MATERIALS AND SOLID MECHANICS LABORATORY

<table>
<tr><td colspan="10">III Semester: ME</td></tr>
<tr><th>Course Code</th><th>Category</th><th colspan="3">Hours / Week</th><th>Credits</th><th colspan="3">Maximum Marks</th></tr>
<tr><td rowspan="2">AMEC09</td><td rowspan="2">Core</td><td>L</td><td>T</td><td>P</td><td>C</td><td>CIA</td><td>SEE</td><td>Total</td></tr>
<tr><td>0</td><td>0</td><td>3</td><td>1.5</td><td>30</td><td>70</td><td>100</td></tr>
<tr><td>Contact Classes: Nil</td><td>Tutorial Classes: Nil</td><td colspan="4">Practical Classes: 45</td><td colspan="3">Total Classes: 45</td></tr>
<tr><td colspan="9">Prerequisite: Fundamentals of solid mechanics</td></tr>
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I. COURSE OVERVIEW:
This laboratory course concerned with the micro structures of both ferrous and nonferrous materials, mechanical properties of materials such as percentage elongation, modulus of elasticity, hardness of materials, modulus of rigidity etc. Investigating the mechanical properties of materials are highly important before going to fabrication of products for yielding the higher performance.

II. COURSE OBJECTIVES:
The students will try to learn:
1. The processes of cold/hot working, re-crystallization, grain growth and microstructural properties of materials.
2. The parameters such as factor of safety, Poisson's ratio, three elastic moduli and their relationships in the selection and characterization of a material.
3. The theory of pure torsion, bending, stiffness, slope and deflection of beams.

III. COURSE OUTCOMES

CO 1	Utilize the concepts crystallography, crystal structures, crystallographic planes, and miller indices to analyse the microstructural properties of materials.
CO 2	Make use of the Jominy end quench test apparatus to measure the capacity of steel hardenability in depth under a given set of conditions.
CO 3	Distinguish the regions of elasticity and plasticity, stress-strain relationships under various types of loads by conducting a tensile test on universal testing machine.
CO 4	Analyze the mechanical properties of a material by conducting compression and torsion tests on different materials.
CO 5	Compare the hardness values of ferrous and nonferrous materials by conducting experiments on Rockwell and Brinell's hardness testing machines.
CO 6	Determine the impact strength of a material by adopting Charpy and Izod test procedures.

Dos

1) For safety purpose the students should compulsorily wear shoes.
2) Students should come in uniform prescribed.
   i. For boys, half sleeve shirts, tucked in trousers
   ii. For ladies, half sleeve overcoat, hair put inside the overcoat
3) Be punctual to the classes.
4) To come prepared with procedure relevant to the experiment.

Don’t

1) Don’t operate any machine without knowledge and permission of the lab personnel
2) Don’t unplug any machine from power supply.
3) Don’t remove any parts of the machine

IV. COURE CONTENT:

EXERCISES ON MATERIALS AND SOLID MECHANICS LABORATORY

1. Getting Started Exercises

1.1 Introduction to Laboratory

The solid Mechanics Laboratory is well equipped with destructive testing machineries. Students will be able to understand the basic concepts of Solid Mechanics and enable to apply them to practical problems in this laboratory. Different types of tests are conducted in this laboratory as per standards (ASTM and IS) for mechanical properties of various materials such as Young's Modulus, Shear Modulus, Hardness, Toughness, Stiffness, etc. Many students of Final year are utilizing this laboratory for their project works for testing of various materials like composite materials, ferrous and nonferrous alloys.

- To familiarize students with lab equipments
- Inform the students on lab evaluation process
- Inform the students about laboratory precautions
- To familiarize students sample preparations
- Learning outcomes of the lab

2. Microstructure of Steels

Metallic materials, when considered in a broad sense, may be divided into two large groups, ferrous and nonferrous. The ferrous materials are iron-based, and the nonferrous materials have some element other than iron as the principal constituent. The bulk of the nonferrous materials is made up of the alloys of copper, aluminium, magnesium, nickel, tin, lead, and zinc. The temperature at which the allotropic changes take place in iron is influenced by alloying elements, the most important of which is carbon. This is the part between pure iron and an interstitial compound, iron carbide, Fe,C, containing 6.67 percent carbon by weight.

2.1. Study of microstructure of steels

- Introduction
- Procedure
- Observations
- Further probing experiments

2.2. Observations

The microstructure of low carbon steels as shown in fig. 2.1

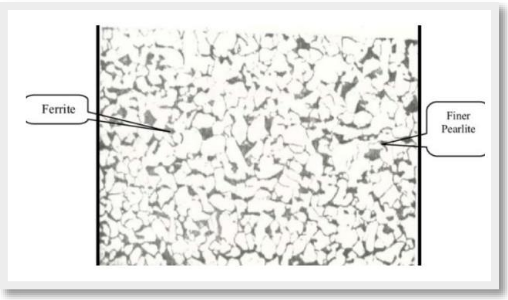

fig. 2.1: Microstructure of low carbon steels

The microstructure of medium carbon steels as shown in fig. 2.2

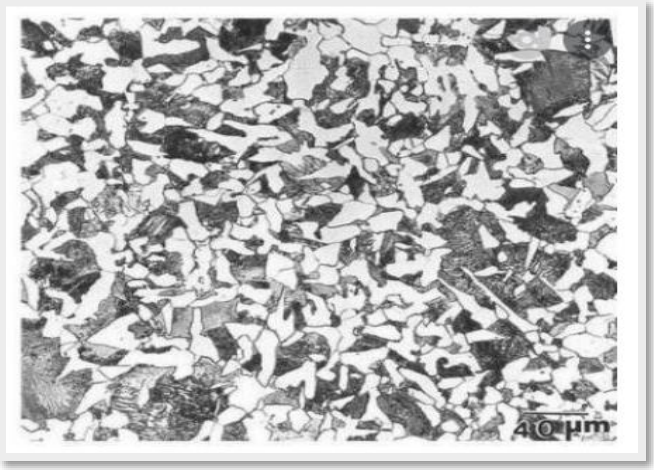

fig. 2.2: Microstructure of medium carbon steels

2.3. Precautions

- Wear tight overalls and shoe for safety.
- Be aware about mounting press and the time of etching process.
- Don't touch the specimen when it is so hot and use tongs for hold it.
- Be away at the time of belt polishing and disc polishing.

2.4. Further Probing Experiments

1. Change the values of magnification lens and obtain the microstructures.
2. Obtain the microstructures of LCS, MCS and HCS using trinocular.

3. Microstructure of Cast Iron

3.1. Introduction

Cast irons are a class of ferrous alloys with carbon contents above 2.14 % by weightage; in practice, however, most cast irons contain between 3.0 and 4.5 % of Carbon and, in addition, other alloying elements. A re-examination of the iron–iron carbide phase diagram reveals that alloys within this composition range become completely liquid at temperatures between approximately 1150 and 13000C (2100 and 2350F), which is considerably lower than for steels. Thus, they are easily melted and amenable to casting. Furthermore, some cast irons are very brittle, and casting is the most convenient fabrication technique.

3.2. Procedure

1. Cut the specimen into required shape by using cutoff machine.
2. Mount the specimen in mounting press by adding 2 spoons of Bakelite powder.
3. Polish the specimen on belt polisher to make the surface even.
4. Then polish the specimen again by using sand and emery papers.
5. After polishing the specimen is again polish on the belt polisher by adding 2-3 drops of water.
6. Observe the micro-structure of specimen under microscope and note it down.
7. Apply approximate etchant to the specimen.
8. Observe the micro scope structure and note it down.

3.3. Observation

The microstructure of medium Grey Cast Iron as shown in fig.3.1

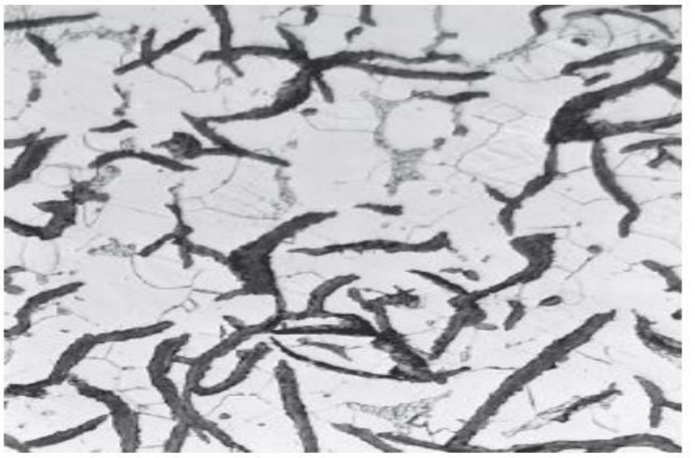

fig. 3.1: Microstructure of Grey Cast Iron

3.4. Further Probing Experiments

1. Change the values of magnification lens and obtain the microstructures.
2. Obtain the microstructures of different cast irons using trinocular.

4. Microstructure of Copper

4.1. Introduction

Steel and other ferrous alloys are consumed in exceedingly large quantities because they have such a wide range of mechanical properties, may be fabricated with relative ease, and are economical to produce. However, they have some distinct limitations chiefly (1) a relatively high density, (2) a comparatively low electrical conductivity, and (3) an inherent susceptibility to corrosion in some common environments. Thus, for many applications it is advantageous or even necessary to use other alloys that have more suitable property combinations. Alloy systems are classified either according to the base metal or according to some specific characteristic that a group of alloys share.

4.2. Procedure

1. Cut the specimen into required shape by using cutoff machine.
2. Mount the specimen in mounting press by adding 2 spoons of Bakelite powder.
3. Polish the specimen on belt polisher to make the surface even.
4. Then polish the specimen again by using sand and emery papers.
5. After polishing the specimen is again polish on the belt polisher by adding 2-3 drops of water.
6. Observe the micro-structure of specimen under microscope and note it down.
7. Apply approximate etchant to the specimen.
8. Observe the micro scope structure and note it down.

4.3. Observation

The microstructure of Copper as shown in fig.4.1

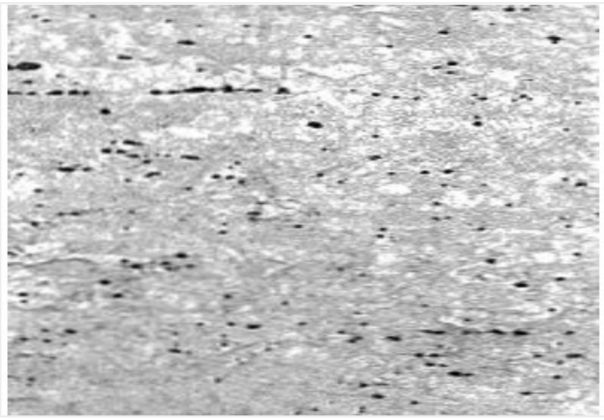

fig.4.1: Microstructure of Copper

4.4. Further Probing Experiments

1. Change the values of magnification lens and obtain the microstructures.
2. Obtain the microstructures of different copper alloys using trinocular.

5. Microstructure of High Carbon Steels

5.1. Introduction

Steels are iron–carbon alloys that may contain appreciable concentrations of other alloying elements; there are thousands of alloys that have different compositions and/or heat treatments. The mechanical properties are sensitive to the content of carbon, which is normally less than 1.0 percentage by weight. Some of the more common steels are classified according to carbon concentration—namely, into low, medium and high carbon types. Subclasses also exist within each group according to the concentration of other alloying elements. Plain carbon steels contain only residual concentrations of impurities other than carbon and a little manganese. For alloy steels, more alloying elements are intentionally added in specific concentrations. High-Carbon Steels are normally having carbon contents between 0.60 and 1.4 percentage by weight, are the hardest, strongest, and yet least ductile of the carbon steels.

5.2. Procedure

1. Cut the specimen into required shape by using cutoff machine.
2. Mount the specimen in mounting press by adding 2 spoons of Bakelite powder.
3. Polish the specimen on belt polisher to make the surface even.
4. Then polish the specimen again by using sand and emery papers.
5. After polishing the specimen is again polish on the belt polisher by adding 2-3 drops of water.
6. Observe the micro-structure of specimen under microscope and note it down.
7. Apply approximate etchant to the specimen.
8. Observe the micro scope structure and note it down.

5.3. Observation

The microstructure of High Carbon Steel as shown in fig.5.1

fig.5.1: Microstructure of High Carbon Steels

5.4. Further Probing Experiments

1. Change the values of magnification lens and obtain the microstructures.
2. Obtain the microstructures of different high carbon steels using trinocular.

6. Tension test of Mild Steel

6.1. Introduction

The objective of this experiment is to evaluate the mechanical (tensile) properties of selected metallic materials using the tensile test method. These mechanical properties include modulus of elasticity, yield strength, ultimate tensile strength, failure strength, ductility, and strain to failure.

6.2. Procedure

1. Measure the original length and diameter of the specimen. The length may either be length of gauge section which is marked on the specimen with a preset punch or the total length of the specimen.
2. Insert the specimen into grips of the test machine and attach strain-measuring device to it.
3. Begin the load application and record load versus elongation data.
4. Take readings more frequently as yield point is approached.
5. Measure elongation values with the help of dividers and a ruler.
6. Continue the test till Fracture occurs.
7. By joining the two broken halves of the specimen together, measure the final length and diameter of specimen as shown in fig.6.1.

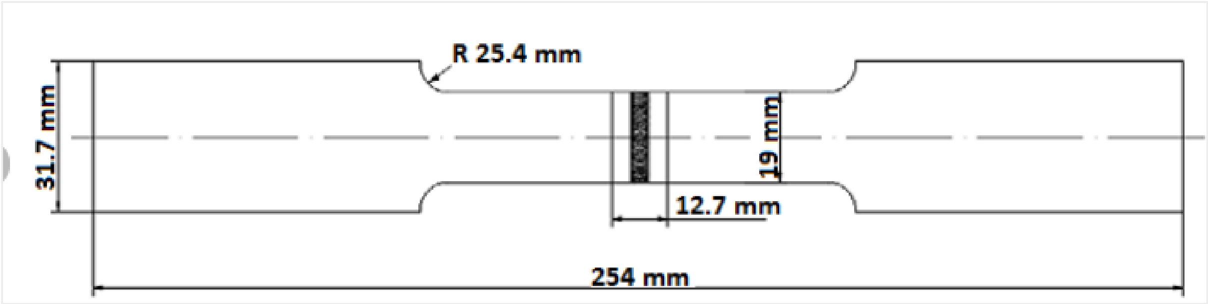

fig.6.1: Tension test specimen preparation

6.3. Further Probing Experiments

1. Calculate the Young's Modulus for ductile materials.
2. Generate stress Vs strain diagram for different materials using servo driven Universal Testing Machine.

7. Torsion test of Mild Steel

7.1. Introduction

The stress resulting from torsion load can be determined by means of the torsion test. This test resembles the tension test in that a load deflection curve is also development (which is transformed to a shear-strain curve). In a torsion test, a solid or hollow cylindrical specimen is twisted and the resultant deformation, measured as the angle through which the bar is twisted. The test then consists of measuring the angle of twist, Φ (rad) at selected increments of torque, T (N.m). Expressing Φ as the angular deflection curve per unit gage length.

7.2. Procedure

1. Measure the original length and diameter of the specimen. The length may either be length of gauge section which is marked on the specimen with a preset punch or the total length of the specimen.
2. Insert the specimen into grips of the test machine and attach strain-measuring device to it.
3. Begin the load application and record load versus elongation data.
4. Take readings more frequently as yield point is approached.
5. Measure elongation values with the help of dividers and a ruler.
6. Continue the test till Fracture occurs.
7. By joining the two broken halves of the specimen together, measure the final length and diameter of specimen as shown in fig.7.1. (All dimensions are in mm).

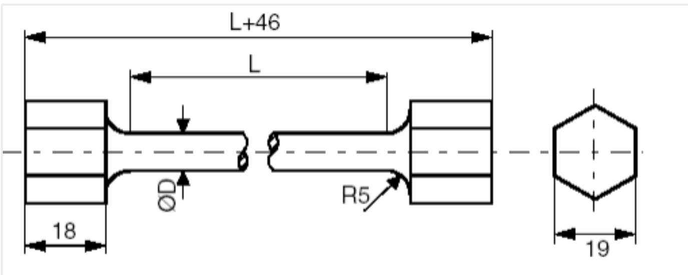

fig.7.1: Torsion test specimen dimensions

7.3. Precautions

1. Wear tight overalls and shoe for safety.
2. If the strain measuring device is an extensometer it should be removed before necking begins.
3. Measure deflection on scale accurately and carefully.

7.4. Further Probing Experiments

1. Calculate the Young's Modulus for various ductile materials.
2. Generate stress Vs strain diagram for different materials using servo driven Universal Testing Machine.

8. Brinell Hardness test

8.1. Introduction

Hardness is defined as a material's ability to resist permanent indentation (that is plastic deformation). Typically, the harder the material, the better it resists wear or deformation. The term hardness, thus, also refers to local surface stiffness of a material or its resistance to scratching, abrasion, or cutting.

8.2. Objectives

1. To determine the hardness number from Brinell hardness test.
2. To measure the ultimate tensile strength of the specimen from the Brinell hardness test.
3. The specimen prepared as per the given dimensions in fig.8.1

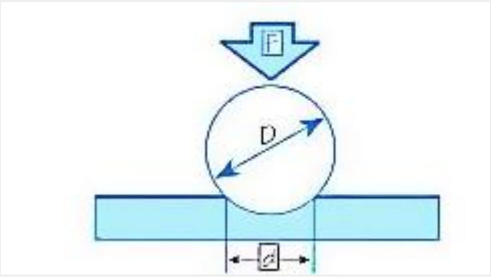

fig.8.1: Brinell hardness test

D = Ball diameter
d = impression diameter
F = load
HB = Brinell result

8.3 Further Probing Experiments

1. Measure the hardness values for different conventional materials.
2. Compare the hardness values same material with different loads and comment on the results.

9. Rockwell Hardness test

9.1. Introduction

Hardness is defined as a material's ability to resist permanent indentation (that is plastic deformation). Typically, the harder the material, the better it resists wear or deformation. The term hardness, thus, also refers to local surface stiffness of a material or its resistance to scratching, abrasion, or cutting.

9.2. Procedure

1. To determine the Brinell hardness number from the Rockwell hardness test
2. To find the ultimate tensile strength of the metal specimens from the Brinell hardness number by using empirical relationships as shown in fig.9.1

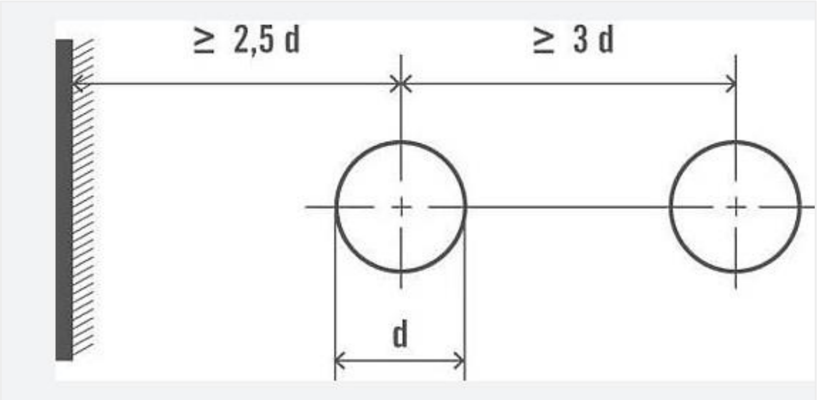

fig.9.1: Rockwell Hardness test specimen as per ISO 6508

9.3 Further Probing Experiments

1. Measure the hardness values for different materials which needs unusual scales.
2. Compare the hardness values same material with different loads and comment on the results.

10. Spring test

10.1. Introduction

Spring test is used to determine the stiffness of helical spring. Stiffness is the ability of a material withstand load per unit deflection. The modulus of rigidity of a spring material varies as a function of chemical composition, cold working, and degree of aging,

10.2. Procedure

1. Measure the diameter of the wire of the spring by using the micrometre.
2. Measure the diameter of spring coils by using the Vernier calliper
3. Count the number of turns.
4. Insert the spring in the spring testing machine and load the spring by a suitable weight and note the corresponding axial deflection in tension or compression.
5. Increase the load and take the corresponding axial deflection readings.
6. Plot a curve between load and deflection. The shape of the curve gives the stiffness of the spring.

10.3 Further Probing Experiments

1. Measure the hardness values for different materials which needs unusual scales.
2. Compare the hardness values same material with different loads and comment on the results.

11. Compression test

11.1. Introduction

In modern design offices, a special care is taken at the time of designing a structure that it should be able to withstand the stresses, under the various load conditions, without failure. For doing so, it is very essential to have a complete information about the various properties of the selected material and its dimensions. This information can be obtained by experimental investigations in a well-equipped material testing laboratory.

11.2. Procedure

- Select some brick with uniform shape and size.
- Measure all dimensions. (LxBxH) Now fill the frog of the brick with fine sand. And
- Place the brick on the lower platform of compression testing machine and lower the spindle till the upper motion of ram is offered by a specimen the oil pressure start increasing the pointer start returning to zero leaving the drug pointer that is maximum reading which can be noted down.

11.3. Further probing questions

1. Measure the compressive strength of nonferrous material
2. Determine the compressive strength of the metallic column

12. Charpy impact test

12.1. Introduction

Impact test determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

12.2. Procedure

1. With the striking hammer (pendulum) in safe test position, firmly hold the steel specimen in impact testing machines vice in such a way that the notch faces the hammer and is half inside and half above the top surface of the vice.
2. Bring the striking hammer to its top most striking position unless it is already there, and lock it at that position.
3. Bring indicator of the machine to zero, or follow the instructions of the operating manual supplied with the machine as shown in figure below.

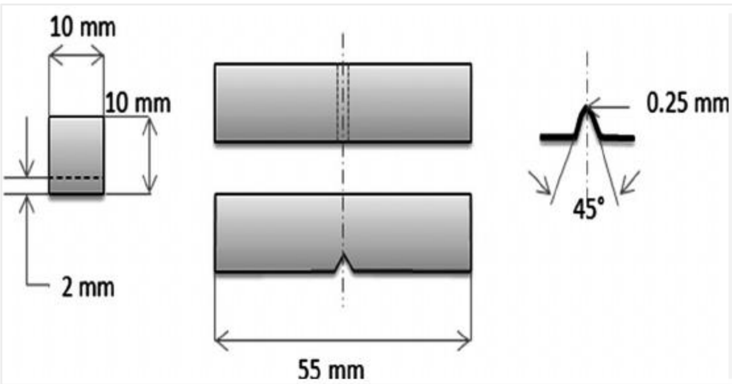

fig.12.1: Charpy Impact Test Specimen Dimensions

12.3 Further Probing Experiments

1. Calculate the impact strength of a unnotched specimens.
2. Determine the impact strength of a U-Notched specimens.

13. Izod impact test

13.1. Introduction

Impact test determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

13.2. Procedure

1. With the striking hammer (pendulum) in safe test position, firmly hold the steel specimen in impact testing machines vice in such a way that the notch faces the hammer and is half inside and half above the top surface of the vice.
2. Bring the striking hammer to its top most striking position unless it is already there, and lock it at that position.
3. Bring indicator of the machine to zero, or follow the instructions of the operating manual supplied with the machine.
4. Release the hammer. It will fall due to gravity and break the specimen through its momentum, the total energy is not absorbed by the specimen. Then it continues to swing.
5. At its topmost height after breaking the specimen, the indicator stops moving, while the pendulum falls back. Note the indicator at that topmost final position as shown in fig.13.1

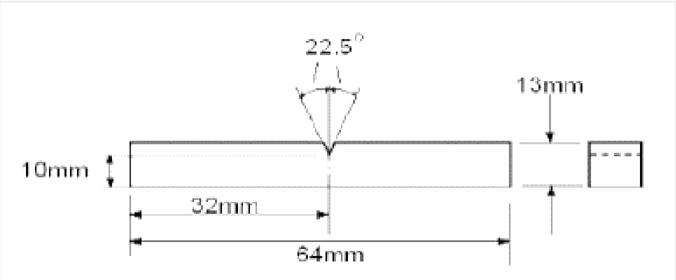

fig.13.1: Izod impact test specimen dimensions

13.3 Further Probing Experiments

1. Calculate the impact strength of unnotched specimens.
2. Determine the impact strength of U-Notched specimens.

14. Shear test

14.1. Introduction

Shear test determines the shear strength of the material during shear loading condition. This
absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

14.2. Procedure

- Insert the specimen in position and grip one end of the attachment in the upper portion and one end in the lower portion.
- Switch on the main switch of universal testing machine machine.

- The drag indicator in contact with the main indicator.
- Select the suitable range of loads and space the corresponding weight in the pendulum and balance if necessary, with the help of small balancing weights.
- Operate (push) buttons for driving the motor to drive the pump.
- Gradually move the head control level in left-hand direction till the specimen shears.

14.3 Further Probing Experiments

- Determine the shear strength of the rectangular specimen
- Determine the shear strength of the brittle material

V. TEXT BOOKS:

1. William, Callister, “Material Science and Engineering”, Wiley, 9th edition, 2014.
2. Egor V Popov, “Engineering Mechanics of Solids”, Pearson, 2nd edition, 2015.

VI. WEB REFERENCES:

1. https://www.labtesting.com/about/capabilities/metal-and-material-analysis/metallurgical-analysis/

VII. Electronics References

1. .https://onlinecourses.nptel.ac.in/noc23_me140/preview
2. https://archive.nptel.ac.in/courses/105/105/105105108/
3. https://nptel.ac.in/courses/112107146

VIII. Materials Online

1. Course template
2. Lab manual