Bearys institute of Technology

Lands end, Near Mangaluru University
Innoli, Mangaluru - 574153

MATERIAL SCIENCE AND ENGINEERING LABORATORY MANUAL

(BME303)

[2022 SCHEME]

SEMESTER – III / IV

DEPARTMENT OF MECHANICAL ENGINEERING

Prepared by: Dr. Sandeep Nambiar S.

MATERIAL SCIENCE AND ENGINEERING		Semester	III
Course Code	**BME303**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 8-10 Lab slots	Total Marks	100
Credits	04	Exam Hours	3
Examination nature (SEE)	**Theory**		

Course objectives:

- Explain the basic concepts of geometrical crystallography, crystal structure and imperfections in Solids.
- Construct the phase diagrams to know the phase transformations and concept of diffusion in solids.
- Identify the heat treatment, cooling method for controlling the microstructure and plastic deformation to modify their properties.
- Explain the powder metallurgy process, types and surface modifications.
- Apply the method of materials selection, material data, properties and knowledge sources for computer-aided selection of materials.

Teaching-Learning Process (General Instructions)

These are sample Strategies; that teachers can use to accelerate the attainment of the various course outcomes.

- Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Videodemonstrations or Simulations.
- Chalk and Talk method for Problem Solving.
- Adopt flipped classroom teaching method.
- Adopt collaborative (Group Learning) learning in the class.
- Adopt Problem Based Learning (PBL), which fosters students' analytical skills and develops thinking skills such asevaluating, generalizing, and analysing information.

MODULE-1

Structure of Materials

Introduction: Classification of materials, crystalline and non-crystalline solids, atomic bonding: Ionic Bonding and Metallic bonding.

Crystal Structure: Crystal Lattice, Unit Cell, Planes and directions in a lattice, Planar Atomic Density, Coordination number, atomic Packing Factor of all the Cubic structures and Hexa Close Packed structure. Classification and Coordination of voids, Bragg's Law.

Imperfections in Solids: Types of imperfections, Point defects: vacancies, interstitials, line defects, 2-D and 3D-defects, Concept of free volume in amorphous solids. Slip, Twinning.

MODULE-2

Physical Metallurgy

Alloy Systems: Classification of Solid solutions, Hume- Rothery Rules

Diffusion: Diffusion Mechanisms: Vacancy Diffusion and Interstitial Diffusion, Fick's laws of diffusion, Factors affecting diffusion.

Phase Diagrams: Gibbs Phase Rule, Solubility limit, phase equilibrium and Phase Diagrams: Isomorphous systems, Invariant Binary Reactions: Eutectic reaction, Eutectoid reaction and Peritectic reaction, Lever Rule, Iron-Carbon Diagram. Effect of common alloying elements in steel. Numerical on Lever rule.

MODULE-3

Nucleation and growth: Introduction to homogeneous and heterogeneous nucleation, critical radius for nucleation.

Heat treatment: Annealing, Normalizing, hardening, Tempering, Nitriding, Cyaniding, Induction Hardening and Flame Hardening, Recent advances in heat treat technology. TTT diagram, Recovery-Recrystallization-Grain Growth. Strengthening mechanisms: Strain hardening, Precipitation hardening (Solid-Solution Strengthening), Grain refinement.

MODULE-4
Surface coating technologies: Introduction, coating materials, coating technologies, types of coating: Electro-plating, Chemical Vapor Deposition(CVD), Physical Vapor Deposition(PVD), High Velocity Oxy-Fuel Coating, advantages and disadvantages of surface coating. **Powder metallurgy:** Introduction, Powder Production Techniques: Different Mechanical methods: Chopping or Cutting, Abrasion methods, Machining methods, Ball Milling and Chemical method: Chemical reduction method. **Characterization of powders (Particle Size & Shape Distribution), Powder Shaping:** Particle Packing Modifications, Lubricants & Binders, Powder Compaction & Process, Sintering and Application of Powder Metallurgy.
MODULE-5
Engineering Materials and Their Properties: Classification, **Ferrous materials:** Properties, Compositions and uses of Grey cast iron and steel. **Non-Ferrous materials:** Properties, Compositions and uses of Copper, Brass, Bronze. **Composite materials** - Definition, classification, types of matrix materials & reinforcements, Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs) and Polymer Matrix Composites (PMCs), Particulate-reinforced and fiber- reinforced composites, Applications of composite materials. Mechanical and functional properties of Engineering Materials **The Design Process and Materials Data:** Types of design, design tools and materials data, processes of obtainingmaterials data, materials databases. **Material Selection Charts:** Selection criteria for materials, material property Charts, deriving property limits and material indices.

PRACTICAL COMPONENT OF IPCC*(May cover all / major modules)*

Sl.NO	Experiments
1	Specimen preparation for macro and micro structural examinations and study the macrostructure and microstructure of a sample metal/ alloys.
2	Study the heat treatment processes (Hardening and tempering) of steel/Aluminium specimens.
3	To determine the hardness values of Mild Steel/ Aluminium by Rockwell hardness/Vickers Hardness.
4	To determine the hardness values of Copper/ Brass by Brinell's Hardness testing machine.
5	To determine the tensile strength, modulus of elasticity, yield stress, % of elongation and % of reduction in area of Cast Iron, Mild Steel/Brass/ Aluminium and to observe the necking.
6	To conduct a wear test on Mild steel/ Cast Iron/Aluminium/ Copper to find the volumetric wear rate and coefficient of friction.
7	To determine the Impact strength of the mild steel using Izod test and Charpy test.
8	Study the chemical corrosion and its protection. ***Demonstration***
9	Study the properties of various types of plastics. ***Demonstration***
10	Computer Aided Selection of Materials: Application of GRANTA Edupack for material selection: Case studies based on material properties. ***Demonstration***

Course outcomes (Course Skill Set):

At the end of the course the student will be able to:

1. Understand the atomic arrangement in crystalline materials and describe the periodic arrangement of atoms in terms of unit cell parameters.
2. Understand the importance of phase diagrams and the phase transformations.
3. Explain various heat treatment methods for controlling the microstructure..

4. Correlate between material properties with component design and identify various kinds of defects.
5. Apply the method of materials selection, material data and knowledge sources for computer-aided selection of materials.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

CIE for the theory component of the IPCC (maximum marks 50)

- IPCC means practical portion integrated with the theory of the course.
- CIE marks for the theory component are **25 marks** and that for the practical component is **25 marks**.
- 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests, each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.
- Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

CIE for the practical component of the IPCC

- **15 marks** for the conduction of the experiment and preparation of laboratory record, and **10 marks** for the test to be conducted after the completion of all the laboratory sessions.
- On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to **15 marks**.
- The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be conducted for 50 marks and scaled down to **10 marks.**
- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

SEE for IPCC

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours**)

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scoredby the student shall be proportionally scaled down to 50 Marks

The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component.

Suggested Learning Resources:

Text Books:

1. Callister Jr, W.D., Rethwisch, D.G., (2018), Materials Science and Engineering: An Introduction, 10th Edition, Hoboken, NJ: Wiley.
2. Ashby, M.F. (2010), Materials Selection in Mechanical Design, 4th Edition, Butterworth- Heinemann.
3. Azaroff, L.V., (2001) Introduction to solids, 1st Edition, McGraw Hill Book Company.
4. Avner, S.H., (2017), Introduction to Physical Metallurgy, 2nd Edition, McGraw Hill Education.

Reference Books

1. Jones, D.R.H., and Ashby,M.F., (2011), Engineering Materials 1: An Introduction to Properties, Application and Design, 4th Edition, Butterworth-Heinemann.
2. Jones, D.R.H., and Ashby,M.F., (2012), Engineering Materials 2: An Introduction to Microstructure and Processing, 4th Edition, Butterworth-Heinemann.
3. Abbaschian, R., Abbaschian, L., Reed-Hill, R. E., (2009), Physical Metallurgy Principles, 4th Edition, Cengate Learning.
4. P. C. Angelo and R. Subramanian: Powder Metallurgy- Science, Technology and Applications, PHI, New Delhi,2008.

Web links and Video Lectures (e-Resources):

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1. Bhattacharya,B., Materials Selection and Design, NPTEL Course Material, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, http://nptel.ac.in/courses/112104122/
2. Prasad, R., Introduction to Materials Science and Engineering, NPTEL Course Material, Department of Materials

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

Course seminar

Industrial tour/Visit to Advanced Research Centres

INDEX

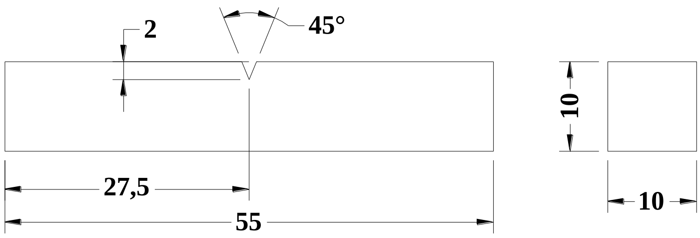
Technical data:

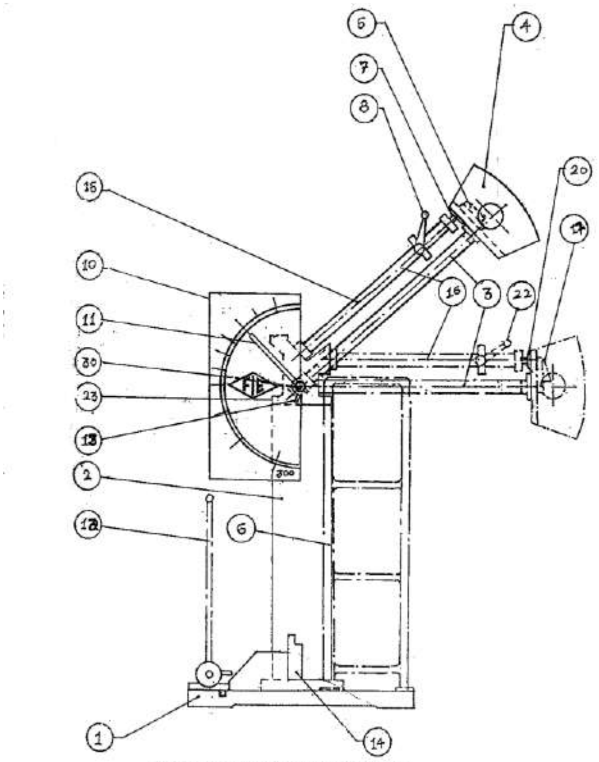
Maximum Impact Energy of pendulum	= 300 Joules
Minimum value of scale graduation	= 2 Joules
Distance between supports	= 40 mm
Angle of test piece supports	= 90º
Angle of inclination of supports	= 0º
Maximum width of the striker	= 10 – 18 mm
Angle of striking edge	= 30º
Weight of the machine	= 415 Kg (Approx.)

Observation:

1) Material of the given specimen =
2) Initial Energy = Joules.
3) Width of the specimen, b = mm.
4) Depth of the specimen below the notch, d = mm.

Specimen:





IMPACT TESTING MACHINIE

LIST OF PARTS

1. Base with specimen support fitted
2. Column
3. Pendulum pipe
4. Pendulum Hammer
5. Striker for Charpy test
6. Guard

7/20.Latch for Charpy / Izod test

8/22. Lever to release the pendulum

10. Dial
11. Reading pointer
12. Brake for pendulum
13. Pointer Carrier
14. Specimen support

15/16. Latching tube for Charpy / Izod test

17. Striker for Izod test
23. Bearing housing
30. Pendulum shaft

1. CHARPY IMPACT TEST

Aim: To determine the impact strength of given specimen under dynamic loading.

Apparatus:

1) Vernier Caliper.
2) Steel rule.
3) Impact testing machine.

Theory: An impact test signifies toughness of material that is ability of material to absorb energy during plastic deformation. Static tension tests of un notched specimen do not reveal the susceptibility of a metal to brittle fracture. This important factor is determined by impact test. Toughness takes into account both the strength ductility of the material. Several engineering materials have to withstand impact or suddenly applied loads while in service. Impact strengths are generally lower as compared to strengths achieved under slowly applied loads. Of all types of impact tests, the notched bar tests are extensively used. Therefore, the impact test measures the energy necessary to fracture a standard notch bar by applying an impulse load. There are mainly 2 types of impact tests, namely i) Charpy Impact test

ii) Izode Impact test

In Charpy impact testing simply supported mode of loading is used.

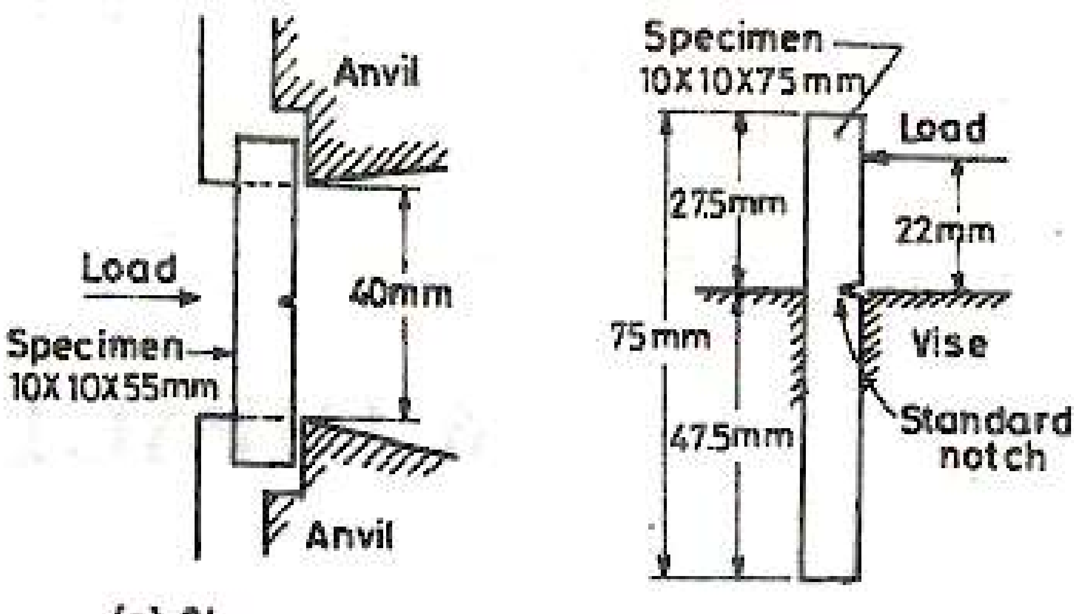
Notch: A slot or groove of specified characteristics intentionally cut in a test piece so as to concentrate the stress, thus localizing the rupture.

Procedure:

1. A standard test piece of overall length of 55mm, a square cross-section of 10mm side with central 'V' notch with 2 mm depth of 45 º angles is taken to conduct the test and the dimensions are noted down.
2. The hammer is lifted and locked in position and the pointer is adjusted to coincide with initial position (i.e., maximum value) in the Charpy scale.
3. Pendulum is released and friction losses are found (Generally it's adjusted by the machine manufacturer).
4. Again the Pendulum is lifted and locked, then the test piece/ specimen is fixed as a simply supported beam with center & such that it is on the tension side (Notch is facing opposite to the striker).
5. Then the hammer is released without any shock & is allowed to strike the specimen.
6. The reading indicated by the pointer is noted.

Calculation

1) Area of cross section of the specimen below the notch, a	= b x d	
	=	mm^2
2) Energy absorbed by the specimen for failure, k	=	Joules.
3) Impact strength	=	k / a
	=	Joules / mm^2



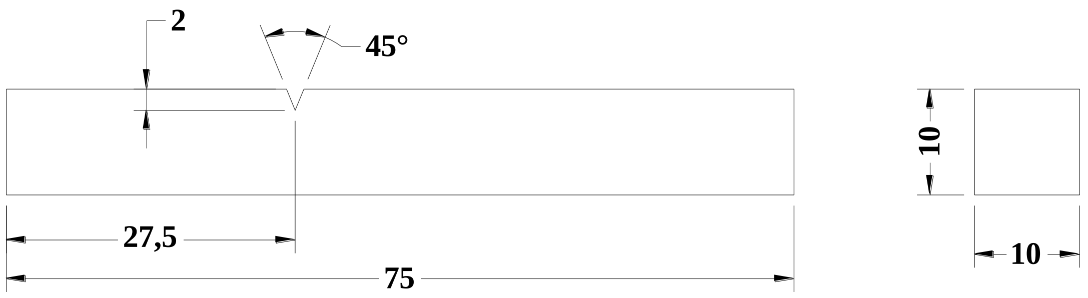
(a) Charpy (b) Izod

Precautions to be taken:

1. Nobody should stand within the range of the swing of the pendulum.
2. Lock the pendulum while placing the specimen.
3. Specimen should be placed carefully, considering the correct position of the V - notch, unless striker may be damaged.
4. Pendulum brakes should not be applied when the pendulum is returning.

Result: Impact strength of a given specimen = Joules / mm^2

Specimen:



Technical data:

Maximum Impact Energy of pendulum = 168 Joules

Distance between base of specimen notch (or top or grips) and the point of specimen hit by the hammer = 22 mm ± 0.5

Angle of striking edge = 75º ± 1º

Angle of rise of the pendulum = 135º

Observation:

1) Initial Energy = Joules.
2) Width of the specimen, b = mm.
3) Depth of the specimen below the notch, d = mm.

Calculation:

1 .Area of the specimen below the notch, a = b x d

= mm^2

2. Energy absorbed by the specimen for failure, k = Joules
3. Impact value = k / a

= Joules / mm^2

2. IZOD IMPACT TEST

Aim: To determine the impact strength of given specimen under dynamic loading.

Apparatus:

1. Vernier Caliper.
2. Scale.
3. Impact testing machine.

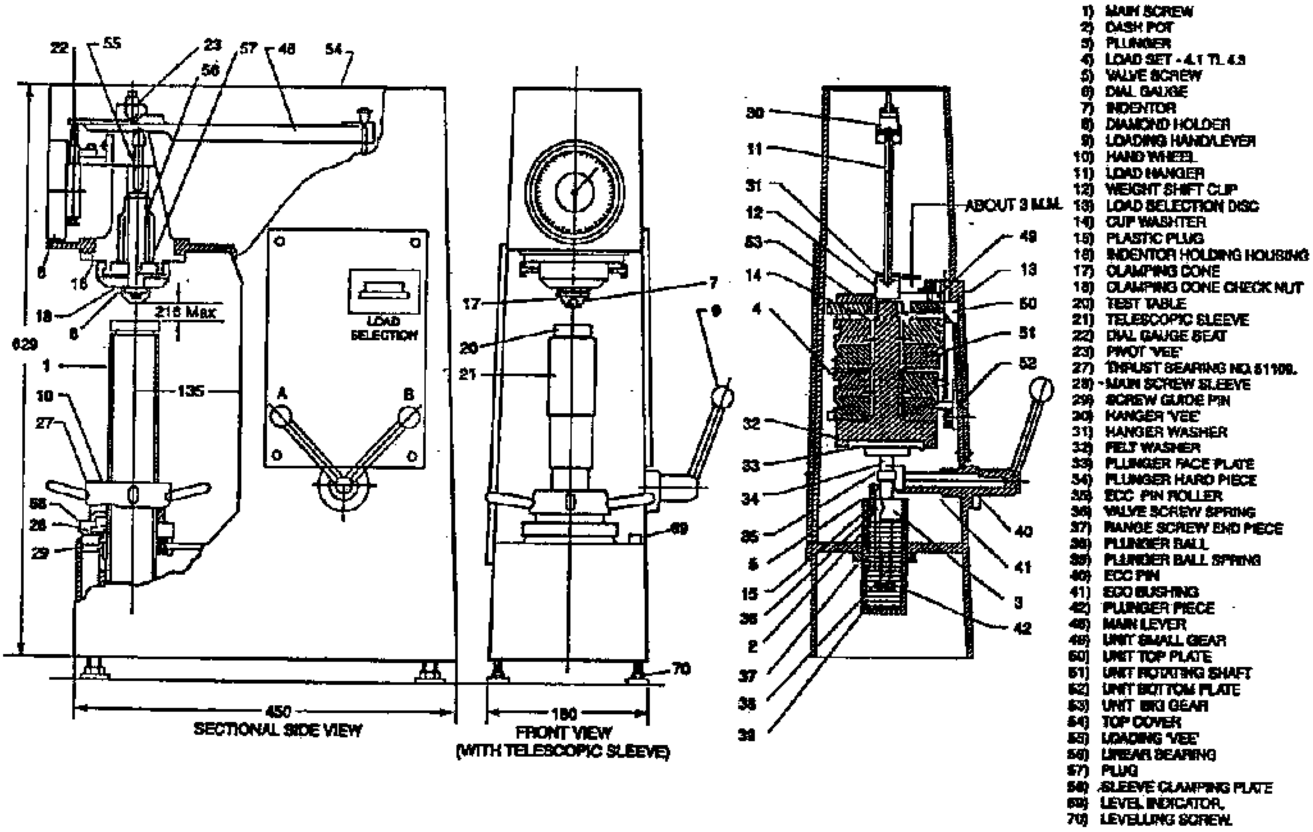
Theory: For deciding the suitability of a material which is expected to resist repeated shocks, the ordinary static tensile test is not found satisfactory. Testing machines have been devised so that a specimen can be subjected to a single shock or a number of repeated shocks. The energy required to break the specimen is taken as the measure of the resistance of the material against shock loading.

In case of Izode test the mode of loading is cantilever in nature.

Procedure:

1. A standard test piece of overall length 75mm & a square cross section of 10mm side with standard 45º notch, 2mm deep at a distance 27.5 mm from end, is taken to conduct the test and the dimensions are noted down.
2. The hammer is lifted and locked in position and the pointer is adjusted to coincide with initial position (i.e., maximum value) in the Charpy scale.
3. Pendulum is released and friction losses are found (Generally it's adjusted by the machine manufacturer).
4. Again the Pendulum is lifted and locked, then the test piece/ specimen is placed vertically upwards in the anvil such that the shorter distance between one end of the specimen and groove will be protruding up and also the groove in the specimen should face the striking end of the hammer.
5. Then the hammer is released without any shock & is allowed to strike the specimen.
6. The hammer strikes the specimen & breaks it. The reading indicated by the pointer is recorded.

Result: Impact strength of the given specimen = Joules / mm^2



Rockwell Hardness Testing Machine

Sl No.	Material	Major Load in kg	Indenter	Scale
1	Hard Steel	150	Diamond Cone 120º	C
2	Mild Steel	100	1.58mm dia Ball Indenter	B
3	Aluminium	100	1.58mm dia Ball Indenter	B
4	Brass	100	1.58mm dia Ball Indenter	B
5	Copper	100	1.58mm dia Ball Indenter	B

3. ROCKWELL HARDNESS TEST

Aim: To find the Rockwell hardness number of a given specimen.

Apparatus: 1. Rockwell Hardness testing machine,
2. Indenters.

Theory: Rockwell hardness tester is used to find the hardness value of ferrous and non-ferrous materials, which is determined through an indentation produced under a static load. A small indenter, either a small diameter steel ball or a diamond tipped cone called a brale, is first seated firmly against the material by the application of a 'minor' load of 10 Kg. This causes a very slight penetration into the surface, usually elastic in nature. The indicator on the dial of the tester is then set to zero, and a 'major' load is then applied to the indenter to produce a deeper penetration. After the indicating pointer has come to rest, the major load is removed. With the minor load still applied, the tester now indicates the appropriate Rockwell hardness number on the dial gauge. This number is actually an indentation of the depth of plastic or permanent penetration produced by the major load.

Different combinations of major loads and indenters are available and are used for materials with various levels of strength. Because of the different scales, Rockwell hardness numbers must always be accompanied by a letter indicating the particular combination of load and indenter used in the test. The notation HRC 60 indicates that a brale indenter was used in combination with a major load of 150 Kg, and a reading of 60 was obtained. The B and C scales are used more extensively than the others, B being common for Copper and Aluminum and C for Steels.

The Rockwell test should not used for thin materials on rough surfaces, or on materials that are not homogenous, such as gray cast iron. Because of the small size of the indentation, variations in roughness, composition or structure can greatly influence the results. In comparison with the Brinnel test, the Rockwell test offers the attractive advantage of direct readings in a single step. Because it can be conducted more rapidly, it is frequently used for monitoring the quality of products during mass production. Furthermore, it has the additional advantage of producing a smaller indentation that can be easily concealed on the finished product or easily removed in a later operation.

Procedure:

1. Clean the surface of the specimen to free from oil and dust.
2. Place the specimen on the table & fix appropriate indenter.
3. Raise the table by rotating the hand wheel clockwise until the specimen contacts with the indentor and then wheel is slowly and consistently rotated till the small pointer in the dial reaches to the red mark position.
4. Select the suitable major load by referring the given table. Apply major load by pushing back the lever on the right side of the machine to its extent.
5. Load is allowed to act on the specimen till the reading of indicator becomes steady. Then remove the major load by operating hand lever.
6. Read the hardness number from the appropriate scale.
7. Minor load is released by rotating the hand wheel in CCW direction.
8. More number of trials may be taken to get the steady result.

Precautions:

1. Apply the minor load carefully; it should not be less or more than the required.
2. Surface on which indentation is carried out should be sufficiently away from the earlier indentation marks.
3. Indenter should be fixed firmly.
4. Before applying the minor load, check the position of the lever which is used to apply the major load. It must be in the withdrawal position.

Result: Rockwell hardness number for the given specimen =

Observations & Calculations:

Sl No.	Material	Load P in Kgf	Diagonal length in mm 'D			VHN
			D1	D2	Average D	
1	Mild steel	30				
2	Copper	20				
3	Brass	20				
4	Aluminium	10				

VHN = Load / Area of impression = P / $\{D^2/\sin(\theta/2)\}$

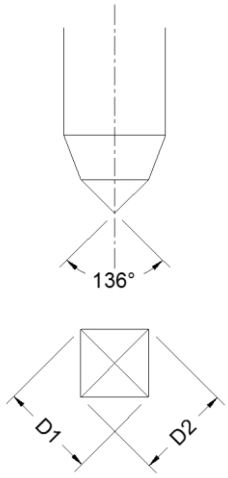
$= 2P \sin(\theta/2) / D^2$

$= 1.854\, P / D^2$

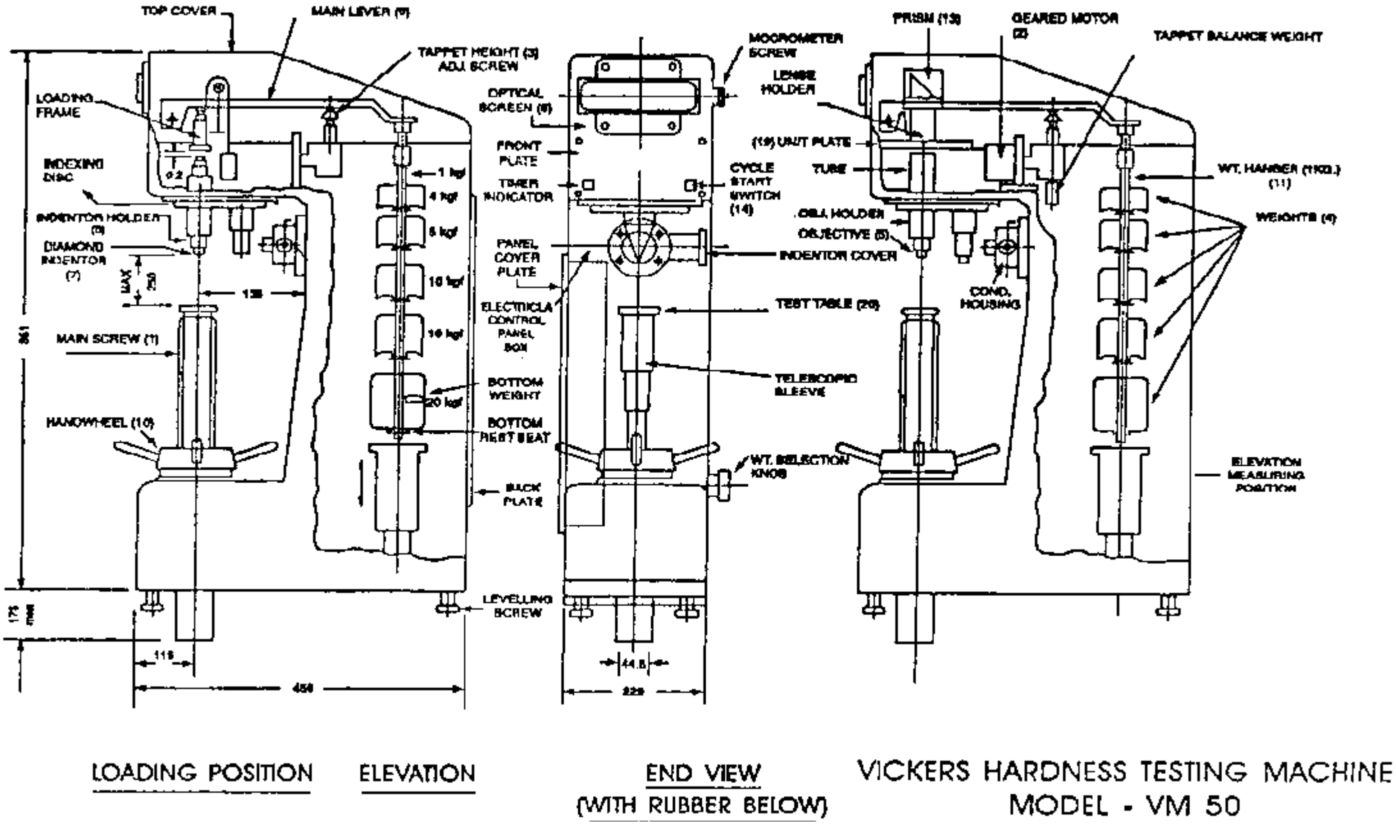
Where $\theta = 136^0$

P = Load in Kgf

D = Diagonal length



Mean Diameter= (D1+D2)/2



4. VICKERS HARDNESS TEST

Aim: To find the Vickers hardness number of a given specimen.

Apparatus:

1. Vickers Hardness testing machine,
2. Cone Indenter.

Theory:

The Vickers hardness test is also similar to the Rockwell & Brinnel tests, but a square based diamond pyramid is used as the indenter. The Vickers hardness number is defined as load divided by the surface area of the indention expressed in units of kilograms per square millimeter. The advantage of the Vickers approach is the increased accuracy in determining the diagonal of a square impression as opposed to the diameter of a circle and the assurance that even light loads will produce plastic deformation.

Like the other indentation hardness methods, the Vickers test offers a number of attractive features: (1) it is simple to conduct, (2) little time is involved, (3) little surface preparation is required, (4) the test can be done on location, (5) it is relatively inexpensive, and (6) it often provides results that can be used to evaluate material strength or access product quality.

Procedure:

1. Clean the surface of the specimen to free from oil and dust.
2. Place the specimen on the table & fix appropriate indenter.
3. Check the clarity of the specimen on the optical screen by adjusting the knob.
4. Rotate the indexing disc so as to bring the indenter over the specimen.
5. Keep pressing ‘START’ button until ‘DWELL’ light glows, i.e. desired load is applied on the specimen through indentation.
6. Wait for a while, automatically load will be released.
7. Index indenter head to next position so that objective of optical system will be exactly over the specimen.
8. The indentation is now projected on front focusing screen. Measure diagonal of impression in both axes.
9. Calculate Vickers hardness number for the given specimen by using formula,

$$VHN = 1.854\ P / D^2$$

Where, P= Load in Kgf,

D= Diagonal length in mm.

Result: Vickers hardness number of a given specimen =

Tabular Column:

Diameter of the indenter D = mm

Type of material	Trial No.	Force Applied (P) Kgf	Indentation dia (d) mm	BHN	Average BHN

Type of material	Trial No.	Force Applied (P) Kgf	Indentation dia (d) mm	BHN	Average BHN

Type of material	Trial No.	Force Applied (P) Kgf	Indentation dia (d) mm	BHN	Average BHN

5. BRINNEL HARDNESS TEST

Aim: To determine the hardness number of a given specimen.

Apparatus:

1. Brinnel hardness testing machine,
2. Brinnell's microscope.

Theory:

The Brinnel hardness test was one of the earliest accepted methods of measuring methods of measuring hardness. A tungsten carbide or hardened steel ball 1 cm in diameter, is pressed into a flat surface of the material by a standard load of 500, 1500, or 30000 Kg, and the load is maintained for 5 to 10 seconds to permit the full amount of plastic deformation to occur. The load and ball are then removed, and the diameter of the resulting spherical indentation (usually in the range of 2 to 5mm) is measured using a special grid or traveling microscope. The Brinnel hardness number is equal to the load divided by the spherical surface area of the indentation when the units are expressed as kilograms per square millimeter.

Brinnel hardness number (BHN) $= \frac{\text{Load (N)}}{\text{Surface area of indentation in mm}^2}$

$$= \frac{2P}{\pi D\left[D - \sqrt{D^2 - d^2}\right]}$$

Where, P= Load applied in Kgf,

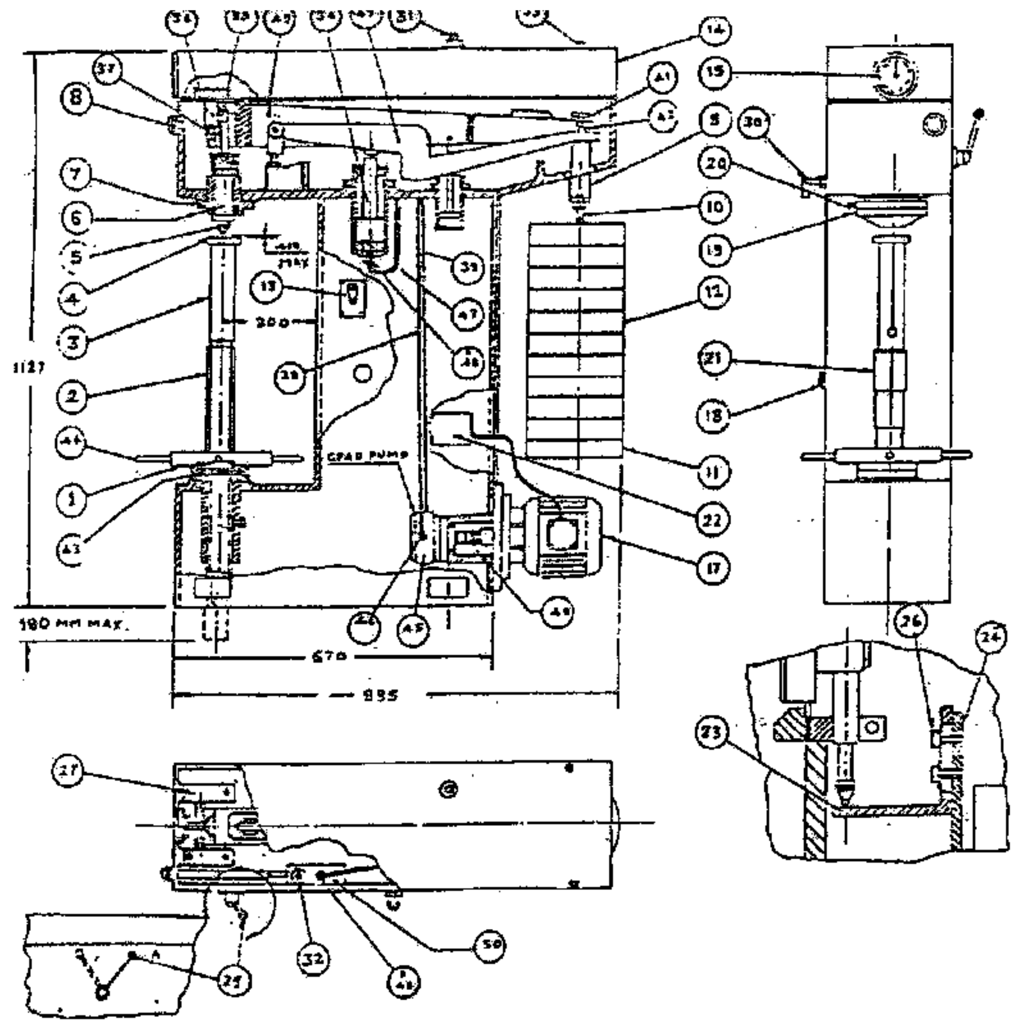
D= Diameter of the steel ball (mm)

d= diameter of the indent (mm)

In actual practice, the Brinnel hardness number is determined from tables that correlate the Brinnel number with the diameter of the indentation for the various loads.

The Brinnel test measures the hardness over a relatively large area and is indifferent to a small-scale variation in structure. In addition, it is relatively simple and easy to conduct, and is used extensively on iron and steels. On the negative side, the Brinnel test has the following limitations:

1. It cannot be used on very hard or very soft materials.
2. The results may not be valid for thin specimens. It is best if the thickness of the material is at least 10 times the depth of the indentation. Some standards specify the minimum hardness for which the tests on thin specimens will be considered valid.
3. The test is not valid for case hardened surfaces.
4. The test must be conducted far enough from the edge of the material that no edge bulging can occur.
5. The substantial indentation may be objectionable on certain finished parts.
6. The edge or rim of the indentation may not be clearly defined or may be difficult to see on materials of different colors.



1. HAND WHEEL
2. MAIN SCREW
3. MAIN SCREW EXTENSION
4. TEST TABLE
5. BALL HOLDER
6. PLUNGER
7. BED CAP
8. LOADING SPEED ADJ. KNOB
9. HANGER
10. WEIGHT SHAFT
11. BOTTOM WEIGHT
12. WEIGHTS
13. STARTER
14. TOP COVER
15. DIAL GAUGE
17. MOTOR
18. PLASTIC BUSHING
19. CLAMPING DEVICE
20. CLAMPING TIGHTENING SCREW
21. TELESCOPIC COVER
22. TERMINAL BOX
23. ANGLE PLATE
24. SIDE PLATE
25. SIDE SCREW
27. PIVOT PLATE
29. HAND LEVER
30. DRAIN PLUGE
31. OIL LEVEL GAUGE STICK
32. RELIEF VALVE
33. TOP COVER STUD
34. CYLINDER ASSEMBLY
35. PLUNGER VEE MALE
36. PIVOT VEE FEMALE
37. PIVOT VEE MALE
38. 1/4" ID AND 3/8" OD PIPE
39. 1/4" ID AND 3/8" OD PIPE
40. COUPLING FOR MOTOR & GEAR PUMP
41. HANGER MALE FEMALE VEE
42. LOADING ROUND VEE
43. THRUST BEARING NO. 51109
44. HANDLE OF HANDWHEEL
45. GEAR PUMP
46. 5/16" NUT WITH FERRULE
47. 3/8" ID AND 1/2" OD PIPE
48. 1/2" NUT WITH FERRULE (A & B)
49. MAIN LEVER WITHOUT KNIFE EDGE
50. CONTROL BODY

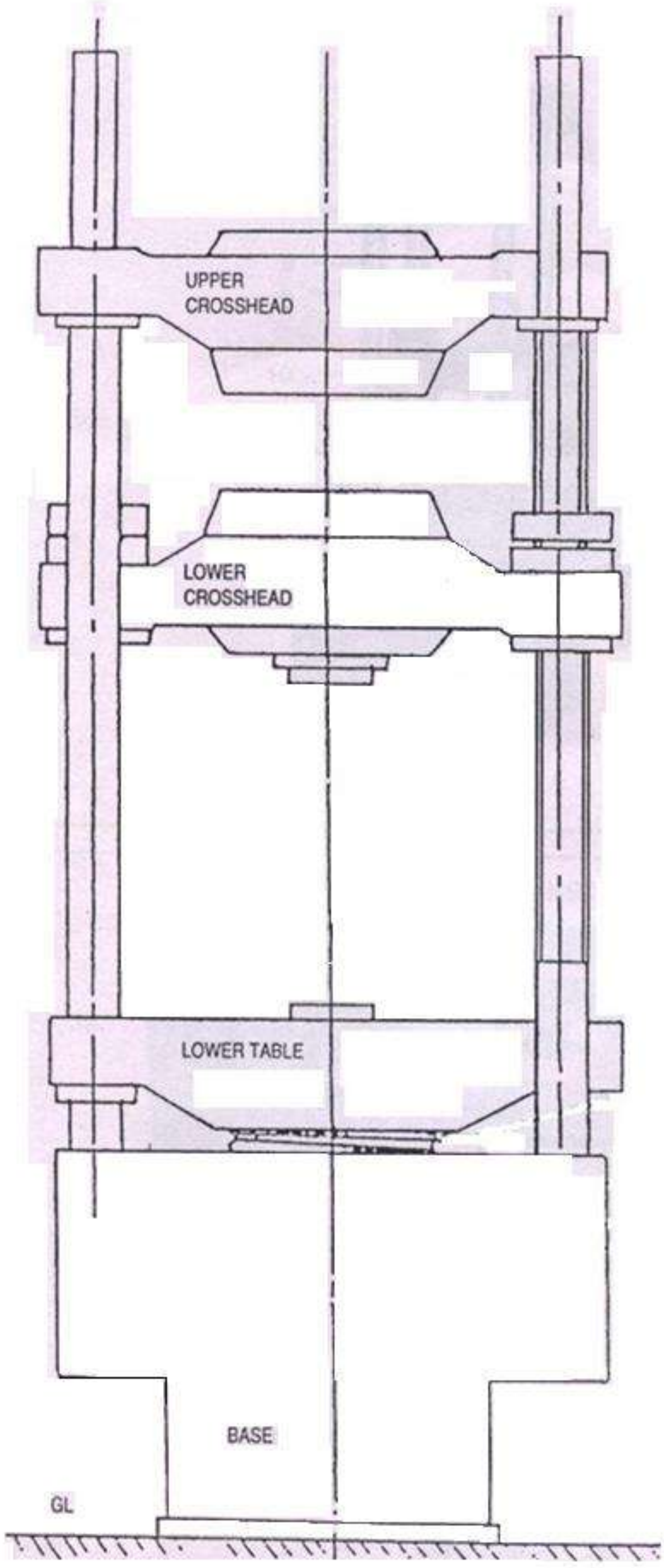
Brinnel Hardness Testing Machine

Procedure:

1. Place the specimen on the anvil so that its surface will be normal to the direction of the applied load.
2. With the hand wheel, raise the anvil until the specimen just makes contact with the ball.
3. Select the ball diameter (indenter) depending upon the load and time of application of the load according to the material to be tested as given in the load test table.
4. Apply the load gradually and maintain it for 15 seconds.
5. Release the load and remove the specimen. Measure the diameter of impression (indentation) left by the ball indenter.
6. Make three trials for each specimen for calculating the hardness number

Result:

1. Hardness number of a given specimen =



BACK SIDE OF MACHINE

6. UNIVERSAL TESTING MACHINE

Theory:

Applicability:

The UTE type Universal Testing Machines serves for conducting tests in tension, compression, shear and transverse for metals and materials.

The testing machine is operated hydraulically; drive is performed by the help of electric motor.

Description of the machine:

The machine comprises of three main parts.

1. Machine frame i.e., loading unit,
2. Hydraulic system,
3. Electronic control panel.

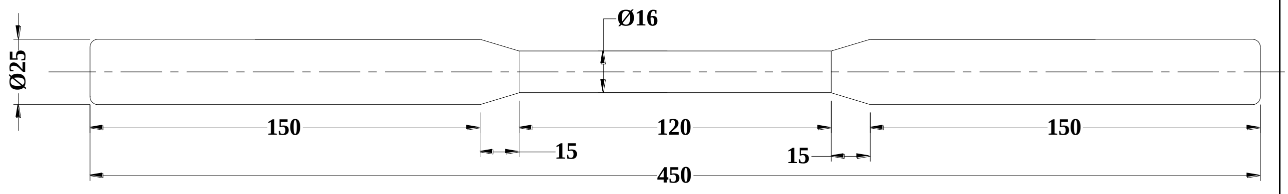
The machine frame consists of two cross heads and a lower table. Middle cross head is adjusted by means of a geared motor.

The loading unit consists of robust base. The main hydraulic cylinder is fitted in centre of the base. The lower table is connected to the main piston. The lower table is rigidly connected to the upper cross head.

In tension test, jaw locking handles are provided on middle and upper cross head to lock the jaws in order to clamp the specimen while the experiment is conducted. This arrangement ensures firm clamping of the specimen and easy take out of the broken specimen.

The space between the lower table and middle cross head is used for compression, shear and transverse tests. The space between the middle and the upper cross head is only used for tension test.

Two valves on the control panel, one at the left side and other at the right side are used to control the oil flow in the hydraulic system.



Observations and Tabulations:

1. To find Least Count of the Vernier Caliper:

Value of one M.S.D. (M) = mm.

No. of V.S.D. (N) =

Least count = M / N

= mm.

2. Diameter of the specimen before test (d_i) = mm.

3. Initial length of the specimen (l_i) = mm.

4. Initial gauge length (L_i) = mm.

5. Final gauge length (L_f) = mm.

6. Least Count of Extensometer = mm.

7. Diameter of the specimen after test (d_f) = mm.

Sl No.	Load kN	Extensometer Reading in divisions			Displacement Reading in mm	Remarks
		A	B	Average		

6a. TENSION TEST ON MILD STEEL

Aim:

1. To study the behavior of mild steel specimen under the action of gradually increased load.
2. To determine:
   a) Yield stress,
   b) Ultimate stress,
   c) Breaking stress,
   d) Percentage elongation,
   e) Percentage reduction in area.
   f) Modulus of Elasticity.

Apparatus: 1. Universal Testing Machine,
2. Gripping Device,
3. Extensometer,
4. Steel rule, Vernier Caliper, punch and hammer.

Gripping Device:

To grip securely the round specimen, the flat inner sides of the jaws have a V-shaped groove. Depending upon the size of the specimen, jaws with appropriate V- grooves in them are selected.

Extensometer:

The gauge length of the extensometer used is adjustable up to a maximum value of 120 mm. There are pair of knife edges at top and bottom which are used to grip the specimen between gauge points. The top knife edges are fixed while the extension of the specimen causes the bottom knife edges to move down. The movement of these knife edges are magnified by a lever and transmitted to two dial gauges (one on either side) by a rack and pinion mechanism. The least count of the extensometer is 0.01 mm and it can measure up to 3 mm. Two springs, one fixed at the bottom and the other placed at the top will keep the extensometer in position.

Procedure:

1. Measure the diameter of the specimen at different sections and find the average diameter using Vernier Caliper.
2. Mark gauge length by making two punch marks on the specimen and measure it.
3. Fix the specimen in between the middle and upper cross head of UTM.
4. Fix the extensometer on the specimen such that the knife edges are bears against punch marks on the specimen.
5. Adjust the reading of dial gauge A and B of the extensometer to zero.
6. Start the UTM and apply the load gradually (By closing LCV, open RCV slowly). The interval is so chosen as to get at least eight readings before the yield point.
7. Note down the extensometer and displacement readings at regular load increments.

Calculations:

1. Initial cross sectional area (A_i) = $\pi d_i^2 / 4$ = mm^2.

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

3. Percentage reduction in area = $[(A_i - A_f) / A_i] \times 100$

=

4. Percentage Elongation = $[(L_f - L_i) / L_i] \times 100$

=

5. Yield Stress = Yield Load / Initial Area = F_y / A_i

= kN/mm^2

6. Ultimate Stress = Ultimate load / Initial Area = F_u / A_i

= kN/mm^2

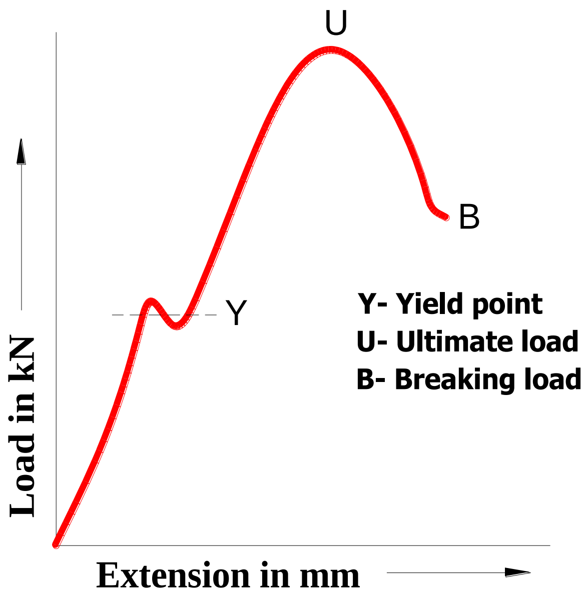
7. Breaking Stress = Breaking load / Initial Area = F_b / A_i

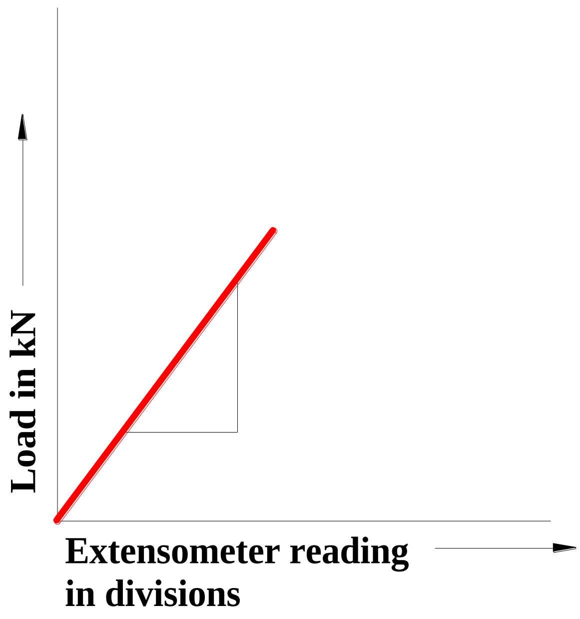
= kN/mm^2

8. Modulus of Elasticity = Slope x $[L_i / A_i]$

{Where, slope = DY/DX, found out by the graph}

= kN/mm^2





8. As the yield point is approached the load reading remains constant with slight variations and pointer of extensometer and displacement readings moves very rapidly. Note down the yield point reading and remove extensometer from the specimen.
9. Increase the load gradually; note down the change in length from the scale readings.
10. After the maximum load reaches, the load reading stops and starts decreasing. Finally specimen breaks into two pieces. Note down the maximum load and breaking load.
11. Remove the specimen from UTM and measure the final diameter at neck and also measure final gauge length.
12. Plot the graphs of load v/s extensometer reading and load v/s displacement.

Result:

a) Yield stress	=	kN/mm2
b) Ultimate stress	=	kN/mm2
c) Breaking stress	=	kN/mm2
d) Percentage Elongation	=	
e) Percentage reduction in area	=	
f) Modulus of Elasticity	=	kN/mm2

Observations & Tabulations:

1. Least count of the vernier caliper = mm.
2. Initial Diameter of the specimen (d_i) = mm.
3. Final Diameter of the specimen (d_f) = mm.

(Diameter at the bulged portion)

4. Initial length of the specimen L_i = mm.
5. Final length of the specimen L_f = mm.

Calculations:

1. Initial cross sectional area A_i $= \pi di^2 / 4$

   = mm^2
2. Final cross sectional area A_f $= \pi d_f^2 / 4$

   = mm^2
3. Percentage decrease in length $= \{(L_i - L_f) / L_i\} \times 100$

   =
4. Percentage increase in area $= \{(A_f - A_i) / A_i\} \times 100$

   =
5. Compressive stress = Maximum Compressive load / Initial Area

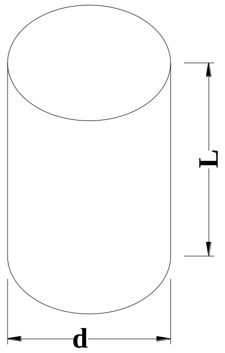
   $= F_c / A_i$

   = kN / mm^2
6. Modulus of elasticity = Slope x (Li / Ai)

   Where slope = Dy /Dx, found out by the graph

   = kN / mm^2

Specimen:



Sl No.	Load in kN	Displacement Reading in mm
1		
2		
3		
-		
-		
-		
34		
35		

11. HEAT TREATMENT

Aim: To conduct annealing, normalizing, hardening and tempering of steel & to study their Rockwell hardness.

Apparatus: Heating (Muffle) furnace and Rockwell hardness testing machine.

Theory: Heat treatment is an important operation in the manufacturing process of many machine parts and tools. Only by heat treatment is to possible to impart the high mechanical properties to steel required for the normal operation of modern machinery and tools.

Heating furnace: A heating 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.

A. Annealing of steel: Annealing is one of the most important widely used operations in the heat treatment of steel. The purpose of annealing is to obtain softness, improve machinability, increase or restore ductility and toughness, relieve internal stresses, reduce or eliminate structural inhomogenity, refine grain size, and to prepare steel for subsequent heat treatment. There are several types of annealing;

Full annealing consists in heating hypo eutectoid steel 30 to 50^0 C above the critical point, holding it at this temperature, and then slowly cooling (depending on the composition).

Slow cooling is required in annealing to enable the austenite to decompose at low degrees of super cooling.

Holding is followed by cooling with the furnace for **6 to 8 hours** to **800-850^0 C** and then further **cooling in air**. After homogenizing, castings undergo full annealing to refine their structure.

B. Normalizing of steel:

This process consists in heating steel to a temperature from **40 to 50^0 C above critical point**, holding at this temperature for a short time, and subsequent **cooling in air**. Normalizing is used to eliminate coarse- grained structures obtained in previous working (rolling, forging etc.), to increase the strength of medium carbon steels to a certain extent, to improve the machinability of low carbon steels, to improve the structure in welds, to reduce internal stresses, to eliminate the cementite network in hypereutectoid steels etc.

Normalized carbon steel consists of pearlite and ferrite in hypo eutectoid steels and of pearlite and cementite in hypereutectoid steels.

More rapid cooling, is used in normalizing, causes the austenite to decompose at lower temperatures. This increases the dispersity of the ferrous- cementite mixture and increases the amount of eutectoid. Therefore, normalized steel has a higher strength and is harder than annealed steel.

Cooling in air employed in normalizing alloy steels, in which the austenite is very stable, results in austenite decomposition at high degrees of super cooling. It is even possible to obtain a hardened steel structure, i.e., martensite, in this case. After being normalized, such steels will be very hard and must undergo high temperature tempering at 550-650^0 C to enable them to be machined.

It is essential to note that two heat treating operations, normalizing and high tempering, require less time than annealing. Therefore, these two operations are often substituted for annealing in the treatment of alloy steels.

Normalizing is frequently applied as a final heat treatment for items which are to operate at relatively high stresses.

Normalizing is extensively used for improving the properties of steel castings. Normalized castings have a higher yield point, tensile strength, and impact strength than annealed castings.

The annealing and normalizing temperature for carbon steel are given below:

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

C. Hardening of steel:

Hardening is a heat treating process in which steel is heated to a **temperature above the critical point**, held at this temperature and then **rapidly cooled (quenched) in water, oil or molten salt baths.**

The hardening temperature of steel depends upon its chemical composition and principally, upon its carbon content. The hardening temperature for carbon steels are given below:

Grade of steel	Hardening temperature (° C)
25 C8	870-890
30 C8	850-870
35 C8	840-860
40 C8	830-850
45 C8	820-840

Effect of hardening temperature upon hardness for tool steel is given below:

Hardening Temperature (° C)	740	760	780	800	820	840	860	880	900
Rockwell (HRC)Hardness number	65	65	65	64	63	62	62	61	60

D. Tempering of steel:

Tempering is the process of softening steel in order to make it suitable for a given purpose. The treatment follows immediately after hardening and is very important in the heat treatment of steel. The **hardened steel is reheated to a certain temperature** depending upon the results desired. The primary object of tempering is to release internal stresses set up during hardening. Tempering not only reduces hardness but also has a decided effect on all other physical properties.

At low tempering temperatures (up to 200 or 250^{0}C), the hardness changes only to a small extent. A further increase in the tempering temperature reduces the hardness. The properties of steel after structural improvement, i.e., hardening followed by high tempering, are always higher than those of annealed steel. This is due to the difference in structure of the ferrite-cementite mixture.

Effect of tempering on the magnitude of residual (internal) stresses is the volume increase and the fact that the martensitic transformation does not take place at the same time, throughout the cross-section of the part being hardened; inevitably lead to high internal stresses. Purely thermal stresses, due to non uniform cooling of surface and internal layers, also appear.

Procedure:

1. Heat the given steel specimen in a box type furnace until the specimen reaches required temperature.
2. Keep the specimen in the furnace up to the required holding temperature.
3. Cool the specimen as per required heat treatment operation.
4. Determine the hardness of the specimen using Rockwell hardness-testing machine.

Observations and result:

A. Annealing temperature (^{0} C) =
Holding time (min) =
Rockwell hardness (HRB) =

B. Normalizing temperature (^{0}C) =
Holding time (min) =
Rockwell hardness (HRB) =

C. Hardening temperature (^{0} C) =
Holding time (min) =
Rockwell hardness (HRC) =

D. Tempering temperature (^{0}C) =
Holding time (min) =
Rockwell hardness (HRC) =

Viva Questions

Hardness Tests

1. Define hardness.
2. What are the uses of hardness tests?
3. Mention the types of hardness tests, with brief explanation.
4. What are the advantages of Rockwell test over Brinnel's test?
5. What are the advantages of Vickers hardness over Brinnel's or any other tests?
6. Classify how to find hardness of any material & how it depends on other factors?
7. What is difference between hardness and strength?
8. Explain significance of different hardness numbers with example.
9. Differentiate between hardness and toughness.
10. What is an indenter and indentation?
11. What are types of hardness measurements?
12. Derive the expression for finding hardness incase of Brinnel hardness number.
13. What are the different sizes of ball indenters in BHN?
14. What is the load ranges in different hardness testing machines?

Universal Testing Machine

1. What are the uses and different types of tests that can be performed on UTM and their uses?
2. What is strain hardening & bouschinger effect?
3. What is fracture? Name different types.
4. What is the significance of stress- strain diagram & draw stress strain diagram for ductile and brittle material?
5. What is strain energy?
6. Differentiate between ductile & brittle material.
7. What is proof stress?
8. Give the broad classification of metals.
9. Define the following mechanical properties of metals:
    a) Malleability, resilience, ductility, impact, fatigue and bending strength, stiffness, elasticity, plasticity & creep.
10. Define the terms:
    a) Proportional limit,
    b) Elastic limit,
    c) Yield point,
    d) Ultimate tensile strength,
    e) Rupture strength.
11. Define stress and strain.
12. Define Hook's law.
13. Name the important parts of UTM.
14. What is the purpose of using extensometer in tensile test?
15. What type of failure occurs in brittle and ductile material during tension and compression test?
16. What are the precautions are to be taken while conducting the different tests in UTM?
17. How do you evaluate toughness in tensile testing in UTM?
18. What is meant by deformation? Name different types of it.
19. Explain single shear and double shear.
20. What is susceptibility?
21. What is offset yield strength?