Unit 3

Testing of materials-Destructive, Non-Destructive, Hardness-Rockwell, Brinell, Vickers, Knoop, Meyers, Tensile Test, Compressive Test, Impact Test-Izod, Charpy

Reference Books

1. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 1988.
2. Mechanical Behaviour of Materials, William F. Hosford, Cambridge University Press, 2010.
3. Materials Science & Engineering: An Introduction, William D. Callister, Jr., John Wiley & Sons, Inc., 2007**.**

Unit 3

Testing of materials-Destructive, Non-Destructive

- Destructive tests are the tests where the utility of the specimen is exhausted after performing the test e.g. tensile test, impact test etc
- Non-destructive tests are the tests where the samples can be used even after performing the test e.g., Dye penetrant test, eddy current test etc

Hardness

- Material hardness is a property which enables it to resist localised plastic deformation, usually by penetration or indentation. The term can also apply to deformation from scratching.
- The greater the hardness of materials, the greater resistance it has to deformation.

There are three main types of hardness measurements:

Scratch hardness

- It is the measure of how resistant a sample is to permanent plastic deformation due to friction from a sharp object. The Mohs scale is used to measure it.
- The Mohs scale of mineral hardness is based on the ability of one natural sample of mineral to scratch another mineral visibly. The hardness of the material is ranked on the scale between the material it just scratches and the material that it fails to scratch.
- Mohs scale has talc as the softest and diamond as the hardest.

Indentation Hardness

- It measures the resistance of a sample to material deformation due to a constant compression load from a sharp object.
- The hardness is calculated by measuring the force applied and comparing this to some geometrical aspect of the indentation such as the surface area or depth.
- The three most commonly used are Brinell test, Vicker test, and Rockwell test.

- Brinell Hardness

➢ The Brinell hardness test consists of applying a constant load, usually in the range 500–3000 N, for a specified period of time (10–30 s) using a 5 or 10 mm diameter hardened steel or tungsten carbide ball on the flat surface of a work piece.

➢ The Brinell hardness number (HB), is obtained by dividing the load by the measured surface area of the indentation, left on the test surface.

➢ $HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$ where D is the ball diameter (mm), d is the diameter of the resultant recovered circular indentation (mm) and P is the applied load (kg).

➢ A value reported as "60 HB 10/1500/30" means that a Brinell Hardness of 60 was obtained using a 10mm diameter ball with a 1500 kg load applied for 30 seconds.

- Rockwell Hardness

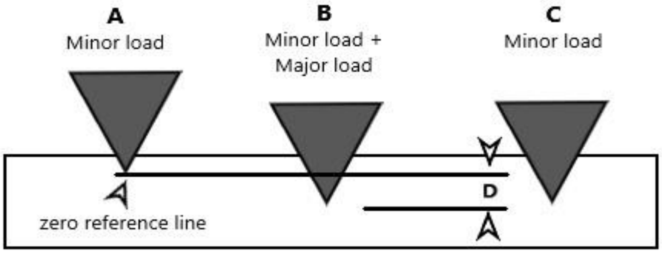
- The Rockwell Hardness test uses a machine to apply a specific load and then measure the depth of the resulting impression.
- A minor load is first applied which causes a small initial penetration to seat the indenter and remove effects of any surface irregularities. Then, the dial is set to zero and the major load is applied. Upon removal of the major load, the depth reading is taken while the minor load is still on. The hardness number may then be read directly from the scale.
- A variety of indenters may be used, conical diamond with a round tip for harder metals to ball indenters with a diameter ranging from 1/16" to ½" for softer materials.
- The test can be visualized as shown below in the diagram

A = Depth reached by indenter after application of preload (minor load).

B = Position of indenter during Total load, Minor plus Major loads.

C = Final position reached by indenter after elastic recovery of sample material.

D = Distance measurement taken representing difference between preload and major load position. This distance is used to calculate the Rockwell Hardness Number.



- Vicker Hardness

- It calculates the hardness of a material from the size of an impression produced under load by a pyramid-shaped diamond indenter.
- The indenter employed in the Vickers test is a square-based pyramid whose opposite sides meet at the apex at an angle of 136°. The diamond is pressed into the surface of the material at loads ranging up to around 120 kg, and the size of the impression (normally less than 0.5 mm) is measured with the aid of a calibrated microscope.
- The Vickers number (HV) is calculated using the following formula : $HV = 1.854(\frac{F}{D^2})$,with F being the applied load (measured in kgF) and D^2 the area of the indentation (measured in mm^2).
- The Vickers hardness test method can be also used as a microhardness test method and is mostly used for small parts, thin sections, or case depth work.
- The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness.

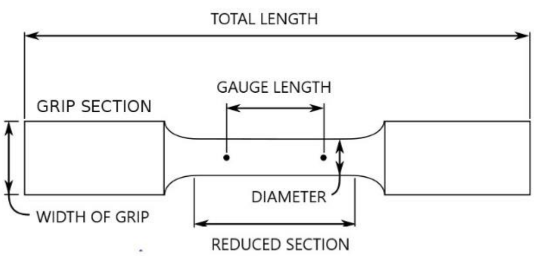
Rebound Hardness

- Rebound hardness, also known as dynamic hardness measures the height of the "bounce" of a diamond-tipped hammer dropped from a fixed height onto a material. This type of hardness is related to elasticity.

Tensile Test

- The tensile test measures the resistance of a material to a static or slowly applied force. It is considered as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. Other parameters obtained from tensile test are resilience, toughness, yield stress already explained in unit 2.
- The tensile sample has the shape of a dog-bone as shown in figure. The enlarged shoulders are for gripping. The cross-sectional area of gauge section is less than shoulders and grip section so that the deformation is localised in this region.

- The tensile samples are usually cylindrical, but may be flat also. The standard diameter is 12.5mm and the gauge length is typically 50mm. There are standards that cover tensile testing: ASTM Standards E 8 and E 8M and AS1391 (1991).



- The result of a tensile test is obtained as a load elongation data/diagram which is then converted into stress-strain diagram.
- The stress strain diagram and the related concepts are already explained in unit 2.
- Before performing the test, the gauge length, strain rate and test temperature is notified.
- The machine starts to pull the sample with the defined strain rate and the extensometer records the elongation with the subsequent load applied.
- The data is then converted into engineering stress-strain diagram by dividing with the original area (load) and original length (elongation)
- For the true stress-strain diagram, the engineering stress and strain are converted into true stress and strain (using the formulae in Unit 2).
- The fracture surface is examined to determine if the fracture was ductile or brittle.

Compression Test

- Tensile test is limited by necking and hence the materials are tested at higher strain rates by compression
- The problems associated with compression are friction and buckling

- Friction prevents the lateral spreading of the ends of the specimen as a result of which the specimen becomes barrel shaped
- Friction is reduced by lubrication and by maintaining a proper height to diameter ratio.
- If h/d is large (greater than 3), the specimen will buckle
- During compression, the load carrying cross-sectional area increases as opposed to tension. The engineering stress is thus greater than the true strain
- Both stresses and strains are negative in compression.

Impact Test

- The test refers to the condition where a material is subjected to high strain rate under triaxial state of stress.
- Two standard tests are Izod and V-Notch Charpy. They are used to measure impact energy/ notch toughness
- For both tests, the samples are in the shape of a bar with square cross-section into which a V-notch is machined. V-notch is important for inducing the triaxial stress
- The load is applied as the impact blow from a hammer positioned at a height 'h'.
- When the pendulum descends, it hits the sample and continues to raise to a height 'h''
- The energy difference is computed from the height difference h' and h
- Izod sample is like a cantilever beam. Supported at one end by the sample holder and the notch faces the hammer.
- The Charpy sample is held like a simply supported beam with the notched side facing away from the hammer.
- Impact tests are used to determine whether or not a material experiences ductile to brittle transition temperature. This is done by testing at different temperatures and observing the fractured surfaces. The ductile fracture surface is fibrous and dull whereas the brittle one is shiny and relatively smooth.