INSTITUTE OF AERONAUTICAL ENGINEERING



(Autonomous) Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

MECHANICS OF SOLIDS AND FLUID DYNAMICS LABORATORY									
III Semester: AE									
Course Code	Category	Hours / Week		Credits	Maximum Marks				
AAED05	Core	L	Т	Р	С	CIA	SEE	Total	
		-	-	2	1	40	60	100	
Contact Classes: Nil	Tutorial Classes: Nil	Practical Classes: 45 Total Classes: 45							
Prerequisite: Mechanics of solids, Fluid Dynamics									

I. COURSE OVERVIEW:

The Mechanics of Solids and Fluid Dynamics Laboratory provides undergraduate students with a comprehensive understanding of both material strength and fluid behavior through hands-on experiments. In the Mechanics of Solids section, students perform experiments to measure material properties such as impact strength, tensile strength, compressive strength, hardness, and ductility. This lab is also utilized for project work, testing various materials like composites, ferrous and nonferrous alloys, and identifying suitable materials for aero structures based on their mechanical properties.

The Fluid Dynamics section explores fluid properties and involves experiments with incompressible flow. Students gain fundamental knowledge of basic measurements and devices used in fluid dynamics. This course introduces flow behavior, fluid forces, and analytical tools. It covers various flow measurement devices, pumps, and turbines, teaching students how to assess their performance. Hands-on experience includes investigating fluid statics principles, the kinematics and kinetics of fluid flow, and the operation of turbomachinery. This integrated laboratory ensures a thorough practical understanding of both solid mechanics and fluid dynamics, essential for applications in engineering and research.

II. COURSE OBJECTIVES:

The students will try to learn:

- I. The mechanics of materials and structural analysis through a series of experiments using appropriate codes and standards
- II. The behavior and failure modes using deflection of beams and columns for choosing the safety factor for engineering applications.
- III. Application of Bernoulli's theorem in measurement of rate of discharge in pumps.
- IV. The flow measurement and performance of pumps and turbines under various speeds.

III. COURSE OUTCOMES:

After successful completion of the course, students will be able to:

- CO1 Compare the hardness of ferrous and non-ferrous materials using hardness testing machines for identifying suitable industrial applications.
- CO2 Choose the regions of elasticity and plasticity, stress-strain relationships using universal testing machine for determining the safety factor.
- CO3 Summarize performance of a material or product using torsion tests, when undergoes rotational motion when in service.
- CO4 Demonstrate the validation of Bernoulli's theorem for incompressible, steady, continuous flow in order for regulating discharges in pipes.
- CO5 Illustrate the critical Reynolds number using Reynolds apparatus for transition of laminar flow into turbulent flow.
- CO6 Make use of the jet impact apparatus to investigate the reaction forces generated due to changes in momentum.

IV. COURSE CONTENT:

EXERCISES ON MECHANICS OF SOLIDS LABORATORY 1. Getting Started Exercises

1.1 Introduction to Laboratory

The Mechanics of Solids (MoS) Laboratory is equipped with advanced destructive testing machinery, enabling students to grasp fundamental concepts and apply them to practical problems. The laboratory conducts various tests as per ASTM and IS standards to estimate mechanical properties such as Young's Modulus, Shear Modulus, Hardness, Toughness, and Stiffness. Final-year students utilize this lab to test materials like composites, ferrous and nonferrous alloys, for designing components in aircraft and machine elements. The lab aims to:

- Familiarize students with lab equipment
- Inform students about the lab evaluation process
- Provide guidance on laboratory precautions
- Introduce sample preparation techniques

The Fluid Dynamics Laboratory is designed to explore fluid properties and conduct experiments with incompressible flow. This course provides fundamental knowledge of basic measurements and devices used in fluid dynamics. It introduces flow behaviour, fluid forces, and analytical tools. Students learn about various flow measurement devices, pumps, and turbines, and assess their performance. Hands-on experience covers principles of fluid statics, kinematics and kinetics of fluid flow, and turbo machinery operation. This comprehensive approach ensures students gain practical insights into fluid dynamics and its applications.

2. Brinell Hardness test

2.1. 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.

2.2.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.1



2.3 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.

3. Tension test of Mild Steel

3.1.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.

3.2. 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.2.



Fig.2: Tension test specimen preparation

3.3. 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.

4. Torsion test of Mild Steel

4.1.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, $\Phi(rad)$ at selected increments of torque, T (N.m). Expressing Φ as the angular deflection curve per unit gage length.

4.2. 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.3. (All dimensions are in mm).



Fig.3 Torsion test specimen dimensions

4.3.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.

4.4.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.

5. Izod Impact test

5.1. 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.

5.2. 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.4



Fig.4: Izod impact test specimen dimensions

6. Charpy impact test

6.2 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.

6.3 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.5 below.



Fig.5. Charpy impact test specimen dimensions

6.4 Further Probing Experiments

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

7. Compression test

7.1 Short columns

Compression tests on short columns are used to determine a material's behaviour under applied crushing loads, and are typically conducted by applying compressive pressure using a universal testing machine. By using this experiment the load corresponding to the crushing stress, is called crushing load will be determined for the short columns.

During the test, various properties of the material are calculated and plotted as a stress-strain diagram which is used to determine qualities such as elastic limit, proportional limit, yield point, yield strength and, for some materials, compressive strength

7.2 Long columns

Compression tests on long columns are used to determine a material's behaviour under applied buckling loads, and are typically conducted by applying compressive pressure using a universal testing machine. The column will fail due to buckling before the yield strength of the member is reached. Buckling occurs suddenly, and is characterized by large deflections perpendicular to the axis of the column. The stability of long columns also effects end conditions, which are 1. Both ends hinged, 2. Both ends fixed, 3. One end is fixed and the other hinged, and 4. One end is fixed and the other free. During the test, various properties of the material are calculated and plotted as a stress-strain diagram which is used to determine qualities such as elastic limit, proportional limit, yield point, yield strength and, for some materials, compressive strength (Table 1).

Table 1.

S,No	Columns	Types of end conditions,
1	Columns with Both Ends Hinged	$ \begin{array}{c} & & & \\ & & & & \\ & & & \\ & & & $
2	Columns with One End Fixed and the Other Free	P $B = a \rightarrow B_{1}$ $B = a \rightarrow B_{1}$ A
3	Columns with Both Ends Fixed	P B M_{0} $\frac{l}{4}$ $\frac{l}{2}$ $\frac{l}{2}$ M_{0} $\frac{l}{4}$



7.3 Further Probing Experiments

- 1. Calculate the compressive strength of a non ferrous metal cube.
- 2. Determine the compressive strength of a metallic columns
- 3. Calculate the compressive strength of a non ferrous metal cube.
- 4. Determine the compressive strength of a metallic columns

8. Spring test

8.1 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,

8.2 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.

8.3 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.

9. Deflection test for cantilever beam

9.1.1 Introduction

In Designing of beams two design criteria ate important, one Strength which is resist to shear force and bending moment, and other is the stiffness, which is resistance to deflection under different types of loads. There are many methods to find out the slope and deflection at a section in a loaded beam, but 1. Double integration method and 2. Macaulay's methods are the important.

9.1.2 Procedure

In this experiment Macaulay's method is using out the slopes and deflection of beams with the following rules

- a. Always take origin on the extreme left of the beam.
- b. Take left clockwise moment as negative and left anticlockwise moment as positive.
- c. While calculating the slopes and deflections, it is convenient to use the values first in terms of kN and metres as shown in figure 6.



Fig. 6. Experiment Macaulay Method

9.2 Deflection test for simple supported beam

9.2.1 Introduction

In Designing of beams two design criteria ate important, one Strength which is resist to shear force and bending moment, and other is the stiffness, which is resistance to deflection under different types of loads. There are many methods to find out the slope and deflection at a section in a loaded beam, but 1. Double integration method and 2. Macaulay's methods are the important.

9.2.2 Procedure

In this experiment Macaulay's method (Fig.7) is using out the slopes and deflection of beams with the following rules

- a. Always take origin on the extreme left of the beam.
- b. Take left clockwise moment as negative and left anticlockwise moment as positive.
- c. While calculating the slopes and deflections, it is convenient to use the values first in terms of kN and metres.



Fig.7. Demonstration of forces for Macaulay,s method

9.3 Further Probing Experiments

- 1. Measure the slope and deflection values for cantilever beam with different loads.
- 2. Repeat the same experiment, by changing the point of applications of loads.

10. Exercises on Verification of Bernoulli's theorem.

10.1 Bernoulli's theorem

Start the pump, adjust the flow, note down the piezometer readings and time (t), calculate the pressure head, velocity head, and datum head, and verify the Bernoulli's Theorem, using the experimental setup, shown in figure 8.



Fig.8. Bernoulli experiment setup

Try

- 1. Vary the mass flow rate and verify Bernoulli's theorem
- 2. Change the fluid type and verify Bernoulli's theorem

11. Exercises on Impact of Jets on Vanes

11.1 Jets on Vanes

1. Fix the given vane and add dead weight, note down the forces, note down the time, calculate the flow speed, discharge, and coefficient of impact vanes, shown in figure 9.



Figure 9. Lay out of the jets on vanes experimental set up

Try

- 1. Change the vane angle to 45° and repeat the same experiment
- 2. Change the vane angle to 60° and repeat the same experiment
- 3. Change the orifice geometry and find the coefficient of impact vanes

12. Exercises on Performance of Centrifugal Pumps

12.1 Centrifugal Pump

Start the pump, operate the valves, note down the readings for pressure head, time (t), calculate the actual discharge, input power, output power, and calculate the efficiency of the centrifugal pump, using the experimental setup, shown in figure 10.



Fig.10. Centrifugal pump experiment setup

Try

- 1. Note down the time for 15 cm rise of water and calculate the efficiency of the centrifugal pump.
- 2. Note down the time for 30 cm rise of water and calculate the efficiency of the centrifugal pump.

13. Exercise on Performance of Reciprocating Pump

13.1 Reciprocating Pump

Start the pump, operate the valves, note down the readings for delivery valve, pressure head reading, time (t), calculate the actual discharge, input power, output power, and calculate the efficiency of the centrifugal pump, using the experimental setup, shown in figure 11.

Try

- 1. Note down the time for 15 cm rise of water and calculate the efficiency of the centrifugal pump
- 2. Note down the time for 30 cm rise of water and calculate the efficiency of the centrifugal pump



Fig. 11: Reciprocating pump setup

14. Exercise on Pelton Wheel Turbine

14.1 Introduction

Introduction 1. Start the pump, adjust the nozzle opening about half, note down the pressure gauge, vacuum gauge readings, speed of the turbine, manometer readings (h1 & h2), and calculate output power, input power, and efficiency of the Pelton wheel turbine, using the experimental setup, shown in figure 12.



Fig. 12: Schematic diagram of a Pelton turbine

Try

- 1. Adjust the nozzle opening for full, and calculate the efficiency of the Pelton wheel turbine
- 2. Note down the time for 30 cm rise of water and calculate the efficiency of the centrifugal pump
- 3. Performance characteristics of Pelton wheel turbine for change in the bucket design
- 4. Performance characteristics of Pelton wheel turbine for change in datum head

V. TEXT BOOKS:

1. Gere, Timoshenko, "Mechanics of Materials", McGraw Hill, 3rd edition, 1993.

VI. REFERENCE BOOKS:

- 1. R. S Kurmi, Gupta, "Strength of Materials", S. Chand, 24th edition, 2005.
- 2. William Nash, "Strength of Materials", Tata McGraw Hill, 4th edition, 2004.

VII. ELECTRONICS RESOURCES:

- https://nptel.ac.in/courses/112107147/
 https://vssut.ac.in/lecture_notes/lecture1423904647.pdf
 https://web.mit.edu/emech/dontindex-build/

VIII. MATERIALS ONLINE

1. Course template

2. Lab manual