

# Material & Thermodynamic Science



# Mechanical Testing

# Mechanical Testing

The serviceability, integrity and safety of any part in a machine is dependent upon the mechanical properties of the materials it is made from. To determine these properties tests are used.

Consequently, mechanical tests are a crucial part of ensuring materials and components meet their designed specifications.

In this lesson we will examine the three mechanical tests:

- Tensile Tests
- Hardness Tests
- Impact Tests.

# Tensile Testing

The Australian Standard for tensile testing is AS 1391. In a tensile test, a specimen is strained in uniaxial tension in order to determine its tensile properties. The test is normally carried out at room temperature.

The test machine is basically a device to 'pull' on a test sample coupled to a device which measures the amount of 'pull' (Force) subjected to the sample.

Most tensile testing machines are also designed to carry out compression testing and are called Universal test machines. These machines are also capable of performing bend tests.

# Tensile Testing Machine



# Tensile Testing -Terms and Units

**Gauge Length:** That part of the test sample over which the extension is measured.

**Original Gauge Length (Lo)** is gauge length before sample is strained.

**Final gauge length (Lu)** is distance between the gauge points after the sample has fractured and two parts have been carefully aligned together in a straight line.

**Strain:** Strain is increase in length per unit length. At any point in the testing the **Extension** is equal to actual distance between gauge points (L1) minus original length (Lo). So we get:

$$\text{STRAIN } (\epsilon) = \frac{\text{Extension (m)}}{\text{Original length (m)}} = \frac{L_1 - L_0}{L_0}$$

# Tensile Testing -Terms and Units

**Elongation (A):** Elongation is the extension expressed as a percentage of the original gauge length.

$$\text{Elongation (A)} = \frac{L_u - L_o}{L_o} \times 100$$

**% Reduction of Area (Z):** As the sample is stretched its cross sectional area will decrease. % Reduction of area is a measure of the change in cross sectional area due to the sample been strained.

$$\% \text{ Reduction Area (Z)} = \frac{S_o - S_u}{S_o} \times 100$$

$S_o$  = Original cross sectional area before straining the sample.

$S_u$  = Final cross sectional area **after sample has fractured**.



# Tensile Testing -Terms and Units

**Force:** Force is the amount of 'pull' on the sample and is measured in Newtons (N) or kilonewtons (kN).

**STRESS:** Stress is the force per unit area and is measured in Pascals (Pa).

$$\text{STRESS } (\sigma) = \frac{\text{Force (N)}}{\text{Area (m}^2\text{)}}$$

# Tensile Test Samples

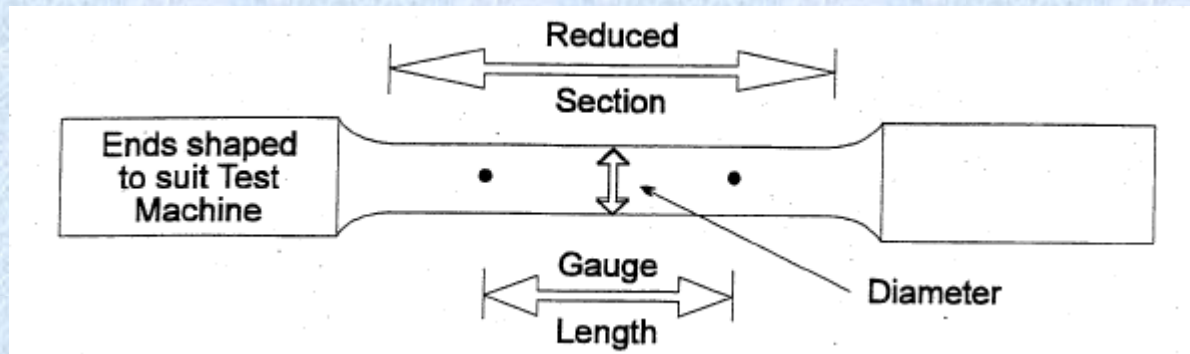
The standard AS 1391 specifies the preferred shape and dimensions of test pieces for the tensile test. For a circular test sample, this relates the original gauge length ( $L_0$ ) to the original sample diameter ( $d$ ) with:

$$L_0 = 5d$$

Some typical preferred dimensions for test samples is shown below:

**Table 6.1 Dimensions of circular section proportional test pieces**

Cross-sectional area $\text{mm}^2 (S_0)$	Diameter D (mm)	Gauge Length $L_0$ (mm)	Minimum Parallel Length (mm) $L_C=L_0+0.5D$
314	20	100	110
176	15	75	83
78.5	10	50	55
19.6	5	25	28



# Tensile Test - Properties Determined

**Yield Stress:** If a material reaches a yield point, plastic deformation will start and will continue for almost constant force. The stress at which the yield point occurs is called the **yield stress**.

**Proof Stress:** This is the stress at which non-proportional elongation occurs. This is often specified for materials that do not exhibit a marked yield stress.

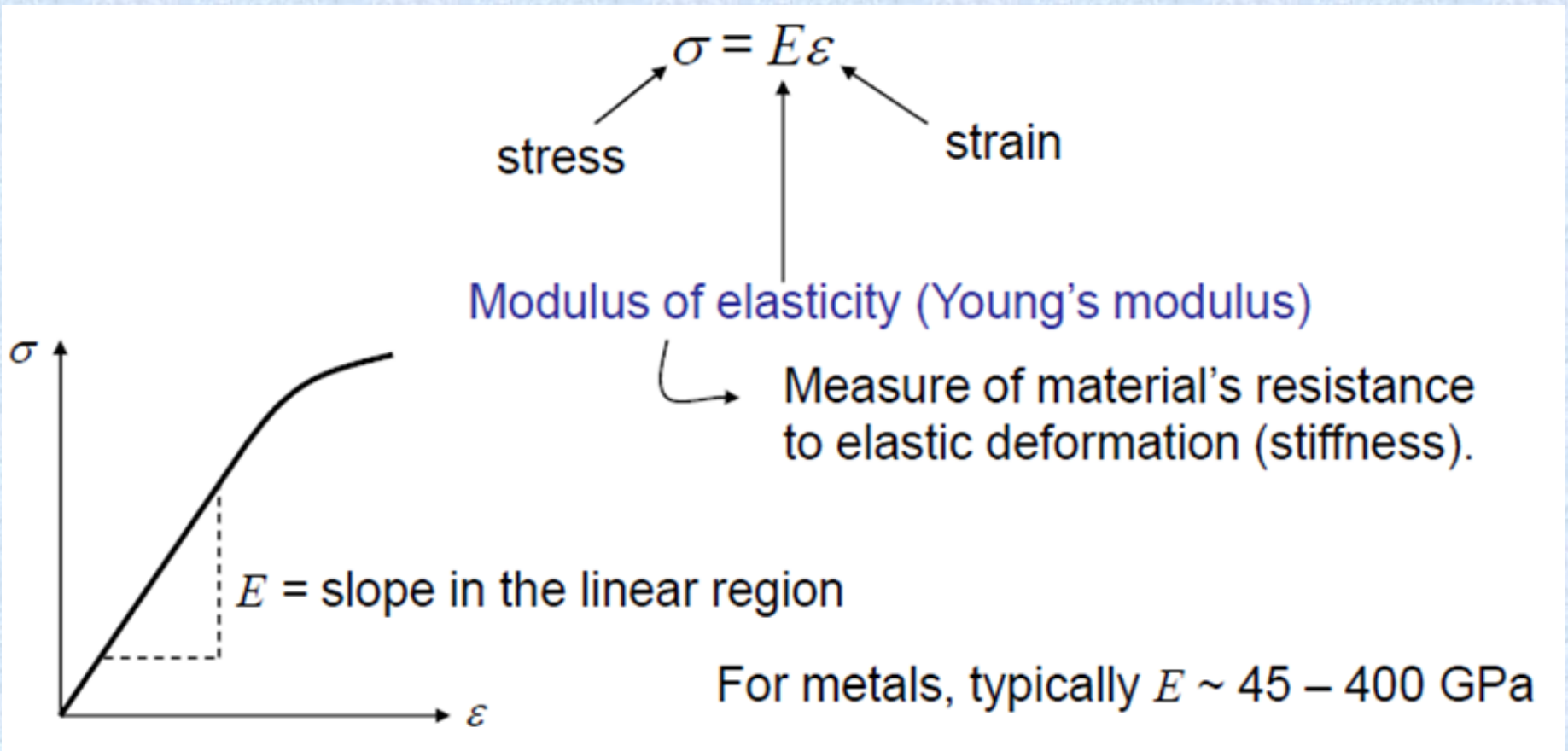
**Tensile Strength:** The stress corresponding to the maximum force recorded during the tensile test.

**Young's Modulus of Elasticity:** This is determined by the stress/strain graph and is the slope of the elastic (linear) part of the graph.

$$\text{Young's Modulus of Elasticity} = E = \frac{\text{Stress}}{\text{Strain}}$$

**% Elongation and %Area Reduction:** These can easily be determined by direct measurements of the test sample before and after testing.

# Stress / Strain Graph



# Stress / Strain Graphical Analysis

Let us look at some tensile test data for a sample and from this analyse its strength properties. Firstly, here is the actual data:

Original Diameter = 13.82mm

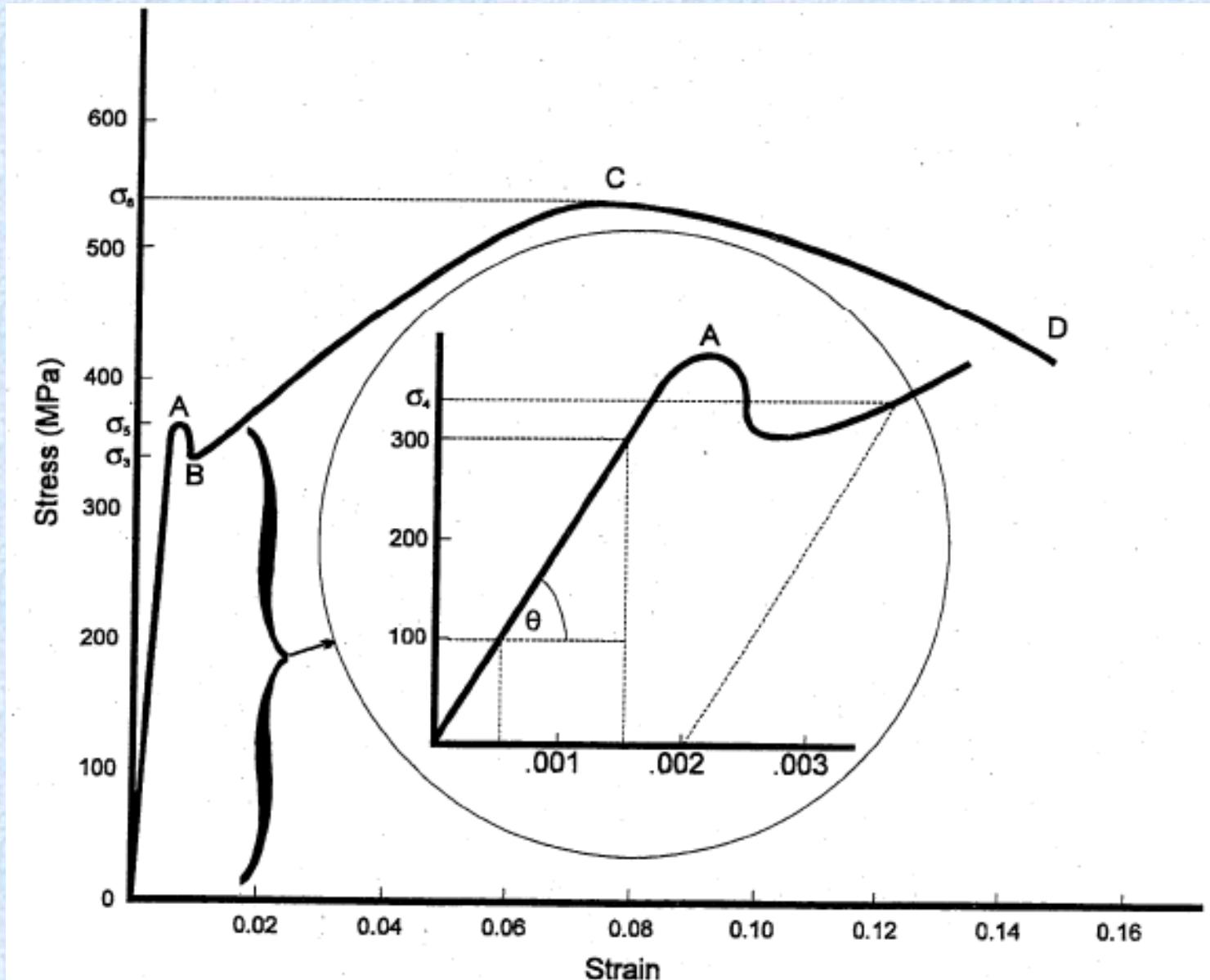
Original Gauge Length = 69.0mm

Final Diameter = 10.15mm

Final Gauge Length = 81.0mm

Force (kN)	Extension (mm)	Stress(MPa) (Force/area)	Strain (Extension/Gauge Length)
4.5	0.0103	30	0.00015
9	0.0207	60	0.0003
18	0.042	120	0.00061
27	0.062	180	0.0009
36	0.082	240	0.0012
45	0.104	300	0.0015
53	0.124	353	0.0018
50	0.32	333	0.0046
60	1.30	400	0.019
70	2.85	467	0.041
81	4.75	540	0.069
67.5	9.50	450	0.138
63	10.30	420	0.149

# Stress / Strain Graph

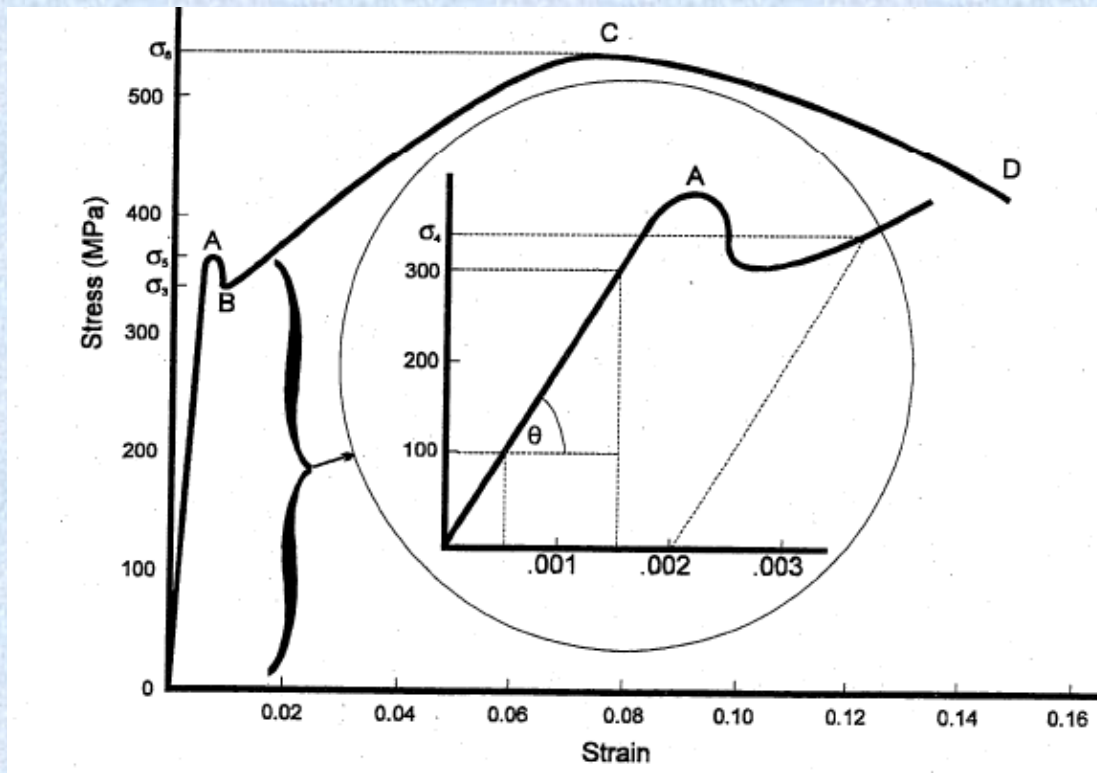


# Stress / Strain Graphical Analysis

**O to A:** During this part of the graph material behaves elastically. If stress is reduced to zero at any point below A, the strain will also reduce to zero.

**A to B:** Just beyond A yielding begins and is complete by B. At any point beyond A removal of the stress will result in only partial recovery of strain.

**C to D:** Point C represents the point at which the stress reaches a maximum value. Beyond C the material starts to locally 'neck-down'. At point D the material fractures.



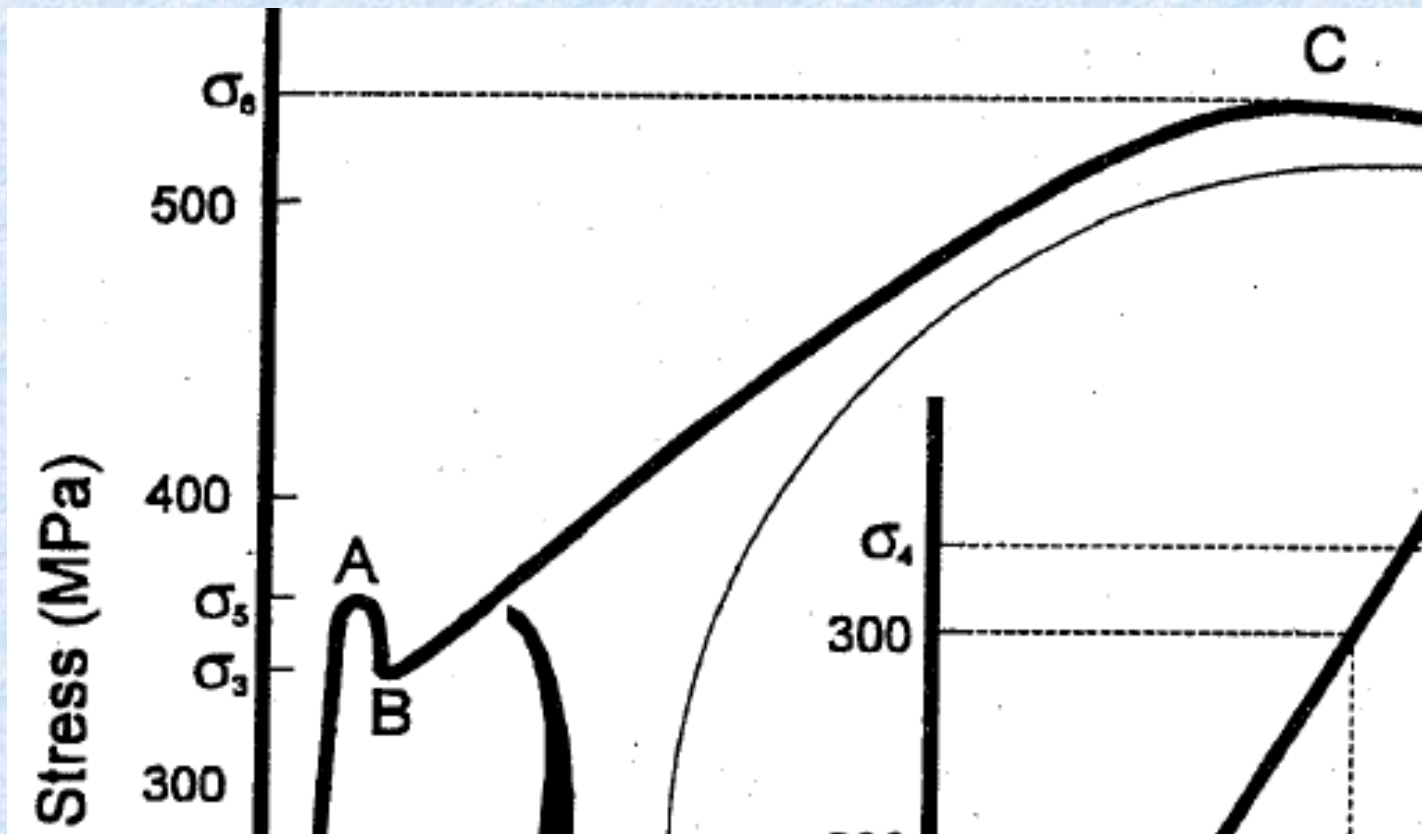
# Stress / Strain Graphical Analysis

From this graph we can determine the following values:

The lower yield stress –  $\sigma_3$  is 325 MPa

The upper yield stress –  $\sigma_5$  is 370 MPa

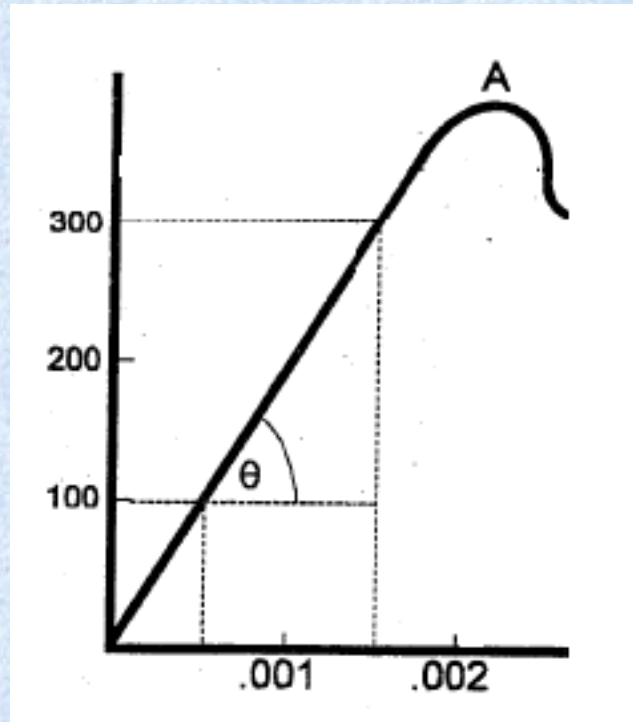
The tensile strength –  $\sigma_6$  is 540 MPa



# Stress / Strain Graphical Analysis

We can also determine the Young's Modulus of Elasticity (**E**) by examining the linear elastic section of the graph:

$$E = \text{Slope of graph} = \frac{\sigma_2 - \sigma_1}{E_2 - E_1} = \frac{300 - 100}{0.0015 - 0.0005} = \frac{200}{0.001} = 200,000 \text{ MPa}$$



# Stress / Strain Graphical Analysis

Finally, referring back to the original test sample data, we can determine both % Elongation and % Reduction in area using..

## Table 6.2 Tensile Test Data

Original Diameter = 13.82mm

Original Gauge Length = 69.0mm

Final Diameter = 10.15mm

Final Gauge Length = 81.0mm

Percentage elongation (A) for the material is equal to:

$$\frac{L_u - L_0}{L_0} \times 100 = \frac{81 - 69}{69} \times 100 = 17.4\%$$

Percentage reduction of area (Z) for the material is equal to:

$$\frac{S_0 - S_u}{S_0} \times 100 = \frac{150 - 81}{150} \times 100 = 46\%$$

# Hardness Testing

There are many methods of determining hardness.

The earliest hardness tests relied upon a file or similar device to scratch a test sample. This is called the Mohs hardness test.

The Mohs hardness test consists of 10 minerals arranged in order of increasing hardness. The hardness of the sample is determined from the Mohs scale as the first mineral that will scratch the test sample.

## MOHS SCALE OF MINERAL HARDNESS

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

# Modern Hardness Testing

Modern hardness testing uses the principle of using a standard force to push an indenter into the surface of the material.

The hardness is determined from the diameter or depth of the resulting indentation.

There are four standardised hardness tests:

- Brinell Test – AS 1816
- Vickers Test – AS 1817
- Rockwell Test – AS 1815
- Superficial Rockwell Test – AS 2015

# Brinell Hardness Test

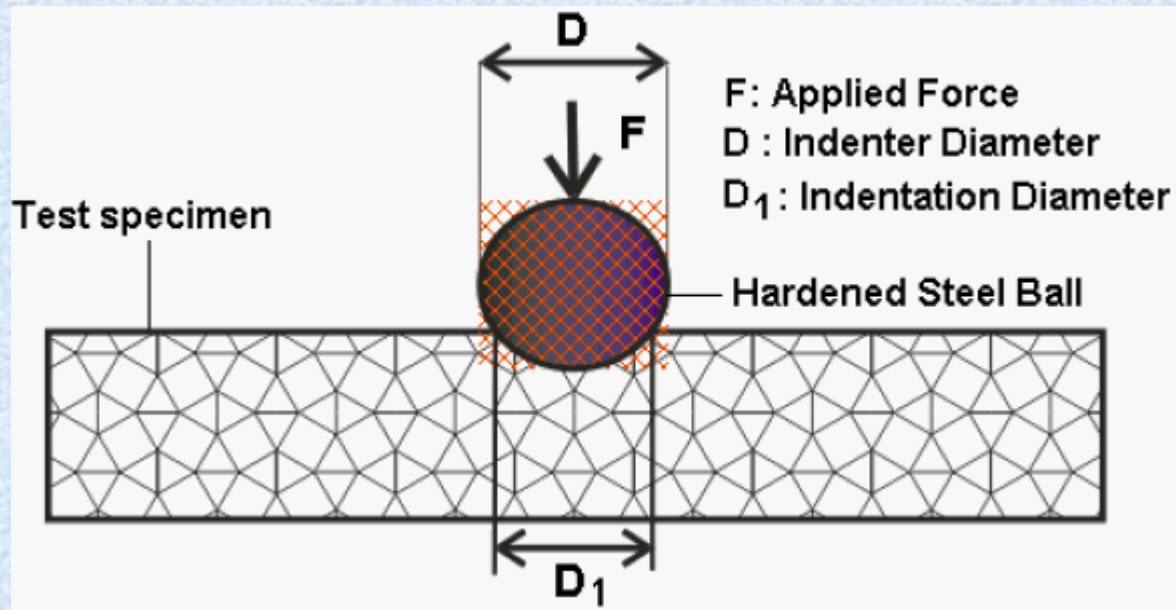
This test uses a steel ball as an indenter. The ball is pressed into the surface of the test sample using forces ranging from 9.8N to 29,400 N. Standard ball diameters and forces for particular materials is shown below:

**Table 6.3 Ball diameters and forces for the Brinell Hardness Test**

Ball diameter (mm)	$P/D^2=30$		$P/D^2=10$		$P/D^2=5$		$P/D^2=1$	
	N	Kg	N	Kg	N	Kg	N	Kg
1	294	{30}	98	{10}	49	{5}	9.8	{1}
2	1176	{120}	392	{40}	196	{20}	39.2	{4}
5	7350	{750}	2450	{250}	1225	{125}	245	{25}
10	29400	{3000}	9800	{1000}	4900	{500}	980	{100}
Used for	Ferrous Metals		Copper		Aluminium		Lead, Tin and their alloys	

Note:  $P/D^2$  is the ratio of mass in kg to diameter<sup>2</sup> of the indeter.

# Brinell Hardness Testing



# Brinell Hardness Test

Brinell hardness is determined from the formula:

$$HB = \frac{0.204F}{\pi D(D - \sqrt{D^2 - d^2})}$$

where F = applied force in Newtons  
D = indenter diameter in mm  
d = indentation diameter in mm

# Brinell Hardness Test

Tables of Brinell hardness numbers determined using this formula are available for a number of force and indenter diameter combinations. An important criterion in the Brinell test is the ratio  $P/D^2$ , where

$$P = \text{mass in kg} = \frac{\text{Force (Newtons)}}{9.80665}$$

$D$  = indenter diameter in mm

In order to maintain a correct Brinell hardness, this ratio must be kept constant. Hence it is not possible to change masses (and hence forces) or indenter diameters at will. Standard  $P/D^2$  ratios for different materials are shown in table 6.3.

# Brinell Hardness Test

Brinell hardness test results are always reported as:  
 $x\text{HB}_y / z$  eg. 250HB10 / 3000

where  $x$  = hardness number  
 $y$  = indenter diameter in mm  
 $z$  = mass used in kg

# Vickers Hardness Test

This test uses a square based pyramidal diamond indenter in which the angle between opposite faces is  $360^\circ$ . The force may be varied from 49 N to 1176 N. Unlike the Brinell test, Vickers hardness test is independent of the  $P/D^2$  ratio.

In this test the diagonal length of the square impression is measured and used as the data for determining hardness.

Vickers hardness is then determined from tables or from the formula:

$$HV = \frac{0.1891F}{d^2}$$

where  $F$  = force in Newtons

$d$  = diagonal of indentation in mm

Vickers hardness test results are always reported as:

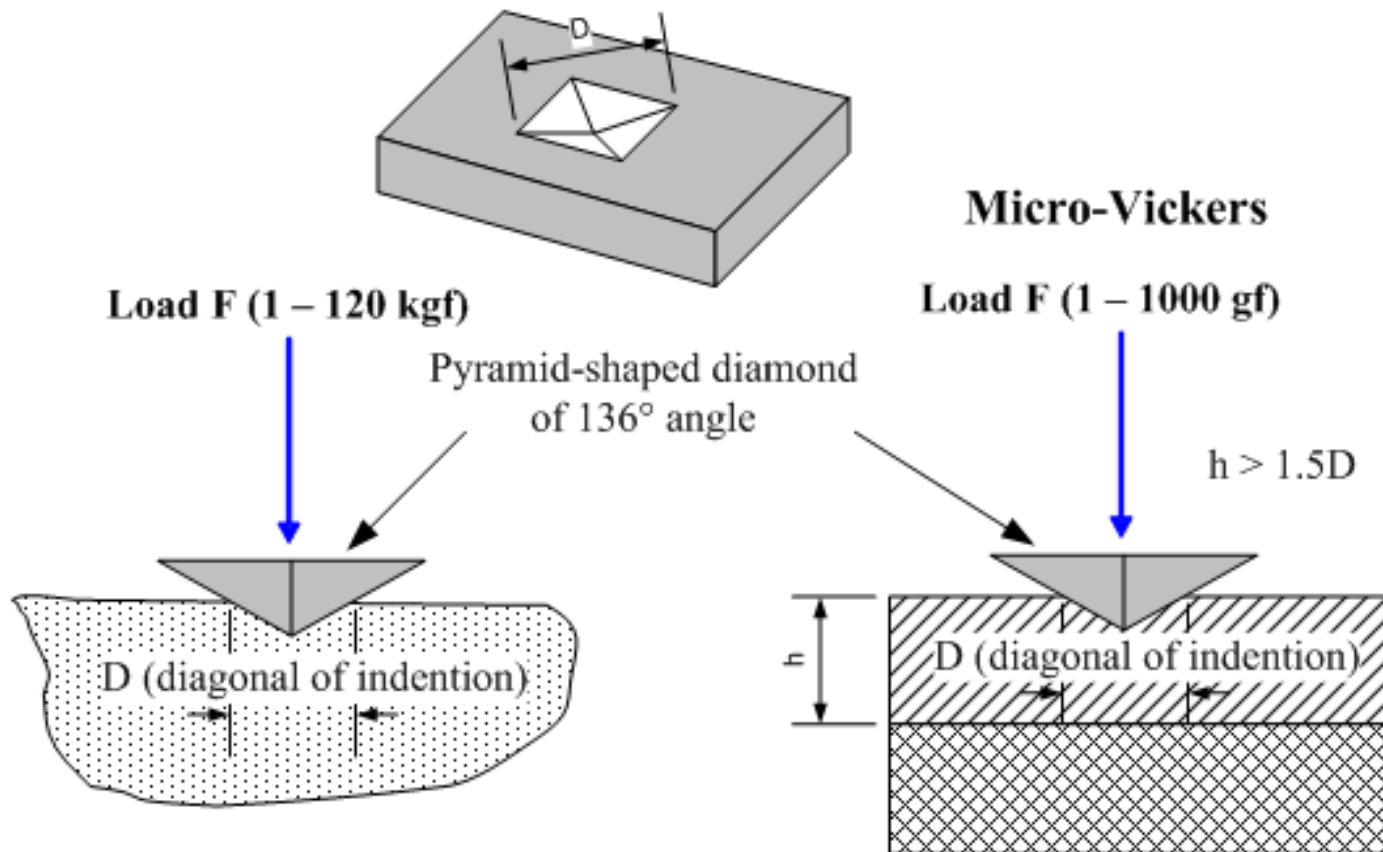
$x$  HV  $y$  (e.g. 250 HV 30)

where  $x$  = hardness number and

$y$  = mass used in kg

# Vickers Hardness Test

## Vickers Hardness Test



# Rockwell Hardness Test

This test uses three different indenters and three different forces, making a total of 9 different Rockwell hardness scales.

The main difference in this test to Brinell and Vickers is that depth of penetration is measured as the hardness parameter instead of diameter or diagonal of indentation. A direct reading dial gauge is attached to the indenter to measure the permanent displacement of the indentation.

The three indenters are:

- A conical diamond (brale) indenter with an apex angle of  $120^\circ$
- A 1.588 mm diameter steel ball
- A 3.175 mm diameter steel ball

The three forces are:

- 588 N utilising a mass of 60 kg
- 980 N utilising a mass of 100 kg
- 1470 N utilising a mass of 150 kg

Details of the nine scales are shown in table 6.4.

# Rockwell Hardness Test



# Rockwell Hardness Test

Table 6.4 Rockwell Hardness Scales

Rockwell Scale	Indenter	Total Force (N)	Total Mass (kg)	Typical Applications
A	Diamond cone	588	60	Cemented carbide; Thin hard steel
B	1.588 mm ball	980	100	Copper and aluminium alloys; soft steels
C	Diamond cone	1470	150	Harder steels
D	Diamond cone	980	100	Case hardened steels
E	3.175 mm ball	980	100	Cast iron; aluminium alloys
F	1.588 mm ball	588	60	Soft copper alloys; Thin soft sheet
G	1.588 mm ball	1470	150	Phosphor bronze; Beryllium copper
H	3.175 mm ball	588	60	Aluminium; lead; zinc
K	3.175 mm ball	1470	150	Soft bearing metals

the Rockwell hardness test are reported as:

x HR y (e.g. 45 HRC)

where x = hardness number

y = Rockwell hardness scale used

# Superficial Rockwell Hardness Test

This test works on the same principle as the Rockwell test, except much lighter forces are used resulting in much small indentations.

Two indenters are used – a conical diamond and a 1.588 mm diameter steel ball with three forces available 147 N, 294 N and 441 N.

There are two principal scales, the 'N' scale which uses the diamond cone indenter and the 'T' scale which uses the 1.588 mm ball indenter. Test results are reported as:

x HR y z (e.g. 45 HR 15 N)

where x = hardness value  
y = mass employed in kg  
z = scale used (N or T).

# Impact Testing

The definition of impact toughness of a material is the energy required to fracture it, and the unit for measuring this property is the joule (J). Thus impact toughness is a measure of the ability of a material to withstand a shock load.

The most common impact tests are the Izod and Charpy tests.

Both use a pendulum type test machine in which a pendulum swings from a fixed height and strikes the sample.

The energy absorbed in fracturing the sample is recorded by a pointer pushed around the scale by the pendulum.

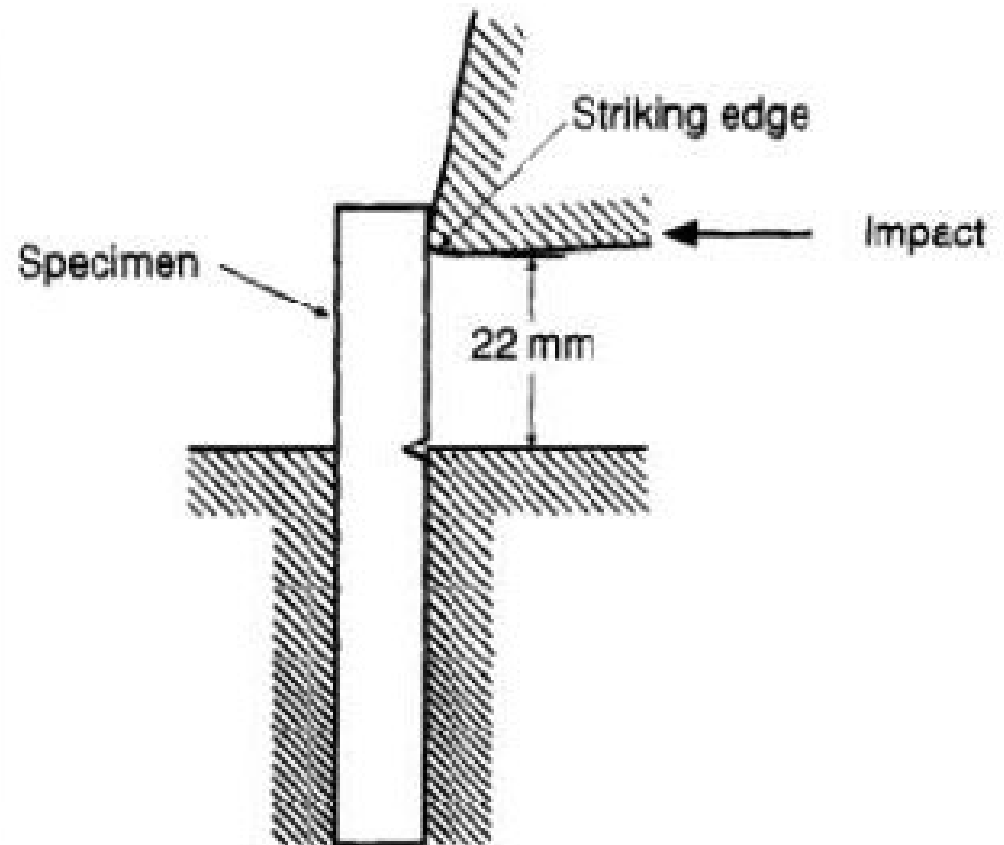
# IZOD Impact Testing

The IZOD test (AS 1554/1) uses a round (or sometimes square) sample containing a 45° vee-notch on one face. The sample is clamped vertically as a cantilever with the notch facing the pendulum.

The Izod test pendulum strikes the specimen 22 mm above the notch with a striking energy of 170 joules.

It takes more energy to fracture a tough material than a brittle material and this energy to cause fracture is read directly from the scale attached to the machine.

# IZOD Impact Testing



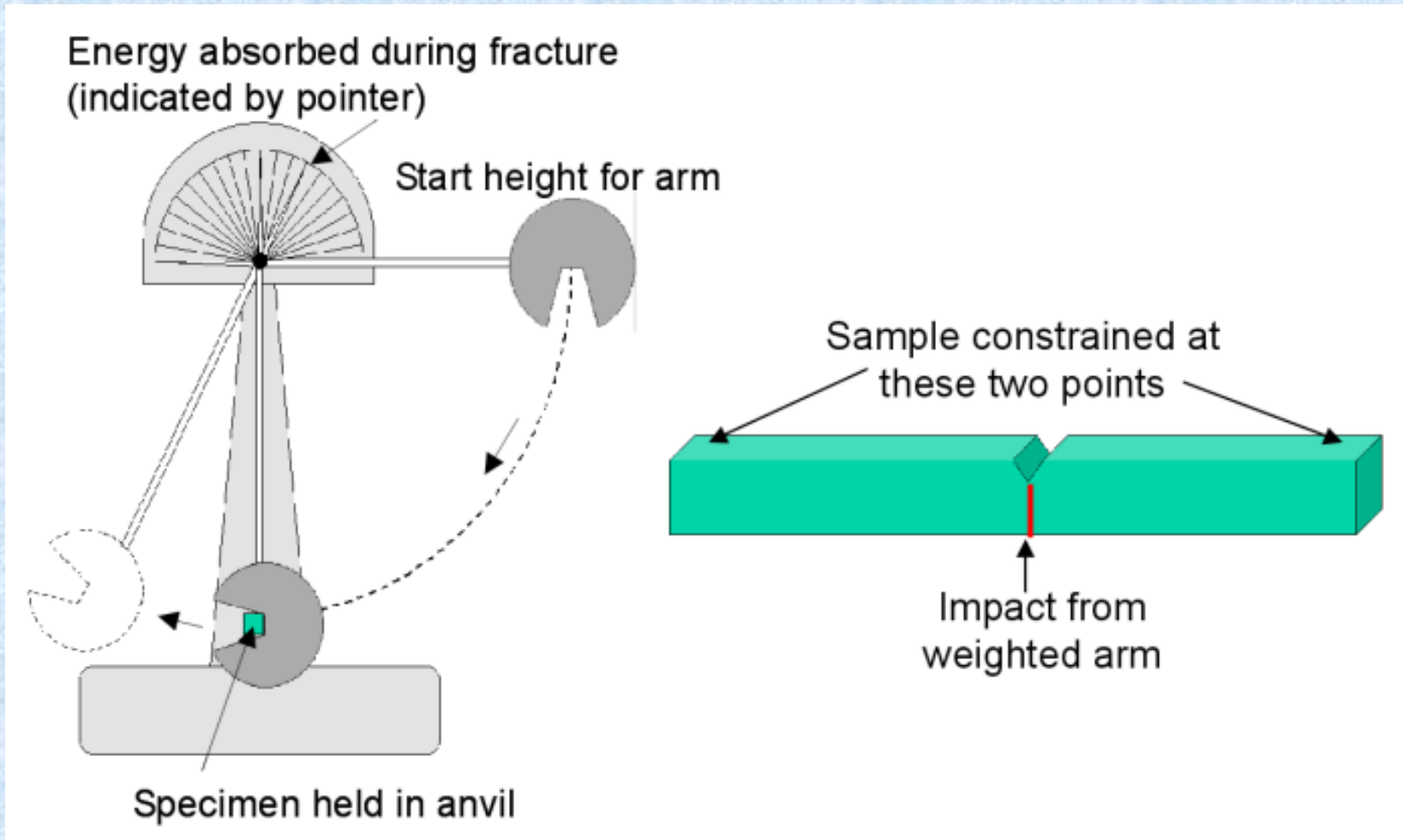
# Charpy Impact Testing

The Charpy test (AS 1554/2) uses a 10 mm square sample containing a 45° vee-notch machined 2 mm deep across the centre of one face. The sample is supported on a horizontal beam and is struck directly **behind** the notch by the falling pendulum.

The Charpy test pendulum strikes the specimen with a striking energy of either 160 or 320 joules – depending upon the toughness of the test sample.

It takes more energy to fracture a tough material than a brittle material and this energy to cause fracture is read directly from the scale attached to the machine.

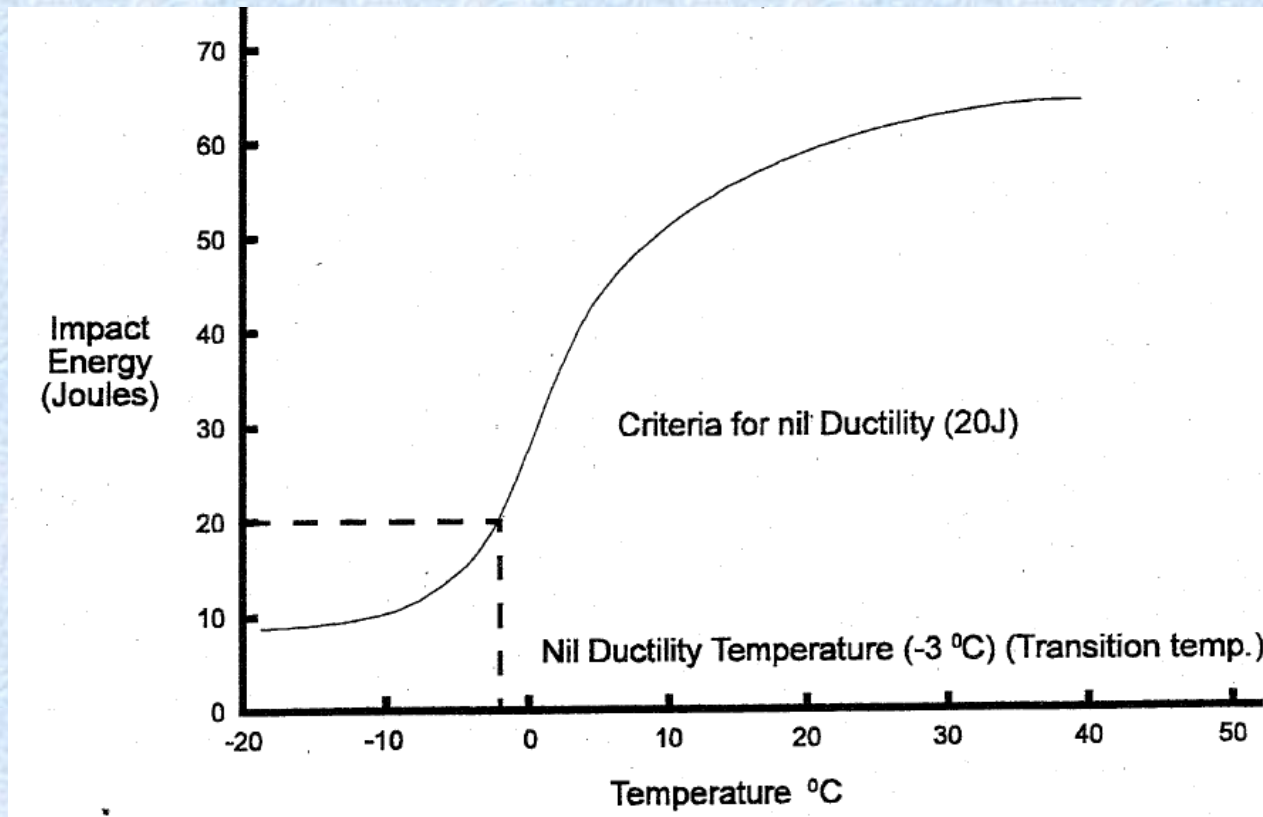
# Charpy Toughness Test



# Impact Testing and Temperature

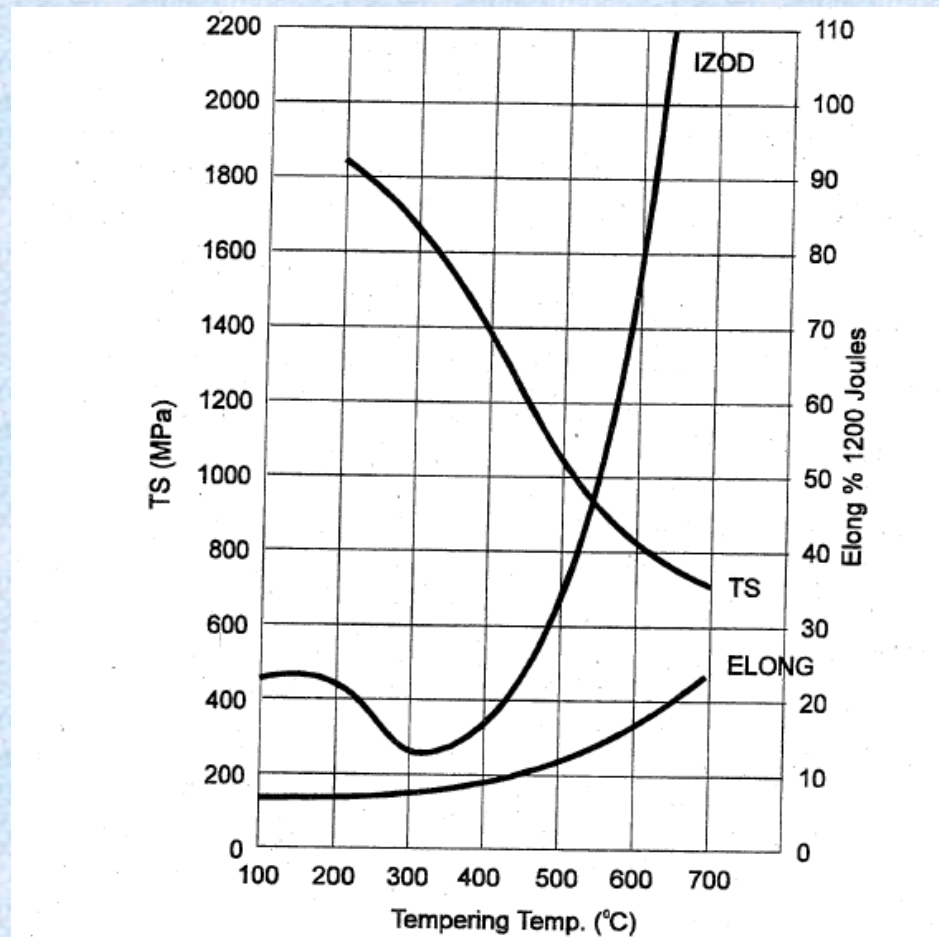
The Charpy test has an advantage over the Izod test in that it can be used for testing toughness at temperatures above or below room temperature.

Impact toughness, due to presence of notches, can be greatly affected by temperature. At low temperatures notch toughness can fall rapidly. This temperature at which toughness rapidly drops is the **Transition Temperature**.



# Temper Brittleness

Another effect that occurs in hardened steels is known as **Temper Brittleness**. This is a lowering of impact strength as the tempering temperature of the steel is raised over a range from about 200°C to 500°C. This effect can only be detected using Izod or Charpy impact tests.



**Table 6.5 Typical properties of some selected materials**

Material	Tensile Strength (MPa)	Yield Stress (MPa)	Young's Modulus (MPa)	Ductility	Use
<b>METALS</b>					
Aluminium	90-165	35-150	70,000	H	Cooking Utensils
Al-Cu Alloy	200-470	75-325	70,000	L	Structural
Al-Mg Alloy	200-290	90-255	70,000	H	Automotive, Aircraft
Copper	220-360	45-200	110,000	M	Busbars
70-30 Brass	275	75	110,000	H	Lamp Fixtures
Manganese Bronze	450	265	110,000	M	Pump Shafts
Beryllium Copper	480-1200	205-900	110,000	H	Springs
Lead	17	2.5	14,000	H	Flashing, Batteries
Magnesium	240-270	215-220	43,500	L	Aircraft Structure
Mild Steel	450	350	210,000	H	Structural
Alloy Steel	2000	1500	210,000	M	Constructional
Tool Steel	2500	2200	210,000	L	Machining, Forming Tools
Stainless Steel	760	510	195,000	H	Corrosion
Nickel	350-800	150-630	210,000	M	Heat, Corrosion
Titanium	230-650	150-580	106,000	H	Corrosion
Grey Iron	170-270	135-240	205,000	L	Light Structural
Nodular Iron	550	380	205,000	M	Crankshafts
<b>NON METALS</b>					
Polyethylene	Jul-30	-	100-1250	H	Packaging
PVC	Oct-40	-	2000-4800	M	Piping
Nylon	50-70	-	2800	H	Wear
Phenolformaldehyde	35-55	-	7000	L	Insulators
Glass	500-10000	-	70000	L	Windows,
Wood	1.5-5.5	-	12000	M	Structural
Fibreglass	170	-	68000	L	Marine
Epoxy	68	-	6800	L	Voltage Regulators
Ductility	H = High M = Medium L = Low				

# Non-Destructive Testing

# Non-Destructive Testing

Non-destructive testing methods include all those test methods designed to test the properties of a material without affecting the material in any way or impairing its usefulness.

There are many types of non-destructive testing; including visual inspection. Visual inspection however is subject to human error and cannot be considered as an adequate testing method on its own.

Non-destructive tests may be divided into two distinct groups:

1. Tests to locate defects in the sample and compliance with a reference sample.
2. Tests to check dimensional, physical or mechanical characteristics against a know reference sample.

# Non-Destructive Tests

Let us examine the following non-destructive tests:

- Liquid Penetrant Tests
- Magnetic Particle Tests
- Eddy Current Tests
- Radiographic Tests
- Ultrasonic Tests
- Strain Gauging Tests

# Liquid Penetrant Tests

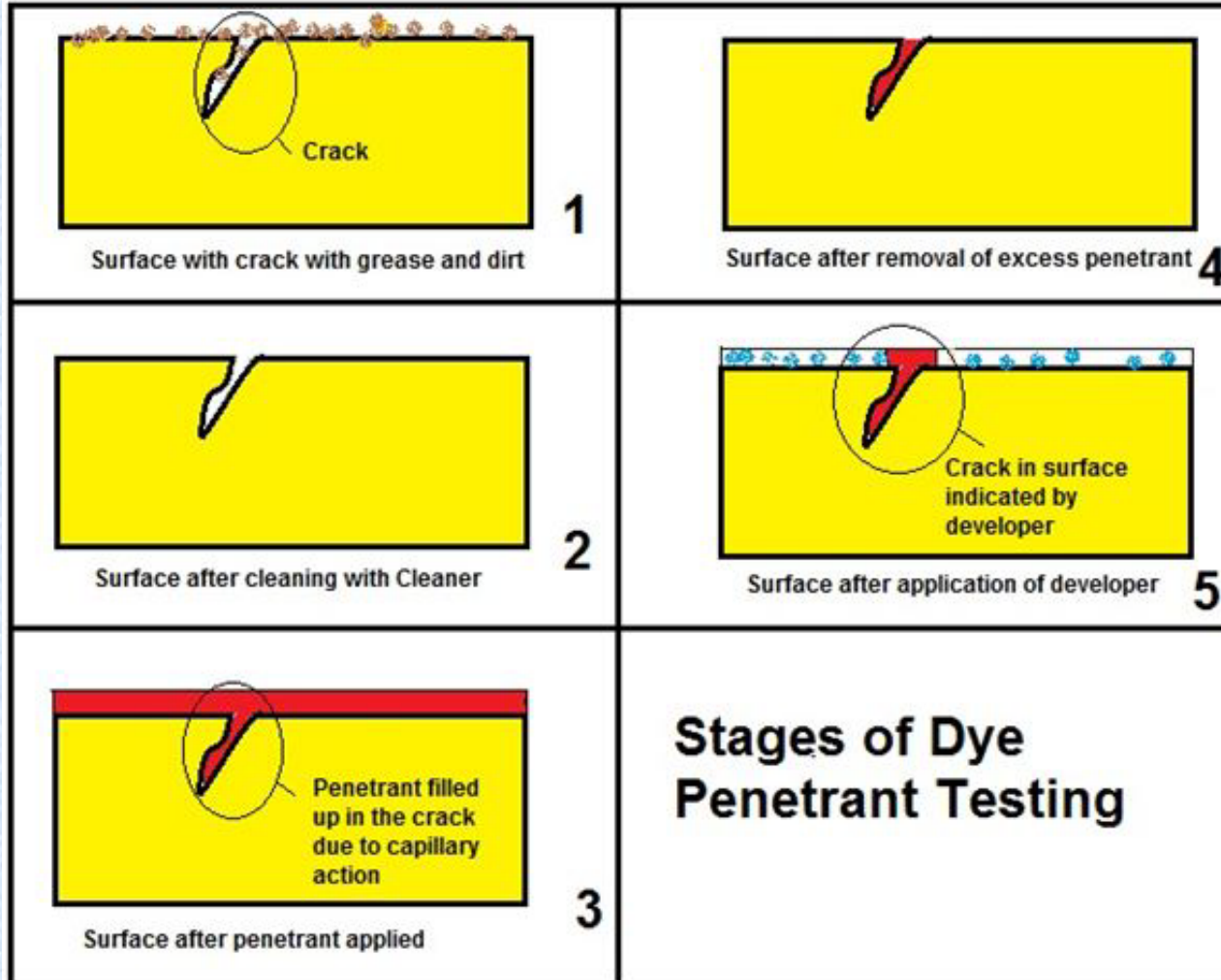
Liquid penetrant inspection can be used for the detection of discontinuities that are open to the surface under test in solid and non-porous materials. It can be used in metals and non-metals to detect surface imperfections too small to be seen.

Two types of penetrants are used – Red dye for use in daylight inspection and Fluorescent dye penetrants in dark light conditions using ultraviolet light. Liquid penetrants seep into all types of surface openings (down to 0.1  $\mu\text{m}$  in width) by capillary action.

Three precautions should be followed when using penetrant testing:

1. Part must be perfectly clean with no surface contamination.
2. Part must not be reactive to penetrant been used.
3. Some penetrants are flammable and should be used away from naked flames and sparks.

# Liquid Penetrant Testing



# Liquid Penetrant Testing

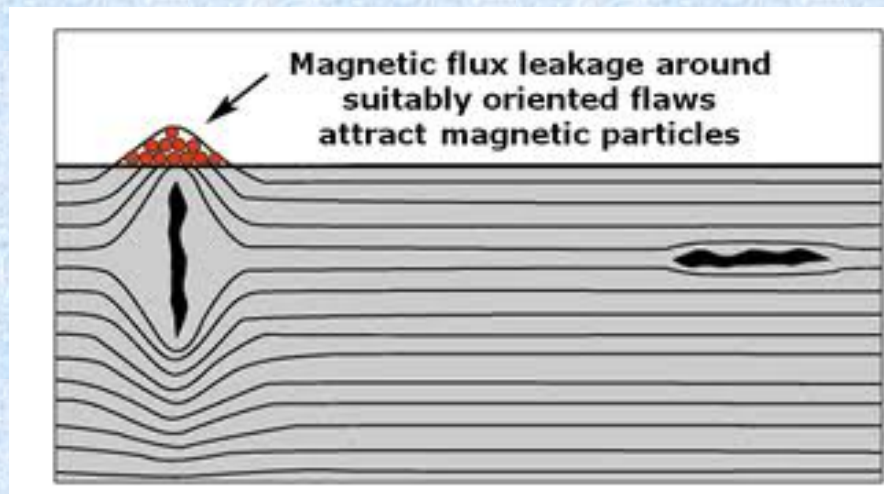


# Magnetic Particle Testing

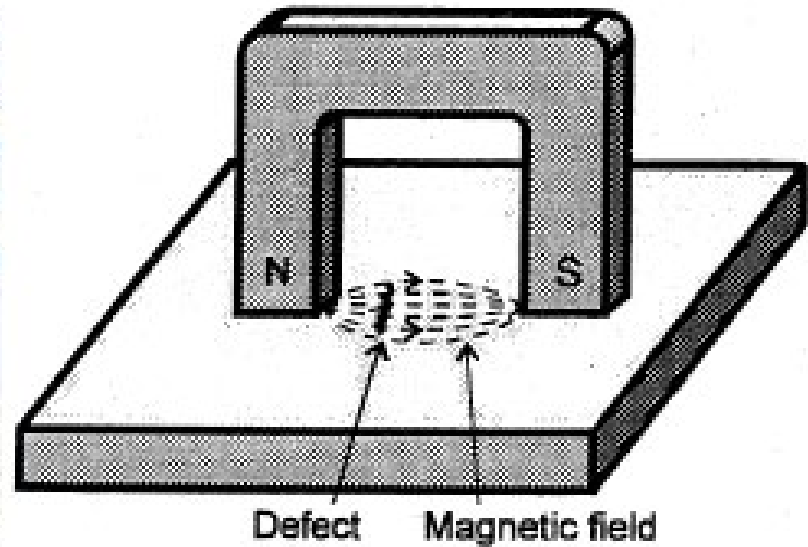
This test is used on ferromagnetic materials to detect surface and sub-surface discontinuities. The test uses a ferromagnetic powder to detect a leakage field of magnetism in the magnetised sample area.

The test is based on the principle that if a part is magnetised, irregularities in the part due to cracks will cause an abrupt change in the path of the magnetic flux resulting in a local flux leakage field. This flux is detected by application of a fine powdered magnetic material which tends to accumulate at the areas of flux leakage.

Note, magnetic particle testing will not easily detect defects that are in the same direction as the generated magnetic field.

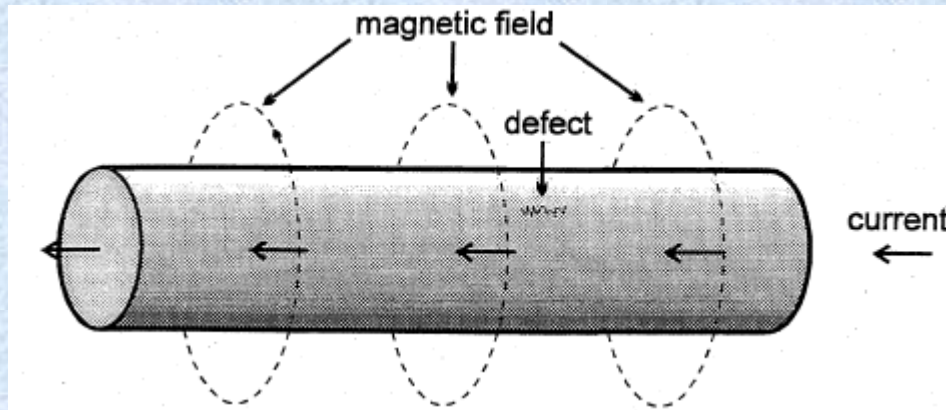


# Magnetic Particle Testing

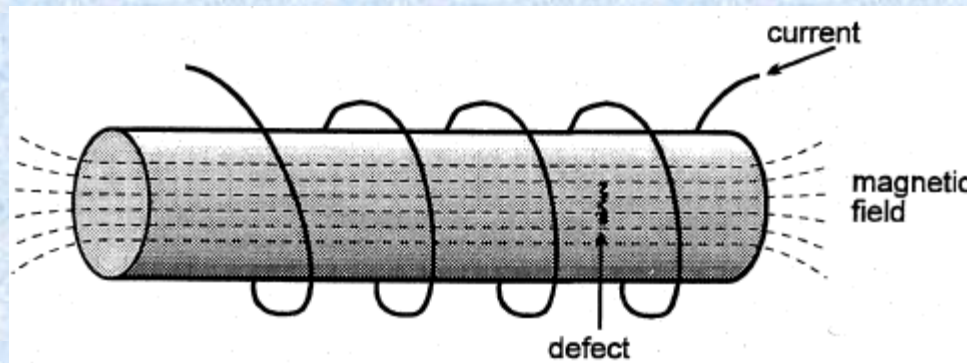


# Generating the Magnetic Field

**Circular magnetisation** generates circles of magnetic fields across the sample and is used to detect longitudinal imperfections in the sample.



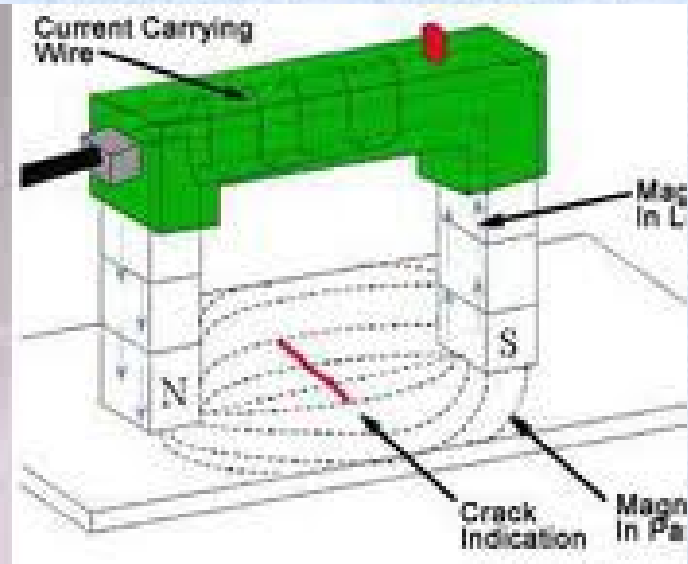
**Longitudinal magnetism** generates magnetic field lines along the surface of the material and is used to detect transverse discontinuities in the test sample.



# Generating the Magnetic Field

Another method of generating magnetism is to use an external magnet (an electromagnet) with the test sample placed between the poles of the electromagnet.

This provides a very portable method for performing the test. Also, the electromagnet can be oriented in different dimensions to detect different cases of surface defects.



# Magnetic Particle Testing Limitations

The limitations of magnetic particle testing are as follow:

1. The part must be capable of being magnetised – that is, part must be made of ferromagnetic material.
2. The test will only detect surface defects or defects very close to the surface.
3. The test will only detect defects that are causing a break in the path of the magnetic flux – typically this means defects that are **not** parallel to the magnetic field lines.
4. Even ferromagnetic materials lose their magnetic properties at elevated temperatures. Hence, magnetic particle testing is best suited to lower temperature testing.

# Eddy Current Inspection Testing

Whilst ferromagnetic materials are the only materials that exhibit a reaction to magnetic fields, all metals are effected by magnetic induction – produced by the presence of a current carrying coil. These effects can be sensed by changes in the current through the coil or by using a second sensing coil.

The induced circulating currents in a metal surface caused by an changing magnetic field are called eddy currents.

The extent and intensity of the eddy currents is affected by the two factors:

- Electrical conductivity of the metal
- Magnetic properties of the metal

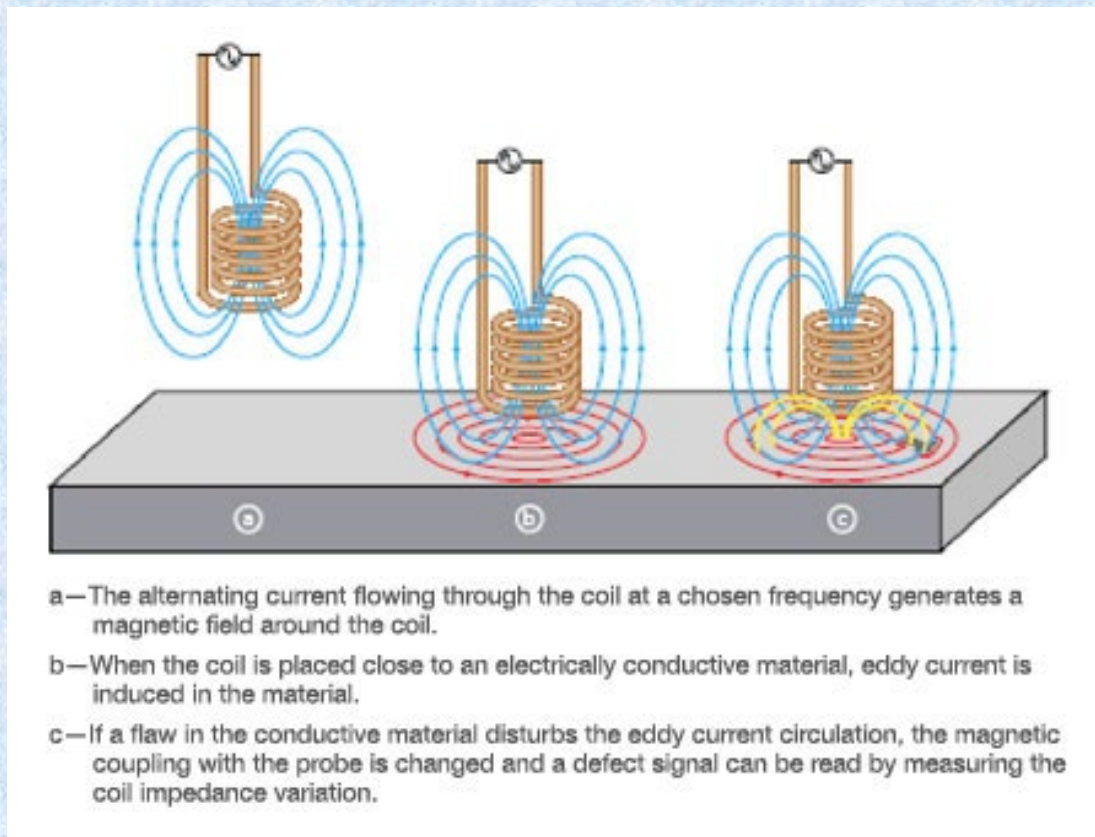
These two factors are in turn affected by:

- Metal composition
- Metallurgical structure
- The presence of discontinuities and defects in the material
- Size, shape and thickness of the material

# Eddy Current Inspection Testing

Unfortunately, it is often difficult to isolate just one of the affecting factors so most eddy current inspection testing is carried out by comparing the results to that of a known sample.

Eddy current testing is mainly used in the aircraft industry for detecting corrosion and the breakdown of bonding in laminated materials in the aircraft.



# Eddy Current Inspection Testing



# Radiographic Inspection Testing

Radiographic inspection, or radiography, uses the differential absorption of ionising electromagnetic radiation of very short wavelength by the test sample.

The wavelength of the electromagnetic waves is typically around  $10^{-7}$  mm - which is less than the average distance between the atomic nuclei in most materials!

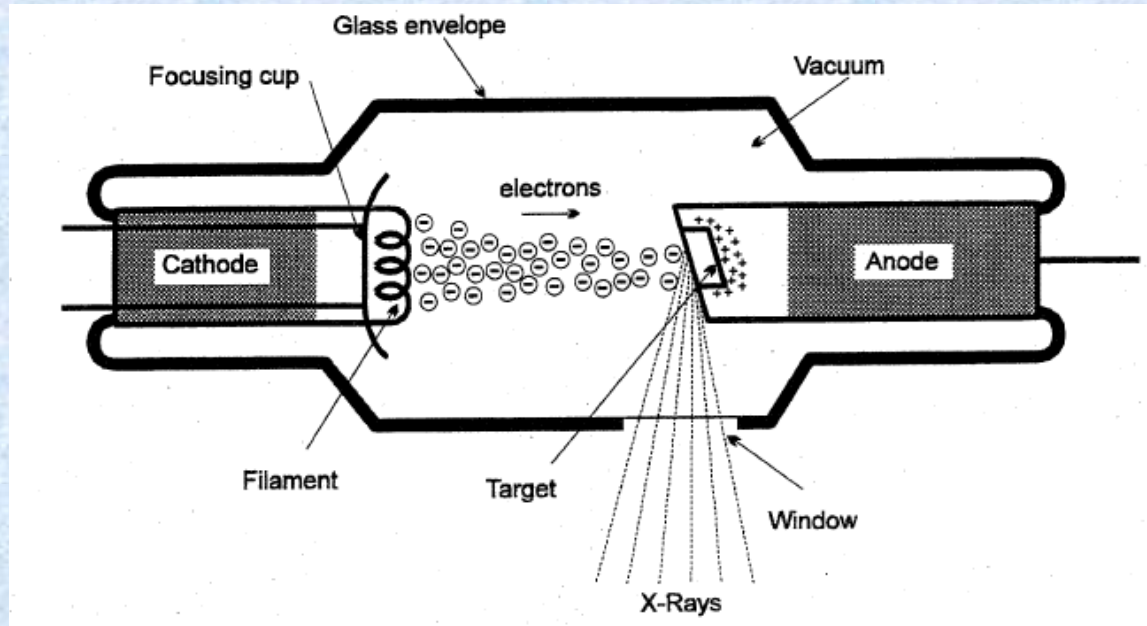
Because of this very short wavelength, this means the radiation can pass through most solid matter allowing excellent penetration into the material.

There are two sources of the ionising radiation:

1. **X-rays:** These are produced using an X-Ray tube. The X-ray tube consists of a glass envelope with a heating cathode used to excite electrons targeting a copper anode.
2. **Gamma Rays:** These are a form of electromagnetic radiation produced as a result of radioactive decay from radioisotopes – such as Cobalt 60.

# Radiographic Inspection Testing

## X-ray Tube:



The half life for various radioisotopes used in gamma rays for radiography is shown in the table below:

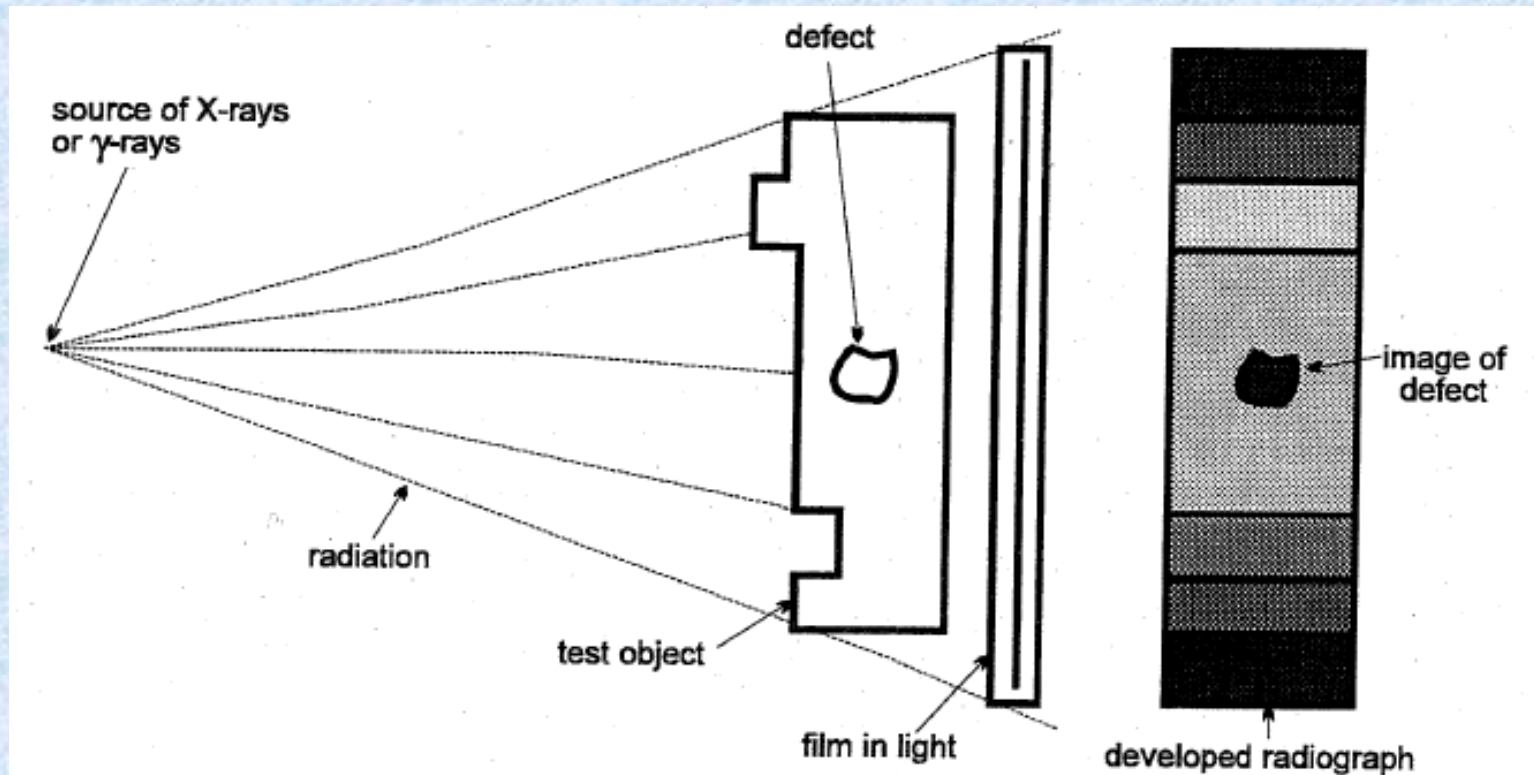
**Table 7.2 Half lives of Radioisotopes**

Radioisotope	Half-Life
Iridium 192	74 days
Cobalt 60	5.3 years
Ytterbium 169	33 days

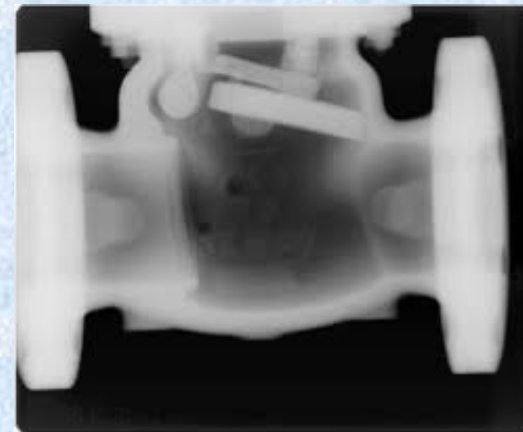
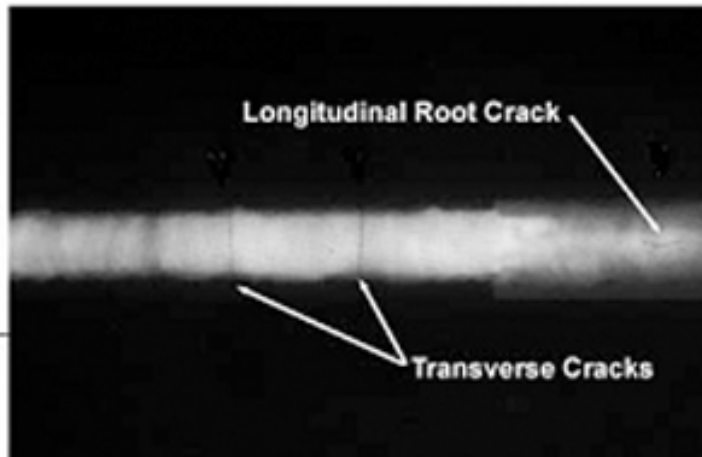
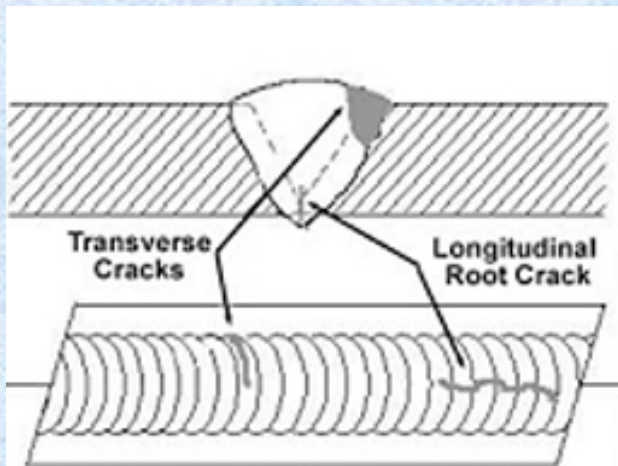
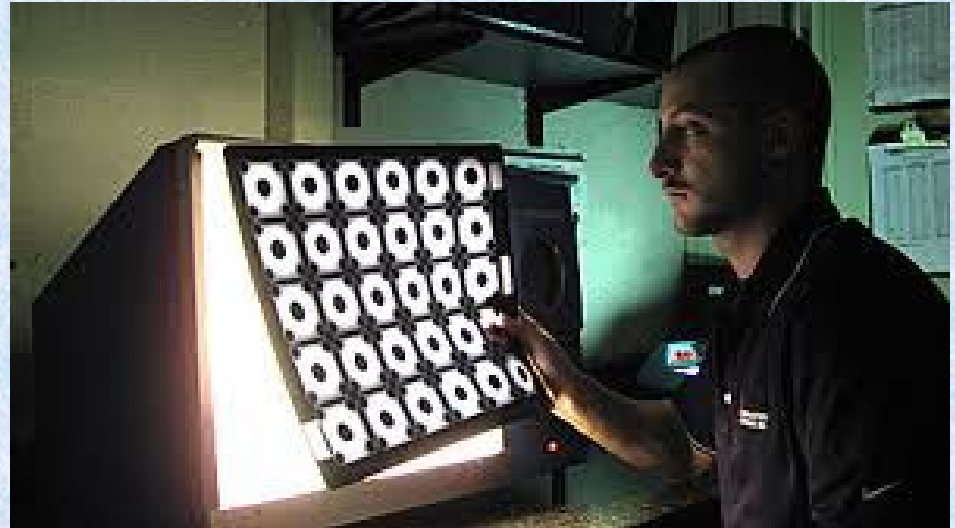
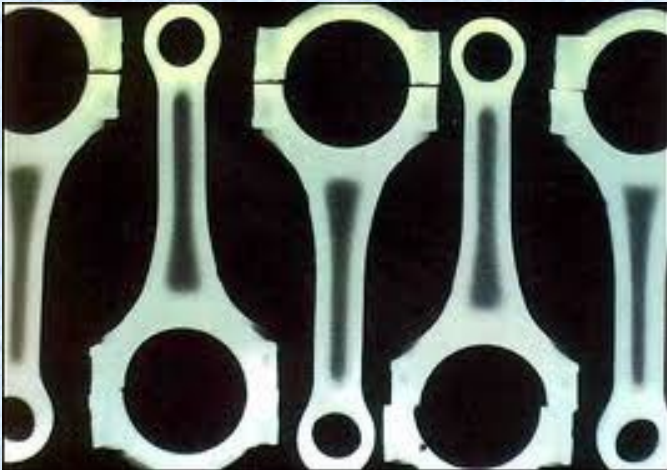
# Radiographic Inspection Testing

Both X-rays and gamma rays are partly absorbed as they pass through the test material. The rate of absorption depends upon the wavelength of the radiation and the density of the sample material.

The radiation source is placed on one side of the test sample and a sensitive photographic film is placed on the other side. The presence of a defect in the sample will change the effective thickness (density) of the material and this will in turn affect the amount of radiation reaching the film.



# Radiographic Inspection Testing



# Radiographic Inspection Testing

Radiographic testing can be hazardous due to the destructive nature of X-rays and gamma rays on human tissue and blood cells. Strict control of all radiation producing apparatus and radioisotopes is mandatory by law.

Radiography can detect differences in materials thickness as little as 1%.

It is ideal for testing casings and weldments - although for ferrous metals the maximum thickness that can be tested (using Cobalt 60 as a source) is limited to about 200 mm.



# Ultrasonic Testing

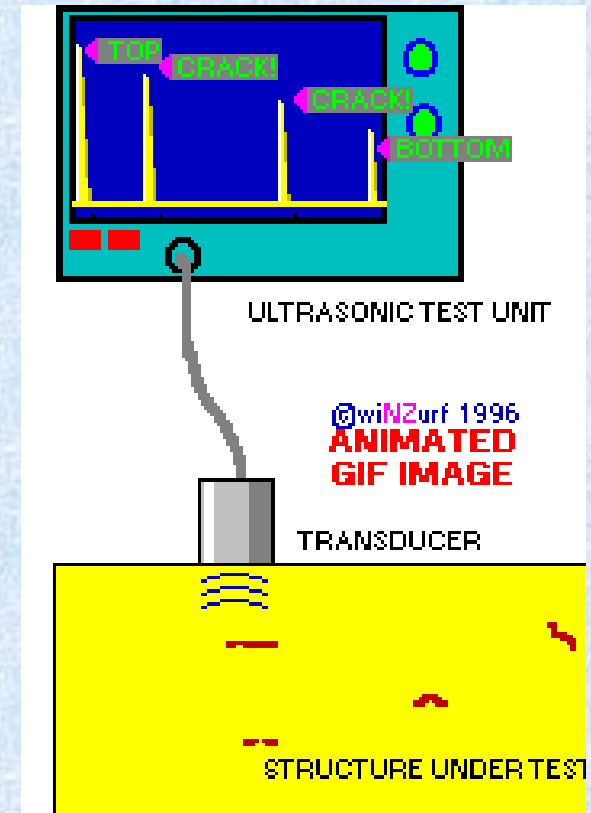
Ultrasonic testing uses pulses of high frequency sound waves beamed into the test material. The reflected echoes of the pulses are analysed to detect the presence of internal discontinuities or defects in the test sample.

The frequency of the ultrasound is typically 1 to 5 MHz.

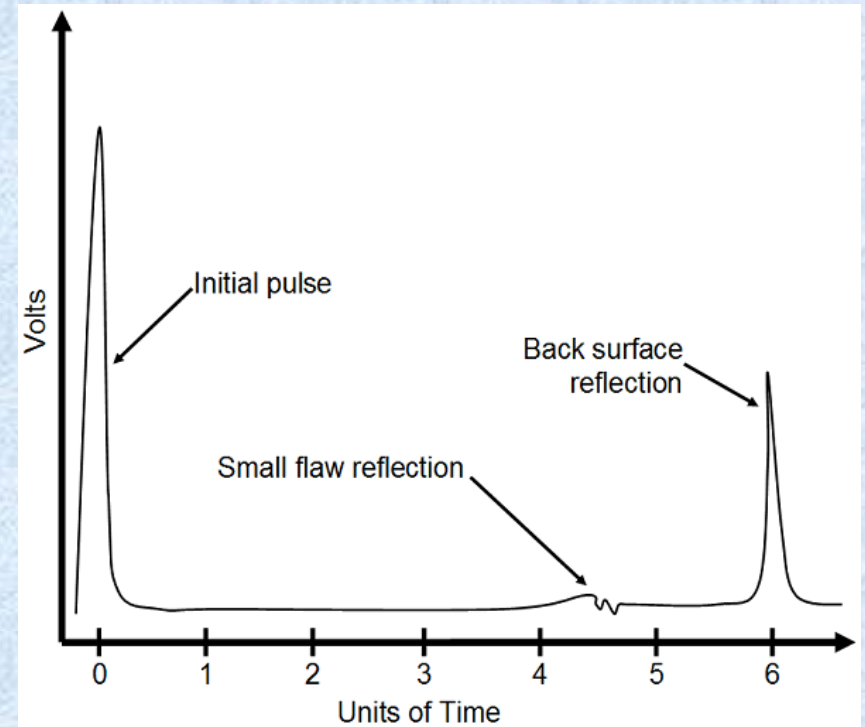
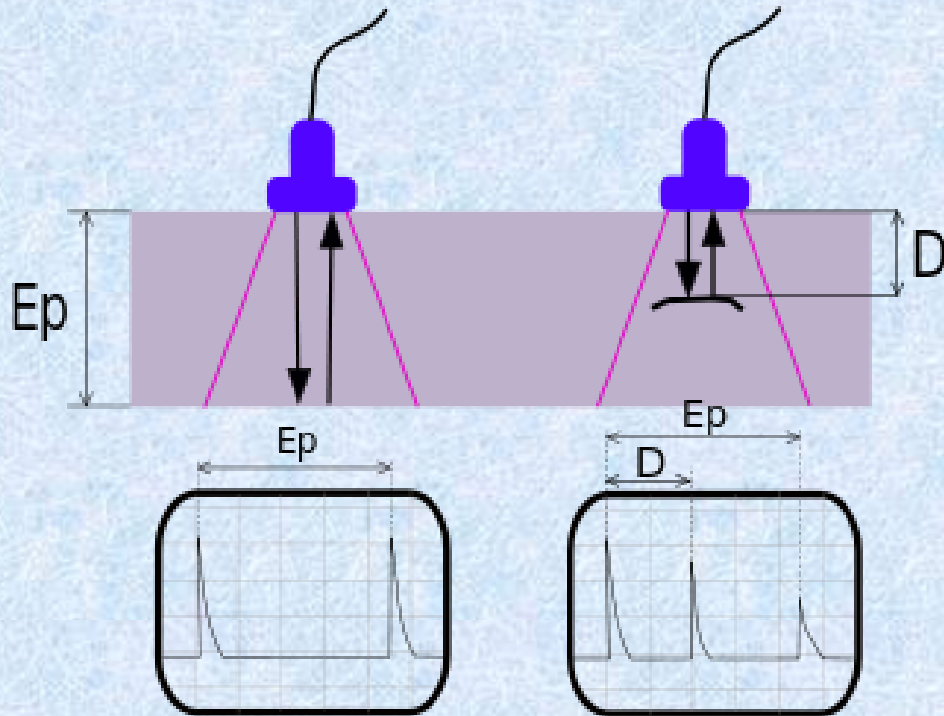
Ultrasound waves transmit through solid materials faster than through air.

Waves initiated at one surface of a solid will reflect off any interface within the solid (such as due to a crack) and also off the opposite surface of the sample. The reflections obey the same physics laws as light - that is; angle of incidence equals angle of reflection.

By analysing the relative times for ultrasound pulses to be reflected back from the defects versus opposite face it is possible to interpret the internal structure of the test sample.



# Ultrasonic Testing



# Ultrasonic Testing

Ultrasonic testing is one of the most widely used methods of non-destructive testing and is used for testing forgings, castings, weldments, piping, plate, aircraft, railroad, automotive and marine components.

It is used not only as a quality acceptance test but also as a means of monitoring parts in service for the formation and growth of fatigue cracks.

Ultrasonic thickness testers have a digital readout to test thickness to an accuracy of 0.1 mm.



# Ultrasonic Testing

Ultrasonic testing offers four key advantages over radiographic testing, namely:

- It has very high penetrating power and can be used to test steel with a thickness of up to 6 metres!
- It is very sensitive and can detect even the most minuscule defect.
- It requires access to only one surface in order to do the test.
- It is safe to use and causes no harm to the operator.



# Strain Gauging tests

One of the key problems that arises in the design and manufacture of materials is the distribution of Stress throughout the sample.

Directly measuring regions of Stress is extremely difficult. However, measuring Strain is much easier.

Strain gauging testing uses the principle of Young's modulus to determine the Stress in a test sample by analysing the respective Strain and then using the mathematical relationship:

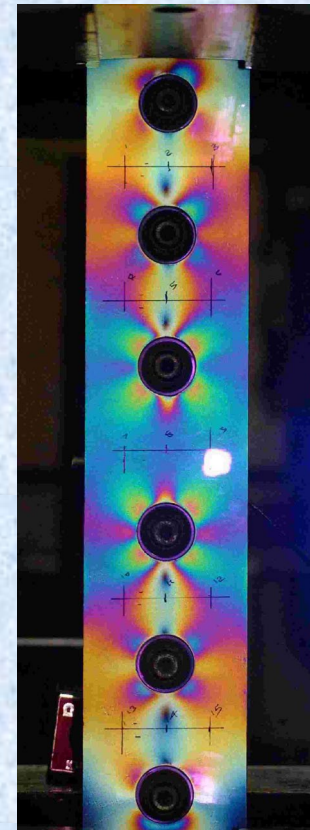
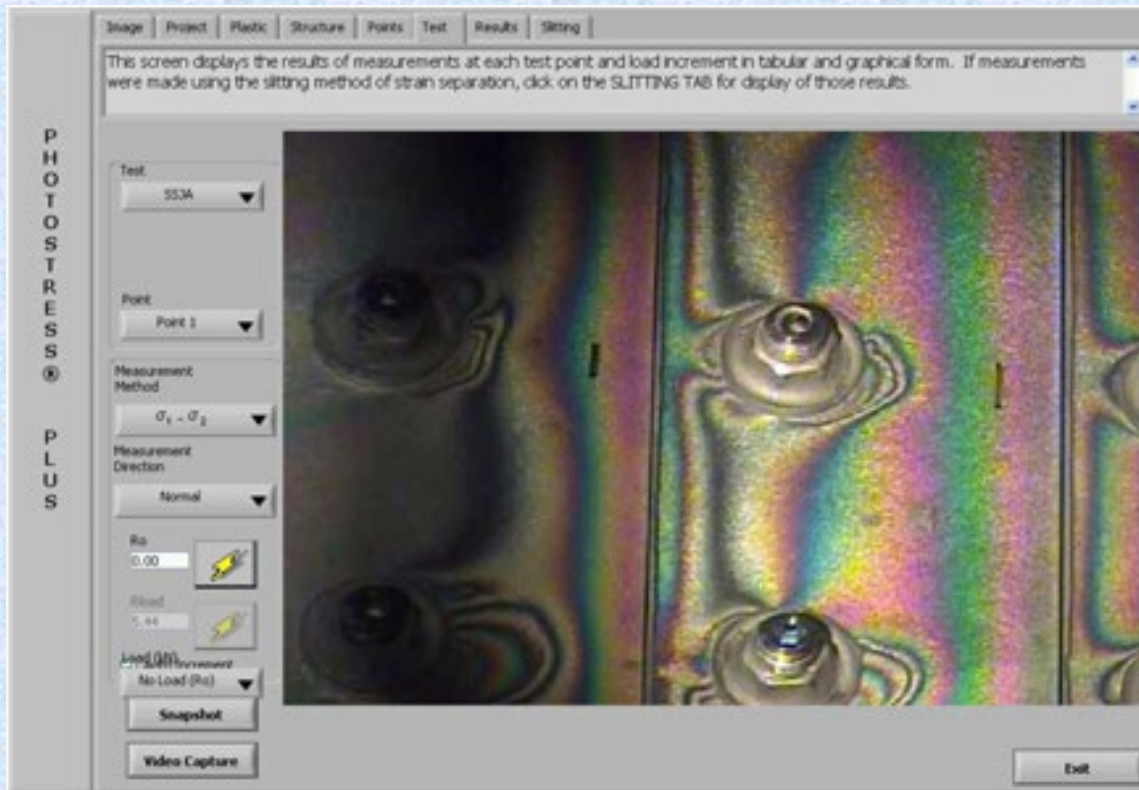
$$\text{Stress} = \text{Young's modulus} \times \text{Strain}$$

The three principle methods for determining Strains are:

- Photo-elastic coatings
- Brittle lacquer coating
- Resistance strain gauges.

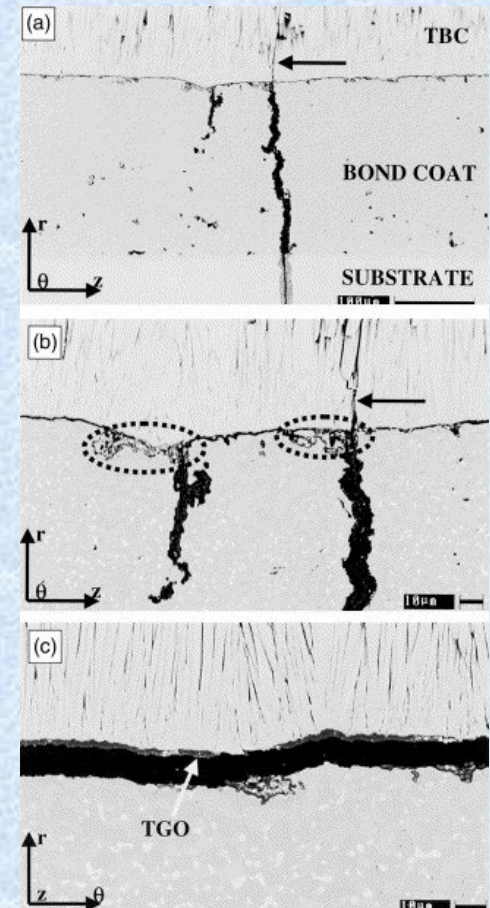
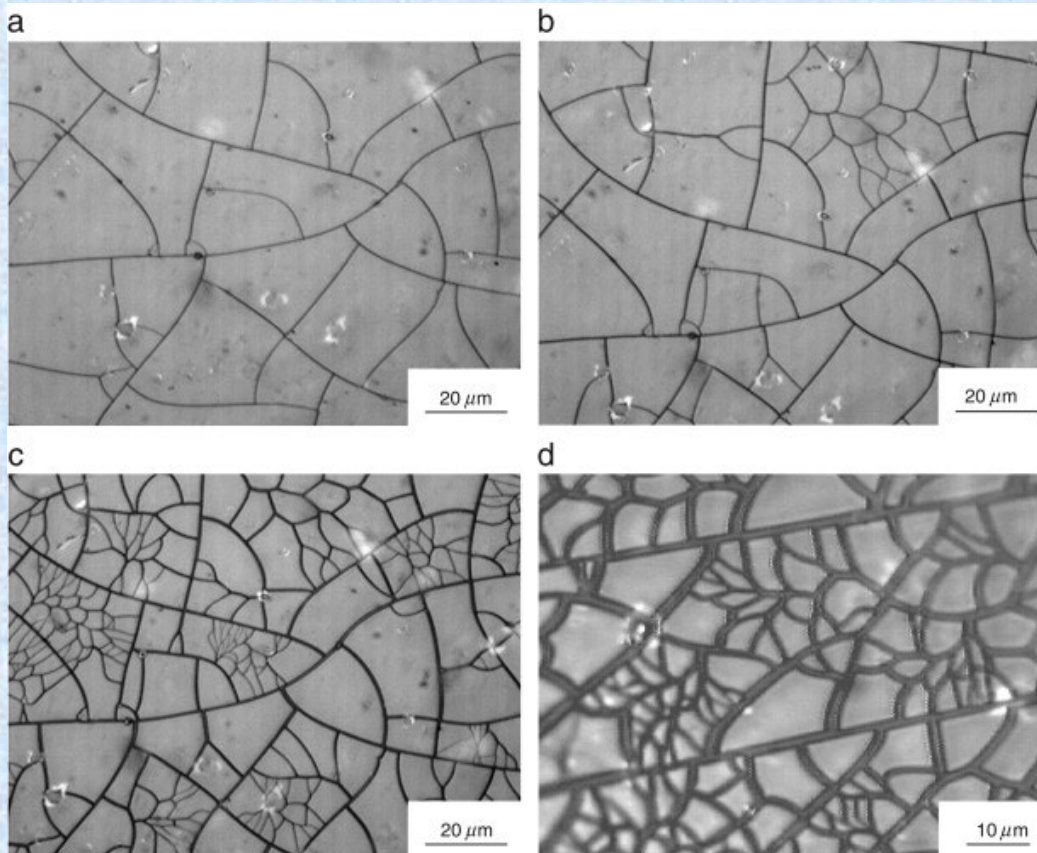
# Photo-elastic Strain Gauging

In this method, a suitable plastic coating is applied onto the surface of the part and then illuminated by polarised light. As the part is loaded with Stress, fringes of different shades of colour will be observed corresponding to regions of Strain.



# Brittle Lacquer Coatings

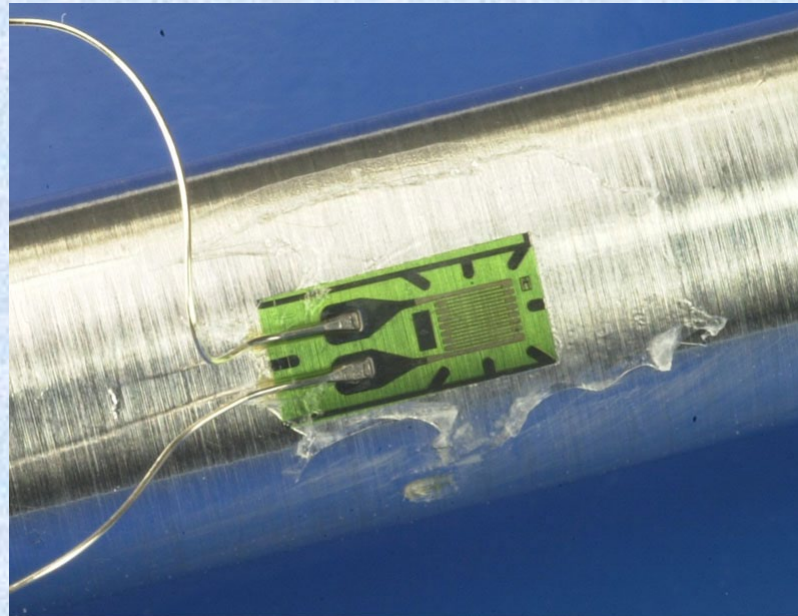
In this method, the surface of the test sample is coated with a brittle lacquer and is then placed under Stress. The deformation of the sample will cause the lacquer to crack along lines normal to the direction of the deformation or Strain.



# Resistance Strain Gauges

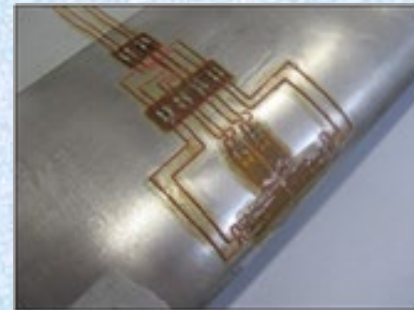
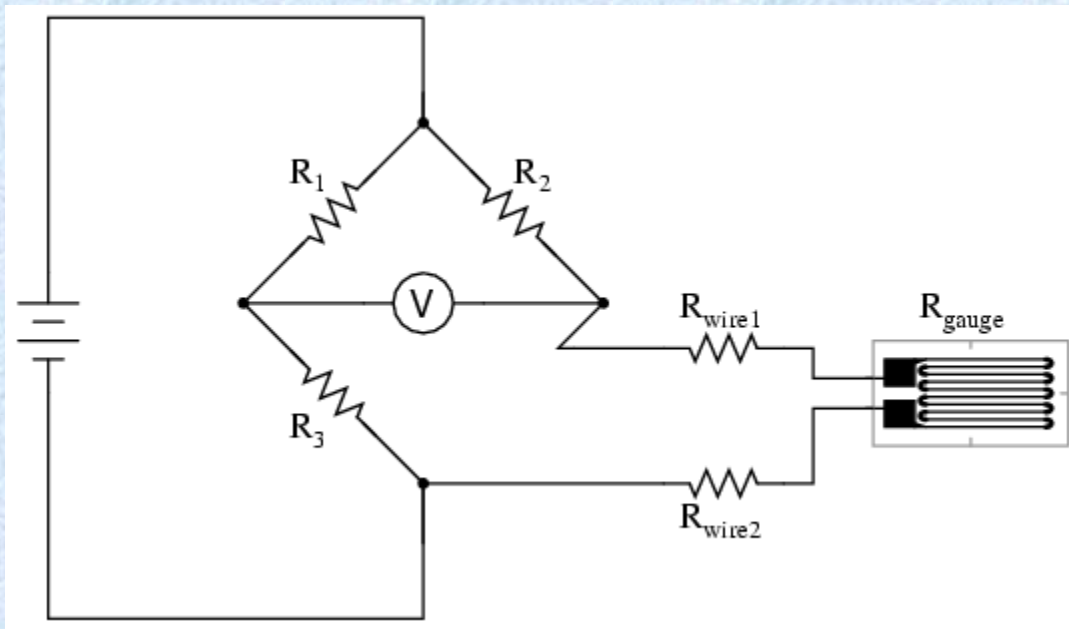
Electrical resistance of a wire varies in proportion to the Strain applied to the wire. Tensile Strains cause an increase in resistance and compressive Strains cause a decrease in resistance.

Electrical Strain gauges work on this principle. Electric Strain gauges are made by looping one or more lengths of fine wire back and forth such that all loops are in the same plane. The wire is then cemented to a paper or plastic carrier which in turn is attached directly to the surface of the sample.

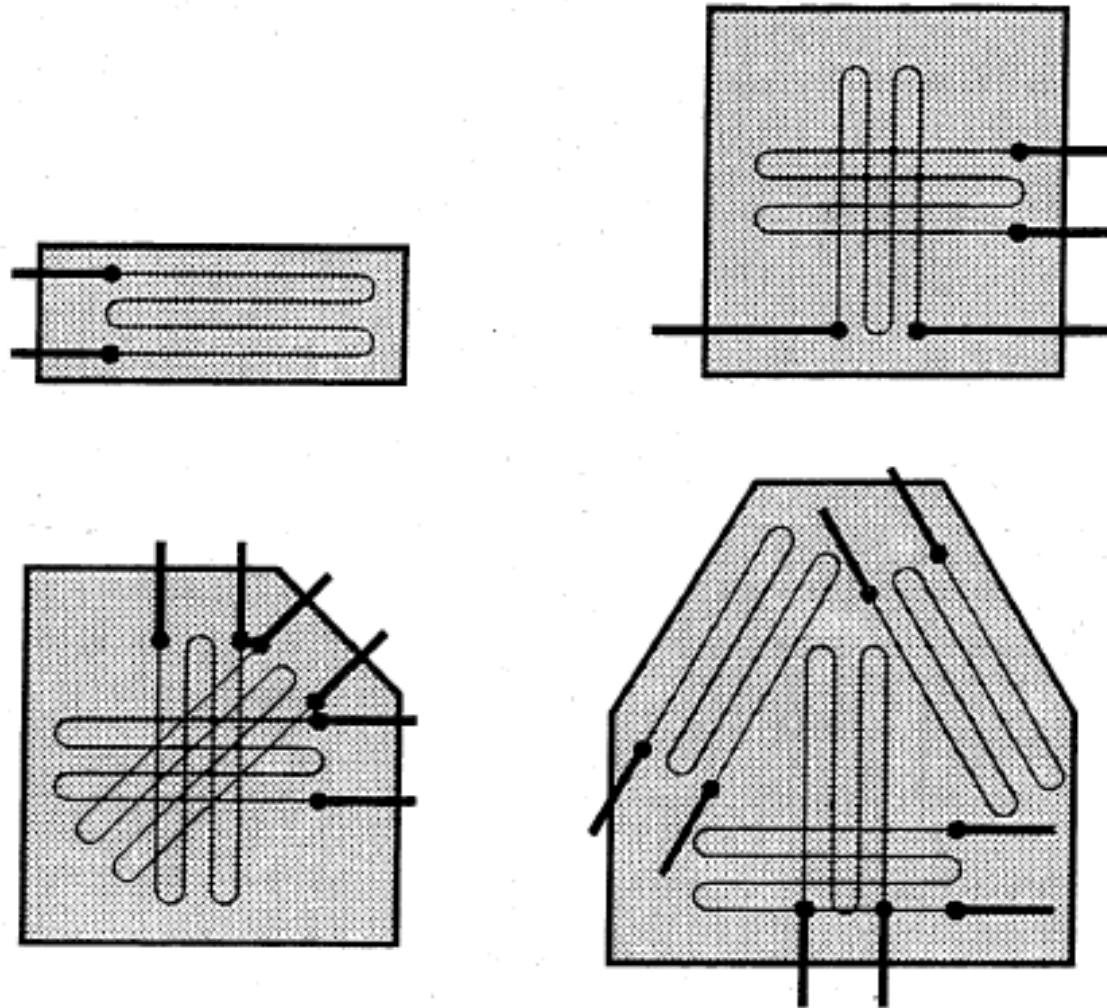


# Resistance Strain Gauges

Since the electrical resistance output changes from Strain gauges is very small, the gauges are usually connected to a sensitive Wheatstone bridge arrangement for amplifying the signal.



# Resistance Strain Gauges



*Fig 7.7 Layout of Typical Resistance Strain Gauges*