Testing of materials are generally classified in two categories:

1. Destructive testing (tensile test, hardness test, fatigue test, creep test and impact test)

2. Non-destructive testing (dye penetrant test, magnetic test, ultrasonic test, radiography, eddy current test etc.)

DESTRUCTIVE TESTING

HARNESS TESTING

HARDNESS- Hardness usually implies resistance to deformation, resistance to permanent or plastic deformation or resistance to indentation.

There are three general types of hardness measurements depending upon the manner in which the test is conducted.

These are :

1. Scratch hardness
2. Indentation hardness
3. Rebound, or dynamic, hardness.

Only indentation hardness is of major engineering interest for metals

BRINELL HARDNESS TEST

In this test, hardness is measured by pressing a hard steel ball into the surface of the test piece, using a known load. It is important to choose the combination of load and bail size carefully so that the indentation is free from distortion and suitable for measurement. The relationship of the Brinell hardness [H_B] which is between load P (kg), the diameter D (mm) of the hardened ball indenter and the diameter d (mm) of the indentation on the surface is given by the expression-

$$H_B = \frac{\text{Load(Kg)}}{\text{Area of curved surface of indentation}}$$

$$= \text{kgf/mn}^2 \text{ or N/mm}^2$$

$$H_B = \frac{P(\text{Kg})}{1/2\Pi \times D\left[D - \sqrt{D^2 - d^2}\right](\text{mm}^2)}$$

For different materials, the ratio P/D^2 has been standardized in order to obtain accurate and comparative results such as-

$$K = P/D^2, \text{ where K is a constant}$$

VICKER'S HARDNESS TEST

This test is preferable to the Brinell test where hard materials are concerned, as it uses a diamond indenter. (Diamond is the hardest material known-approximately 6000 H_B). The diamond indenter is in the form of a square-based pyramid with an angle of 136° between opposite faces. Since only one type of indenter is used the load has to be varied for different hardness ranges. Standard loads are 5, 10, 20, 30, 50 and 100 kg.

Hardness number (HD) is calculated by dividing the load by the projected area of the indentation-

$$H_V = \frac{\text{Load(Kg)}}{\text{Surface area of indentation } (mm^2)}$$

$$H_V = \frac{P(Kg)}{\left[d^2 / 2\sin\frac{1}{2}(136^\circ)\right](mm^2)}$$

$$= \frac{2P\sin 68^\circ}{d^2} = 1.854\frac{P}{d^2}$$

Here $\alpha = 136^\circ$

Where, P is the load in Kg and d (mm) is the diagonal of the impression made by the indenter made by the diamond.

ROCKWELL HARDNESS TEST

The Rockwell test is used in industry as it is quick, simple and direct reading. Universal electronic hardness testing machines are now used at large scale which, at the turn of a switch, can provide either Brinell, Vickers Or Rockwell tests and show the hardness number as a digital readout automatically.

In principle the Rockwell hardness test compares the differences in depth of penetration of the indenter when using forces of two different values. That is, a minor force is first applied (to take up the backlash and pierce the skin of the component) and the scale are set to read zero.

Then a major force is applied over and above the minor force and the increased depth of penetration is shown on the scales of the machine as a direct reading of hardness without the need for calculation or conversion tables.

CREEP TEST

Creep testing is done in the tensile mode, and the type of test-piece used is similar to the normal tensile test-piece. Generally, creep testing is carried out under constant- load conditions and utilizes dead weights acting through a simple lever system.

In the creep testing an extensometer readings are noted at regular time intervals until the required amount of data has been obtained, or until the test-piece fractured, depending on whether the object of the test is to determine the creep rate or to determine the total creep strain.

Creep deformation strength: highest stress that a material can bear for a specific duration at a certain temperature without excessive deformation which is predecided.

Creep rupture strength- Highest stress that a material can bear for a specific duration at a certain temp, without rupture.

THREE STAGES- .

1) Primary creep (Decreasing creep rate)

2) Secondary creep (constant creep rate)

3) Tertiary creep (rapid creep rate)

TENSILE TEST

The main principle of the tensile test is denotes the resistance of a material to a tensile load applied axially to a specimen. It is very important to the tensile test to be considered is the standard dimensions and profiles are adhered to.

In a simple tensile test, a sample is typically pulled to its breaking point to determine the ultimate tensile strength of the material. The amount of force (F) applied to the sample and the elongation (ΔL) of the sample are measured throughout the test.

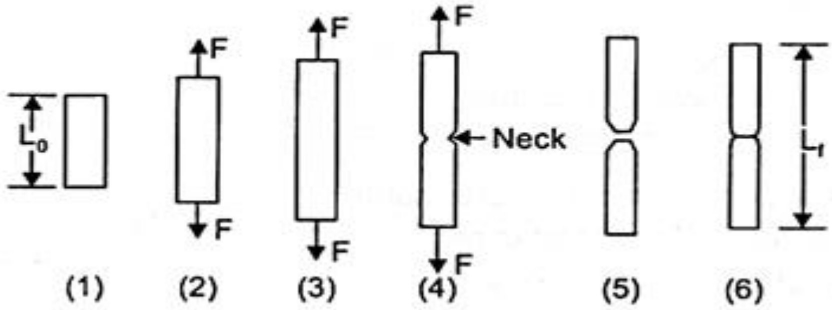

FIGURE : Typical progress of a tensile test : (1) beginning of test, no load; (2) uniform elongation and reduction of cross-sectional area; (3) continued elongation, maximum load reached; (4) necking begins, load begins to decrease; and (5) fracture. If pieces are put back together as in (6), final length can be measured.

Material properties are often expressed in terms of **stress** (force per unit area, **σ**) and **strain** (percent change in length, **ε**). To obtain stress, the force measurements are divided by the sample's cross sectional area (**σ =** F/A). Strain measurements are obtained by dividing the change in length by the initial length of the sample (**ε =** ΔL/L). These values are then presented on an XY plot called a **stress-strain curve**.

IMPACT TEST

Impact test **determines the amount of energy absorbed by a material during fracture**.

This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

It is to determine whether the material is brittle or ductile in nature.

In impact loading notches are made intentionally in its specimens to increase the stress concentration so as to increase tendency to fracture as most of the mechanical components have stress raisers. To with stand impact force, a notched material must be toughed.

Two classes of specimens have been standardized for notched-impact testing. i.e

1. Charpy 2. Izod

Charpy bar specimens:- The Charpy specimen has a square cross-section (10x10mm) and contains a 45° V notch, 2 mm deep with a 0.25 mm root radius. The specimen is supported as a beaming a horizontal position and loaded behind the notch by the impact of a heavy swinging pendulum. The specimen is forced to bend and fracture at a high strain ratio the order of 103/s.

Izod specimen:- Which is used rarely today, has either a circular or square cross section and contains a V notch near the clamped end.

In the **Izod test**, a 10mm square, notched specimen is used, it is preferred to use a specimen that have a more than one or two and even three notched in the same specimen. The striker of the pendulum hits the specimen with a kinetic energy of 162.72 J at a velocity of 3.8 m/s. Izod test suitable for room and high temp. Angle of (α): $\alpha < 90°$, normally 90°.

A second type of impact test is the **Charpy test**. While in the Izod test the specimen is supported as a cantilever, but in the Charpy test it is supported as a beam. It is struck with a kinetic energy of 298.3 J at a velocity of 5m/s. The Charpy impact test is use for testing the toughness of polymers.

NON-DESTRUCTIVE TESTING

NDT is the method of detection and measurement of properties or condition of materials, structures, machines without damaging or destroying their operational capabilities.

Some of the applications of NDTs are detecting:

(i) Surface cracks

(ii) Material composition

(iii) Internal inclusions

(iv) Internal voids and discontinuities and

(v) Condition of internal stresses.

TYPES OF NON DESTRUCTIVE TESTING

Magnetic particle inspection :

Magnetic particle inspection (often abbreviated MT or MPI) is a nondestructive inspection method that provides detection of linear flaws located at or near the surface of ferromagnetic materials. It is viewed primarily as a surface examination method.

Magnetic Particle Inspection (MPI) is a very effective method for location of surface breaking and slight sub-surface defects such as cracking, pores, cold lap, lack of sidewall fusion in welds etc in magnetic materials.

There are many different techniques. The most versatile technique is using a 110v AC hand held electromagnetic yoke magnet, a white strippable paint as contrast background and a magnetic "ink" composed of iron powder particles in a liquid carrier base.

The area is magnetised with the yoke magnet. In the event of a surface or slightly sub surface defect being present, the lines of magnetic force will deform around the defect.

The magnetic ink is applied and the iron powder particles will bridge the gap caused by the defect and give a visible indication against the white contrast background.

Magnetic Particle Inspection (MPI) provides very good defect resolution and is used extensively on..
Welded fabrications in magnetic material, Castings, Locating fatigue cracks in items subject to cyclical stress

Ultrasonic Test:

High frequency ultrasonic (sound) waves are applied to the test piece by a piezoelectric crystal. If the test piece is free from cracks, or flawless, then it reflects ultrasonic waves without distortion.

If there are any flaws in the specimen, the time taken by the ultrasonic waves will be less as the reflection of these waves will be from flaw points and not from the bottom of the specimen.

Cathode ray oscilloscope (CRO) is used to receive the sound signals, whose time base circuit is connected to it. This test is a very fast method used to test aerospace components and automobiles. This test is generally used to detect internal cracks like shrinkage cavities, hot tears, zones of corrosion and non-metallic inclusions.

Liquid-Penetration Test:

This test is used for detection of small defects which are very small to detect with the naked eye. This test is used to detect surface cracks or flaws in non-ferrous metals. This test employs a visible colour contrast dye penetrant technique for the detection of open surface flaws in metallic and non-metallic objects. The penetrants are applied by spraying over the surface of material to be inspected. The excess penetrant is then washed or cleaned. Absorbent powder is then applied to absorb the penetrants in the cracks, voids which reveals the flaws.

This test reveals flaws such as shrinkage cracks, porosity, fatigue cracks, grinding cracks, forging cracks, seams, heat treatment cracks and leaks etc., on castings, welding, and machined parts, cutting tools, pipes and tubes. If the fluorescent penetrant is used, the developed surface must be examined under ultra violet light to see the presence of defects. This technique is used for non-porous and non-absorbent materials.

Radiography:

Done in/on radiographic film by x-rays to know about crack or flaws in welding etc. to have better results. Radiography technique is based upon exposing the components to short wavelength radiations in the form of X-rays (wave length less than 10^{-11} cm to about 40×10^{-8} cm) or gamma (γ) rays (wavelength about 0.005×10^{-8} to 3×10^{-8} cm) from a suitable source such as an X-ray tube or cobalt 60.
These tests are used to detect defects such as blow holes, cracks, shrinkage cavities and slag inclusions. These defects are of special importance in components designed to withstand high temperatures and pressure employed in power plant atomic reactors, chemical and pressure vessels and oil refining equipments, because then (i.e., defects) cause stress concentration which may frequently lead to part failure.

In X-ray radiography, the portion of the casting where defects are suspected is exposed to X-rays emitted from the X-ray tube. A cassette containing X-ray film is placed behind and in contact with the casting perpendicular to the rays. During exposure, X-rays penetrate the casting and thus affect the X-ray film.