DEPARTMENT OF

MECHANICAL ENGINEERING

MATERIAL TESTING LAB MANUAL

(*18MEL37A/47A*)

As per VTU Syllabus CBCS scheme for III Semester

BAPUJI INSTITUTE OF ENGINEERING AND TECHNOLOGY
DAVANGERE- 577 004

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2018

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As per VTU Syllabus CBCS scheme for III Semester

Name : .....

USN : .....

Semester: ..... Batch No.....

Vijay Kumar T N
Faculty Incharge

Suresh U M
Instructor

BAPUJI INSTITUTE OF ENGINEERING AND TECHNOLOGY

DAVANGERE- 577 004

VISION OF THE INSTITUTE

To be center of excellence recognized nationally and internationally, in distinctive areas of engineering education and research, based on a culture of innovation and invention.

MISSION OF THE INSTITUTE

BIET contributes to the growth and development of its students by imparting a broad based engineering education and empowering them to be successful in their chosen field by inculcating in them positive approach, leadership qualities and ethical values.

VISION OF THE DEPARTMENT

The department endeavors to be a center of excellence, to provide quality education leading the students to become professional mechanical engineers with ethics, contributing to the society through research, innovation, entrepreneurial and leadership qualities.

MISSION OF THE DEPARTMENT

l. To impart quality technical education through effective teaching-learning process leading to development of professional skills and attitude to excel in Mechanical Engineering.

2. To interact with institutes of repute, to enhance academic and research activities.

3. To inculcate creative thinking abilities among students and develop entrepreneurial skills.

4. To imbibe ethical, environmental friendly and moral values amongst students through broad based education

PROGRAM EDUCATIONAL OBJECTIVES (PEO'S)

1. Enable to understand mechanical engineering systems those are technically viable, economically feasible and socially acceptable to enhance quality of life.
2. Apply modern tools and techniques to solve problems in mechanical and allied engineering streams.
3. Communicate effectively using innovative tools, to demonstrate leadership and entrepreneurial skills.
4. Be a professional having ethical attitude with multidisciplinary approach to achieve self and organizational goals.
5. Utilize the best academic environment to create opportunity to cultivate lifelong learning skills needed to succeed in profession.

PROGRAM SPECIFIC OUTCOMES (PSO'S)

PS01:-Apply the acquired knowledge in design, thermal, manufacturing and interdisciplinary areas for solving industry and socially relevant problems.

PS02:-To enhance the abilities of students by imparting knowledge in emerging technologies to make them confident mechanical engineers.

B. E. MECHANICAL ENGINEERING
Choice Based Credit System (CBCS) and Outcome Based Education (OBE)
SEMESTER – III

MATERIAL TESTING LAB

Course Code	**18MEL37A/47A**	CIE Marks	40
Teaching Hours/Week (L:T:P)	0:2:2	SEE Marks	60
Credits	02	Exam Hours	03

Course Learning Objectives:

- To learn the concept of the preparation of samples to perform characterization such as microstructure, volume fraction of phases and grain size.
- To understand mechanical behavior of various engineering materials by conducting standard tests. To learn material failure modes and the different loads causing failure.
- To learn the concepts of improving the mechanical properties of materials by different methods like heat treatment, surface treatment etc.

Sl. No.	Experiments
	PART A
1	Preparation of specimen for Metallographic examination of different engineering materials. To report microstructures of plain carbon steel, tool steel, gray C.I, SG iron, Brass, Bronze & Composites.
2	Heat treatment: Annealing, normalizing, hardening and tempering of steel. Metallographic specimens of heat treated components to be supplied and students should report microstructures of furnace cooled, water cooled, air cooled, tempered steel. Students should be able to distinguish the phase changes in a heat treated specimen compared to Untreated specimen.
3	Brinell, Rockwell and Vickers's Hardness tests on untreated and heat treated specimens.
4	To study the defects of Cast and Welded components using Non-destructive tests like: a) Ultrasonic flaw detection b) Magnetic crack detection c) Dye penetration testing.
	PART B
1	Tensile, shear and compression tests of steel, aluminum and cast iron specimens using Universal Testing Machine
2	Torsion Test on steel bar.
3	Bending Test on steel and wood specimens.
4	Izod and Charpy Tests on Mild steel and C.I Specimen.
5	To study the wear characteristics of ferrous and non-ferrous materials under different parameters.
6	Fatigue Test (demonstration only).

Course Outcomes: At the end of the course, the student will be able to:

CO1.To learn the concept of the preparation of samples to perform characterization such as micro structure, volume fraction of phases and grain size.
CO 2.To understand mechanical behavior of various engineering materials by conducting standard tests.
CO 3.To learn material failure modes and the different loads causing failure.
CO 4.To learn the concepts of improving the mechanical properties of materials by different methods like heat treatment, and surface treatment

DO's

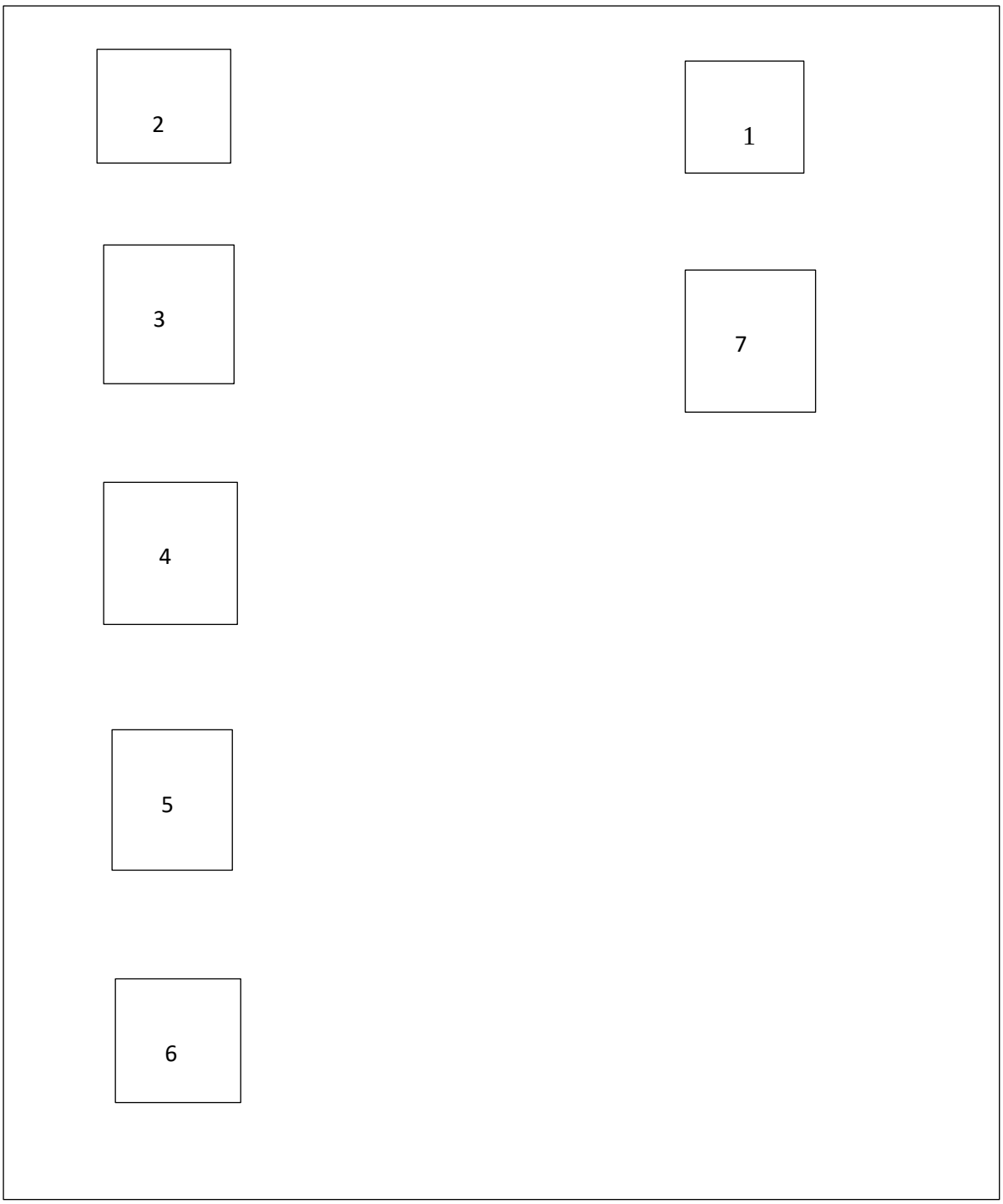
1. Students must always wear uniform and shoes before entering the lab.
2. Proper code of conduct and ethics must be followed in the lab.
3. Windows and doors to be kept open for proper ventilation and air circulation.
4. Note down the specifications of the experimental setup before performing the experiment.
5. Check for the electrical connections and inform if any discrepancy found to the attention of lecturer/lab instructor.
6. Perform the experiment under the supervision/guidance of a lecturer/lab instructor only.
7. After the observations are noted down switch off the electrical connections.
8. In case of fire use fire extinguisher/throw the sand provided in the lab.
9. In case of any physical injuries or emergencies use first aid box provided.
10. Any unsafe conditions prevailing in the lab can be brought to the notice of the lab in charge.

DONT's

1. Do not operate any experimental setup to its maximum value.
2. Do not touch/ handle the experimental setups/Test Rigs without their prior knowledge,
3. Never overcrowd the experimental setup/Test Rig, Leave sufficient space for the person to operate the equipment's.
4. Never rest your hands on the equipment or on the display board, because it has fragile measurement devices like thermometers, manometers, etc.

CONTENTS

LAYOUT OF MATERIAL TESTING LABORATORY



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PART A

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.

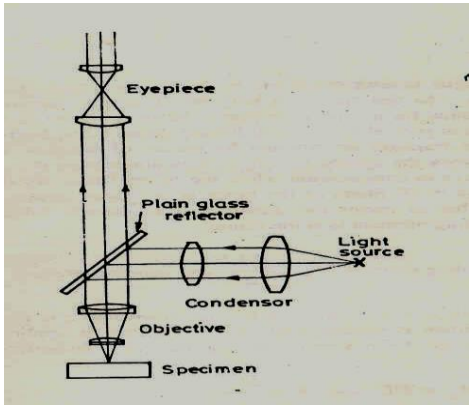


Fig.Standard metallurgical microscope

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

(A) ANNEALING AND NORMALISING OF STEEL

Object: To anneal or normalize the given steel specimen and determine the Rockwell hardness.

Apparatus: Austenitizing furnace (upto-1000°C), and Rockwell hardness testing machine.

Theory: The microstructure of steel part can be modified by heat treatment techniques, that is, by controlled heating and cooling of the alloys at various rates. These treatments induce phase transformations that greatly influence mechanical properties of steel. The various heat-treatment process are annealing, normalizing, hardening and tempering.

Annealing of steel is the process of heating the steel specimen to its austenising temperature, holding it there long enough to dissolve the cementite and disperse the carbon uniformly, and then cool it very slowly to change the structure to the softest state. The low rate of cooling is achieved by turning the furnace off and letting the closed furnace cool down to ambient temperature. The annealing temperature of hypo-eutectoid steel is

t_{annel} = Upper critical temperature + 30°C to 50°C

To avoid excessive softness in the annealing of steels, the cooling cycle may be done completely in still air. This process is called normalizing. In normalizing, the part is heated to normalizing temperature and is withdrawn from the furnace. It is then cooled in still air at the room temperature. The more drastically cooled austenite decomposes into a more dispersed aggregate made up of pearlite. After annealing and normalizing, a fine grain structure is obtained provided if there is no super heating. The normalizing temperature is usually 30°C to 50°C more than that of annealing temperature. The annealing and normalizing temperature for carbon steels are given in table-1.

Table: Details of grade, annealing, and normalizing temperature

Grade of steel	Annealing temperature (°C)	Normalizing temperature (°C)
30C8	850-870	850-900
35C8	840-860	840-890
40C8	840-850	830-880
45C8	820-840	820-870

The purposes of annealing are:

1. To obtain softness.
2. To improve machinability.
3. To increase ductility and toughness.
4. To relieve internal stresses.
5. To refine the grain size.
6. To prepare steel for subsequent cold working.

The purposes of normalizing the steel are:

1. To eliminate coarse-grained structure obtained in previous working (rolling, forging, or stamping).
2. To increase the strength of medium carbon steels.
3. To improve machinability of low carbon steel.
4. To reduce internal stresses.

The hardness of annealed and normalized carbon steels is given in table-2.

Table: Conditions of different types of steels

Condition	Low carbon steel (RB)	Medium carbon steel (RB)	High carbon steel (RB)
Annealed	72	85	91
Normalized	78	92	99

Heat treating furnace: A heat-treating furnace is a refractory lined chamber in which the metal parts are heated to the required temperature. Usually the furnace consists of a box-like structure of steel shell, door, refractory lining, heating source, temperature controls, and temperature indicators. Heat-treating furnaces may be classified on the basis of the following:

1. According to use: Annealing furnace, Hardening furnace, Tempering furnace, etc.
2. According to the type of work: Batch type furnace, and continuous furnace.
3. According to the source of heat: Reverberatory furnace (coal, coke, oil or gas fired) and Electric furnace.
4. According to working environment: The working media in which the heating of article may be performed are air, protective gas atmosphere, and oil bath or salt bath.

Procedure for annealing:

1. Heat the given steel specimen in a box type furnace until the specimen reaches the annealing temperature.
2. Keep the specimen in the furnace at the annealing temperature for some time.
3. Cool the specimen by switching off the furnace.
4. Remove the steel specimen from the furnace when the furnace is cooled down to atmospheric temperature.
5. Determine the hardness of the annealed specimen using Rockwell hardness-testing machine.

Observations and result:

Annealing temperature (^{O}C) =

Holding time (min.) =

Rockwell hardness (HRB) =

Procedure for normalizing:

1. Heat the given steel specimen in a box type furnace until the specimen reaches normalizing temperature.
2. Keep the specimen in the furnace at the normalizing temperature for some time.
3. Remove the specimen from the furnace and cool it in the still air at atmospheric temperature.
4. Determine the hardness of the normalized specimen using Rockwell hardness-testing machine.

Observations and result:

Normalizing temperature (^{O}C) =

Holding time (min.) =

Rockwell hardness (HRB) =

EXPERIMENT NO. 2

(B) 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. 2

(C) TEMPERING OF STEEL

Object: To temper the given hardened steel specimen and to determine the Rockwell hardness number.

Apparatus: Tempering furnace with oil or salt bath, and Rockwell hardness testing machine.

Theory: The structure of the hardened steel mainly consists of tetragonal martensite, the hardness of which is very high. At the sometime, the hardened steel will have low ductile properties, very poor impact strength, and brittle. Because of this hardened steel must be tempered. In tempering the tetragonal martensite gradually changes to heterogeneous mixture consisting of alpha solution being depleted of carbon and with a decreasing degree of tetragonality, and highly dispersed carbides. As a result of this primary transformation, some decrease in hardness takes place, and on the other hand there is a progressive increase in plasticity and impact strength.

The steel specimen must be tempered as soon as possible after quenching. The tempering temperature of cutting tools of carbon steels is 160°C to 200°C and tools subjected to shock such as dies; punches are 200°C to 300°C. Low tempering (up to 250°C) of tools is carried out either in oil baths or in salt baths. Furnaces used for tempering are usually of batch type. Heating the steel for tempering is carried out either in oil bath (for low tempering) or salt bath (for high tempering). Liquid transfers heat more uniformly and have greater capacity. Temperature control in low tempering is achieved by watching the So-called temper colors, which appear on the ground surface of steel at temperatures from 200°C to 300°C. The temperature of tempering and duration of tempering are the most important factors in tempering. The table-1 gives the holding time for tempering.

Table : Gives the details of holding time for tempering.

Diameter or thickness of part (mm)	1 - 20	21 - 40	41 - 60	Over 60
Holding time (hrs.)	1	1.5	2	2.5

Depending upon the grade of steel, the steel part is then cooled either by slow cooling in the furnace or rapid cooling. Self-tempering is the process of tempering the parts by using the heat left out during quenching. Fig.5.1 shows the variation of Rockwell C hardness number with increase in temperature.

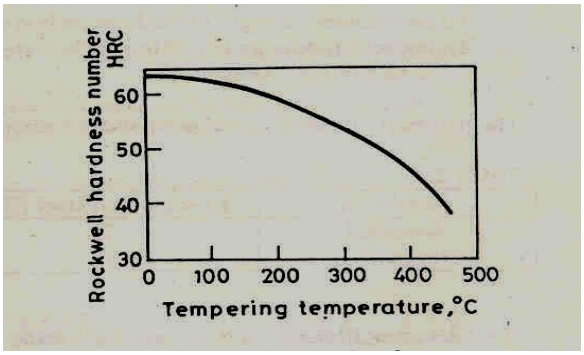


Fig. shows the variation of Rockwell C hardness number with increase in temperature.

Procedure:

1. Heat the given hardened steel specimen in oil or salt bath using a tempering furnace until the desired tempering temperature is reached.
2. Keep the specimen at tempering for some time.
3. Remove the specimen from the furnace and cool it in still air.
4. Find the hardness of the tempered steel specimen using Rockwell hardness tester.

Observations and result:

Tempering temperature, °C =

Holding time (hrs). =

Rockwell hardness (RC) =

EXPERIMENT NO. 3

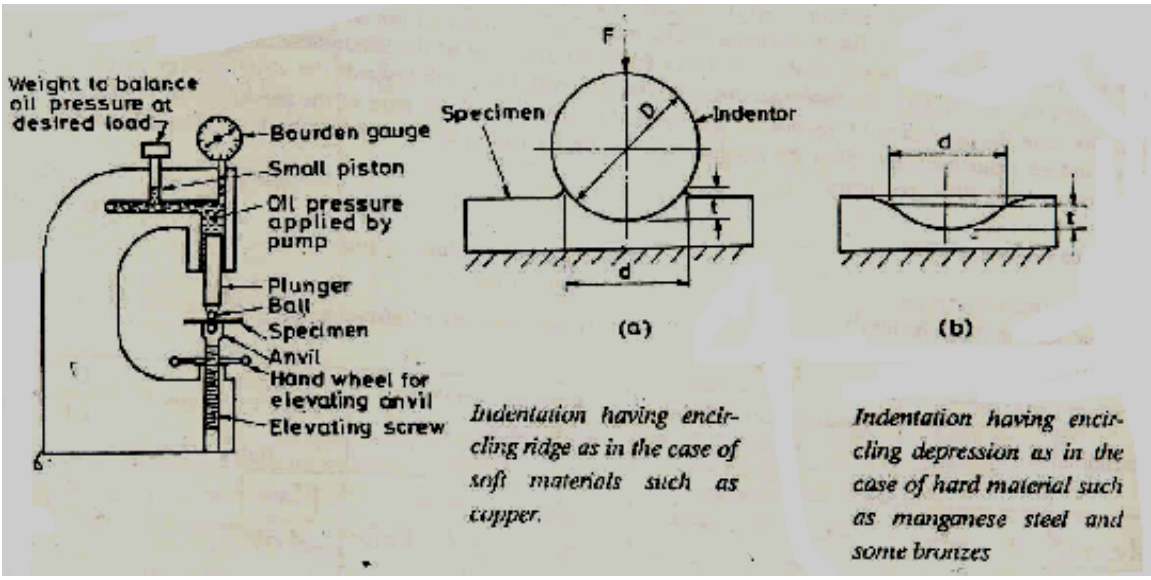
(A) BRINELL HARDNESS TEST

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) = $2F /(\pi D (D-\sqrt{(D^2-d^2)})) = F / (\pi d\ t)$

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. 3

(B) ROCKWELL HARDNESS TEST

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

Apparatus: Rockwell hardness tester.

Theory: In Rockwell hardness test, the depth of indentation of a diamond core or small steel ball determines the hardness of the material. The Rockwell test differs from the Brinell test in that the indenters and the loads are smaller and that the resulting indentation is smaller and shallower.

Rockwell hardness tester consists of an anvil, which can be moved up or down by turning the hand wheel, which is situated, at the bottom of the spindle. The load can be applied by simply operating a hand lever, which is just below the hand wheel. The indenter or penetrator in the Rockwell test may be either a conical-shaped diamond called a brale with a 120^0 apex angle or a hardened steel ball 1.5875-mm (1/6-inch) in diameter. The brale is used for testing materials with a high hardness and the steel ball for soft materials. Two consecutive loads intend the brale or the ball, a minor load F_1 (equal to 10 kgf.) which does not deform the metal and is used to seat the indenter, and an additional major load F_2 that equals 90 kgf. (total 100 kgf.) for the ball (scale B) and 140 kgf. (total 150 kgf.) for brale (scale C) is applied for indentation. The depth of penetration effected by the additional load is the measure of Rockwell hardness. The Rockwell hardness is read directly on the dial of the instrument that is graduated in the hardness units. The dial has two sets of figures, one red (scale B) and the other black (scale C) which differ by 30 hardness number, (i.e., B-30 is at C-0). It is made so, to avoid the negative hardness values on the B-scale, if used to test very soft materials. This also facilitates in establishing that the highest hardness that can be measured with a 1.5875-mm diameter ball indenter is only B-100 and for higher hardness the C-scale should be employed.

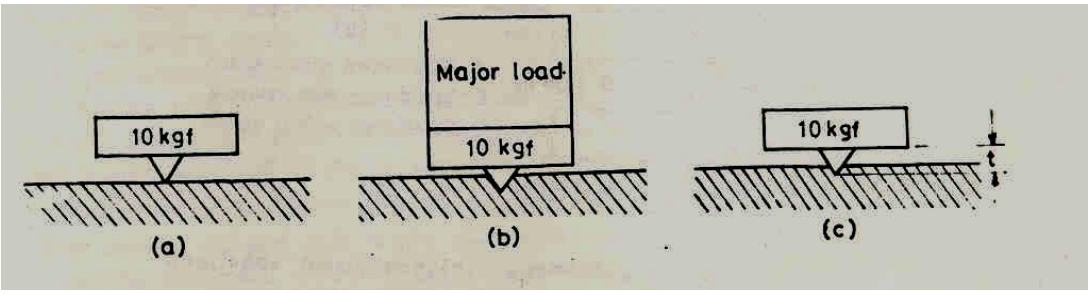


Fig. stages of Rockwell hardness tests.

Procedure: Place the specimen on the anvil so that its surface will be normal to the direction of the applied load. Note the type and size of the indenter. Raise the anvil and the test specimen by means of the elevating screw. The small pointer in the dial starts to move, once the specimen touches the indenter. Continue to raise the work slowly until the small pointer comes to the red dot. This indicates that the minor load of 10 kgf. is acting upon the indenter. Turn the dial until the mark B-30 (i.e.,C-0), which is also designated by the red arrow and the word 'SET' is directly behind the pointer. Release the operating handle so as to apply the major load, which is the increment over the already applied minor load. The indenter starts to go down into the specimen. This can be seen from the dial. The pointer starts to move during the period of loading. Immediately after the major load has been fully applied gently bring back the operating handle to its latched position. Read the position of the pointer on the selected scale, which gives the Rockwell hardness number. Make three independent hardness determinations on each specimen.

Observations and tabulation:

Material	Scale symbol	Indenter	Total load F (kgf)	Rockwell hardness number (HRB or HRC)

EXPERIMENT NO. 3

(C) 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.

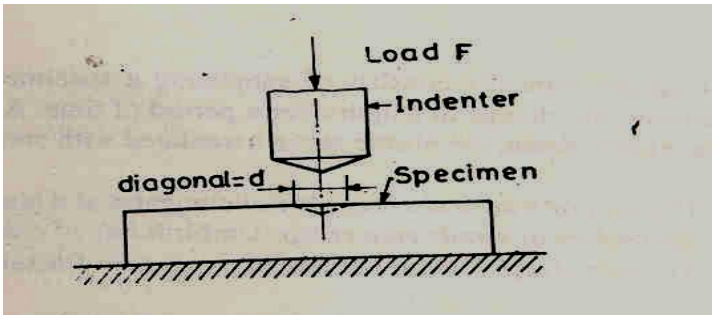
Theory: In Vickers hardness test, the hardness of the material is determined by indentation of a square based diamond pyramid (with an angle of 136 degrees between opposite faces). Vickers hardness testing is more versatile than Brinell hardness testing. Instead of changing the indenters as well as the 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. 4

NON- DESTRUCTIVE TESTS

(a) 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 from the 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 also has a time base connected to it, so that the position of the signal on the screen gives an indication of 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.

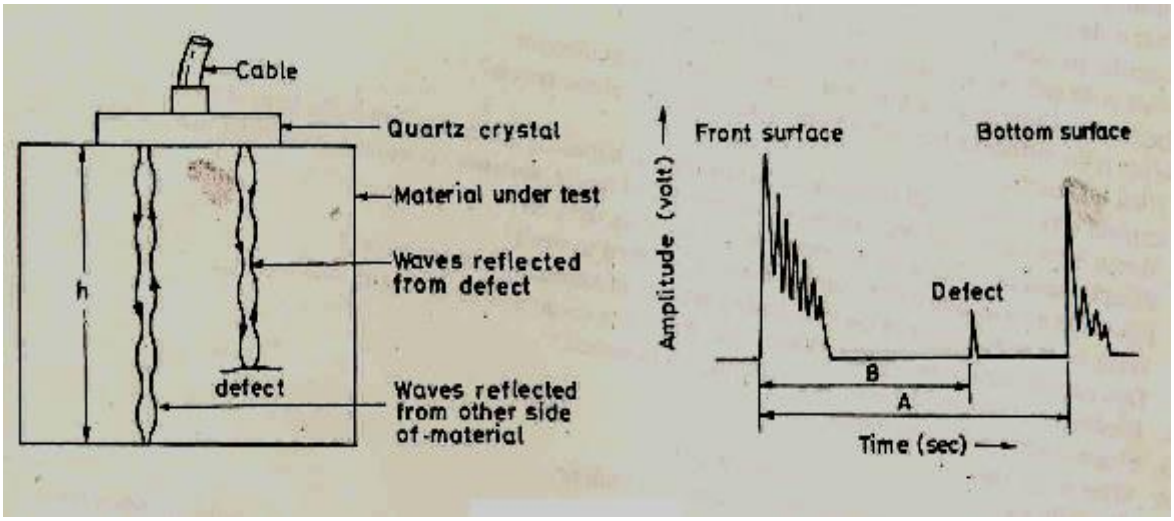
Returning echoes on the CRT causes short vertical spikes called pips. These are spaced along the baseline & according to their time of receipt. Since the sound travels through the material at a constant speed, the spacing of the pips can be considered as indicating thickness. Selecting and expanding 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. 4

(B) 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 defect.

EXPERIMENT NO. 4

(D)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, etc.

PART B

EXPERIMENT NO. 1

(A) 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"$\sigma_p = Fp/A_o$ where F_p. is load at the elastic limit.

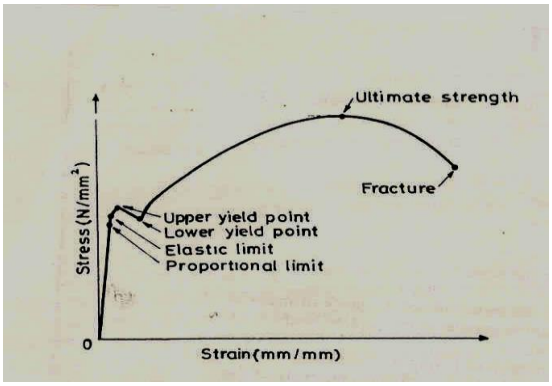


Fig. stress strain diagram for Mild steel

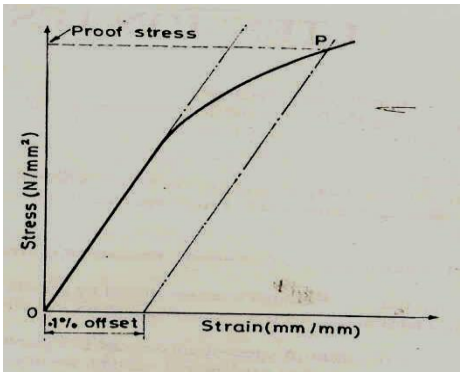


Fig. graph of offset and proof stress

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., $E_2 = \tan \theta_2$

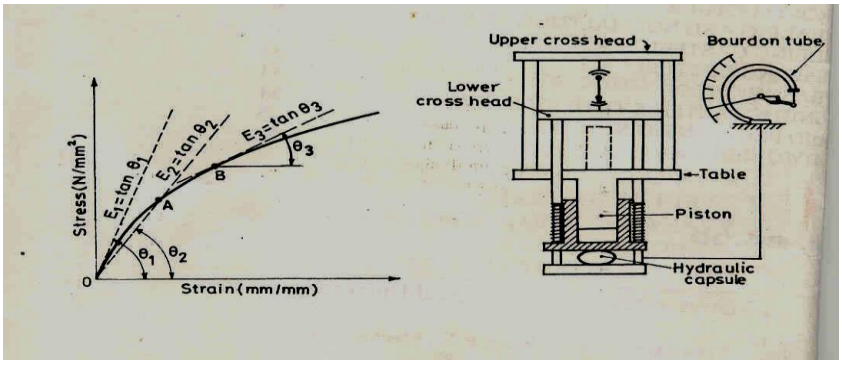
3. The slope of the tangent to stress-strain curve at selected point B is called the tangent modulus

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.

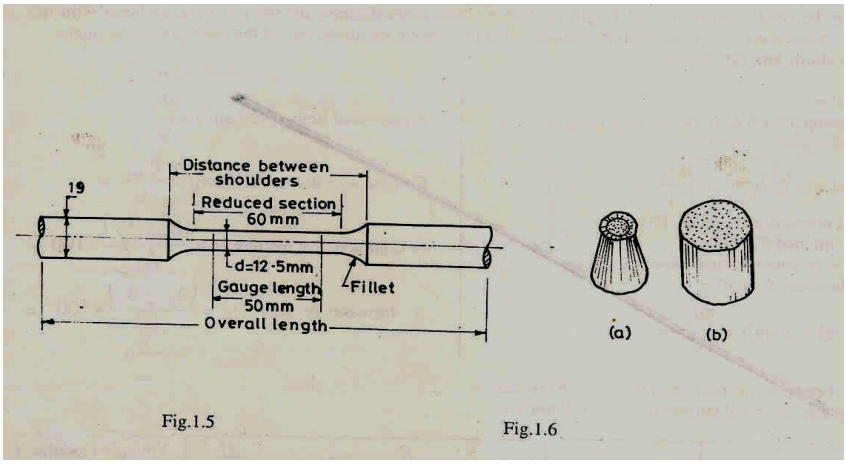


Fig.1.5 Fig.1.6

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 ($N\ mm/mm^3$) = σ_e^2 / 2E =

Modulus of toughness T_o ($N\ mm/mm^3$) = σ_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)

EXPERIMENT NO. 1

(B) COMPRESSION TEST

Object: To study the behavior of the given materials under compressive loading and to determine the following properties.

1. Proportional limit,
2. Modulus of elasticity
3. Compressive strength
4. Percentage contraction
5. Percentage increase in area
6. Initial tangent modulus of elasticity.

Apparatus: Universal testing machine, micrometer caliper, scale and compress meter.

Theory: In compression test the operation is accomplished by subjecting a piece of material to end loading which produces crushing action. In a compression test, the piece shortens. Although compressive mechanical properties in the plastic range cannot be determined for ductile materials because the ultimate and breaking loads cannot be determined, the elastic properties of strength, stiffness, and resilience can be determined as for tension. The moduli of elasticity and yield strengths for many metals rind alloys are approximately equal in tension and compression. The determination of accurate stress-strain diagram in compression is considerably more difficult than for tension. Difficulties arise because of; 1. Irregularities of alignment, which are accentuated with increase in loading and result in lateral deflection and bending stresses, 2. The introduction of lateral restraining forces at the ends of the specimen owing to the friction forces between the specimen ends and bearing plates, and 3. The possibility of failure produced by lateral buckling if

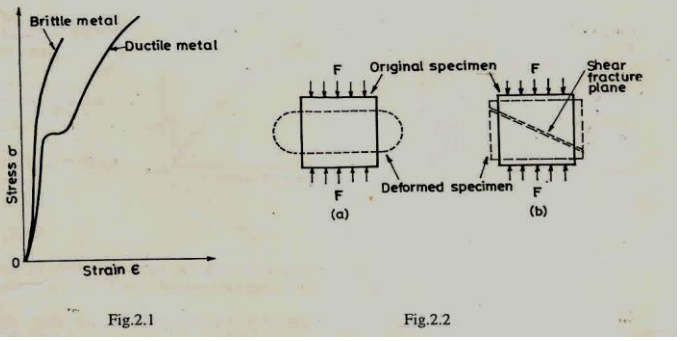


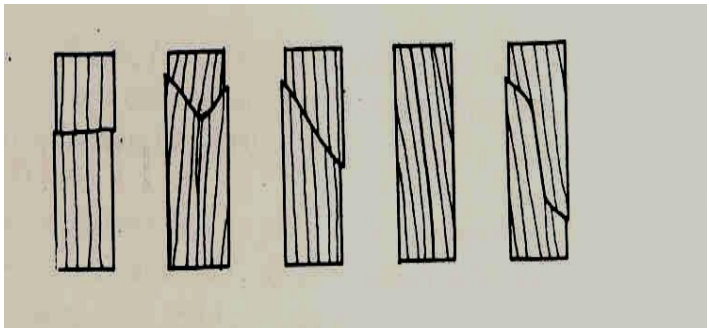
Fig.2.1

Fig.2.2

the specimen is too long. The engineering stress-strain curve for brittle and ductile material in compression test are shown in fig.2.1

Specimen: For uniform stressing of compression, a circular section is to be preferred over other shapes. A ratio of length to diameter of 2 is commonly employed in order to prevent the specimen failing by bending, although the height -to-diameter used varies for different materials

Fracture appearance: In compression of ductile materials, as the load increase in the plastic range, the cross-section increases. This increase in cross sectional area tends to decrease the true stress and thereby increase the load resistance. For this reason it becomes difficult to fracture the ductile specimen, and continued applications of load increases the lateral deformation until a flat disc is produced as shown in fig.2.2a. Large lateral deformations are not produced in the brittle material but failure results by shear and sliding along an inclined plane as shown in fig.2.2b. Brittle materials commonly rupture either along a diagonal plane (cast iron) or with a cone (concrete) or a pyramidal (stone cube) shaped fracture, sometime called an hourglass. Various types of failure of wood loaded parallel with grains are shown in fig.2.3.



Procedure: The average diameter d_m and the length of the specimen L_o are measured. Place thew specimen between the table and the lower cross head of the universal testing machine. Set the load dial of the machine to suitable range and adjust the testing machine and compressometer to read zero. Apply load at slow speed, and make simultaneous observations of the load F and compressometer reading ΔL. Record the yield point and the maximum load in the case of ductile material or the breaking load in the case of brittle material. Remove the broken specimen (if it is brittle) from the machine. Observe the location and character of the fracture and measure the final diameter d_f and length L_f. Plot a stress-strain diagram for the test in accordance with the general

instructions and compute all properties called for. Repeat the above test on the other given specimens.

Observations 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 proportional limit F_p (N) =

Maximum load F_{max}(N) =

Final gauge length L_f, (mm) =

Final diameter d_f (mm) =

Final area A_f (mm^2) = $(\pi d_f^2)/4$

Proportional limit σ_p (N / mm^2) = F_p / A_o =

Compressive strength (N / mm^2) = F_{max} / A_o =

% contraction at fracture Dc = $(L_o - L_f) / L_o$ X 100 =

% Increase in area Da = $(A_f - A_o) / A_o$ X 100 =

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

From the graph initial tangent modulus (N / mm^2) =

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

EXPERIMENT NO. 1

(C) SHEAR TEST

Object: To determine the ultimate shear stress of the given specimen in single and in double shear.

Apparatus: Universal testing machine, and micrometer caliper.

Theory: A shearing stress acts parallel to a plane whereas tensile and compressive stresses acts normal to a plane. There are two main types of shear stresses used in laboratory tests. One is called direct or transverse shear stress and corresponds to the type of stress encountered in rivets, bolts, and beams. The other type of shear stress is called pure or torsional shear and represents the kind of shear stress encountered in a shaft subjected to pure torsion. Direct shear tests are usually conducted to obtain a measure of shear strength and the torsion tests are usually employed to evaluate the basic shear properties of a material.

For direct shear test of metal, a bar is usually sheared in some device that clamps a portion of the specimen while the remaining portion is subjected to a load by means of suitable dies. One method of applying shear load to the specimen is shown in fig.4.l. As in fig.4.1 (a), a cylindrical specimen A is placed in the center hole of the fixed block Band the load is applied to the block C there by producing single shear. If the specimen is extended to D and the gap between the two fixed blocks is bridged as shown in fig.4.l (b), the specimen will fail in double shear since two shear surfaces resist the load. It should be noted that the unit single shear strength of steel is usually greater than that double shear strength.

Ultimate shear strength $\tau = F / A$ for single shear

and $\tau = F / (2A)$ for double shear.

Where F is the fracture load and A is the cross sectional area. In this experiment the failure of the material is not due to entirely by shear, but partially by bending and crushing as well.

Procedure: The average diameter d of the specimen with a micrometer caliper is measured. For single shear test, fix the specimen as shown in fig.4.1 (a) and apply the load slowly at right angles to the axis of the piece through the central block. Note the fracture load. Report the shape and texture of the fractured surface. Repeat the above test by fixing the specimen as in fig.4.1 (b) for double shear.

Observations and tabulation:

Material	Type of shear	Diameter d (mm)	Fracture load F (N)	Area $A=\pi d^2/4$ (mm^2)	Ultimate shear strength τ (N/mm^2)

EXPERIMENT NO. 2

TORSION TEST

Object: To determine the behavior of ductile steel when subjected to torsion, and obtain the following torsional properties: 1.Modoulus of rigidity. 2. Elastic shear strength. 3. Modulus of resilience, 4.Ultimate shear strength, 5.Modulus of toughness, and, 6.Ductility.

Apparatus: Torsion testing machine, micrometer caliper and scale.

Theory: A method of finding the shear properties of a material is by the use of torsion test. Torsional shearing stress on circular cross section varies from zero at the axis of twist to a maximum at the extreme fibers. Within elastic range, the general equation of torsion is

$$(M_t / J) = (G\theta / L) = (\tau / r)$$

In which M_t is the torsional moment in N-mm. J is the polar moment of inertia in mm^4 ($J= \pi d^4/32$ for solid rod), G is the modulus of rigidity in N/mm^2, θ is the angular distortion in radians, L is the gauge length in mm. τ is the shear-stress in N/mm^2 and r is the radius of the rod in mm. From the above equations, for the solid rod, torque $M_t = (\tau \pi d^3/ 16)$

When testing to destruction, the material ultimately becomes perfectly plastic. In such a case the intensity of the shear stress, instead of being proportional to the distance from the axis of the bar, is practically uniform over the L whole section. Therefore in the plastic range, $M_t = (\tau \pi d^3/ 12)$

Definitions: Within the elastic range, the shear stress is proportional to the shear strain. The constant of proportionality G is the modulus of elasticity in shear or the modulus of rigidity, $G =(M_t L) /(J\theta)$

Elastic shear strength is the stress at the yield point. $\tau_y= (M_{ry} r) / J$. where M_{ry} is the yield torque.

Modulus of resilience is the average work per unit volume required to stress a material in torsion to the Proportional limit. $U= \tau_y ^2/ (4G)$

Plastic shear strength in torsion is the maximum stress on the outer fiber corresponding to maximum torque. M_{tu} i.e., $\tau_u = (M_{tu}\ r) / J$.

Modulus of toughness is the average work done per unit volume required to fracture a specimen. Since the total work is the area under the torque-twist diagram, for ductile materials an approximate measure of this area is $M_{tu}\ \theta_f$ where θ_f is the fracture angle of twist. Toughness $T_o = M_{tu}\ \theta_f / (AL)$ where A is the cross sectional area.

Ductility in torsion is determined by comparing the final finer length ljat rapture with the original fiber or gauge length L.

Ductility $D = (L_f - L) /(L) \times l\ 00$ where the final fiber length $L_f = \sqrt{(L^2 + (r\theta_f)^2)}$

r is the radius of the specimen in mm, and θ_f is the angle of twist at fracture in radians.

Torsion testing machine: A sketch of screw type torsion machine is shown in fig.5.l. Torque is applied by hand through the crank and then through the worm and worm gear (not shown) to turn the chuck. The specimen is placed in two similar chucks one at each end of the specimen, by means of centering jaws. As the specimen is twisted, it swings the heavy pendulum, and the amount of twisting moment exerted by and transmitted through the specimen is equal to Wa, where W is the weight of the pendulum and a is the horizontal motion of its center of gravity. The movement of the pendulum is translated to a calibrated scale that directly measures the twisting moment.

Specimens: Torsion testing specimens are generally circular in cross section, either solid or hollow. For solid rod, the length of the specimen is recommended to be 10 times the diameter. The ends are such that they can securely gripped without developing stresses sufficiently localized to cause failure in the grips. In order to obtain an approximately uniform stress and strain distribution along the cross section, this test is usually performed on a thin tubular specimen.

Fracture appearance: Torsion fracture is the shear fracture and is quite distinct from either the tension or compression fracture, there is no localized reduction of area or elongation. When a ductile material is subjected to a twisting moment, the fracture is generally plane and perpendicular

to the axis as shown in fig.5.2 (a). One end of the specimen usually makes several complete revolutions relative to the other before fracture takes place. For brittle material the angle to twist is much less, and the failure is spiral in form known as the helicoidal surface as shown in fig.5.2 (b). This type of fracture may easily be obtained by twisting a piece of chalk in torsion with fingers.

Procedure: Measure the diameter d of the specimen at several sections with the micrometer to obtain a mean value. Measure the gauge length L. Adjust the torsion machine to read zero and then insert the specimen into the two chucks. Apply the load at slow speed. Take reading of torque M_t, and angle of twist θ simultaneously until failure occurs. Note the torque at yield M_{ty} and at fracture M_{tu}. Note the character of the fracture. Plot a graph between torque M_t as ordinate against angle of twist θ as abscissa. Compute the required quantities.

Observations and tabulation:

Diameter of specimen d (mm) =

Length of specimen L (mm) =

Yield torque M_{ty} (N-mm) =

Angle of twist at fracture θ_f ^{0} =

Area of specimen A (mm^2) $=\pi d^4 /4 =$

Polar moment of inertia J (mm^4) $=\pi d^4 / 32 =$

Yield shear strength τ_y (N/mm^2) $= (M_{ty} d) / 2J$

Final fiber length L_f (mm) $= \sqrt{(L^2 + (r\theta_f)^2)}$

Ductility D $= (L_f – L) / (L)$ X 100 =

Modulus of resilience U ($N\text{-}mm/mm^3$) $= \tau_y^2 / (4G)$

Plastic shear strength τ_u (N/mm^2) $= M_{tu} d / (2J) =$

Modulus of toughness T_o (N-mm/mm3) $= (M_{tu} \theta_f \pi) / (180 A L) =$

Modulus of rigidity G (N/mm^2) = (L / J) x slope of the straight line portion of the graph =

Angle of twist θ^o	Torque M_t (N/mm)	Shear stress $\tau = (M_{tu}\ d) / (2J)$ (N/mm^2)	Shear strain $\gamma = (d\theta / 2L)\ \pi / 180$	Modulus of rigidity $G = \tau / \gamma$ (N/mm^2)

EXPERIMENT NO. 3

BENDING TEST

Object: To study the behavior of the given specimens under bending and to determine the following properties. 1. Elastic strength, 2. Modulus of elasticity, 3. Modulus of resilience, 4. Modulus of rupture, and 5. Toughness.

Apparatus: Universal testing machine, scale, and deflectometer.

Theory: If forces act on a piece of material in such a way that they tend to introduce compressive stresses over one part of a cross section of the piece and tensile stresses over the remaining part, the piece is said to be bending. In a cross section of a beam the line along which the bending stresses are zero is called the neutral axis. In simple bending, the neutral axis passes through the centroid. In bending, stresses are proportional to the distance from the neutral axis, within the proportional limit. Above the proportional limit, bending stresses do not vary linearly across a section. Most members subjected to bending are beams, and for this reason the usual laboratory tests to determine flexure or bending stress-strain properties are made on beams subjected to simple bending. In these tests, specimens are subjected to either center loading or point loading as shown in Fig.5.l

Two-point loading: By applying two loads F/2 at equal distance from the supports (Fig.5.1a), the recommended distance from a support is equal to 1/3 of the specimen gauge length. Maximum bending moment is $M_b = F\ b / 2$

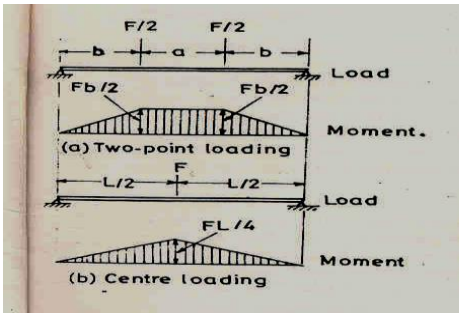


Fig.5.l specimens subjected to load

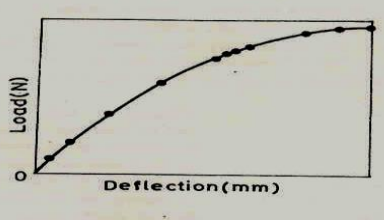


Fig.5.2load v/s deflection

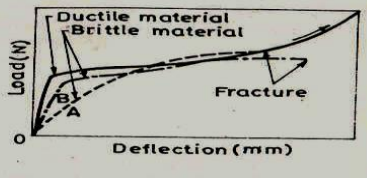


Fig.5.32load v/s deflection

Center loading: By applying a concentrated load F at the span center as shown in Fig 5.lb, the maximum bending moment $M_b = FL / 4$

A load deflection diagram is first obtained by using the above loading arrangement. The load is applied by universal testing machine. To determine the deflection, a deflectometer is placed on the specimen, usually at the center. Loads and deflections are measured to failure at predetermined increments of load or deflection. With these data load-deflection diagram is plotted as shown in Fig.5.2. For most ductile materials, specimens continue to deform without failure and fracture does not occur. For this reason, plastic properties cannot be determined for such materials. In the case of brittle materials including cast iron, wood and various plastics, the deflection diagram can be determined to fracture so that plastic properties can be evaluated. For some brittle material a linear stress-strain relation in the elastic range exists, and both elastic and plastic properties can be defined. Load-deflection diagrams for all three types of materials are shown in Fig. 5.3. These diagrams are used in evaluating the following stress-strain properties in bending.

The bending equation is $(M_b / I) = (\sigma / c) = (E/R)$

Where M_b is the bending moment (N-mm), I is the moment of inertia of the cross section (mm^4), σ is the bending stress (N/mm^2), R is the radius of curvature (mm), E is the modulus of elasticity (N/mm^2), and c is the distance from the neutral axis to the outermost fiber (mm).

Elastic strength is defined as the maximum bending stress in the specimen corresponding to either the proportional limit load F_p or yield load F_y. Based on F_y, the elastic strength in bending is $\sigma_y = M_{by} C / I$, where M_{by} is bending moment corresponding to the load F_y, c is the distance in mm. from the neutral axis to the outermost fiber and I is the moment of inertia of the cross section in mm^4. For rectangular cross section, $1 = (BH.^3) / 12$ and $c = H /2$ in which B is the breadth and H is the depth. L is the length of the span.

The resistance to deformation in bending in the elastic range is called stiffness in bending. A measure of this properly is modulus of elasticity in bending. $E = (FL^3) / (48yI)$ for center loading. y is the deflection in mm.

Resilience is the average work done in stressing a specimen in bending to the proportional limit load F_p. For center loading the modulus of resilience $U = (F_p y_p) / (2 AL)$, where A is the cross-sectional area.

The stress at fracture in bending is known as the modulus of rupture or transverse rupture strength. The modulus of rupture $\sigma_u = M_{bu} C / I$, where M_{bu} is the bending moment at fracture.

Toughness is measured by the average work done per unit volume to fracture the specimen. For specimen with center load and assuming the deflection curve is parabola, the modulus of toughness

$T_o = 2F_f Y_f /(3AL)$. where F_f is the fracture load and Y_f is the maximum deflection.

The failure of beams of brittle material such as cast iron and concrete always occurs by sudden rupture.

Specimens: Specimens for bending tests may be either circular or rectangular cross section. In order to avoid the specimen by shear, the span L must not be too short with respect to the depth H. The value of L = 6H to 12H is common. A value of L < 15B usually safeguards against lateral buckling.

Procedure: Measure the cross-sectional dimensions. Mark the span length L symmetrical with length of the specimen. Firmly place the specimen over the supports. Attach the deflectometer at the center of the span and adjust to zero. Apply the 19ad at the center of the span and at slow speed. Make simultaneous observations of load F and deflection y. Record the breaking load F_f- Observe the location and character of the fracture. Plot a load-deflection diagram for the test in accordance with general instruction and compute all properties called for. Repeat the above test on the other specimens.

Observations and tabulation:

Material:

Span length L (mm) =

Breadth B (mm) =

Depth H (mm) =

Distance c (mm) = H /2

Load at yield point F_y (N) =

Deflection at yield point y_y (mm) =

Maximum load F_f (N) =

Maximum deflection Y_f(mm) =

Area A (mm^2) = BH=

Moment of inertia I (mm^4) = $(BH.^3) / 12$

B.M at yield point M_{by} (N-mm) = $F_yL / 4$ =

Elastic strength σ_y (N / mm^2) =M_y C / I) =

Modulus of resilience U ($N\text{-}mm/mm^3$) =F_yA_y / (2AL) =

Maximum B.M. M_{bu} (N-mm) = $F_f L / 4$ =

Modulus of rupture σ_u (N / mm^2) =M_{bu} C / I) =

Modulus of toughness T_o ($N\text{-}mm/mm^3$) = 2 $F_f A_f$ / (3AL)

Modulus of elasticity E (N/ mm^2) = $(FL^3) / (48yI) = (L^3) / (48I)$ x slope of the load deflection graph

Load F (N)	Deflection Y (mm)	Modulus of elasticity $E = (FL^3) / (48yI)$, (N/ mm^2)

EXPERIMENT NO. 4
IMPACT TEST

Object: To study an impact machine of the pendulum type and to determine the relative impact resistance of the given machine in the form of notched bar Charpy or Izod specimen.

Apparatus: Pendulum impact machine.

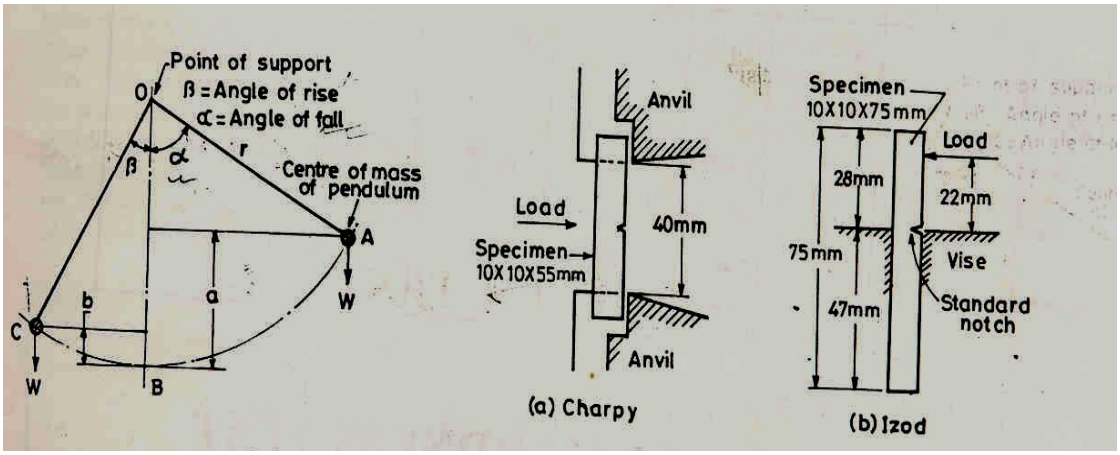
Theory: Impact test is used to measure material's ability to withstand shock loading. Notched-bar impact test is used to determine the tendency of a material to behave in a brittle manner. This type of test will detect difference between materials, which are not observable in a tension test The impact test is carried .out on a pendulum type machine. The principal features of pendulum type impact machines are: I. A moving mass whose kinetic energy is greater enough to cause rupture of the test specimen placed in its path, 2. An anvil and a support on which the specimen is placed to receive the blow, and 3. A means for measuring the residual energy of the moving mass after the specimen has been broken.

The specimen is placed on its anvil and the pendulum, of weight W is raised to a height a as shown in fig.6.1. It can be seen from the figure that pendulum's energy before release (point A) is Wa. After release, the pendulum's potential energy decreases and the kinetic energy increases until just before impact (point B) the former is zero and the later is maximum. At B, the amount of energy necessary to fracture the specimen is dissipated. As the pendulum continues to swing, the remaining kinetic energy is again converted to potential energy, the process being complete when the pendulum reaches the point C, where the potential energy is Wb. Neglecting friction in bearings and air resistance of the pendulum, the fracture energy U is equal to W (a - b). The energy value is sometime called the impact toughness. This is the value indicated by the friction pointer on the graduated scale in most testing machine. If the scale is graduated in degrees, then $U= Wr (\cos \beta - \cos \alpha)$,where α and . β' are angle of fall and angle of raise respectively and , r is the length of pendulum. The impact strength of the specimen $K=U/(AL)$ where A is the cross sectional area at fracture and L is the length of the specimen.

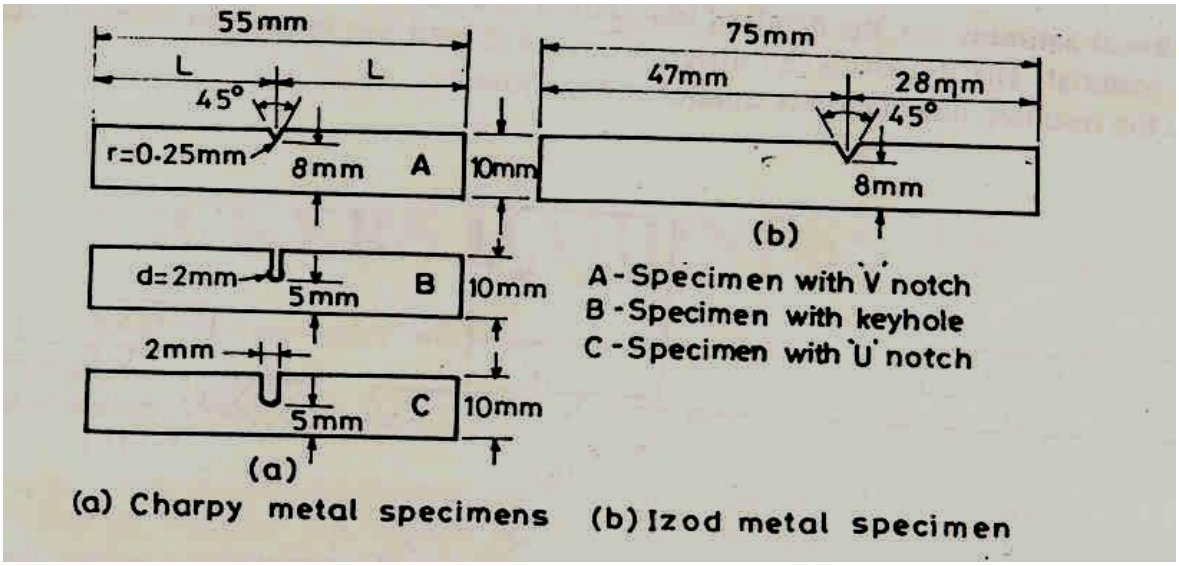
The impact velocity $v = \sqrt{2ga} = \sqrt{2gr(1 - \cos\alpha)}$

Since the initial angle through which the pendulum is raised is constant, the upward swing after fracturing the specimen can be used to measure energy dissipated in breaking the specimen. This upward swing of the pendulum after fracturing the specimen moves a pointer over a circular scale to read the fracture energy.

Two types of specimen have been standardized for notched impact testing, They are Charpy and Jzod specimens. The difference in loading between Charpy and Izod tests is shown in fig.6.2. Although the Izod impact test has long been established as the standard form of test for checking the brittleness of metallic materials, the need has arises for tests at elevated and sub-zero temperatures. For this purpose the Charpy test is more convenient as the specimen does not have to be clamped and can be quickly positioned without significant change in temperature. The notched-bar impact test is most meaningful when conducted over a range of temperature so that the temperature at which the ductile to brittle transition takes place can be determined. It is generally accepted that the Charpy and Izod values are practically the same for metals, which fail with an energy absorption value less than 100 J. Above this value Charpy values are higher than the Izod values. The chief use of impact test is not to compare different materials with one another, but to compare the same material after being subjected to different heat treatments. It is important to note that fracture energy measured by impact test is only a relative energy and cannot be used directly in design equations



Specimens: The standard metal specimen for Charpy test is square prism notched as shown in Fig.6.3. For this test, the specimen is arranged as a simple beam with the notch being on the tension side as shown in Fig.6.2 (a) For Izod test, prismatic or cylindrical specimen notched as shown in Fig.6.3 is clamped to act as vertical cantilever, with the notch on the tension side as in Fig 6.2(b). The purpose of the notch in the bar is to increase the severity of the test. Notch sets up stress concentration, which ensure that fracture does occur.



Fracture appearance: Two distinct zones can often be observed, one bright and granular, the other dull and similar to the cup and cone fracture of a tensile test. The former is due to cleavage of the metal grains and is the true brittle fracture. The latter is due to shear fracture of the metal grains and is accompanied by plastic deformation. The larger the area of brittle fracture, the smaller the amount of energy needed.

Procedure: With no specimen in the anvil, swings the pendulum to ensure freedom of movement and to check the scale. Note the weight W of the pendulum and the radius r of its center of mass (these values may be stamped on the pendulum). Lift the pendulum to its upper position, and adjust the friction pointer to make contact with the pendulum. Note the initial reading on the scale if the graduation is in degrees (angle of fall α^0). If the scale is graduated in energy units, adjust the pointer to read the striking energy. The striking energy for Charpy machine is 280 and the striking energy for Izod machine is

163 J. Measure the lateral dimensions of the specimen at the notch. Using the positioning gauge place the specimen on the anvil. For Charpy test, the specimen is arranged with the notch on the side away from striking edge of the pendulum and directly in line with it as shown in Fig. 6.2(a); An Izod specimen is arranged with the notch towards the striking edge as in Fig.6.2 (b). Release the pendulum to rupture the specimen. Record the angle of raise of the pendulum β° or the energy to rupture from the scale. Stop the pendulum to swing by means of the band brake lever. Repeat the above procedure with other specimens.

Observations and tabulation:

Length of specimen L (mm) =

Area of specimen at notch A (mm^2) =

Weight of pendulum W (N) =

Length of pendulum r (mm) =

Angle of fall (α^0) =

Impact velocity v (m/sec.) $=\sqrt{2gr(1 - \cos\alpha)}$ =

Material	Angle of raise β°	Fracture energy from Fracture energy U J (N mm)	Fracture energy U =Wr (cos β - cos α) J (N mm)	Impact strength K = U /(AL) J / mm^2 (N mm/mm^2

EXPERIMENT NO. 5

WEAR TEST

Object: To study the wear properties of the given specimen and to determine the wear factor.

Apparatus: Wear testing machine, tachometer, scale and digital stop watch.

Theory: Wear is defined as the progressive loss or removal of material from a surface. Usually parts damaged by wear can be repaired or replaced before disastrous failure takes place. Wear is usually classified as adhesive, abrasive, corrosive, fatigue, fretting, and impact wear.

Adhesive wear: If a tangential force is applied between the two sliding blocks, shearing can take place either at the original interface or along a path below or above it, causing adhesive wear. The fracture path depends on whether or not the strength of the adhesive bond of the asperities is greater than the cohesive strength of either of the two sliding bodies. Thus during sliding, fracture at the asperity usually follows a path in the weaker or softer component. A wear fragment is then generated. Although this fragment is attached to the harder component, it eventually becomes detached during further rubbing at the interface and develops into a loose wear particle. This process is known as adhesive wear or sliding wear. Adhesive wear can be reduced by:

1. Selecting materials that do not form strong adhesive bonds.
2. Using a harder material as one of the pair.
3. Using materials that oxidize more easily.

Abrasive wear: Abrasive wear is caused by a hard and rough surface sliding across a surface. This type of wears removes particles by forming microchips, thereby producing grooves or scratches on the softer surface. The abrasive wear resistance of metals is directly proportional to their hardness. Abrasive wear can thus be reduced by increasing the hardness of materials or by reducing the normal load.

Several methods can be used to observe and measure wear. In general, a wear testing machine consists of a means for applying load to a specimen of material which is rubbed at a given speed,- over another piece of material or over an abrasive surface. The amount of wear after a given amount of rubbing is measured either by loss of weight of the specimen or by dimensional changes.

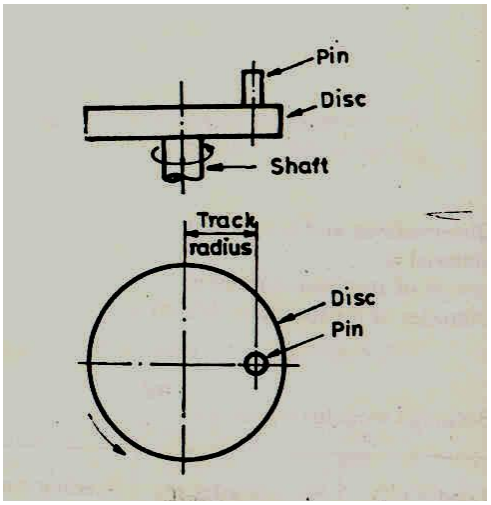


Fig.6.1 pin-on-disc type wear-testing machine

Let V = Wear volume (mm^3).

F = Load on the specimen (N)

v = Rubbing velocity (m/sec.) = $2\pi rn / (60 \times 1000)$

r = Radius of track (mm)

n = Speed in rpm.

t = Test time (sec.)

Wear factor K (mm^3 / N-m) = V / (Fvt)

Fig.6.1 shows a pin-on-disc type wear-testing machine. It consists of a hardened steel disc mounted on a vertical shaft, which is driven by an electric motor through a V-belt drive. The specimen in the form of a pin is mounted on the horizontal arm which intern is mounted on a sliding block to

facilitate changing of the track radius. A displacement sensor is used to measure the reduction in length of the pin and a load cell is used to measure the tangential force on the pin.

Procedure:

1. Clean the surface of the disc and the specimen by alcohol and acetone.
2. Fix the specimen (pin) on the horizontal arm and measure the track radius by a scale.
3. Switch on the motor and measure the speed of the disc n (rpm) by a tachometer.
4. Load the specimen and record the force from the load cell indicator.
5. Adjust the displacement sensor to read zero. .
6. Record the reduction in length ΔL at regular interval.
7. Repeat the above procedure on the other specimens for a given period of time at constant rubbing velocity and with increasing increments of load.
8. Repeat the above procedure on the other specimens for a given period of time at constant load and with increasing the increments of surface velocity (by varying the speed n or by varying the track radius r).

Observations and tabulation:

Load F (N)	Track radius r (mm)	Speed n (rpm)	Time t (sec)	Reduction in length of pin ΔL (mm)	Velocity $v = 2\pi rn / (60 \times 1000)$ (m/sec.)	Wear factor $K = V / Fvt$ (mm^3 / N-m)

Graph: Draw the following graphs :(1).ΔL Vs t., (2). ΔL Vs v, and (3). ΔL Vs F.

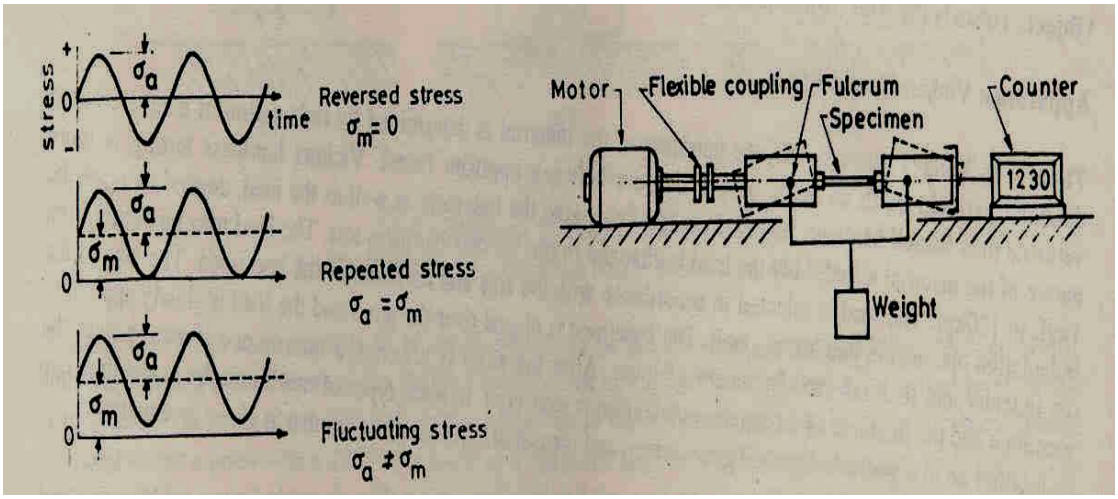
EXPERIMENT NO. 6

FATIGUE TEST (Demonstration)

Object: To study the fatigue-testing machine and to determine the fatigue limit and the fatigue strength.

Apparatus: Fatigue testing machine, and micrometer caliper.

Theory: Failure due to repeatedly applied load is known as fatigue. The physical effect of a repeated load on a material is different from the static load, failure always being brittle fracture regardless of whether the material is brittle or ductile. Mostly fatigue failure occur at stress well below the static elastic strength of the material. Possible forms of loading curves are shown in Fig.10.1. If the applied load changes from any magnitude in one direction to the same magnitude in the opposite direction, the loading is termed completely reversed, where as if the load changes from one magnitude to another (the direction does not necessarily change), the load is said to be fluctuating load.



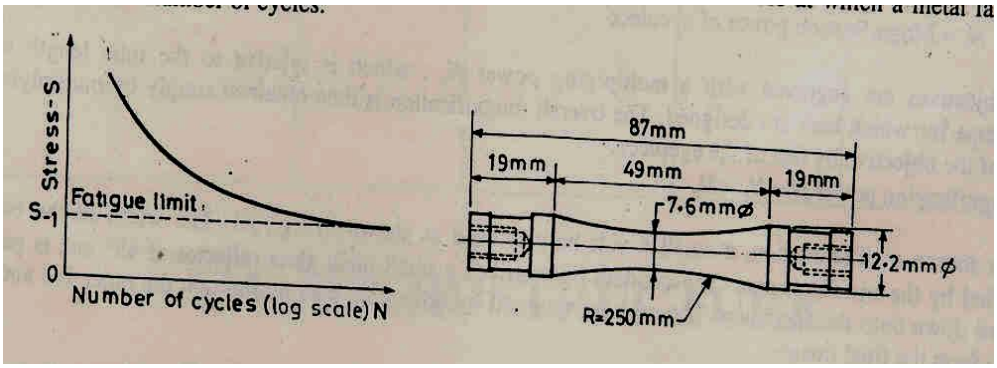
Fatigue testing machine: In the simplest type of machine for fatigue testing, the load applied is of bending type. The test specimen may be of simply supported beam or a cantilever. R.R.Moore rotating beam type machine for a simply supported beam is shown in fig, 10.2. A specimen of circular cross-section is held at its ends in special holders and loaded through two bearings equidistant from the center of the span.. Equal loads on these bearings are applied by means of weights that produce a uniform bending moment in the specimen between the loaded bearings. A motor rotates the specimen. Since the upper fibers of the rotating beam are always in compression while the lower fibers are in tension, it is apparent that a complete cycle of reversed stress in all fibers of the beam is produced during each revolution. A revolution counter is used to find the number of cycles the specimen is repeatedly subjected to the load. For simply supported beam, maximum bending moment is at the center.

Bending moment $M_b = FL / 4$ and bending stress $S = M_b / Z$

Where L is the length of the specimen and z is the sectional modulus. In rotating cantilever beam type, the specimen is rotated while a gravity load is applied to the free end by means of a bearing. For cantilever specimen the maximum bending moment is at the fixed end.

Therefore $M_b = FL$ and $S = M_b / Z$

The testing technique is subjected to a series of identical specimens to loads of different magnitudes and note the number of cycles of stress (or load) N necessary to fracture the specimen. The data are plotted on a semi- logarithmic paper, the stress S being plotted to a linear scale and a number of cycles N to a logarithmic scale as shown in Fig.10.3. This is known as stress-cycle (S-N) diagram and the fatigue limit can be determined from the diagram. Fatigue limit or endurance limit is the stress below which a material can be stressed cyclically an indefinitely large number of times without failure. The fatigue strength is the stress at which a metal fails by fatigue after a certain number of cycles. .



Specimens: All specimens should be taken from the same rod, each specimen should receive same kind of machining and heat treatment. The specimens for tests of the metal have no sharp stress raisers. The surface of the specimen is polished. The standard specimen for rotating beam test is shown in Fig. 10.4.

Fracture appearance: Under repeated loading, a small crack forms in a region of high-localized stress, and a very high stress concentration accompanies the crack. As the load fluctuates, the crack opens and closes and progresses across the section. Frequently this crack propagation continues until there is insufficient cross section left to carry the load and the member ruptures, the failure being fatigue failure. Therefore fractured surface shows two surfaces of distinctly different appearance.

1. A smooth surface where the crack has spread slowly and the walls of the crack are polished by repeated opening and closing. This surface usually shows characteristic beach or clam shell markings.
2. A crystalline or fibrous surface where sudden failure occurred.

Procedure: Measure the diameter d and the length L of the specimen. Securely fasten the specimen in the chucks of the testing machine. Set the maximum load. Set the counter to zero, and start the machine. Note the number of cycles N the specimen experiences before fracture. Repeat the above test on the other specimens with gradually reduced loads. Draw the S-N diagram and obtain the endurance limit.

Observations and tabulation:

Material =

Length of specimen L (mm) =

Diameter of the specimen d (mm) =

Sectional modulus z (mm^3) = $\pi d^3 / 32$

Load F (N)	No. of cycles N	Bending moment $M_b = FL / 4$ (N-mm)	stress $S = M_b / Z$ ($N\text{-}mm^2$)