GOVT CO-ED POLYTECHNIC

BYRONBAZARRAIPUR(C.G.)

LAB MANUAL

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MATERIAL TECHNOLOGY (2037365(037))
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CONTENTS

EXPERIMENT NO. 1

MICROSTRUCTURE

Object: To study the microstructure of the given specimen (micro-section) and to determine the grain size.

Apparatus: Hand press, flat file, emery papers of various grades, rotary polishing machine, and metallurgical microscope.

Theory: Micrograph is the study of the structures of metals and their alloys under a microscope at magnification from x75 to x1500. The observed structure is called the microstructure. The metallographic studies include;

1. Determination of size and shape of the crystallites which constitute an alloy.
2. Reveal the structure characteristic of certain type of mechanical working operations.
3. Detect the micro-defects such as nonmetallic inclusions, micro cracks, etc"
4. Determine the chemical content of alloys.
5. It indicates the quality of heat treatment.

Preparation of specimens for microscopical examination: The various steps involved in preparing a Specimen for microscopic examinations is given below;

1. Selection of specimen: When investigating the properties of a metal, it is essential that the specimen must be homogeneous in composition and crystal structure. A specimen of 10mm diameter or 10mm square is cut from the metal with a saw or water-cooled slitting wheel. The thickness of the specimen should not be more than 12mm. When a specimen is so small that it is difficult to hold, the specimen may be mounted in a suitable compound like thermoplastic resin, by using a hand press. In cases where neither pressure nor heating is desirable, a cold setting thermoplastic resin can be cast round the specimen. A specimen whose surface has been prepared for microanalysis is called micro-section.

2. Grinding: It is first necessary to obtain a reasonably flat surface on the specimen. This can be achieved either by using a fairly coarse file or by using motor-driven emery belt. Care must be taken to avoid overheating of the specimen by rapid grinding methods; since this may lead to alterations in the microstructure. When the original hacksaw marks have been ground out, the specimen should be thoroughly washed.

3. Fine grinding: Fine grinding is carried out on waterproof emery papers of progressively finer grades (220, 320, 400, and 600) that are attached to a plane glass plate. The specimen is drawn back and forth along the entire length of No. 220 paper, so that scratches produced are roughly at right angles to those produced by the preliminary grinding operation. Having removed the primary grinding marks, the specimen is washed thoroughly. Grinding is then continued on No:320 paper, and again turning the specimen through 90° until the previous scratch narks have been removed. This process is repeated with No. 400, and No. 600 papers. Light pressure should be used at all stages.

4. Polishing: The final polishing operation is to remove the fine scratches on the surface by using a rotary polishing machine. The specimen is polished by rubbing it on a soft moist velvet cloth mounted on a flat rotating disc, with the polishing paste. Suitable polishing pastes are fine alumina, magnesia. Chromium oxide, or diamond dust. Polishing is continued until a mirror scratch free finish is obtained. Nonferrous specimens are best finished by hand on a small piece of selvyt cloth wetted with- silvo polishing. This should be accomplished with a circular sweep of the hand instead of back and forth motion used in grinding. During polishing a constant trip of water is fed to the rotating pad. After polishing, the specimen must be washed thoroughly. The grease films if any can be removed by immersing the specimen in boiling ethanol.

5. Etching: To make its structure apparent under the microscope, it is necessary to impart unlike appearances to the constituents. This is generally accomplished by selectively corroding or etching the polished surface by applying a chemical etching reagent. Grain boundaries will etch at different rates than the grains then leaving the grains standing out and they become visible with a reflected light microscope. Various etching reagents for microscopic examination are given in table-1.

Table : Details of different etchants, composition, and characteristics

Type of etchant	Composition	Characteristics and uses
Nital	2 c.c. Nitric acid and 98 c.c. Ethanol	Iron and steel and ferrite Grey cast iron. Etching time 10-30 sec.
Picral	4 gm. Picric acid and 96 c.c. Ethanol	Good for pearlite and spherodised structure. and cast iron (not for (ferritic structure)
Acid ammonium peroxodisulphate	10 c.c. Hydrochloric acid, 10 gm Ammonium peroxodisulphate, 80 c.c. Water.	Stainless steel.
Dilute hydrofluoric acid	0.5 c.c. Hydrofluoric acid, 99.5 c.c Water	Aluminum and its alloys
Ethanoic acid and nitric acid	3 c.c. Acetic acid, 4 c.c. Nitric acid. 16 c.c. Water.	Lead and its alloys
Dilute hydrochloric acid in alcohol	1 c.c. Hydrochloric acid, 99 c.c. Alcohol.	Zinc and its alloys
Mixed nitric acid and Ethanoic acid	50 c.c. Nitric acid and 50 c.c. Ethanoic acid	Nickel and monel metal.
Ammonia hydrogen peroxide	50 c.c. Ammonium hydroxide, 20-50 c.c. Hydrogen peroxide, 50 c.c. Water	Copper brass and bronze

The specimen is immersed in or swabbed with suitable reagent until the polished surface becomes very slightly discolored. The reagent is then thoroughly washed off first with water and then with alcohol. The surface is then dried in warm air, the standard microstructures for various metals are shown in fig.

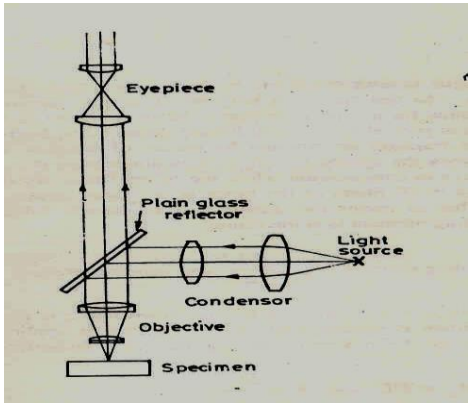


Fig.Standard metallurgical microscope

Grain size: The grain size of a metal can be reported in several ways:

1. Number of grains in unit area of cross-section.
2. Mean diameter of grains.
3. ASTM grain size index N - where 2^{N-1} is the number of grains per square inch at a magnification of x100.

Procedure:

1. Prepare the given specimen as explained above and etch it. .
2. Mount the specimen on the calibrated microscope slide such that the surface is normal to the axis of the instrument.
3. Record the objective magnification and eyepiece magnification to determine the total magnification.
4. Focus the surface of the specimen using coarse adjustment and then by fine adjustment.
5. Observe the microstructure and record it.
6. Identify the material by comparing the microstructure with the standard microstructure.
7. Repeat the same for the other specimens

EXPERIMENT NO. 2

HARDENING OF STEEL

Object: To harden the given steel specimen and to determine the Rockwell hardness of the hardened specimen.

Apparatus: Hardening furnace, and Rockwell hardness testing machine.

Theory: Hardening is a heat treating process in which steel is heated to a temperature above the critical point, held at this temperature, and then quenched in water, oil, or molten salt baths. The optimum hardening temperature is;

For hypo-eutectoid steel, t_{hard} = Upper critical temperature + 30°C to 50°C

For hyper-eutectoid steel, t_{hard} = Lower critical temperature + 30°C to 50°C

The hardening temperature for carbon steels is given in table-l and the effect of hardening temperature upon, hardness for tool steel is shown in table-2.

Table : The hardening temperature for carbon steels

Grade of steel	Hardening temperature (^{0}C)
25 C8	870 to 890
30 C8	850 to 870
35 C8	840 to 860
40 C8	830 to 850
45 C8	820 to 840

Table : Effect of hardening temperature upon, hardness for tool steel

Hardness Temp. (^{0}C)	740	760	780	800	820	840	860	880	900
Rockwell hardness number (HRC)	65	65	65	64	63	62	62	61	60

In hardening, the steel specimen is heated to austenitizing temperature and is quenched in water, or oil, or molten salt bath. Due to the higher rate of cooling, the face-centered cubic structure is transformed into body Centered tetragonal structure. This microstructure is called martensite. The main purpose of hardening is to increase the yield strength and tensile strength of the metal. Hardening increases the surface hardness and thereby increases the wear resistance. Hardened steel is in a stressed condition and is very brittle. After hardening, the steel must be tempered to reduce the brittleness and relieve the internal stresses caused by hardening and to obtain the desired mechanical properties. The heating time and holding time to harden carbon steels are shown in table.

Table: The heating time and holding time to harden carbon steels

Thickness or diameter of part (mm)	25	50	75	100	125	150	200
Heating time (mm)	20	40	60	80	100	120	160
Heating time (mm)	5	10	15	20	25	30	40

When immersing the heated parts in a quenching liquid, the following principal regulations should be adopted:

1. Articles composed of heavy and thin sections must be immersed in the quenching bath with their heavy parts first.
2. Long, slender articles must be immersed vertically.
3. Thin flat parts must be immersed edgewise.

4. Parts in the form of thin rings should be immersed with their axis perpendicular to the surface of the quenching liquid.

Internal stresses setup in quenching: The stresses that develop in rapidly cooled article as a result of an unequal cooling are so called thermal stresses. Apart from thermal stresses so called structural stresses is setup in rapidly cooling parts. These structural stresses are caused by two factors:

1. The unequal specific volumes of astatine and its decomposition products.
2. This structural transformations progressing at different time in the outer layers and the central portion of the article.

Thus the internal stresses setup in rapidly quenched steel articles are a combinations of thermal and structural stresses. When the internal stresses exceed the yield point, the part undergoes plastic deformation. But if the internal stresses exceed the tensile strength of the metal, then cracks will inevitably develop. When steel articles are hardened, many defects may occur in number of ways. They are;

1. Oxidation and decarburisation,

2. Quenching cracks

3. Change in dimensions

4. Soft spots

5. Distortion and warpage.

Procedure:

1. Remove the oil or grease impurities by rinsing the steel specimen in hot water, preferably water soda added.
2. Clean the surface of the steel specimen by wire brush or by sand blasting.
3. Heat the steel specimen in a box type furnace to hardening temperature.
4. Hold the steel specimen at the hardening temperature for some time.

5. Remove the steel specimen from the furnace and immediately quench it in oil or water or salt bath.
6. Find the hardness of the hardened steel part by using Rockwell hardness tester.

Observations and result:

1 Hardening temperature (^{O}C) =

2 Holding time (min.) =

3 Rockwell hardness (HRC) =

EXPERIMENT NO. 3

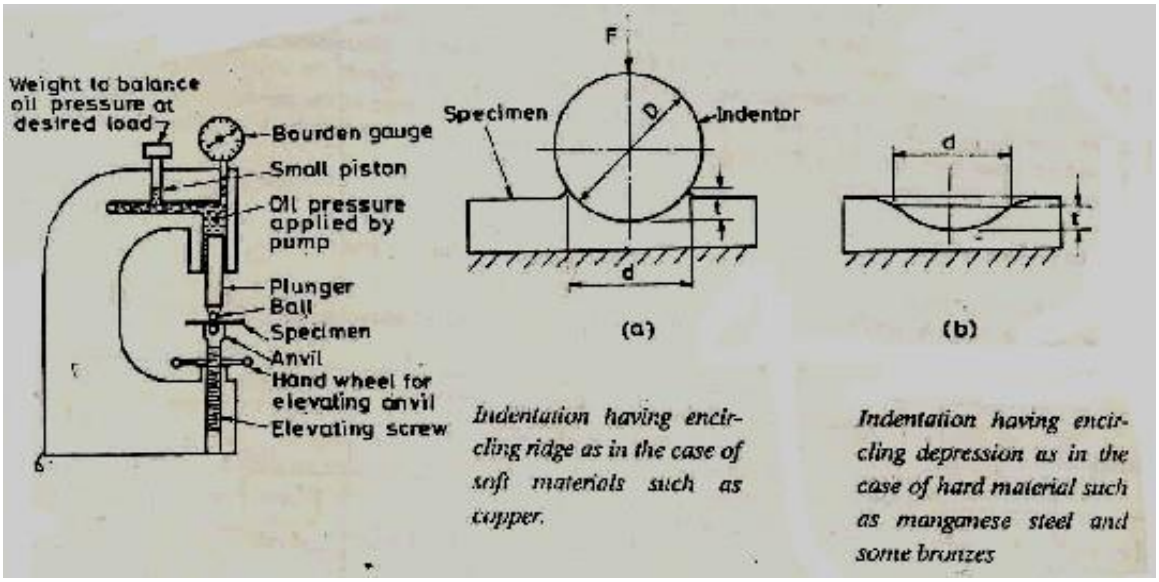
BRINELL HARDNESS TEST

Object: To study the Brinell hardness tester and to determine the hardness number of the given specimen.

Apparatus: Brinell hardness tester, and micrometer microscope.

Theory: Hardness is usually defined as the resistance to permanent indentation. Hardness tests consist in measuring the resistance to plastic deformation of layers of metal near the surface of the specimen. In the process of hardness determination when the metal is indented by a special tip (steel ball), the tip first overcome the resistance metal to elastic deformation and then a small amount of plastic deformation. Upon deeper indentation of the tip it overcomes large plastic deformation. Therefore, hardness test determines the same properties as in other testing methods. This fact enables a relation to be established between the hardness and ultimate tensile strength of ductile metals.

Brinell hardness is one of the oldest and most used types. Brinell tests are static indentation test using relatively large indenters. The principal features of a typical hydraulically operated Brinell testing machine are shown in Fig.7.l. The specimen to be tested is placed on a hardened steel anvil. The anvil is raised or lowered by a steel screw operated by a large hand wheel. Contact is made between specimen and the ball indentor by turning the hand wheel. Load is applied by pumping oil into the main cylinder, which forces the main piston or plunger downwards and presses the ball into the specimen. When the desired load is applied, the balance weight on top of the machine is lifted by action of the small piston, this ensure that an overload is not applied to the ball. After applying the load on the ball for particular time, the load is removed and the diameter of the indentation is measured with a micrometer microscope. The hardness number is defined as the ratio of load in kilograms to the surface area of the indentation in square millimeters.



Brinell hardness number HB (kgf/mm^2) = 2F /(πD (D-$\sqrt{}$ (D^2-d^2))) = F / (πd t)

Where, F is the load in kgf, D is the diameter of the ball in mm, d is the diameter of the impression in mm, and t is the depth of indentation in mm., as shown.

The ball diameter and applied load are constant and are selected from the table-l to suit the composition of metal, its hardness of the test specimen. It is found that the Brinell number varies with the diameter of the ball and the load employed. For strictly comparable results, fixed values must be used for D and F.

Specimens: Specimens must be chosen with care in order to obtain good results. Brinell test is not suitable for extremely hard materials, because the ball itself would deform too much, and is not suitable for thin pieces, because the usual indentation may be greater than the thickness of the piece. It is not adopted for use with case hardened surfaces, because the depth of indentation may be greater than the thickness of the case and because of the yielding of the soft core invalidated the results. The surface of the specimen should be flat and reasonably well polish

Table : Brinell Test conditions

Material	HB	Thickness of test specimen (mm)	Ball diameter D (mm)	Load F (Kgf)	Relation between F and D	Time of load application (sec)
Steel, cast iron	Up to 450	Over 6 mm 6 mm to 3 mm less than 3 mm	10 5 2.5	3000 750 187.5	$F = 30 D^2$	10 to 30*
Copper & its alloys, magnesium alloys	31.8 - 130	Over 6 mm 6 mm to 3 mm less than 3 mm	10 5 2.5	1000 250 62.5	$F = 30 D^2$	30
Alluminium, babbits	8 t0 35	Over 6 mm 6 mm to 3 mm less than 3 mm	10 5 2.5	250 62.5 15.6	$F = 2.5 D^2$	60

*For hardness up to HB 140, the time of load application is 30 sec., for harder materials 10 sec.

Procedure: The load F and the diameter of the ball D must be selected in accordance with the expected hardness of the material, from the table-l and are noted. Place the specimen on the anvil so that its surface will be normal to the direction of the applied load. Raise the anvil by means of hand wheel until the specimen just makes contact with the ball. In some testing machine electrical signals (light on-oft) will indicate its position. Apply the load by means of hand lever. Maintain the full load for the prescribed time. Release the load and remove the specimen from the anvil. Measure the diameter d of the impression left by the ball by means of micrometer microscope. Make three independent hardness determinations on each specimen.

Observations and tabulation:

Material	Thickness of specimen h (mm)	Ball diameter D (mm)	Load F (Kgf)	Time of load application T (sec)	Diameter of indentation d (mm)	HB

EXPERIMENT NO. 4

(A) VICKER'S HARDNESS TEST

Object: To study the Vickers hardness tester and to determine the hardness number of the given specimens.

Apparatus: Vickers hardness tester.

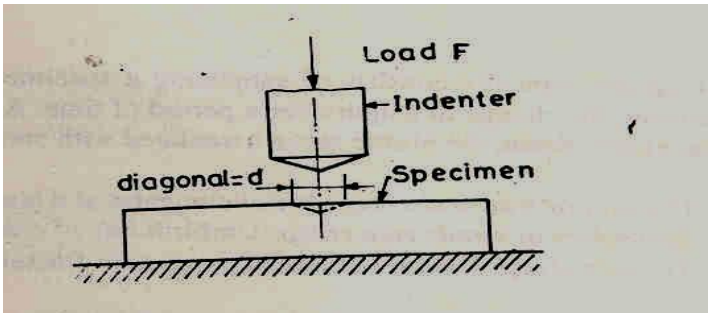
Theory: In Vickers hardness test, the hardness of the material is determined by indentation of a square based diamond pyramid (with an angle of 136 degrees between opposite faces). Vickers hardness testing is more versatile than Brinell hardness testing. Instead of changing the indenters as well as the load, depending upon the nature of the material tested, only the load is changed in the Vickers hardness test. The load may be varied from 1 kgf. to l20 kgf. The load is selected in accordance with the size and hardness of the specimen. The size of the indentation obtained in this test is small. The specimen is placed over the anvil and the load is slowly applied to the indenter and then released by means of lever. After the anvil is lowered, a microscope is swung over the specimen and the diagonal of the square indentation is measured. In some types of machines, the indentation can be focused on to a graduated ground glass screen and measured. The hardness number is given by equation,

$$HV = 2F\sin(\alpha/2) / d^2 = 1.8544F / d^2$$

Where F is load applied in kgf., α is the angle between opposite faces of pyramid which is 136^0, d is the average length of the two diagonals of the impression measured in the plane of the surface of the metal in mm. Vickers and Brinell hardness are expressed in the same units (kgf/mm^2) and coincide for hardness up to about 400. At the higher hardness the Vickers number is larger than Brinell number.

Specimens: Vickers hardness testing is used for determining hardness of specimens of small cross-section or of their external layers on case hardened, nitraded, etc., specimens having a high

hardness. Owing to the fineness and the small size of the indentation obtained, the specimen needs II glassy surface finish for testing.



Procedure: The load F must be selected in accordance with the expected hardness of the material and is noted. Place the specimen on the anvil so that its surface will be normal to direction of the applied load. Raise the anvil by means of a hand wheel until the specimen just makes contact with the indenter. Apply the load by means of hand lever. Maintain the full load for the prescribed time. Release the load and focus the indentation on to graduated ground glass screen. The magnified diagonal length d_1 and d_2 of the indentation are measured by means of the venire mechanism provided in the screen. Make three independent hardness determinations on each specimen.

Observations and tabulation:

Material	Loah F (Kgf)	Diagonal length of indenation (mm)			$HV=1.8544F / d^2$ (kgf/mm^2)
		d_1	D_2	Mean $d = (d_1 + d_2) / 2$	

EXPERIMENT NO. 5

NON- DESTRUCTIVE TESTS

ULTRASONIC FLAW DETECTION TEST

Object: To study the ultrasonic flow detector and to determine the location of the interior crack or cavity in the given specimen.

Apparatus: Ultrasonic flow detector.

Theory: Ultrasonic flaw detector is a device, which is used to detect internal discontinuities in the material by nondestructive means. It makes use of phenomenon of back reflection (echo) of waves by surfaces. When ultrasonic waves are made to pass through the test material, portion of the sound is immediately reflected from the surface at which they enter as a very large echo. Part of the sound will continue on into the test material, until it is partially reflected from the back surface as a second echo. If there is a discontinuity in the material, a portion of the sound will be reflected fromthe discontinuity and will return to the receiver as a separate echo between the echoes received from the front and back surface. The signals received are shown on a cathode ray tube, which alsohas a time base connected to it, so that the position of the signal on the screen gives an indicationof the distance between the crystal generator and the surface from which the echo originates.

Sound waves oscillating with a frequency greater than 20,000 cps are inaudible and are known as ultrasound. High frequency sound is produced by a piezoelectric crystal, which is electrically pulsed and then, vibrates at its own natural frequency. In order to transmit the sound waves from the crystal to the metal, it is necessary to provide a liquid couplant. This is accomplished by using a film of oil between the crystal and the test piece. After the crystal has given off its short burst of sound waves, it stops vibrating arid listens for the returning echoes, i.e., one crystal probe is used to send and receive the sound. This cycle of transmitting and then receiving is repeated at an adjustable rate of from 100 to 1000 times per second.

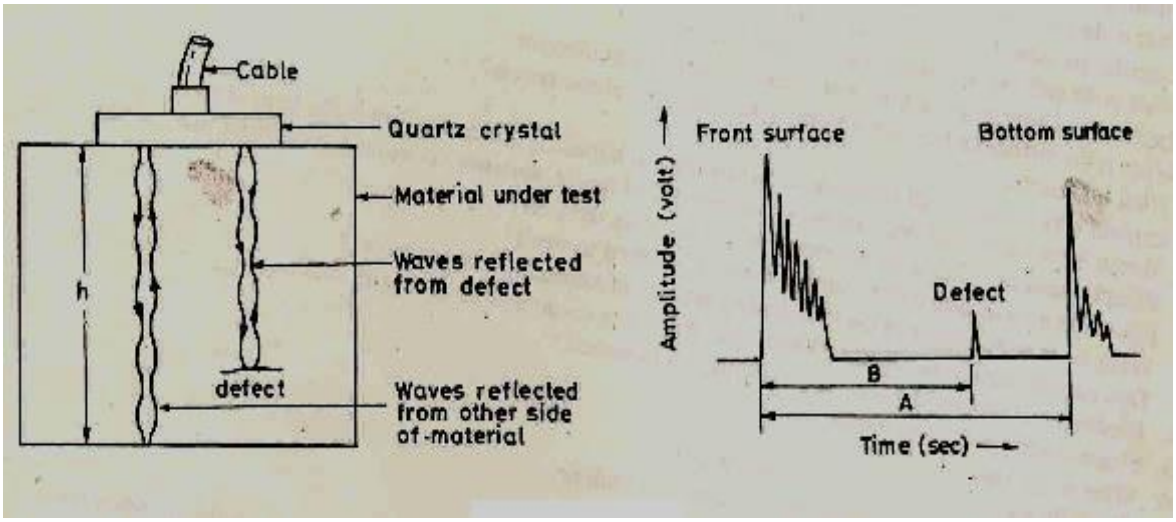
Returning echoes on the CRT causes short vertical spikes called pips. These are spaced along the baseline & according to their time of receipt. Since the sound travels through the material at a constant speed, the spacing of the pips can be considered as indicating thickness. Selecting and expanding full screen size of the CRT can eliminate unwanted echoes caused by reverberations with the test piece.

Let, A = Time elapsed between the pips of front surface echo and bottom surface echo (sec.)

B = Time elapsed between the pips of front surface echo and cavity surface echo (sec.)

h = Thickness of test specimen (mm)

Location of the crack from the front surface x =(B/A) h



Procedure:

1. Clean the surface of the test piece.
2. Place the probe against the surface of test piece using thin oil film.
3. Switch on the power supply of the ultrasonic wave generator.
4. Adjust the number of cycles of transmitting and receiving the signals to the desired value.
5. Select the segment of time, which contain the echo pips.
6. Observe the echo from the cavity if any on the CRT and measure the relative distances of pips on the time axis.

EXPERIMENT NO. 6

MAGNETIC CRACK DETECTION TEST

Object: To detect the surface or subsurface crack of the given ferromagnetic material.

Apparatus: Magnetic field generator, and ferromagnetic powder.

Theory: The magnetic particle method of inspection is a procedure used to determine the presence of the defects at or near the surface of the ferromagnetic objects. This method consists of placing fine ferromagnetic particles on the surface. The particles can be applied either dry or in a liquid carrier such as water or kerosene. When the part is magnetized with a magnetic field, a discontinuity (defects) on the surface causes the particles to gather visibly around it. Thus, the defects become a magnet due to the principle of flux leakage where magnetic field lines are interrupted by the defect and collect the ferromagnetic particles. The collected particles generally take the shape and size of the defects. Sub surface defects can also be detected by this method, provided they are not deep. The ferromagnetic particles may be colored with pigments for better visibility on the metal surfaces. The magnetic fields can be generated either with direct current or alternating current, using yokes, bars, and coils. The equipment may be portable or stationary.

Procedure:

1. Clean the surface of the test specimen to remove scales, oils and grease.
3. Apply a thin layer of ferromagnetic particles over the surface to be tested.
2. Magnetize the test piece.
3. Observe the shape and size of the magnetic particles collected, which is the shape and size of the defec.

EXPERIMENT NO.7

DYE PENTRANTION TEST

Object: To detect the surface defects by penetrate test.

Apparatus: Penetrate, developer, and ultraviolet light source.

Theory: In the liquid penetrate test, liquids are applied to the surface of the part and allowed to penetrate into surface openings, cracks, seams, and porosity. Two commonly known types of liquid penetrates are: (a) Fluorescent penetrants which fluoresce under ultraviolet light, and (b) Visible penetrant, using dyes, usually red in color, which appear as bright outlines on the surface.

The test piece is coated or socked in a1iquid penetrant and the surplus coating is wiped off. The penetrant can seep into cracks as small as 0.1 μm in width. After a short time, a developing agent is added to allow the penetrant to seep back to the surface (due to capillary action) and spread to the edges of openings. The surface is then inspected for defects, either visually in the case of dye-penetrants or under ultraviolet light for fluorescent penetrant. The developer includes dry powders, aqueous liquid, and non-aqueous liquid. This method is capable of detecting variety of surface defects and is used extensively.

Procedure:

1. Clean the test piece surface to remove scales, oil, and grease.
2. Immerse the test piece in the selected penetrant and hold it for some time.
3. Remove the excess penetrant on the test piece surface.
4. Apply the developer on the surface of the test piece.
5. Examine the surface of the test piece under appropriate viewing conditions.
6. Clean the surface to prevent corrosion

EXPERIMENT NO. 8

TENSION TEST

Object: To determine the strength and several properties of the ductile steel to observe the behavior of the Material under load, and to study the fracture and thus determine the followings.

1. Elastic strength in tension: a) Proportional limit, and b) Yield point
2. Modulus of elasticity
3. Modulus of resilience
4. Plastic strength: a) Ultimate strength, and b) Breaking or fracture stress
5. Ductility: a) Percentage elongation, and b) Percentage reduction in area
6. Modulus of toughness.

Apparatus: Universal testing machine, extensometer, micrometer caliper and scale.

Theory: In static tension test, the operation is accomplished by gripping opposite ends of the piece of material and pulling it apart. In a tension test, the test specimen elongates in a direction parallel to the applied load.

Engineering Stress-Strain Diagram: A stress-strain diagram is a graph plotted with values of stress as ordinate and values of strain as abscissa. During extension of fracture, readings may be taken at regular intervals of the load applied or regular intervals of strain meter. The stress plotted are computed by dividing the instantaneous loads by the initial cross-sectional area of the specimen i.e., stress $\sigma = F/A_0$, where F is the load, and A_0 is the initial cross-sectional area of the specimen. For each value of stress, the corresponding strain ε is calculated from the change in gauge length over the previously measured value. i,e., strain $\varepsilon = (L_f - L_0) / L_0$ where L_0 is the initial gauge length and L_f is the extended length due to stress σ.

The general form of engineering stress-strain diagram for a uniaxial tension test on mild steel is shown in Fig.1.1, The initial portion of the curve is a straight line and represents the proportionality of stress to strain. According to Hooke's law, stress $\sigma = E \varepsilon$, the factor of proportionality E is Young's modulus or modulus of elasticity. The point at which this portion of the curve departs from a straight line is the proportional elastic limit or the point beyond which the specimen will not revert to its original length if the load is removed. The elastic limit is thus the maximum stress that the material 'can withstand before undergoing permanent deformation. As the load is increased beyond the elastic limit, a stress is reached at which the material continues to elongate without an increase in load. This stress is called the yield stress. Most deformation beyond the elastic limit is inelastic, or plastic for it will persist in the metal after the load is removed; it is sometimes called permanent set. The peculiar behavior of mild steel during yielding has let to the term's upper and lower yield point. During the stress fluctuation in this region distinct bands appear on the surface of tensile specimens of mild steel. These bands are inclined about 45° to the stress axis, and they are known as Luder's lines. As the tensile specimen is strained beyond its yield point, the stress increases towards a maximum, known as the ultimate tensile strength of the material. Brittle materials fail at this point, and the specimen breaks, but ductile materials begin to decrease rapidly in diameter at some localized area forming a well-defined neck, Since the engineering stress-strain curve is based on a stress calculation using initial area rather than instantaneous area, the engineering stress-strain diagram for ductile metals slopes downward from the maximum stress to the stress at fracture. A typical engineering stress-strain diagram for cast iron is shown in Fig.1.2.

Definitions:

Proportional limit is defined as the stress value beyond which the stress is no longer proportional to strain. i,e., $\sigma_p = Fp/A_o$ where Fp the load at the proportional limit, and A_o is the original area or cross section.

Elastic limit is defined as the maximum stress that can be applied to a material without producing a permanent plastic deformation when the load is removed. Often it is not possible to detect a

difference between the proportional limit and elastic limit. In some cases, however, the elastic limit may be on the curved portion of the stress-strain diagram slightly beyond the proportional limit. i.e"σ_p = Fp/A_o where F_p. is load at the elastic limit.

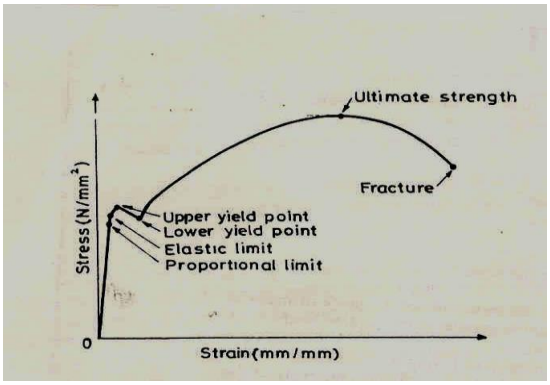


Fig. stress strain diagram for Mild steel

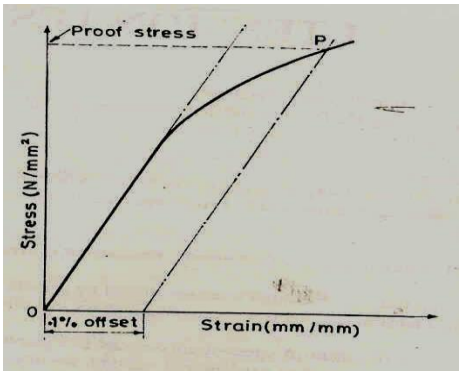


Fig. graph of offset and proof stress

Hooke's law: Within the elastic limit of the material, strain is proportional to the stress producing it. i.e., $\sigma = E \varepsilon$: where E is the constant of proportionality. The name given to the constant E when we are dealing with tensile or compressive stress and strain is the modulus of elasticity or Young's modulus. Modulus of elasticity is a measure of the resistance of a metal to elastic deformation.

Yield point is the maximum stress at which the specimen is deformed without a noticeable increase in the load, $\sigma_y = F_y/A_o$, where F_y is the load at the yield point.

Yield strength is the stress at which a material exhibits a specified limiting permanent set. For brittle material where there is no well-defined yield point, the yield point is determined by offset method. A line offset of an arbitrary amount of 0.2 or 0.1 percent of strain is drawn parallel to the straight line portion of the original stress strain diagram as shown in fig. 1.2. The point of inter-section of the line with the curve corresponds to the yield strength of the material. The offset yield strength is also called as the proof stress

Ultimate tensile strength or tenacity is the maximum stress that a test specimen can bear before fracture, based on original cross sectional area. $\sigma_u = F_{max} / A_o$ where F_{max} is the maximum load.

Breaking stress is the stress at fracture, based on original area. $\sigma_b = F_b/A_o$ where, Fb is the breaking load.

Ductility is the extend of plastic deformation that the material undergoes before fracture. There are two common measure of ductility. 1. Percentage elongation, and 2. Percentage reduction in area.

Percentage elongation is the ratio of change in length at the time of fracture to the original length times 100. % Elongation D,. = $(L_f - L_o) \times 100/Lo$, where L_f the gauge length of the specimen at fracture and L_o, is the original length.

Percentage reduction in area is the ratio of decrease in area of the necked-down section of the test specimen to the original area times 100. % Reduction in area $D_a = (A_o - A_f) \times 100/A_o$.

Resilience: The amount of energy that a unit volume of materials can absorb within the elastic range is called resilience, or in quantitative terms, the modulus of resilience. The area under the load elongation curve up to the elastic limit is equal to the energy absorbed (resilience) by the specimen and the area under the stress-strain curve up to the elastic limit is the energy per unit volume or the modulus of resilience. This energy is the potential energy and is therefore released whenever a member is unloaded.

Toughness of the material is its ability to absorb the energy in the plastic range. The area under the stress-strain curve to the fracture point may be visualized as representing the energy to cause failure per unit volume of the material, which is referred to as modulus of toughness of the material. An approximate formula to measure modulus of toughness is $T_o = \sigma_u (L_f - L_o)/L_o$.

True stress-strain diagram is the plot based on a more exact definition of stress and strain. The true stress is force divided by instantaneous area and true strain is the sum of the strain increments of all past deformations.

True stress $\sigma = F/A$ where A is the instantaneous cross sectional area.

True Strain $\varepsilon = \ln(l/l_o)$ where l is the instantaneous length.

For the material with non-linear stress-strain curves as in fig. 1.3, the slope of the stress-strain curve varies and the modulus of elasticity can no longer be used as a measure of stiffness. Three

different methods have been employed to define stiffness for materials with curved stress-strain diagram. These stiffness values are:

1. The slope of the stress-strain curve at the origin is called initial tangent modulus i.e., $E_1 = \tan \theta_1$

2. The slope of the line joining the origin and a selected point A on the stress-strain curve is called

    a. the secant modulus i.e., $E_2 = \tan \theta_2$

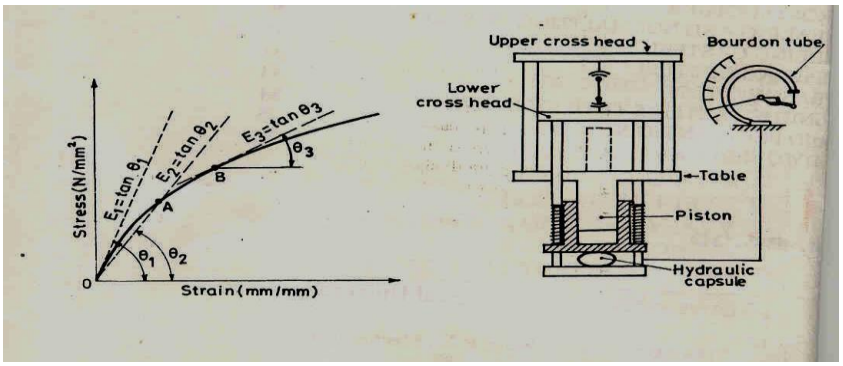
3. The slope of the tangent to stress-strain curve at selected point B is called the tangent modulus

Universal Testing Machine:

The essential parts of testing machine for evaluating the stress-strain properties

1. A means for holding the specimen in the testing machine.
2. A means for applying load to the specimen.
3. A means for measuring the load applied.

    i.e., $E_3 = \tan \theta_3$



Universal testing machines (UTM) are used for tension compression, bending, and transverse shear tests. UTM are generally either of the screw-gear or hydraulic type. Fig. 1.4 shows the essential features of the universal hydraulic machine. A motor driven pump is used to transmit oil to cylinder, thereby producing pressure against a piston. The pressure transmits a force to the tensile specimen by means of upper cross head. The adjustable lower cross head can be moved up or down

by means of an electric motor within the range fixed by automatic cutouts. The force on the lower crosshead, which is fixed during a test, is transmitted to a hydraulic weighing capsule. The weighing capsule is connected to a Bourdon tube for measuring the load on the specimen. Most of the hydraulic machines are provided with devices for applying loads at various rates. These variable load rates -are made possible by setting the valve that controls the flow of oil from the pump to the loading cylinder. For compression test the specimen is placed between the lower crosshead (which is fixed during the test) and the moving table.

Specimen: Specimen must be selected and prepared so as to give a reliable indication of the properties of the materials. Fig. 1.5 shows a standard specimen for tension test of ductile metal. The gauge length is the marked length over which elongation is made and is less than the distance between shoulders. The ends of the round specimen may be shouldered or threaded. The specimen should be symmetrical with respect to the longitudinal axis throughout its length in order to avoid bending during application of load.

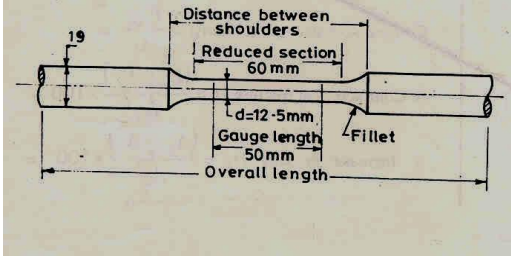


Fig.1.5

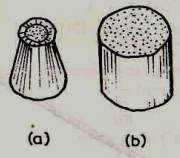


Fig.1.6

Fracture appearance: The fracture of mild steel in the form of standard cylindrical specimen usually has a cup-cone type of silky texture as shown in fig. 1.6(a). The typical fracture of cast iron is gray, flat and granular as shown in fig. 1.6(b).

Procedure: Measure the diameter d_o of the specimen at several sections with a micrometer to obtain a mean value. The gauge length L_o is marked off by means of center punch and is measured. Firmly grip one end of the specimen in the fixed head of the testing machine, such that the punch marks face the front of the machine. Mount thc extensometer centrally on the specimen, the fixing

screws being located in the punch marks. Remove the locking bar of the extensometer. Set the load dial of the machine to a suitable range and adjust the testing machine and extensometer to read zero. Grip the other end of the specimen. Apply load at slow speed, and make simultaneous observations of load F and extensometer readings ΔL When an increment of load leads to disproportionate extension (indicating the yield point) replace the locking bars and remove the extensometer continue to load the specimen taking the extension by means graduated scale. Record the yield point F_y , maximum load F_{max} and load at fracture F_b. Remove the broken specimen from the machine. Observe the location and character of the fracture and measure the diameter at the neck d_f. Place the two parts together and measure the final gauge length L_f. Plot a stress-strain diagram for the test in accordance with the general instruction and compute all properties called for.

Repeat the above test on brittle specimen (Cast Iron) and compute the following properties

1. Proportional limit 2. Modulus of elasticity 3. Modulus of resilience, 4. Yield strength for 0.2% offset, 5. Breaking stress, 6. Percentage elongation, 7. Percentage of reduction in area. 8 modulus of toughness.

Observation and tabulation:

Material:

Initial gauge length L_o (mm) =

Initial diameter d_o (mm) =

Original area A_o (mm^2) = $(\pi\ d_o^2)\ /4$

Load at Yield point F_y (N) =

Maximum load F_{max}(N) =

Load at fracture F_b (N) =

Final gauge length L_f, (mm) =

Final diameter d_f (mm) =

Final area A_f (mm^2) = (π d_f^2) /4

Yield stres σ_y (N/mm^2) = F_y / A_o =

Ultimate Tensile strength σ_u (N/mm^2) = F_{max} / A_o =

Slope of straight line portion of the graph E (N / mm^2) =

Breaking stress σ_b (N / mm^2) = F_b / A_o =

% Elongation D_e = $(L_f - L_o) / L_o$ X 100 =

% Reduction in area D_a = $(A_f - A_o) / A_o$ X 100 =

Modulus of resilience U ($N\ mm / mm^3$) = $\sigma_e^2 / 2E$ =

Modulus of toughness T_o ($N\ mm / mm^3$) = $\sigma_u (L_f - L_o) / L_o$ =

Sl. No.	Load F (N)	Deformation ΔL (mm)	Stress $\sigma = F / A_o$ (N/mm^2)	Strain $\varepsilon = \Delta L / L$ (mm/ mm)	Youngs modulus $E = \sigma / \varepsilon$ (N/mm^2)