ME 161
Introduction to Mechanical Engineering

Please go through class notes and reference materials discussed in the class. This is just a guideline for those who missed the classes

Material Science

Types of Gears

Helical Gear

Spur Gear

Rack & Pinion Gear

Worm Gears

Bevel Gear

Sprockets Gear

Spur Gear:

- These gears are used to transmit the power in same plane or when the driving and driven shafts are parallel to each other. In this type of gear teeth are cut parallel to the axis of the shafts so when is meshes with another spur gear it transmit the power in parallel shaft

Helical Gear:

- On the helical gears teeth are cut at an angle from the axis of it. It has cylindrical roller with helicoid teeth. The main advantage of helical gears is that they work with less noise and vibration because the load is distributed on the full helix as compared to spur gears. It also has less wear and tear due to which they are widely used in industries.

Double Helical or Herringbone Gear:

- This gear has both right and left handed teeth on one gear. This gear is use to provide additional shear area on gear which further required for higher torque transmission. This is same as helical.

Worm Gear:

- This type of gear is used to transmit the power in non intersecting shaft which makes right angle. In this type of arrangement the driving gear is a screw gear and the driven gear is helical gear or gear with spiral teeth.

Rack and Pinion Gear:

- This gear is used in steering system of automobile. In this type of gear, teeth are cut on a straight rectilinear geometry know as rack and one spur gear known as pinion.

Bevel Gear:

- This gear is used to transmit power between perpendiculars. The driving shaft and driven shaft makes a right angle with each other and both the axis of shaft meets each other at one point. This gear has helical or spiral teeth on a conical shaped geometry and meshes with the same gear.

Materials used for gear manufacture

Gears can be made of all sorts of materials, including

- Steel and steel alloy. Steel is the most common material. For superior material strength. These are carbon steel, alloy steel, stainless steel, and tool steel
- Brass(Corrosion , Non- magnet)
- Bronze
- Aluminum
- Aluminum alloys(high strength-to-weight ratio)
- Cast Iron (For outdoor use)
- Thermoplastic. Ex- Nylon. Good heat resistance, low coefficient of friction, self lubricant, corrosion free, non-magnet.
- Ceramic(High temperature, non magnetic, insulator, low coefficient of friction)
- Ductile Iron
- Powdered Metals

Causes of Failure of Gear

- Wear
- Scuffing
- Hertzian Fatigue
- Cracking
- Fracture
- Plastic Deformation
- Bending Fatigue

Gear Maintenance

- Choose the right lubricant
- Apply the correct amount
- Clean and inspect the gears
- Adjust and align the gears
- Protect the gears from harsh conditions
- Schedule regular maintenance

Different types of bearings

Ball Bearings
Ball Bearings utilize balls as the **rolling elements.** They are characterised by **point contact** between the **balls** and the **raceways.** As a rule, ball bearings rotate very quickly but cannot support substantial loads.

Roller Bearings
Roller Bearings are characterized by **line contact**. Line contact offers higher **load rating** than ball bearings of the same size; however the speed ability is lower than a ball bearing due to the increased **friction** of a contact line.

What are bearings ? Their properties & types

Tapered roller bearing takes radial(mainly) and axial loads on the bearing assembly

Thrust bearing is used to support a predominantly axial load

The self aligning ball /roller bearings are insensitive to angular misalignment of the shaft relative to the housing

Deep groove ball bearing accommodate radial and axial loads in both directions

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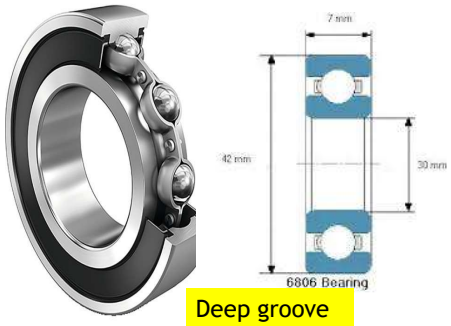
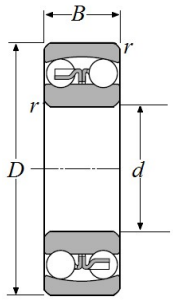
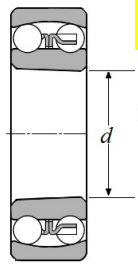


Deep groove

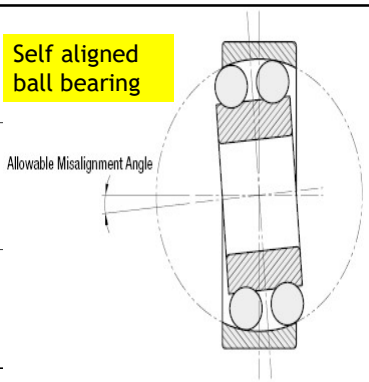


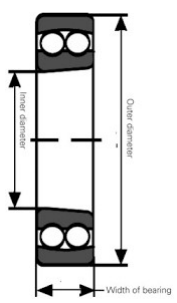
Cylindrical Bore

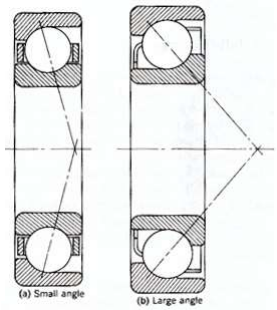


Tapered Bore

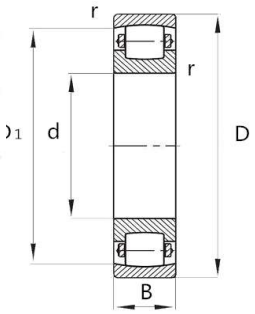
Self aligned ball bearing



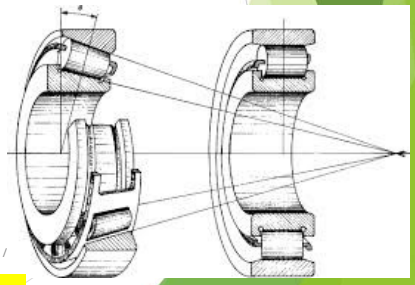




Angular contact ball bearing



Self aligned roller bearing



- All bearings need to demonstrate low friction, guidance with minimum runout or play, quiet running, low lubricant requirements, high temperature resistance, little wear and a long service life.
- In addition to all of these factors, different industries have their own special requirements based on special operating environments. Some of these include:
  - Very high or low temperatures
  - Variances in temperature
  - Moisture
  - Speeds/revolutions per minute
  - Resistance to dirt
  - Ability to function in acid and alkaline solutions
  - Ability to function in liquid gas and process dust
  - Suitable for use in clean environments such as those in medical and food and beverage

Bearing Materials

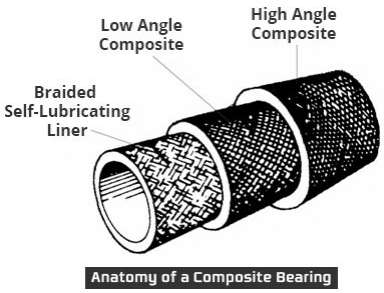
- HIGH CARBON CHROMIUM STEEL
- STAINLESS STEEL BEARINGS
- BRONZE BEARINGS
- CAST IRON BEARINGS
- PLASTIC BEARINGS
- SELF-LUBRICATING BEARINGS
- CERAMIC
- COMPOSITE MATERIAL

Ceramic Bearing

Bronze Bearing

Delrin® [Acetal] Plastic Bearings

Cast iron Bearing



Anatomy of a Composite Bearing

Causes of Bearing Failure

- Foreign Matter/Particle
- Improper Mounting
- Misalignment
- Vibration
- Poor Lubrication
- Bearing Fatigue
- Bearing Corrosion
- High Temperatures
- Poor Storage Conditions

Various types of spring

Helical Compression Spring

Helical Extension Spring

Conical Spring

Torsion Spring

Laminated or Leaf Spring

Disc or Belleville Spring

Spring materials:

The material used to make springs are called a spring steel. Spring steels are mostly low-alloy manganese, low carbon steel or high carbon steel with very high yield strength. Examples of spring materials are as follows:

1. Oil Tempered Steel
2. Stainless Steel
3. Elgiloy (Co-Cr-Ni Alloy) is a "super-alloy"
4. Carbon Value
5. Iconel (Austenitic nickel-chromium-based superalloys)
7. Monel
6. Titanium
7. Chrome Silicon
8. Ceramic
9. One-Directional Glass Fiber Composite Materials
10. Rubber

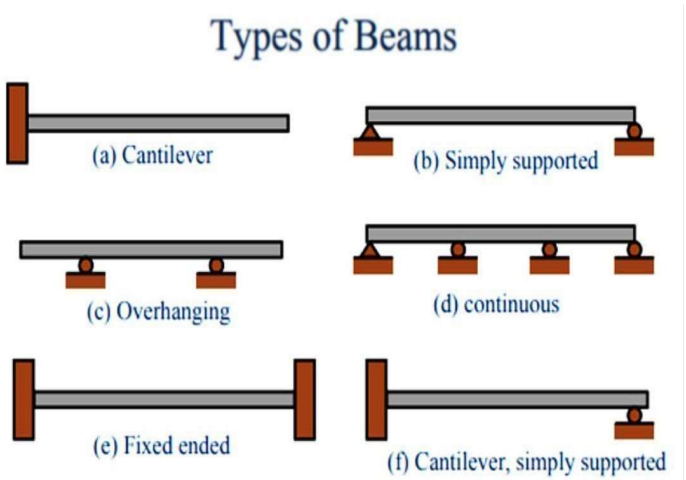
Purposes of spring:

- To absorb shock load
- To store energy
- To measure force
- To motive power
- To Return motion
- To control of vibrations
- To retaining of rings

Causes of Spring Failure

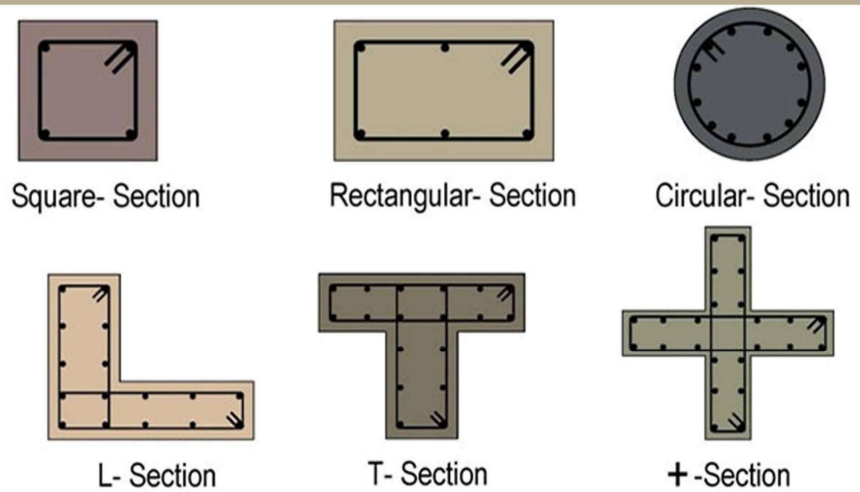
- Non-Calculated Spring Stress
- Incorrect Material Choice
- Incorrect Finish
- Undefined Cycle Life
- Undefined Working Temperature
- Inferior Manufacturing Processes
- Undefined Interaction with Mating Components

TYPES OF BEAMS

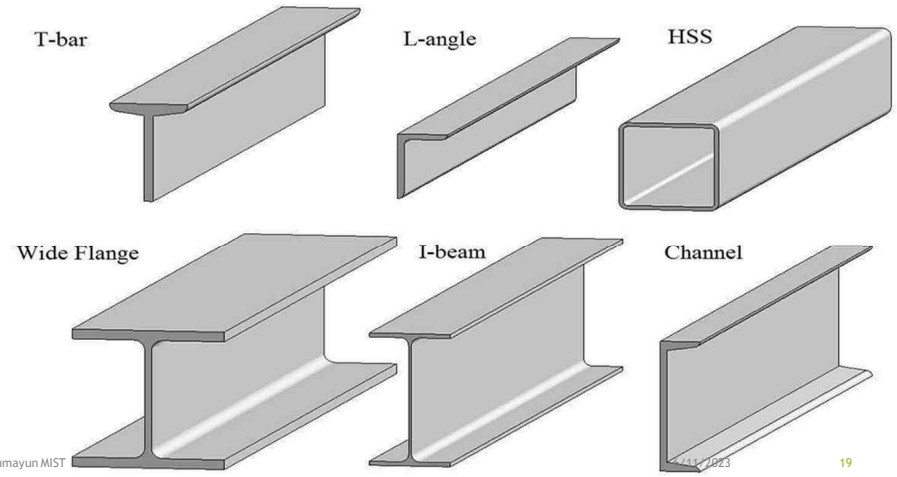


The beam is defined as the structural member which is used to bear different loads. It resists the vertical loads, shear forces and bending moments.

Different Types Of Column



Steel beams



Metals

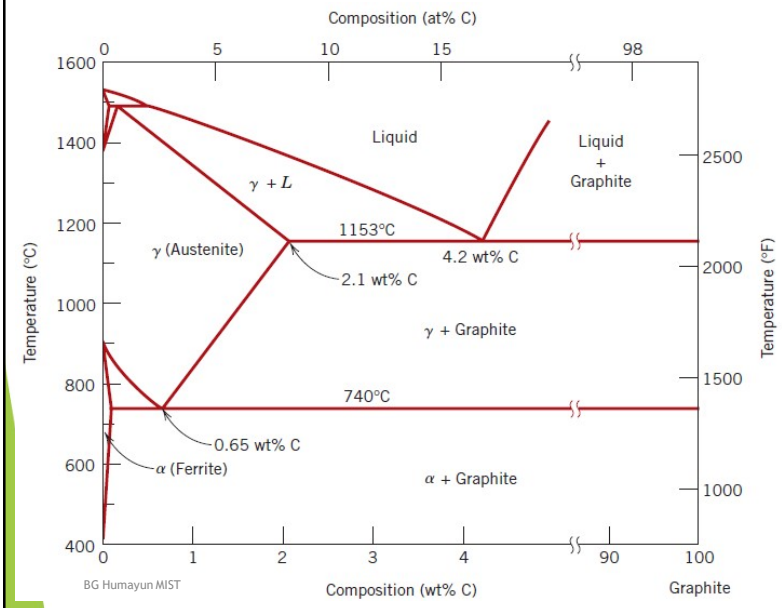
- Metals are solids. (except mercury)
- Metals are hard. (except Lithium, Potassium, Sodium)
- Metals have metallic lustre. (shine)
- Metals are malleable. (can be beaten into thin sheets)
- Metals are ductile. (can be drawn into wires)
- Metals have high melting points. (Gallium and Caesium have low melting points. They melt in the palm of the hand)
- Metals have high boiling points.
- Metals are good conductors of heat. (Best conductors are silver and copper. Poor conductors are Lead and Mercury)
- Metals are good conductors of electricity. (Best conductors are Silver and Copper)
- Metals are sonorous. (produce sound when beaten)

Metals	Non metals
• Metals are solids (except mercury).	•Non metals may be solids, liquids or gases.
• Metals are hard (except sodium, potassium etc.	•Non metals which are solids are brittle (diamond is the hardest).
• Metals have metallic lustre.	•Non metals do not have lustre some have a dull luster.
• Metals have high melting points and boliling points.	•Non metals have low melting points.
• Metals are malleable (can be made into thin sheets).	•Non metals are not malleable.
• Metals are ductile (can be made into thin wires).	•Non metals are not ductile.
• Metals are good conductors of heat and electricity.	•Non metals are bad conductors of heat and electricity (except graphite).
• Metals are sonorus (produces sound).	•Non metals are not sonorus.

An alloy is a homogeneous mixture of a metal with other metals or non metal.

Alloy	Constituents	Uses
Steel	iron, carbon	construction of tools, machines, tanks, vehicles, ships, rails, building, bridges, dams etc.
Stainless steel	iron, chromium	utensils, cutlery, surgical instruments etc.
Brass	copper, zinc	utensils, handicrafts musical instruments etc.
Bronze	copper, tin	statues, medals, bells ornaments etc.

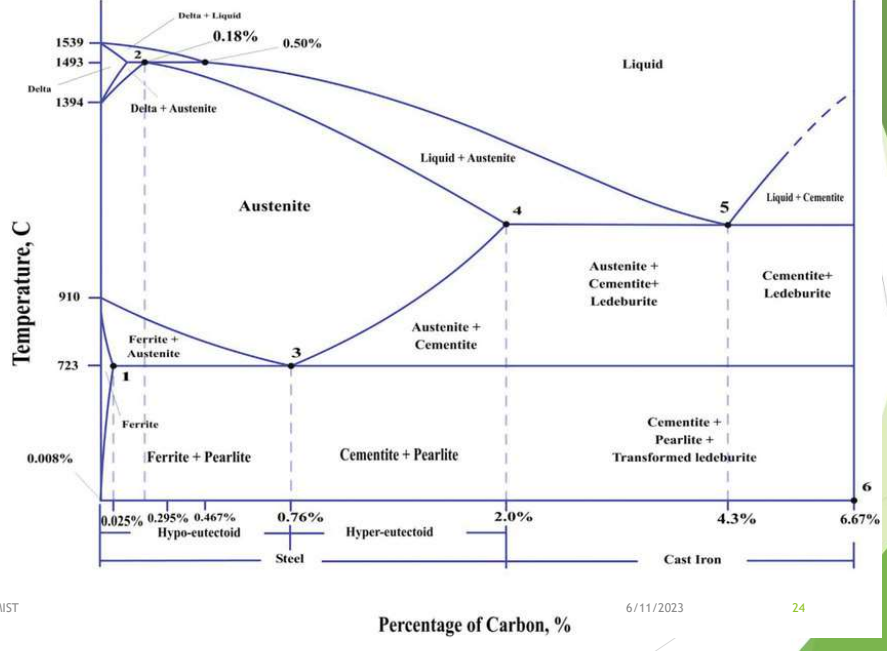
Iron Carbon diagram

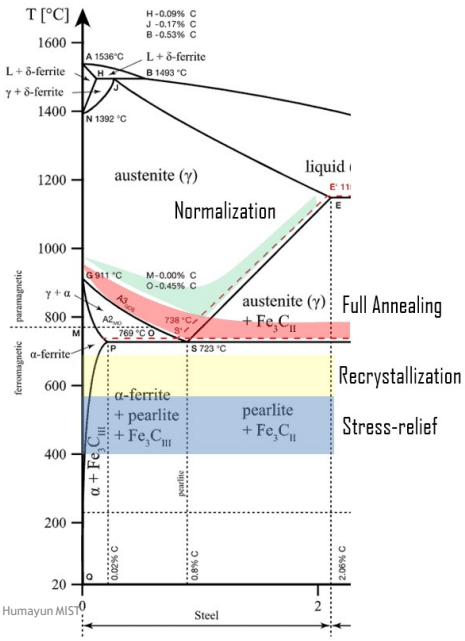


Steel Heat/Colour Chart

Colour	C	F
Faint Red	600	1112
Dark Red	700	1292
Cherry Red	800	1472
Dull Orange	900	1652
Orange	950	1742
Lemon Yellow	1000	1832
Yellow	1050	1922
Bright Yellow	1100	2012
White	1200	2192
Glowing White	1300	2372

- Differences between cast iron and steel
- Various structures
- Various lines and points





The surface of some metals gets corroded when exposed to moist air for a long time. This is called corrosion.

Prevention of corrosion of metals :-

The corrosion of metals can be prevented by:-

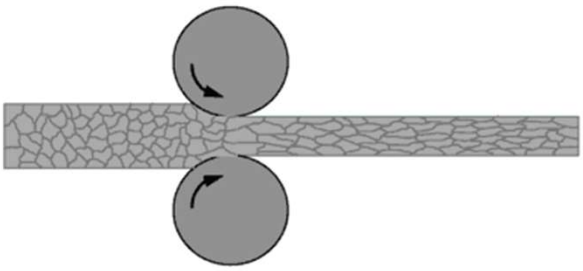
i) Applying oil or grease.

ii) Applying paint

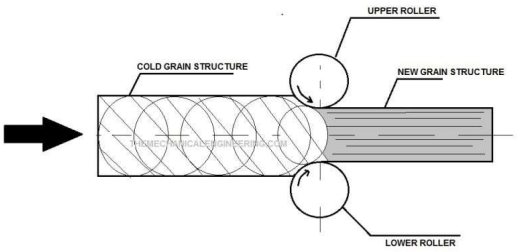
iii) Galvanisation (coating of metals with non corrosive metals like zinc)

iv) Electroplating (coating of metals with non corrosive metals like chromium tin by passing electricity)

v) Alloying (Eg. When iron is alloyed with chromium and nickel, it forms stainless steel which is resistant to corrosion)



Cold work being rolled into copper alloy strip.



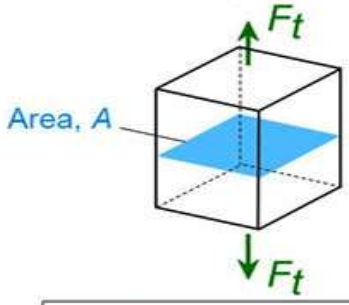
COLD WORKING PROCESS

Stress

- When an external force is applied on a body, it undergoes deformation which is resisted by the body. The magnitude of the resisting force is numerically equal to the applied force. This internal resisting force per unit area of the body is known as stress.
- Stress = Resistive Force/Area
- In equation form: $\sigma = P/A$,
- **Units are**
  - N/m^2, kN/m^2 MPa (Mega Pascal)
  - Psi (lb/in^2), psf (lb/ft^2)

Stress

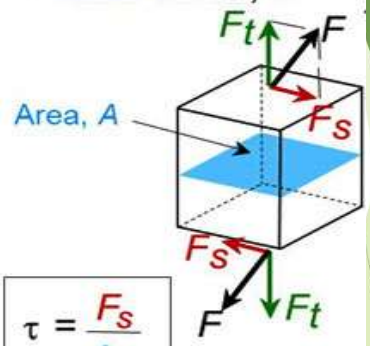
- Tensile stress, σ:



$$\sigma = \frac{F_t}{A_o} = \frac{lb_f}{in^2} \text{ or } \frac{N}{m^2}$$

original area before loading

- Shear stress, τ:



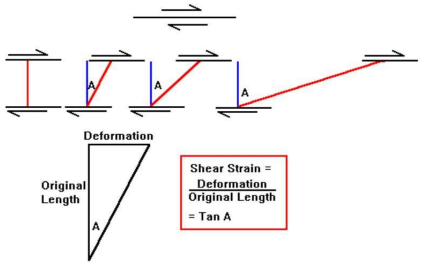
$$\tau = \frac{F_s}{A_o}$$

∴ Stress has units: N/m^2 or lb_f/in^2

Strain

- When a body is subjected to an external force, there is some change of dimension in the body. Numerically the strain is equal to the ratio of change in length to the original length of the body.
- Strain = Change in length/Original length
- In equation form: ε= δL/L
- **Units**
  - m/m, mm/m
  - In/in, in/ft

Shear Strain



Hooks law

- This law states that when a material is loaded, within its elastic limit, the stress is directly proportional to the strain.
- Stress α Strain
- σ α ε
- σ = Eε
- E = σ/ε
- Its unit is same as that of Stress Where, – E is Young's modulus – σ is Stress – ε is Strain

Poisson Ratio

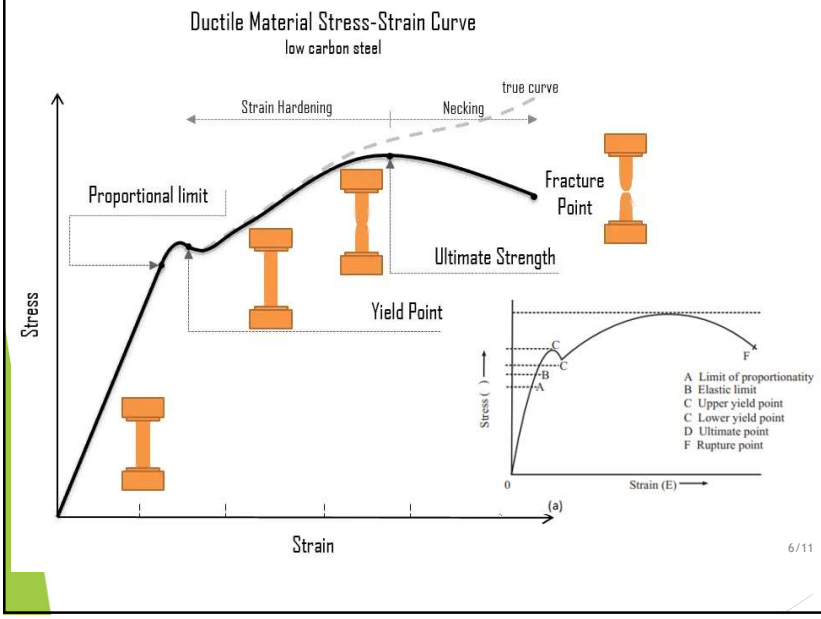
- It is the ratio of the lateral strain to the longitudinal strain and is constant property of each material.
- Poisson' ratio = Lateral strain /Longitudinal strain

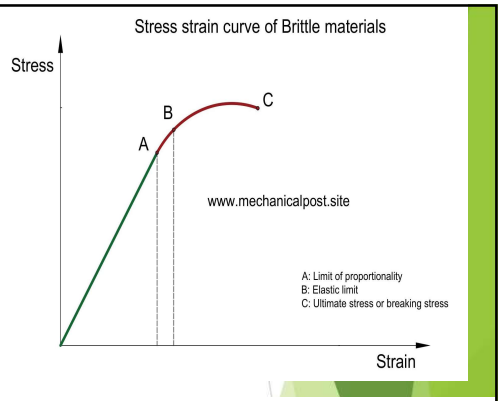
Modulus of Rigidity:

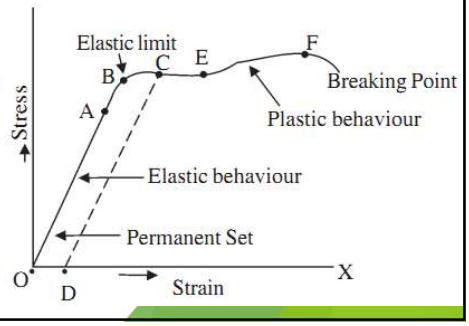
- Its is the ratio of the shear stress to the shear strain.
- G=shearing stress/shearing strain
- Shearing Stress = F/A
- Shear Strain = Δx/l
- G=F×l/A×Δx

$$G \overset{\text{def}}{=} \frac{\tau_{xy}}{\gamma_{xy}} = \frac{F/A}{\Delta x/l} = \frac{Fl}{A\Delta x}$$

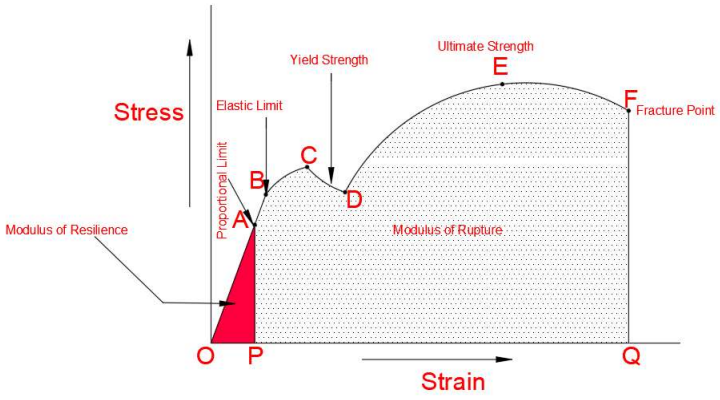
Stress strain curve of Iron



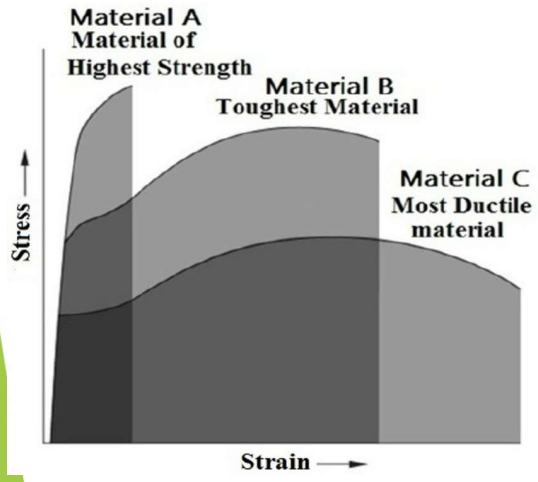




Resilience



toughness



TOUGHNESS

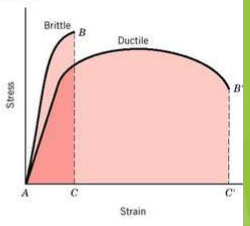
Toughness is the **area under σ - ε curve up to fracture**.

$$Toughness = \int_0^{\epsilon_f} \sigma d\varepsilon$$

Where ϵ_f is the true strain at fracture.

Note that ***toughness*** is the energy per unit volume that has been dissipated up to the point of fracture

Toughness is the material's ability to absorb energy before **fracture**



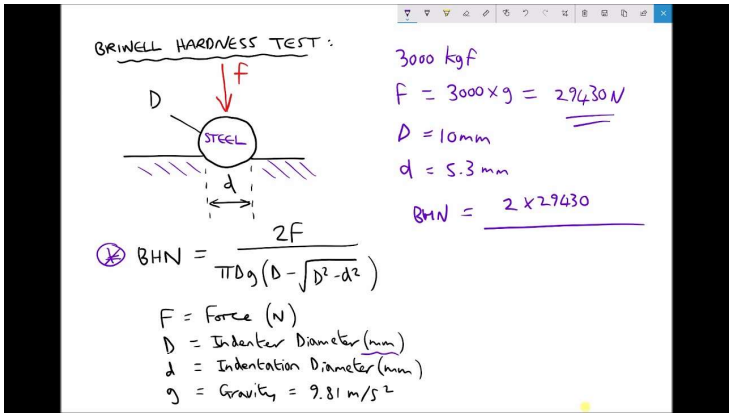
- Similar to Resilience (same units J/m³).
- Larger area ⇒ **tougher** material.

So tough materials have a **combination of** strength **And** ductility **such as ruber**

Can be measured by an impact test.

- **Toughness** is the ability of a material to absorb energy and plastically deform without fracturing. Toughness is the strength with which the material opposes rupture. Toughness is defined as the amount of energy per unit volume that a material can absorb before rupturing.
- **Resilience** is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading. The **modulus of resilience** is defined as the maximum energy that can be absorbed per unit volume without creating a permanent distortion.
- Elasticity, **ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed**. A body with this ability is said to behave (or respond) elastically.
- **Plasticity**, also known as **plastic deformation**, is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces.
- Ductility is **the ability of a material to be drawn or plastically deformed without fracture**. It is therefore an indication of how 'soft' or malleable the material is. The ductility of steels varies depending on the types and levels of alloying elements present.

- **Metal hardness** is **a characteristic that determines the surface wear and abrasive resistance**. The ability of a material to resist denting from impact is related to hardness as well as a material's ductility.
- Heat treatment is **the process of heating metal without letting it reach its molten, or melting, stage, and then cooling the metal in a controlled way to select desired mechanical properties**. Heat treatment is used to either make metal stronger or more malleable, more resistant to abrasion or more ductile.
- **Annealing** is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and reduce its hardness, making it more workable. It involves heating a material above its recrystallization temperature, maintaining a suitable temperature for an appropriate amount of time and then cooling slowly.
- Normalizing involves **heating the steel to an elevated temperature, followed by slow cooling to room temperature**. The heating and slow cooling changes the microstructure of the steel. This reduces the hardness of the steel and will increases its ductility.


BRINELL HARDNESS TEST:
f
D
STEEL
d
3000 kgf
F = 3000 × g = 29430 N
D = 10mm
d = 5.3 mm
BHN = 2 × 29430
BHN = 2F / πDg(D − √(D² − d²))
F = Force (N)
D = Indenter Diameter (mm)
d = Indentation Diameter (mm)
g = Gravity = 9.81 m/s²