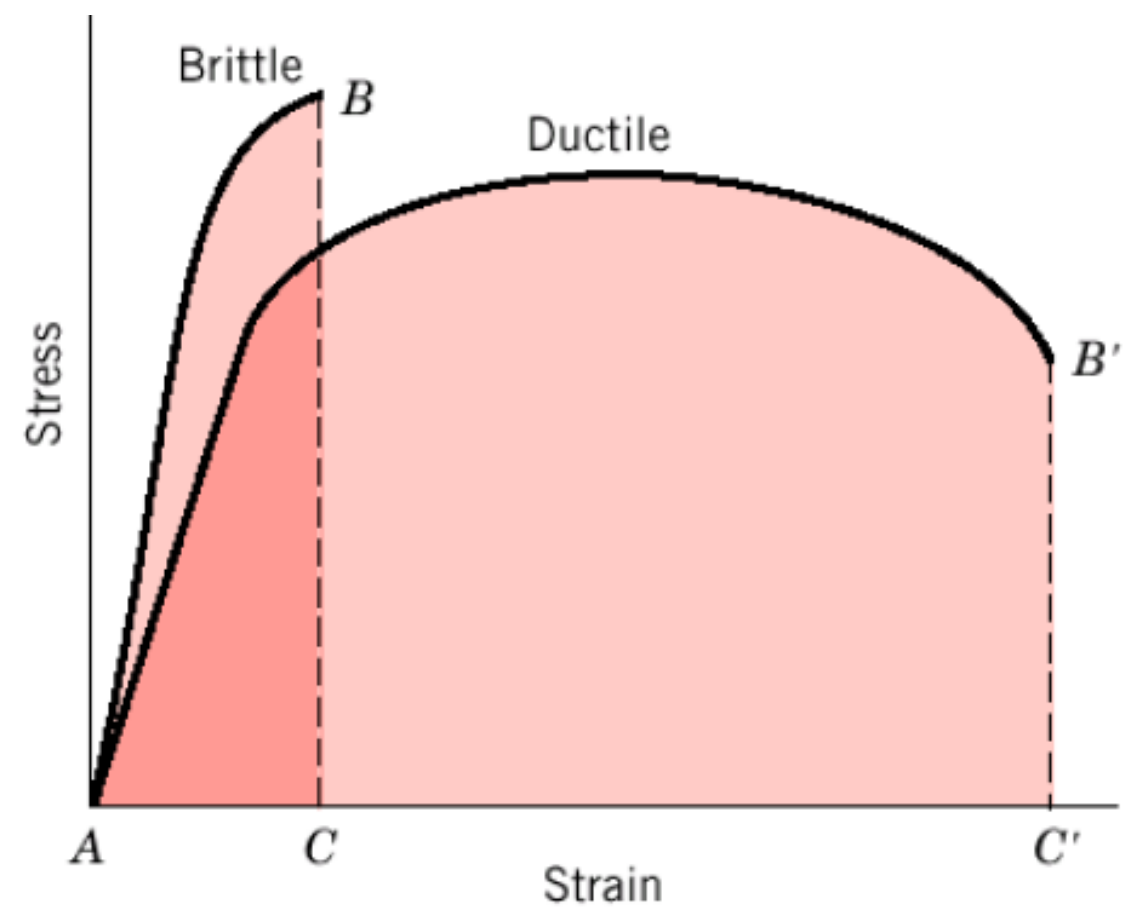
- Measure of the material ability to absorb energy.
- It is measured by two methods.

a) Integration of stress strain curve

- Slow absorption of energy
- Absorbed energy per unit volume

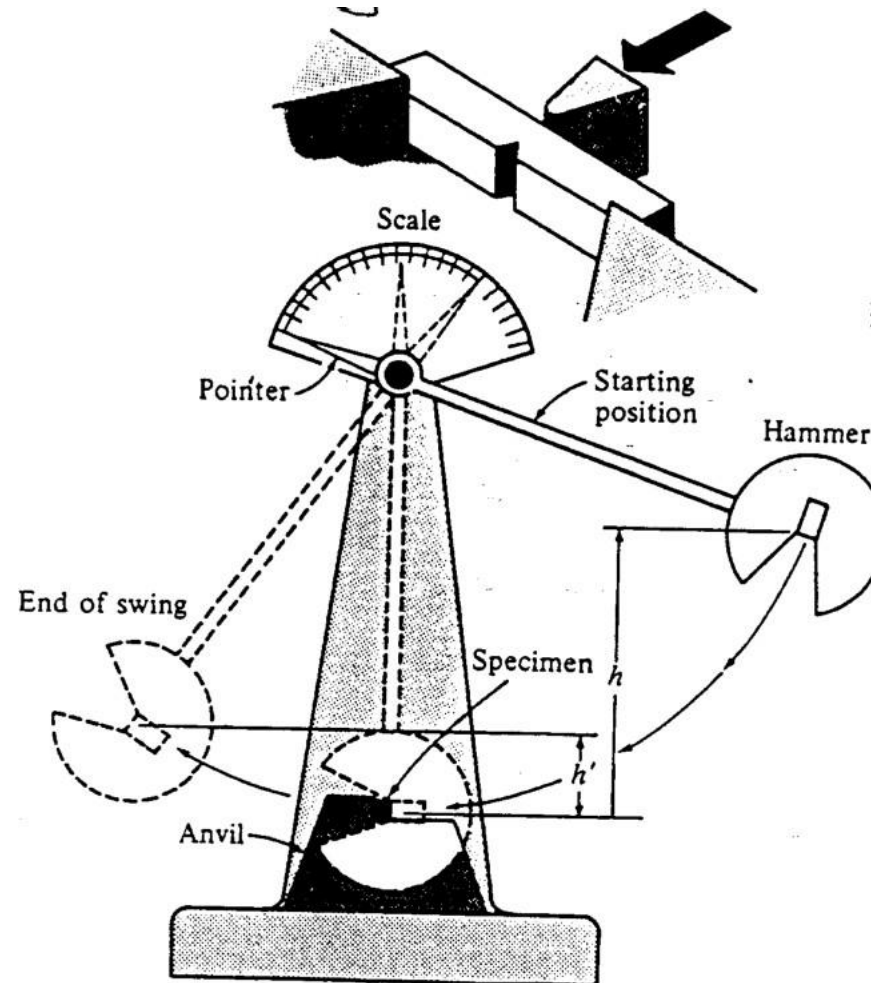
b) Charpy test

- Ability to absorb energy of an impact without fracturing.
- Impact toughness can be measured.



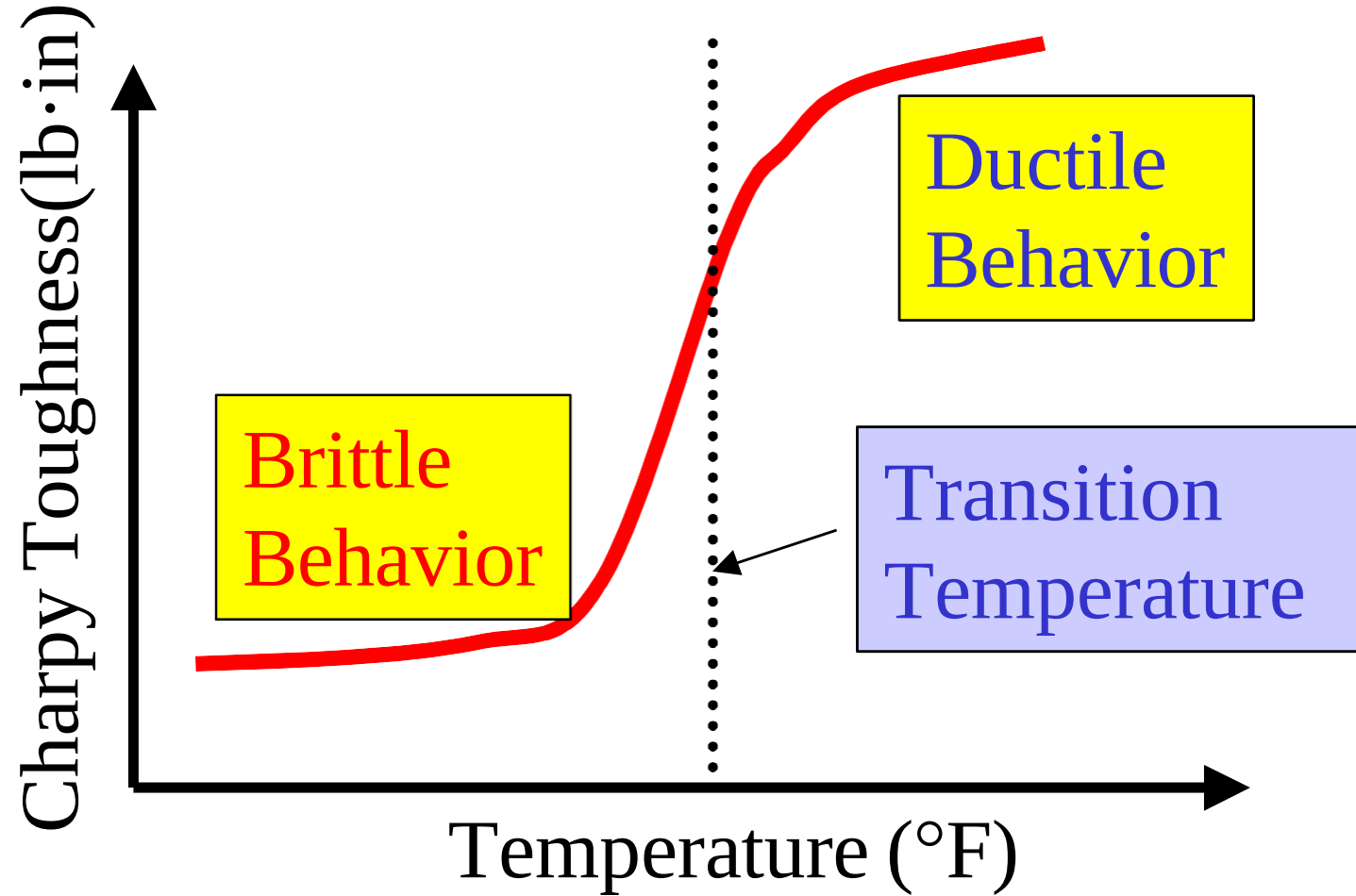
Material Properties

Charpy V-Notch Test:



Material Properties

Charpy V-Notch Test:

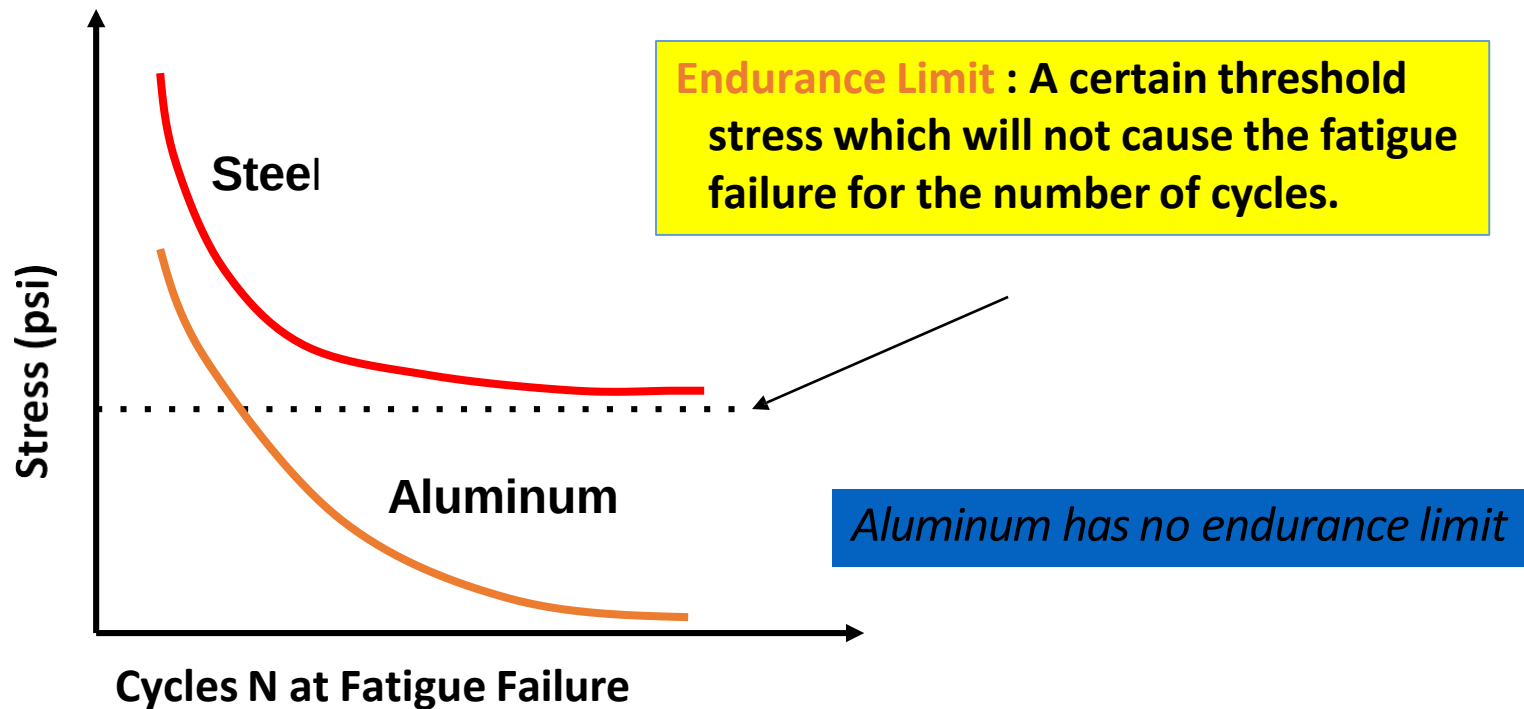


Material Properties

Fatigue:

- The repeated application of stress typically produced by an oscillating load such as vibration.
- Sources of ship vibration are engine, propeller and waves.

MAXIMUM stress decreases as the number of loading cycles increases.



Factors effecting Material Properties

Temperature :

Increasing temperature will:

- Decrease Modulus of Elasticity
(As Long as Structure Does Not Change)
- Decrease Yield Strength
- Decrease Ultimate Tensile Strength
- Decrease Hardness
- Increase Ductility
- Decrease Brittleness

Environment:

- Sulfites, Chlorine, Oxygen in water,
Radiation, Pressure

Ways to Effect / Alter Material Properties

Alloying (Adding other elements to alter the molecular properties):

- Steel: Carbon, chromium, molybdenum, nickel, tungsten, manganese
- Aluminum: Copper, manganese, silicon, zinc, magnesium

Thermal Treatments (Application of heat over varying time):

Annealing:

- Heating higher than its critical temperature then cooling slowly.
- Improves hardness, strength, and ductility.
- Ship's hulls are annealed.

Hardening:

- Heating higher than its critical temperature then cooling rapidly.
- Improves hardness.
- Increases internal stresses, may cause cracking.

For example : The steel is heated above the critical temperature, about 1335°F (724°C).

Ways to Effect / Alter Material Properties

Thermal Treatments:

Tempering:

- Steel is heated below the critical temperature and cooled slowly.
- Used with hardening to reduce the internal stresses.

Hot-Working:

- Forming of shapes while material is hot.
- Less internal stresses due to annealing (change in the molecular structure).

Cold-Working:

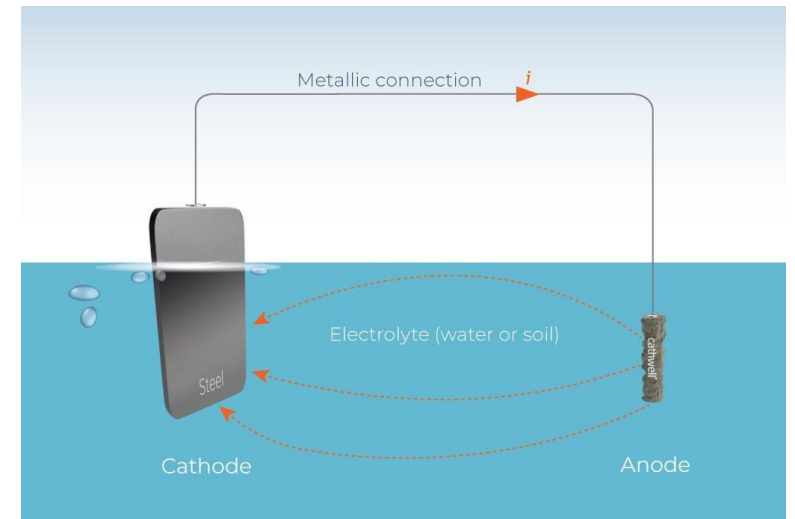
- Forming shapes while material is cold.
- Causes internal stresses, resulting in a stronger shape.

Corrosion & Corrosion Protection

Corrosion is the destruction of metals due to oxidation or other chemical reactions.

Corrosion Protection:

- Design to eliminate conditions favorable to corrosion
- Apply wire brush and painting
- Cathodic Protection
 - Charging the metal to slow/ stop reaction with other elements
 - Providing a sacrificial metal to give up ions instead of the structure giving up ions (and corroding)



Non-Destructive Testing (NDT)

External Tests

Visual Test (VT)

- Naked Eye or Optical Inspection.
- Always done before other NDT's.
- Often only NDT required.

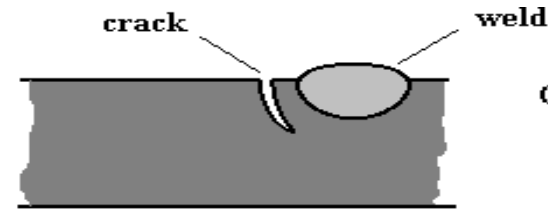
Liquid (Dye) Penetrant Test (PT)

- A liquid penetrant and developer are applied to the test item surface, causing a color change where surface cracks or flaw exist.

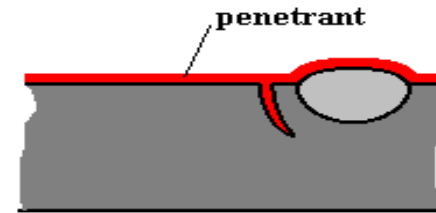
Magnetic Particle Testing (MT)

- The test item is magnetized, then metal particles are applied to the inspection surface. The particles will line up along a surface or near surface crack/flaw giving a visual indication of size and location.

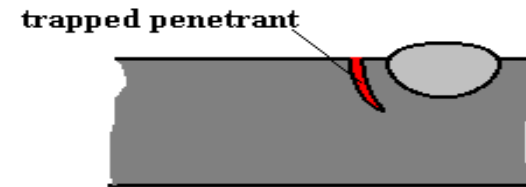
Dye Penetrant Test (PT)



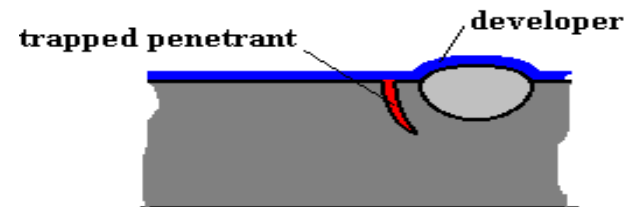
Cleaned surface of a weld which has a crack in the heat affected zone



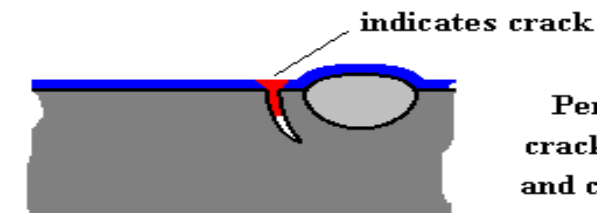
Liquid penetrant is drawn into a crack by capillary action



After the surface is cleaned penetrant remains trapped in the crack



Developer is sprayed onto the surface

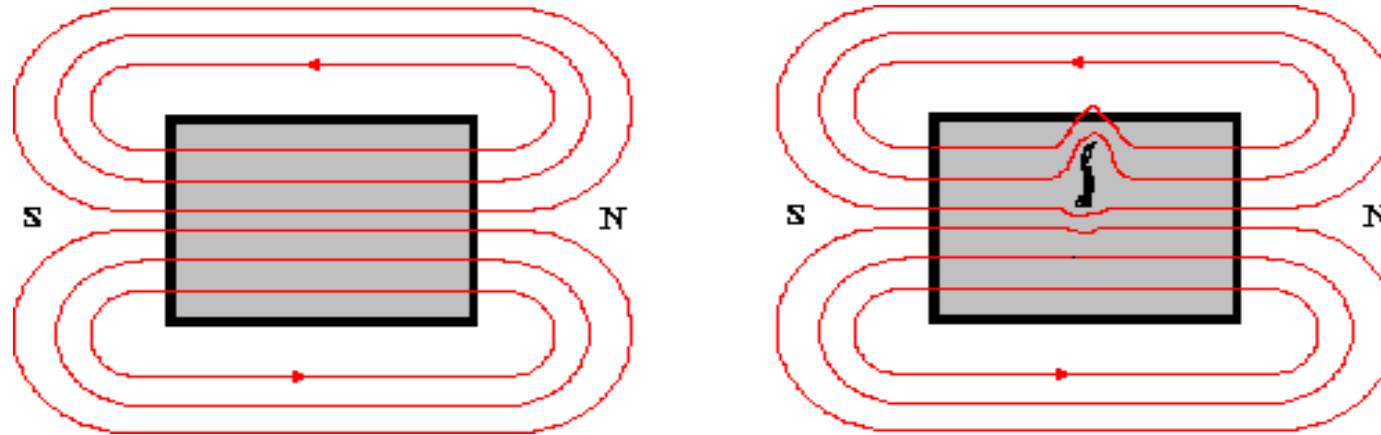


Penetrant migrates from the crack, reacts with the developer and causes a colour change which identifies the crack location

For ferrous and non-ferrous material.
Used on most welded joints.
Followed by radiographic test if required.

Magnetic Particle Test (MT)

- Method that can be used to find surface and near surface flaws in ferromagnetic materials such as steel and iron.
- The technique uses the principle that magnetic fields (flux) will be distorted by the presence of a flaw.



For ferrous material only.
Used on most structural welds.
Followed by radiographic test if required.

Non-Destructive Testing (NDT)

Internal Tests

Ultrasonic Testing (UT)

- A transducer sends ultrasonic waves into the material. Time and distance is displayed on the oscilloscope.
 - Reads material thickness.
 - Identifies bonding in silver brazes.
 - Shows shear wave for flaws in plates.

Radiographic Testing (RT)

- Uses X-ray or gamma ray to record a permanent image on film or a photo-reactive plate for interpretation.
- Detects flaws, breaks, or gaps in materials.

Eddy Current Testing (ET)

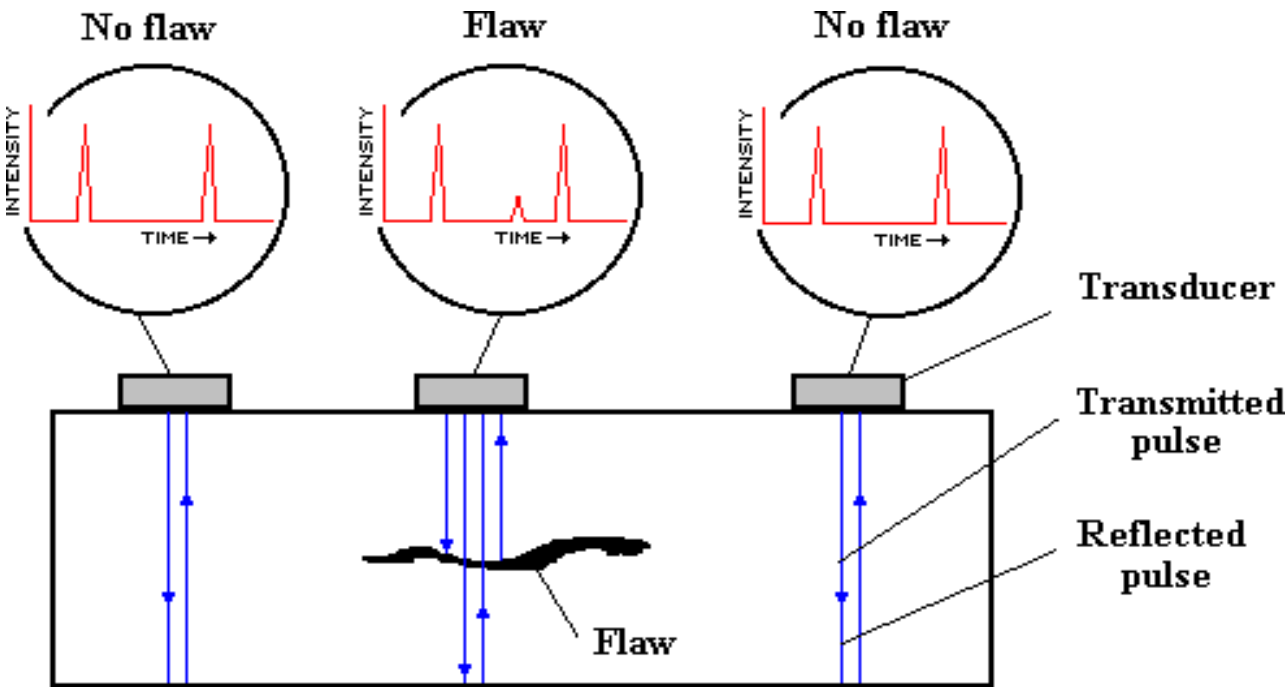
- Uses magnetic ultra sound to produce eddy currents in a material to detect surface cracks. Results displayed on oscilloscope.
- Used only for acceptance, not for final rejection.

Ultrasonic Test (UT)

- Can be used on all metals and nonmetals.
- Excellent technique for detecting deep flaws in tubing, rods, adhesive-joined joints.
- It is used on aircraft to detect structural cracks.
- Needs trained technician to interpret the results.



For example, while sound travels at 343 m/s in air, it travels at 1481 m/s in water (almost 4.3 times as fast) and at **5120 m/s** in iron (almost 15 times as fast).



$$s = \frac{ct}{2}$$

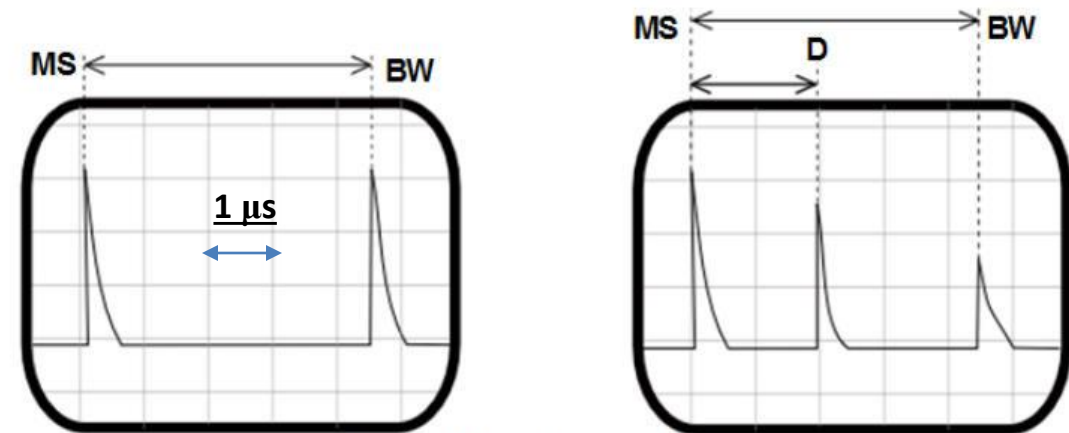
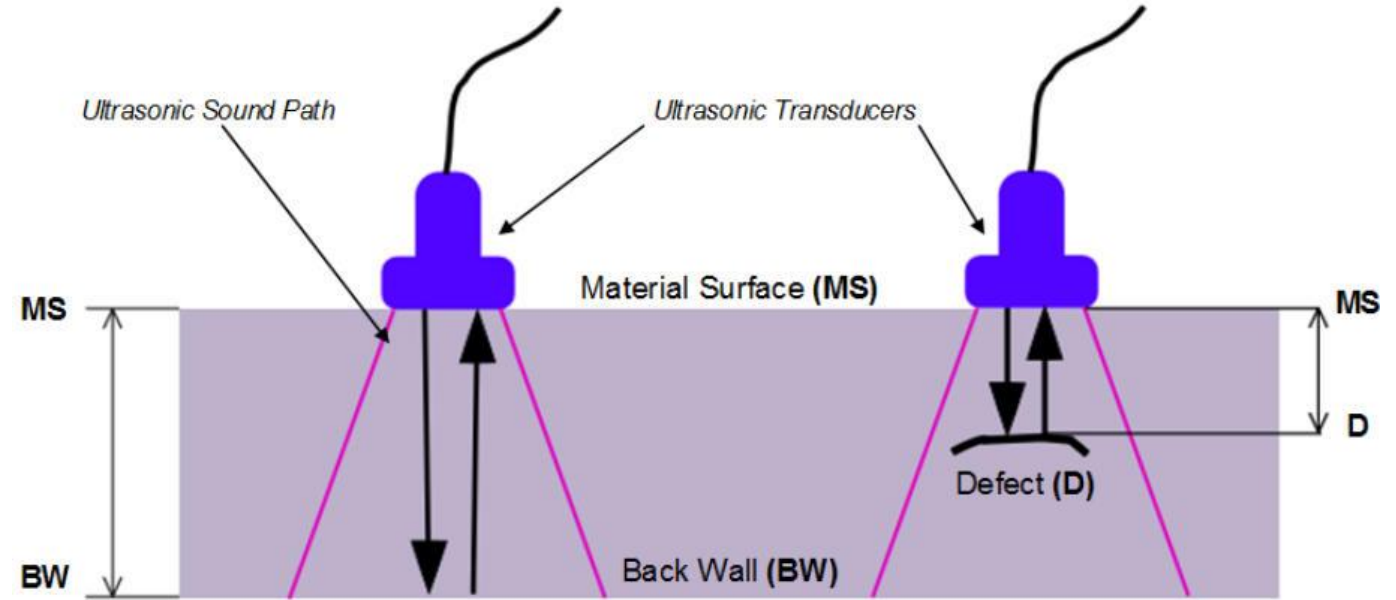
s = sound path [mm]
c = sound velocity [m/s]
t = time of flight [s]

Material	Compressional velocity V_L (m/s)	Shear velocity V_T (m/s)
Aluminum	6320	3130
Steel (1020)	5890	3240
Cast iron	4800	2400
Copper	4660	2330
Titanium	6070	3310

➤ Exercise

the specimen is manufactured by steel alloy

Determine the distance between the material surface (MS) and the defect (D)?



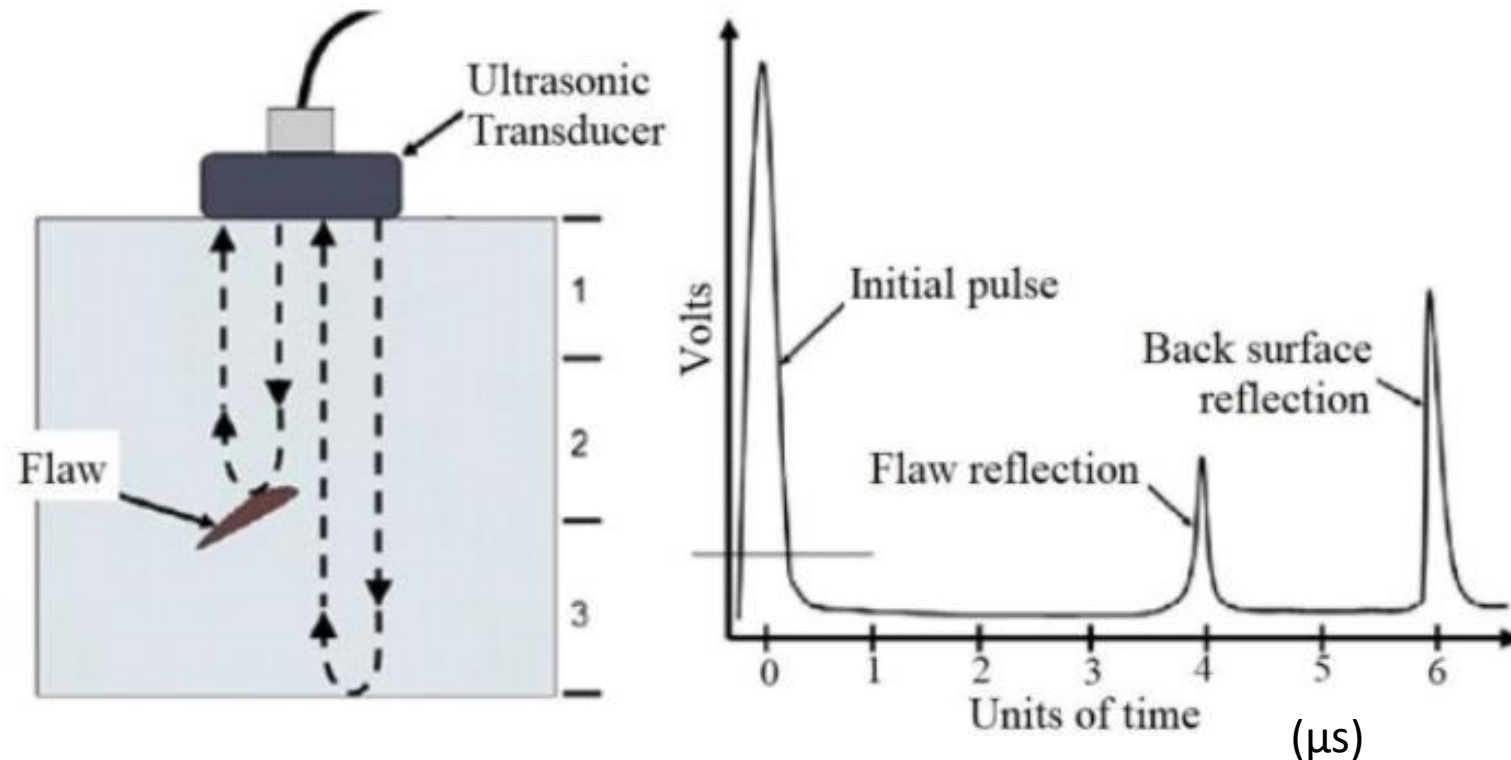
Flaw Detector Screen display.

Shows good material on the left screen and a Defect detected on the right screen

➤ Exercise

A typical non-destructive ultrasonic test is represented schematically in the following image. Briefly explain the principles of ultrasound generation and detection upon reflection from the sample and how these waves are used to determine the depth at which a flaw might exist.

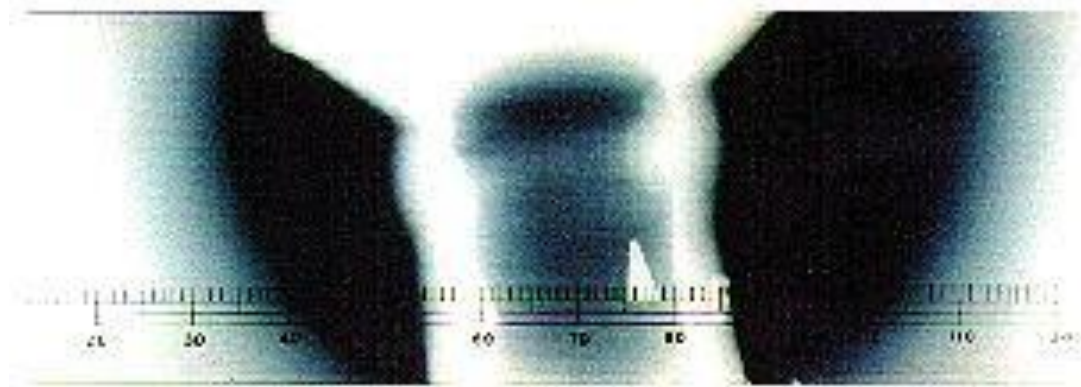
Determine the depth at which the flaw exists?



Radiographic Test (RT)

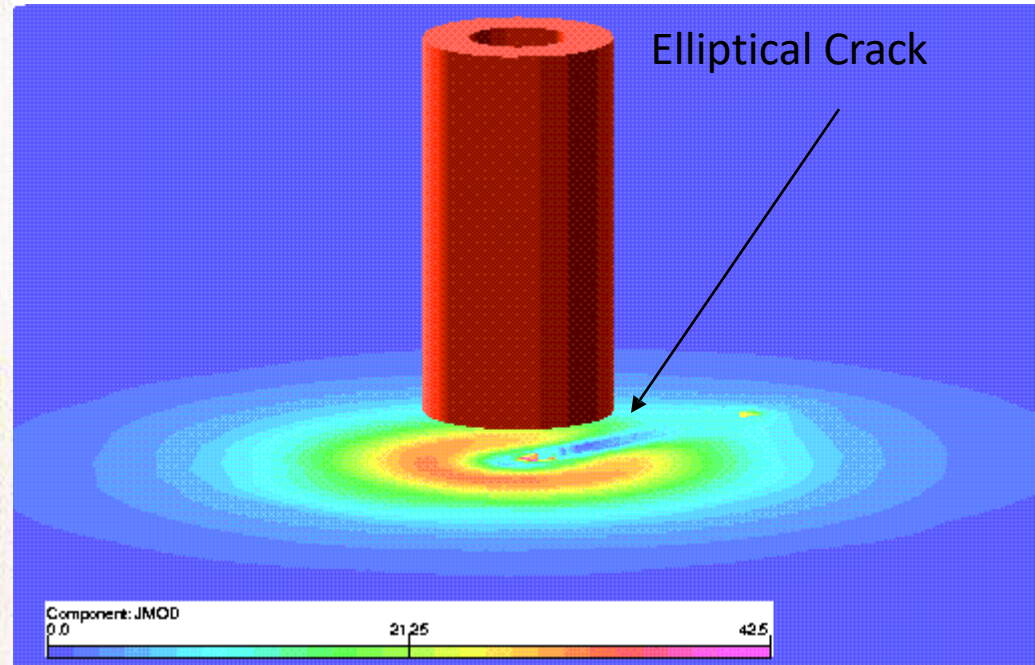
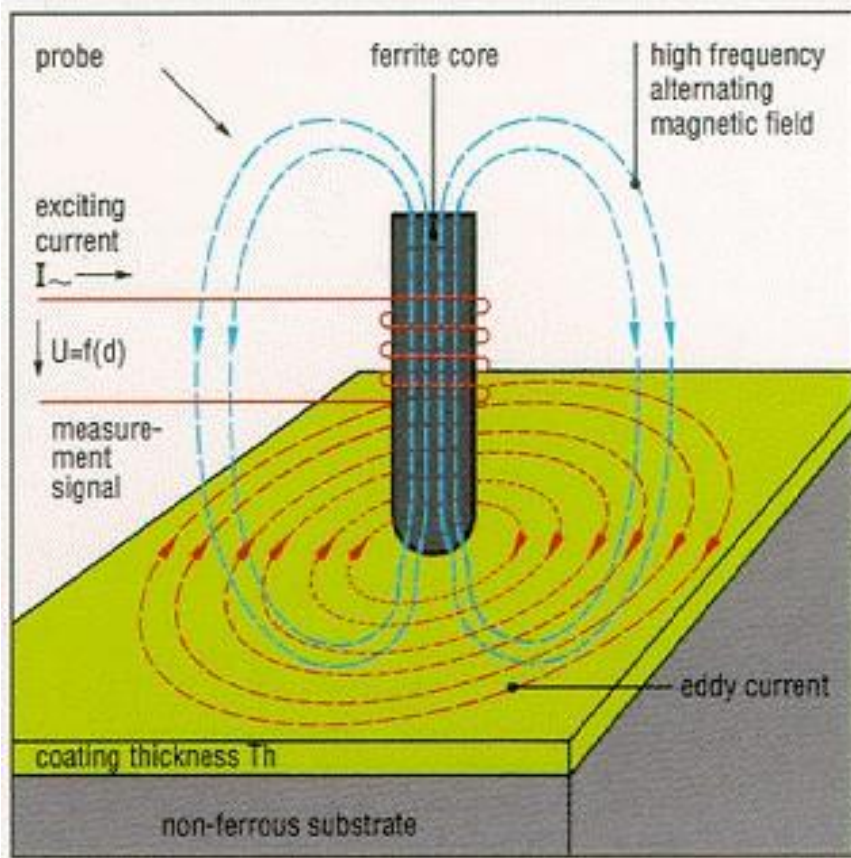
RT requires trained technicians.

RT may have large effect on ship access and watchstanding.



**The picture shows the integrity of welding
for the 2.5mm thick steel plate**

Eddy Current Test (ET)



- Detects cracks on both ferromagnetic and non-ferromagnetic materials.
- If rejected, verification required by:
 - Magnetic Particle Test for ferrous materials.
 - Liquid Penetrant Test for non-ferrous materials.

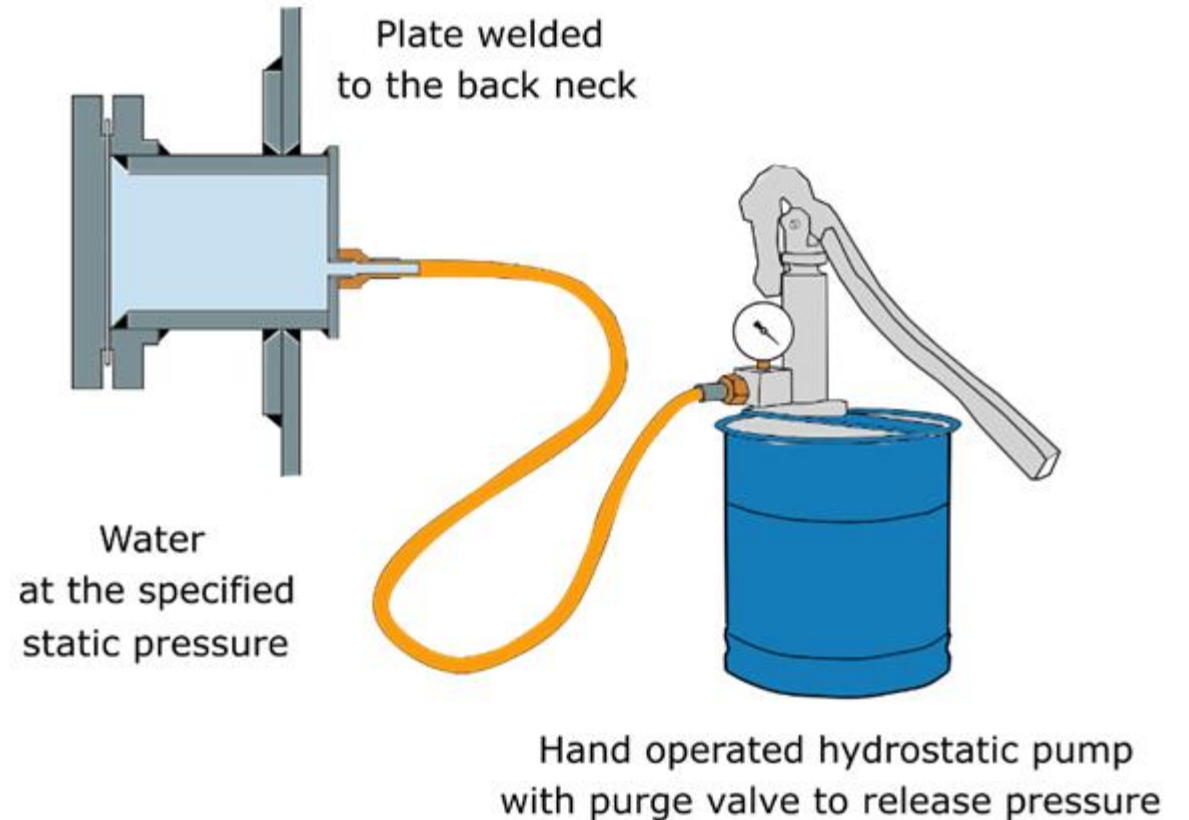
Hydrostatic Tests

Some Systems Subjected to Hydrostatic Testing:

- Drainage Systems
- Firemain/Flush/Seawater Circulations Systems
- Steam Systems
- Compressed Air Systems
- Fuel Systems
- Hydraulic Systems
- Feed/Condensate Systems
- Fresh Water Systems
- Sewage Systems

Subjected to Hydrostatic Testing:

- Valves
- Piping
- Heat Exchangers
- Pumps
- Mechanical Connections
- Flasks



Hydrostatic Tests

- Fluid systems are hydrostatically tested during initial construction, and subsequent to repairs, modifications, and component replacement; to verify the leak tightness of the system.
- Operational pressure tests are performed periodically to determine leak tightness of system mechanical joints.
- Operational pressure tests are also performed instead of hydrostatic tests, when the criteria for the Operating Pressure Test Option are met.
- The basic purpose of all such tests is to ascertain that the system can perform its intended function safely and reliably.

Hydrostatic Tests

Generally, the sequence for testing is:

- a. Establish required prerequisites and initial conditions.
- b. Align the system for testing.
- c. Pressurize the system slowly and incrementally.
- d. Check for leaks at normal operating pressure and two lower incremental pressures.
- e. Continue to increase pressure to hydrostatic test pressure.
- f. Perform required inspections.
- g. Depressurize, remove temporary equipment, and restore the system to the conditions required for subsequent evolutions.

Hydrostatic Tests

Typical Test Requirement:

Must hold 135% of system design pressure for 30 minutes, followed by visual inspection.



The criterion for an acceptable hydrostatic test is there shall be no leakage or permanent deformation of pressure-containing parts, as determined by visual examination, except:

- a. The leakage does not become hazardous to personnel.
- b. The leakage can be adequately contained to protect equipment.
- c. The leakage is within the capacity of the hydrostatic test pump to maintain pressure throughout the test.

Questions in Materials and testing

3.1. Which of the following are the three basic types of static stresses to which a material can be subjected (three correct answers): (a) compression, (b) hardness, (c) reduction in area, (d) shear, (e) tensile, (f) true stress, and (g) yield?

3.2. Which one of the following is the correct definition of ultimate tensile strength, as derived from the results of a tensile test on a metal specimen:

- (a) the stress encountered when the stress–strain curve transforms from elastic to plastic behavior,
- (b) the maximum load divided by the final area of the specimen,
- (c) the maximum load divided by the original area of the specimen, or
- (d) the stress observed when the specimen finally fails?

3.3. If stress values were measured during a tensile test, which of the following would have the higher value:

- (a) engineering stress or (b) true stress?

3.4 Which one of the following materials has the highest hardness:

- (a) alumina ceramic,
- (b) gray cast iron,
- (c) hardened tool steel,
- (d) high carbon steel, or
- (e) polystyrene?

Alumina ceramic (aluminum oxide, Al_2O_3) is known for its exceptional hardness, often ranking just below diamond

Questions in Materials and testing (Home Work 1)

A tensile test uses a test specimen that has a gage length of 50 mm and an area = 200 mm^2 . During the test the specimen yields under a load of 98,000 N. The corresponding gage length = 50.23 mm. This is the 0.2% yield point. The maximum load of 168,000 N is reached at a gage length = 64.2 mm. Determine (a) yield strength, (b) modulus of elasticity, and (c) tensile strength. (d) If fracture occurs at a gage length of 67.3 mm, determine the percent elongation. (e) If the specimen necked to an area = 92 mm^2 , determine the percent reduction in area.

During a tensile test in which the starting gage length = 125.0 mm and the cross-sectional area = 62.5 mm^2 , the following force and gage length data are collected (1) 17,793 N at 125.23 mm, (2) 23,042 N at 131.25 mm, (3) 27,579 N at 140.05 mm, (4) 28,913 N at 147.01 mm, (5) 27,578 N at 153.00 mm, and (6) 20,462 N at 160.10 mm. The maximum load is 28,913 N and the final data point occurred immediately before failure. (a) Plot the engineering stress strain curve. Determine (b) yield strength, (c) modulus of elasticity, and (d) tensile strength.

A bend test is used for a certain hard material. If the transverse rupture strength of the material is known to be 1000 MPa, what is the anticipated load at which the specimen is likely to fail, given that its width = 15 mm, thickness = 10 mm, and length = 60 mm?

A tensile test uses a test specimen that has a gage length of 60 mm and an area = 310 mm² .

During the test the specimen yields under a load of 95000 N. The corresponding gage length = 60.51 mm. This is the 0.2 percent yield point. The maximum load of 17000 N is reached at a gage length = 64.2 mm. Determine:

- (A) yield strength
- (B) modulus of elasticity
- (C) tensile strength
- (D) If fracture accurse at a gage length of 70.11 mm, determine the percent of elongation
- (E) if the specimen necked to an area = 95 mm² , determine the percent reduction in area.

Any Questions?

Periodic Table of the Elements

Group																		18														
1A																		8A														
1	1	11	2															2														
	H	Na																He														
	Hydrogen	Sodium																Helium														
	1.0078	22.990																4.0026														
2	3	4																														
	Li	Be																														
	Lithium	Beryllium																														
	6.938	9.0122																														
3	11	12																														
	Na	Mg																														
	Sodium	Magnesium																														
	22.990	24.305																														
Period			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18														
			3B	4B	5B	6B	7B		8B		1B	2B																				
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36														
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr														
	Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton														
	39.098	40.078	44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.38	69.723	72.63	74.922	78.96	79.904	83.798														
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54														
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe														
	Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon														
	85.468	87.62	88.906	91.224	92.906	95.96	98.9062	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29														
6	55	56				72	73	74	75	76	77	78	79	80	81	82	83	84	85	86												
	Cs	Ba				Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn												
	Cesium	Barium				Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon												
	132.91	137.33				178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	(209)	(210)	(222)												
7	87	88				104	105	106	107	108	109	110	111	112	113	114	115	116	117	118												
	Fr	Ra				Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo												
	Francium	Radium				Rutherfordium	Dubnium	Seaborgium	Bohrium	Hassium	Meitnerium	Damstadtium	Roentgenium	Copernicium	Ununtrium	Flerovium	Ununpentium	Livermorium	Ununseptium	Ununoctium												
	(223)	(226)				(261)	(262)	(266)	(264)	(269)	(268)	(268)	(268)	(268)	(268)	(268)	(268)	(268)	(268)	(268)												
Lanthanides			57	58	59	60	61	62	63	64	65	66	67	68	69	70	71															
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu															
			Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium															
			138.91	140.12	140.91	144.24	(145)	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04	174.97															
Actinides			89	90	91	92	93	94	95	96	97	98	99	100	101	102	103															
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr															
			Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium															
			(227)	232.04	231.04	238.03	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(262)															

Metals, Nonmetals, and Metalloids																	
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	—	Uuq	—	—	—	—
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

metals

metalloids

nonmetals