AEROSPACE STRUCTURES LABORATORY
LAB MANUAL

Year	**:**	**2017 - 2018**
Subject Code	**:**	**AAE104**
Regulations	**:**	**IARE - R16**
Class	**:**	**IV Semester**
Branch	**:**	**Aeronautical Engineering**

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Aeronautical Engineering
INSTITUTE OF AERONAUTICAL ENGINEERING
(AUTONOMOUS)
Dundigal, Hyderabad– 500 043

INSTITUTE OF AERONAUTICAL ENGINEERING

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Certificate

This is to certify that it is a bonafied record of practical work done by Sri/Kum. ____________________________________ bearing the Roll No. ______________________ of _____________ class ______________________________________ branch in the Engineering Physics laboratory during the academic year ____________________ under our supervision.

Head of the Department **Lecture In-Charge**

External Examiner **Internal Examiner**

AEROSPACE STRUCTUTRES LAB SYLLABUS

INSTITUTE OF AERONAUTICAL ENGINEERING

Dundigal, Hyderabad - 500 043

AEROSPACE STRUCTUTRES LABORATORY

OBJECTIVE:

The objective of the lab is to understand and reinforce the concepts of mechanics of structures, which have applications in Aerospace area. Students do a wide variety of experiments using the following equipments: Column buckling apparatus, Thin walled cylindrical pressure vessel apparatus, Unsymmetrical Bending and Shear Centre measurement Apparatus, Shear centre, Deflection of Beams & Cantilevers Apparatus and Continuous and Indeterminate Beam Apparatus.

OUTCOMES:

After completing this course the student must demonstrate the knowledge and ability to:

1. Provide basic knowledge on the mechanical behavior of materials like aluminum, mild steel, and cast iron.
2. Visualize the crack detection using various NDT methods and also discuss the changing strength due to these defects.
3. Understand the concept of locating the shear centre for open and closed section of beams.
4. Obtain buckling strength of both long and short columns using different elastic supports.

INSTITUTE OF AERONAUTICAL ENGINEERING

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PROGRAM OUTCOMES

PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES

AERONAUTICAL ENGINEERING	
PSO1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products.
PSO2	**Problem solving skills**: imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.
PSO3	**Practical implementation and testing skills**: Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies.
PSO4	**Successful career and entrepreneurship**: To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats.

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Expt. No.	Program Outcomes Attained	Program Specific Outcomes Attained
1	PO1, PO2, PO4, PO5, PO6, PO9, PO11, PO12	PSO1, PSO2, PSO3
2	PO1, PO2, PO4, PO5, PO6, PO9, PO11, PO12	PSO1, PSO2, PSO3
3	PO1, PO4, PO9, PO11, PO12	PSO1, PSO2, PSO3
4	PO1, PO2, PO4, PO9, PO11, PO12	PSO1, PSO2, PSO3
5	PO1, PO2, PO4, PO9, PO11, PO12	PSO1, PSO2, PSO3
6	PO1, PO3, PO4, PO5, PO9, PO11, PO12	PSO1, PSO2, PSO3
7	PO1, PO4, PO9, PO11, PO12	PSO1, PSO2, PSO3
8	PO1, PO4, PO9, PO11, PO12	PSO1, PSO2, PSO3
9	PO1, PO2, PO4, PO5, PO9, PO11, PO12	PSO1, PSO2, PSO3
10	PO1, PO3, PO4, PO5, PO9, PO11, PO12	PSO1, PSO2, PSO3
11	PO1, PO3, PO4, PO5, PO9, PO11, PO12	PSO1, PSO2, PSO3
12	PO1, PO3, PO4, PO5, PO9, PO11, PO12	PSO1, PSO2, PSO3

OBJECTIVES:

1. To acquaint students with the fundamentals of aerospace structures.
2. To acquaint students with structural mathematical models.
3. To introduce students to design considerations applied to simple aerospace structural elements.
4. Analytically and numerically calculate the deformation and stress states of aerospace structural components.
5. Evaluate the suitability of simple structural elements for specific aerospace applications given design constraints, such as allowable stresses, deformations, and weight.
6. Recognize structural failure modes such as yielding, fracture, and fatigue.

OUTCOMES:

Upon the completion of Aerospace Structures practical course, the students will be able to:

Understand the basic ideas and practical knowledge of the theory of elasticity for nonlinear and linear elastic bodies.

Understand the buckling of columns and identify the primary and secondary structural instability

Knowledge on riveted, bolted joints and composite sandwich structure.

Testing mechanical behaviour of different kind of structural members.

Implement the theory of deletion of beams and verifying with Castiglione’s theorem.

Analyse Shear centre position of the thin walled beams which consists of open cross section and combination of open closed section beams

Understand the method of non destructive test to identify position crack and its propagation.

EXPERIMENT 1

DIRECT TENSION TEST

AIM: To determine the young's modulus of the given material where tensile stress is applied.

APPARATUS REQUIRED: Universal testing machine (UTM)

SPECIMENS REQUIRED: Mild steel rod of 10 mm dia and 117 mm, steel rule, vernier calipers.

SKETCH:

DESCRIPTION OF APPARATUS:

The machine serves the purpose of conducting tension, compression and bending test. The testing machine is operated hydraulically. Driving is performed by the help of electric motor. The machine is equipped with pendulum dynamometer. A recording device is used for registering load deformation diagram.

DESCRIPTION OF PARTS:

CONTROL PANNEL:

The control panel consists of a complete power pack with drive motor, oil tank, control valves, a pendulum dynamometer, a load indicator system and an autographic recorder.

POWER PACK:

The power pack generates the maximum pressure of 200kgf/cm^2. The hydraulic pump provides continuously non-pulsating oil flow. Hence the load application is very smooth.

LOAD INDICATOR SYSTEM:

This system consists of a large dial and a pointer. A dummy pointer is provided to register the maximum load reached during the test. Different measuring ranges can be selected by operating the range selecting knob. An overload trip switch is incorporated, which automatically cuts out the pump motor when the load range is exceeded.

The load ranges has 4 positions.

i.e., 0 to 40 KN
0 to 100 KN
0 to 200 KN
0 to 400 KN

PENDULUM DYNAMOMETER:

This unit permits selection of favorable hydraulic ratios producing relatively small directional forces. Pressurized oil in the loading cylinder pushes up the measuring piston proportionately and actuates the special dynamometer system. The piston is constantly rotated to eliminate friction. The dynamometer system is also provided with an integral damper and ensures high reliability of operation. The load transmitted to the dynamometer is transferred through a pendulum to the load indicator.

Autographic continuous roll load –Elongation recorder:

This unit is of the open and drums type and is supplied as standard.

GRAPH PAPER:

The graph paper which is there in the UTM machine is used to draw the stress-strain diagram for the given material.

GRAPH DRUM:

Graph drums on which the graph paper is rolled. It is used to draw the stress Vs strain diagram for the given material

ELONGATION SCALE:
On this scale we measure the elongation or compression of the specimen. This is marked from 0 to 20 cm.

PEN HOLDER:
This is placed above the graph drum, which is to be used for holding the pen. While the needle of the pendulum dynamometer is rotating, this is to be moved. By using this pen holder we can draw the stress-strain diagram.

LOADING PLATFORM:
Loading platform is one on which we keep the specimen for doing the compression test. This loading platform is to be moved in to upward direction by switching on the upward switch of the driving motor. And it is moved downwards by pressing the down switch of the driving motor.

ELECTRIC MOTOR:
The electric motor gives the power supply to the system by which we can operate the driving motor properly. This power supply is given to the threading device of the UTM.

THEORY:
The Universal Testing Machine (UTM) mainly consists of two units

1. loading unit and
2. control panel

The specimen is tested on the loading unit and the corresponding readings are taken from the fixed dial on the control panel. The main hydraulic cylinders fitted in the centre of the base and the piston slides over the cylinder when the machine is under operation. A lower table is rigidly connected to an upper cross head by two straight columns. This assembly moves up and down with the main piston. The test is conducted by fixing the specimen in between the lower and upper crossheads by jaws inserts. An elongation scale is also kept sliding which is fitted between lower table and upper crosshead.

The two valves on the control panel one on the right side and the other one on the left side are used to control the oil flow in the hydraulic system. The right side valve is a pressure flow control valve and the left side valve is a return valve to allow the oil from the cylinder to go back to the tank. Control panel also consists of dynamometer which measures and indicates the load on the specimen.

PROCEDURE:

1) Measure the length and diameter of given specimen
2) Fix the load range by placing counter weights on the balancing pendulum at the back of the machine.
3) Grip the specimen vertically and firmly between the jaws of the UTM and adjust the machine to read zero.
4) Before operating the UTM ensure that the oil delivery valve (left) is open and the pressure release valve (right) is closed.
5) After switching on the UTM open the pressure release valve and close the oil delivery valve.
6) Now, push the ‘ON’ button on the control panel and there will be tension acting on the specimen due to fluid pressure.
7) Before applying the pressure adjust the pencil to the graph roll.
8) The yield point is observed when the line needle is suddenly stops for a second and continues to move.
9) At one stage the line needle begins to return, leaving the dummy needle there itself. At this point the ultimate strength of the specimen is observed.
10) After some time the specimen breaks making a huge sound.
11) As the specimen breaks the graph is metallically plotted according to the behaviour of specimen under tension due to applied load.
12) Note and record the required reading and the graph plotted.
13) Remove the broken pieces of the specimen from the machine and safely switch off the machine.
14) Measure the gauge length of the test specimen and diameter of the neck.

S.No.	Load	Deflection	Stress	Strain	Modulus of elasticity
1					
2					
3					
4					
5					

SAMPLE CALCULATIONS:

1. Diameter of the specimen, d =
2. Length of the specimen, L =
3. Yield point found at =
4. Ultimate strength found at =
5. Break point found at =

Stress:

The resistance offered by a body against the deformation is called stress.

$$\text{Stress (f)} = \text{Load(p)/area of cross section (A)}$$

$$= P/A \quad (N / mm^2)$$

Strain:

The ratio of change in length to the original length is called strain

$$\text{Strain (e)} = \frac{\text{Change in length } (\delta l)}{\text{Original length (l)}}$$

Young’s modulus:

The ratio of stress to strain with in the elastic limit is called modulus of elasticity (or) young’s modulus.

E = Stress (f)/ Strain (e)

Tensile Strength:

The tensile strength or ultimate tensile strength is the maximum load obtained in a tensile test divided by the original area of the cross-section of the specimen. It is used for the quality control of the product. It can be co-related to other properties such as hardness and fatigue strength.

$$\mathbf{P_u = P_{max}/A_0}$$

Where P_u = ultimate tensile strength in kg/mm^2

P_{max}= Maximum load obtained in tensile test in Kgs

A_0 = original cross-sectional area of load specimen in mm^2.

Yield Strength:

It is defined as the stress which will produce a small amount of permanent deformation.

Yield strength $\mathbf{P_y = P_e / A_0}$

P_e= load obtained at yield point

A_0 = original area of cross-section in mm^2.

Percentage Elongation:

$\mathbf{\%E = (L-L_0)/ L_0 \times 100}$

E = percentage elongation

L = Increased length or gauge length at fracture.

L_0 = original length.

Total % elongation up to fracture point is an indication of ductility (ability of a material to with stand plastic deformation).

Reduction of Area: It is the ratio of decrease in cross-sectional area to the original area expressed in percentage.

$\% R_A = (A_0-A)/ A_0 \times 100$

R_A = percentage reduction in area.

A_0 = original cross-sectional area

A = final cross-sectional area after fracture.

PRECAUTIONS:

1. Carefully switch 'ON' the machine
2. Hold the loads carefully, so that it doesn't fall on your feet and gets you injured.
3. Set the dial corresponding to the load applied.
4. While operating the machine do not touch the rod column along which the piston moves
5. Be careful while fixing the specimen between the jaws of the UTM
6. Keep your hands away from the parts of the UTM, after the specimen is fixed between the jaws of the machine

RESULTS:

Thus, the young's modulus of the given rod of the material is

E = KN/mm^2

EXPERIMENT NO: 2

DEFLECTION TEST

VERIFICATION OF MAXWELL’S RECIPROCAL THEOREM

AIM:

To verify the Maxwell’s reciprocal theorem.

APPARATUS REQUIRED:

1. Scale
2. Beam Set-up
3. Dial gauge with magnetic stand
4. Weights
5. Weight Hanger
6. Simply supported beam
7. Cantilever beam

SPECIFICATIONS:

FOR SIMPLY SUPPORTED BEAM

Total length of the beam :
Length taken into consideration:
Thickness of the beam :
Material of the beam :

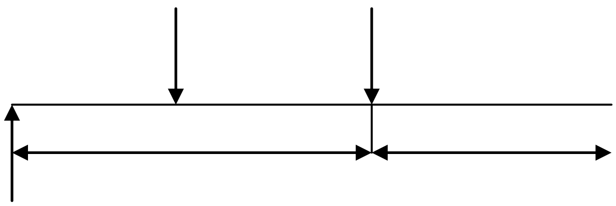
FOR CANTILEVER BEAM

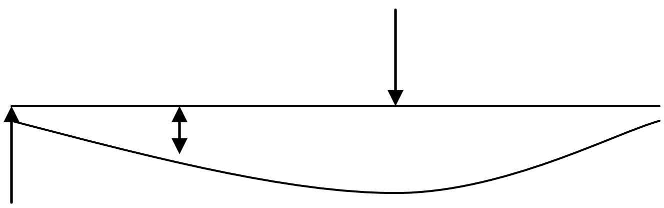
Total length of beam :
Length taken into consideration:
Thickness of the beam :
Material of the beam :

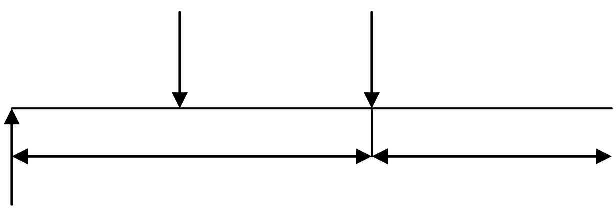
THEORY:

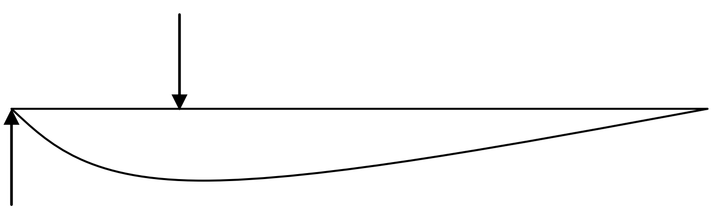
The following are the three versions of Maxwell’s reciprocal theorem.

1) The deflection at point B due to unit load at point A is equal to deflection at point A due to unit load at point B.
2) The slope at point B due to unit moment at point A is equal to the slope at the point A due to unit moment at point B.
3) The slope at point B due to unit load at point A is equal to the deflection at the point A due to unit moment at point B.









PROCEDURE:

1) The given beam is placed on the knife-edge to form a SSB.
2) Measure the length of the beam with scale and calculate L/4 and 3L/4.
3) The 2 points are taken as A and B on the SSB.
4) The dial gauge is placed at point A through the magnetic stand.
5) The hanger is placed on point B. The dial gauge is adjusted for zero without taking any load on the SSB. Then the weights are added in 1000 gms. The deflection at point A is noted for every 1000 gms.
6) Unload the weight hanger and note down the deflections during unloading process.

7) The load and dial gauge are interchanged (i.e) the loads are added at point A and dial gauge at point B.
8) Readings are taken for every 1000 gms of weight and while unloading.
9) A graph between load applied and deflection is drawn for both the cases i.e deflection at A due to load at B and deflection at B due to load at A.
10) The slopes of two graphs are obtained and the slopes are found to be the same, which means Maxwell's theorem is true.

TABULATION:

FOR SIMPLY SUPPORTED BEAM:

Load at A, deflection at B

S.No	Load in gms	Deflection at L/4		Deflection at 3L/4	
		Loading	Unloading	Loading	Unloading

FOR CANTILEVER BEAM:

Load at A, deflection at B

S.No	Load in gms	Deflection at L/4		Deflection at 3L/4	
		Loading	Unloading	Loading	Unloading

PRECAUTIONS:

1. Ensure zero reading on the dial gauge before loading the beam.
2. Note down the readings with parallax error.
3. Do not disturb the apparatus during the experiment.

RESULT:

Thus the Maxwell's reciprocal theorem is verified.

$$\theta_{AB} = \theta_{BA} .$$

EXPERIMENT NO: 3

BUCKLING TEST

(Long Column)

AIM:

To compare theoretical buckling load with actual buckling loads of pinned end struts from experiments and prove the theory and show its limits.

APPARATUS REQUIRED:

1. Scale
2. Strut Set-up
3. Deflection Indicator
4. Weights
5. Weight Hanger

SPECIFICATIONS:

Item	Details
Nett Dimensions	Main Unit: 1350 mm long x 500 mm front to back x 500 mm highDigital Load Display: 170 mm x 60 mm x 200 mm
Nett Weight	Main Unit: 24 kg Digital Load Display: 1.4 kg
Electrical Supply (for the Digital Load Display Power Supply	Input 90 VAC to 264 VAC 50 Hz to 60 Hz at 1A Output 12 VDC at 5 A Centre Positive
Fuse	No fuses fitted.
Operating Environment	Indoor (laboratory) Altitude up to 2000 m Overvoltage category 2 (as specified in EN61010-1). Pollution degree 2 (as specified in EN61010-1).
Maximum Load Capacity of Load Measurement Unit	2000 N
Maximum strut length	Approximately 800 mm in fixed - fixed ends.
Allowable	
Eccentric End Fittings	Offset the loading centre of a 3 mm strut by 5 mm and 7.5 mm.
Standard Struts **Nominal Dimensions**	Strut 1 - Steel, 20 mm x 3 mm x 750 mm Strut 2 - Steel, 20 mm x 3 mm x 700 mm Strut 3 - Steel, 20 mm x 3 mm x 650 mm Strut 4 - Steel, 20 mm x 3 mm x 625 mm Strut 5 - Steel, 20 mm x 3 mm x 600 mm

	Strut 6 - Steel, 20 mm x 3 mm x 550 mm Strut 7 - Brass, 19 mm x 4.8 mm x 750 mm Strut 8 - Aluminum, 19 mm x 4.8 mm x 750 mm Strut 9 - Steel, 15 mm x 4 mm x 750 mm Strut 10 - Steel, 10 mm x 5 mm x 750 mm

Item	Details
Optional Struts **Nominal Dimensions**	Strut A - Hardwood (Mahogany), 20 mm x 6 mm x 550 mm with steel knife edge inserts. Strut B - Plywood (Marine Ply), 20 mm x 6 mm x 550 mm with steel knife edge inserts. Strut C - Glass Fibre, 20 mm x 5.5 mm x 550 mm with steel knife edge inserts. Strut D - Moulded Brass (Extruded brass), D shape, 19 mm x 4.5 mm x 550 mm Strut E - Steel Compound, Two steel struts, bolted together. Both 13 mm x3 mm. One longer (650 mm) with knife edge ends, the other 640 mm. Strut F - Aluminium channel, 13 mm x 13 mm and 1.5 mm thick wall x 750 mm with steel end fittings. Strut G - Aluminium angle, 13 mm x 13 mm and 1.5 mm thick wall x 750 mm with steel end fittings. Strut H - Aluminum angle, 13 mm x 13 mm and 1.5 mm thick wall x 750 mm with steel end fittings. Strut I - Steel Rectangular, 13 mm x 6.4 mm x 650 mm. Strut J - Steel Round, 6.4 mm diameter x 650 mm.

Material	Young's Modulus (Nominal)
Steel	207 $GN.m^{-2}$(207 GPa)
Aluminum	69 $GN.m^{-2}$ (69 GPa)
Brass	105 $GN.m^{-2}$(105 GPa)

THEORY:

Failure of Long and Short Columns

Long and Short Columns

Columns are parts of structures that resist compressive axial loads (usually vertical loads). **Stanchions** are upright (usually metal) columns in buildings. **Struts** are the smaller parts (members) that resist compression in trusses and frames.

Columns can be either **long** (**slender**) or **short** (**fat**) (see Figure). When compressed by too much axial load, long, slender columns fail by suddenly bending out of line (for example - a plastic ruler). They become 'unstable' and 'buckle' at a maximum or 'critical (buckling) load'. Short, fat columns fail in several ways, mostly determined by the material they are made from (for example - concrete crushes and mild steel yields).

In reality, most columns are 'intermediate' - they fail by a combination of effects, where bending starts a material failure. However, this equipment examines a single effect - how slender struts or columns fail by buckling.

The Four Main Factors that Affect Buckling

The words 'long' and 'slender' suggest the length (L) and cross-section of a strut affect its buckling load. However, the cross-sectional shape also affects the buckling load. The '**second moment of area**' (I) is a measure of both the cross-sectional area and shape. It affects the **stiffness** of the strut.

In addition, the **elastic** bending of a strut depends on the **Young's Modulus** (E) of the **material** it is made from. So, the E value affects the buckling load.

Finally, and perhaps slightly less obviously, the buckling load of a slender column depends on its **endconditions**. Firmly clamped or ‘fixed ends’ help the column to withstand higher buckling loads than acolumn that has end fixings that are less rigid.

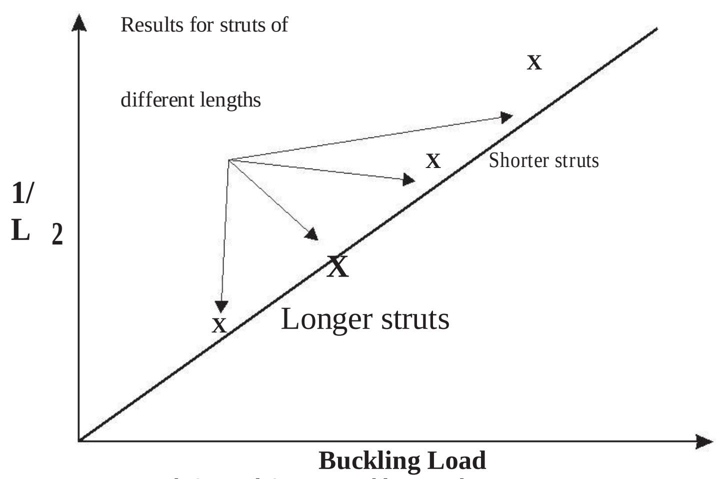
Eulers Maximum (Critical) Axial Buckling Load and ‘Effective Length’

A Swiss mathematician - Leonhard Euler, created a formula that predicts the maximum (critical) axial buckling load (P_{cr}) of a strut.

$$P_{cr} = \frac{\pi^2 EI}{KL^2} \qquad (4)$$

Where K is an ‘effective length factor’ - determined by how you fix the ends of the strut. It is the ratio of the ‘effective length’ (l) between two points, to the overall length (L) of the strut.

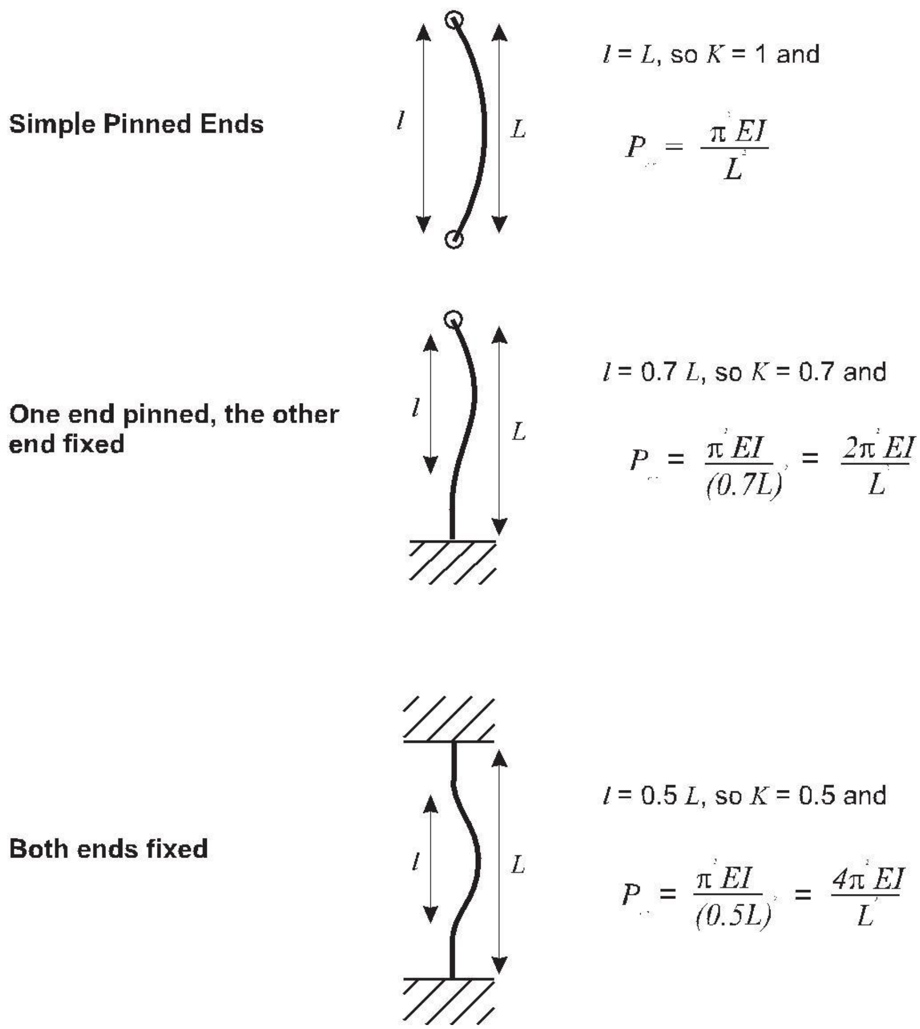
The equation again shows that the Young’s Modulus and cross-sectional dimensions (second moment of area) affect the maximum buckling load. It also shows that the buckling load varies linearly with these quantities. This allows you to see that, for example, a steel strut with an E value of 200 GPa should buckle at twenty times the load of an equivalent wooden strut, if the wood has an E value of only 10 GPa.



Length Squared Against Buckling Load

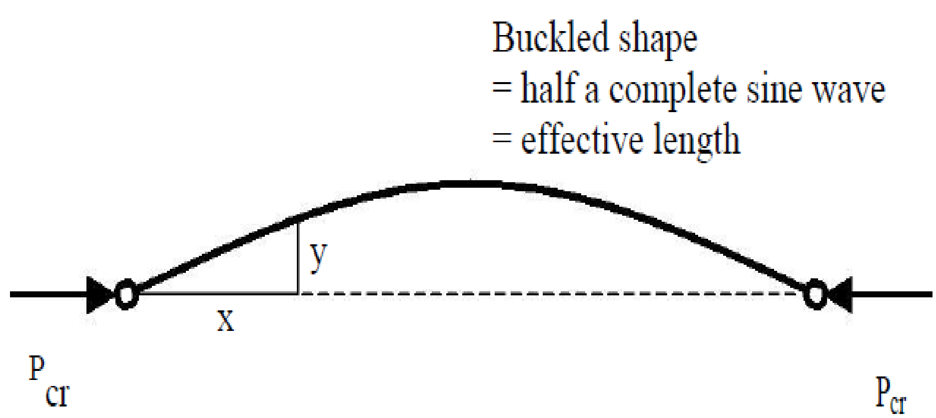
The equation also shows that buckling load is inversely proportional to the square of a column’s length. A chart of $1/L^2$ against buckling load will be linear (see Figure). This proves that longer columns have lower buckling loads, but also shows that buckling load is sensitive to column length (doubling the length will quarter the buckling load).

Figure below shows that the way you fix a strut decides its effective length. A strut with one fixed end has an effective length of 0.7 of its total length. A strut with two fixed ends has an effective length of 0.5 of its total length. This assumes that you fix the ends firmly - any movement in the ends will affect your calculations.



Eulers Equations for Different Strut End Conditions

Shape and Deflection of Buckled Struts



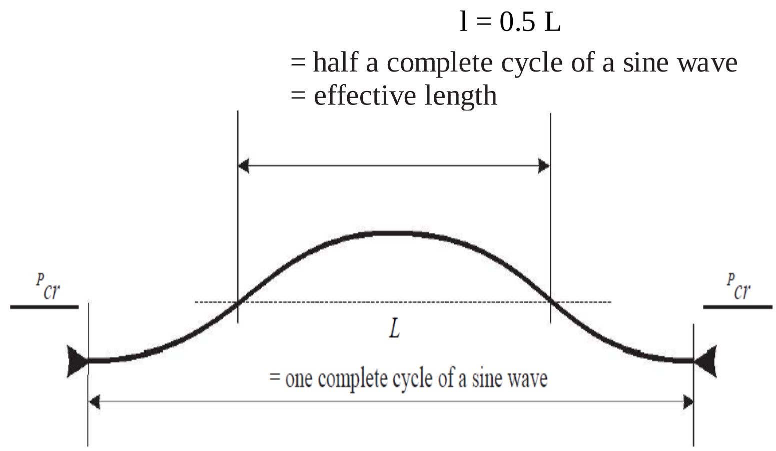
Shape of a Pin-ended Strut Under Load

Figure shows the buckled shape of a Pin-ended strut that is **initially straight**. The shape is symmetrical (half a sine wave), and its bending moment:

$$M = -P_{cr} \times y \text{ (at a distance x and a deflection y)}$$

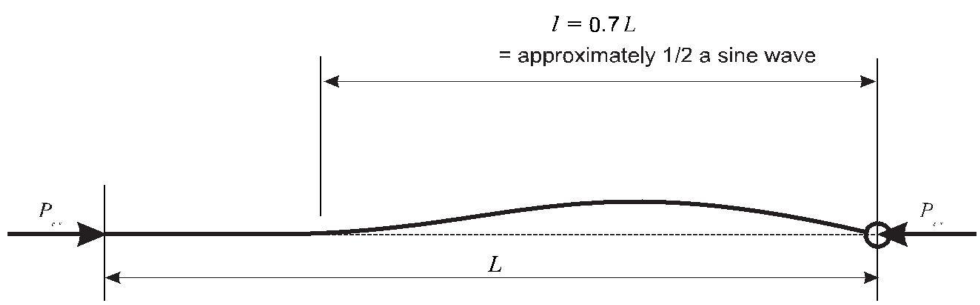
Also, from the standard differential equation of bending:

$$M = EI\,(d^2y/\,dx^2)$$



Shape of a Fixed end Strut Under Load

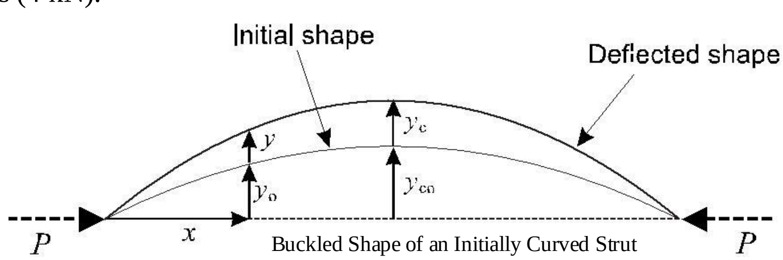
Figure shows that a pinned-end strut under load buckles so that it forms a symmetrical curve (half cycle sine wave). Its effective length is the full length of the strut. Figure shows that a fixed-ended strut buckles so that it forms a full sine wave, but its effective length (that corresponds with the pinned-end strut) is only half its entire length. So, we can **consider a fixed-end strut to have half the effective length of the pinned-end strut**. Figure gives the Euler equation for the fixed end strut. It shows that a fixed-end strut has four times the buckling load of an equivalent pin-ended strut.



Fixed and Pin-ended Strut

For a strut that is fixed at one end but pinned at the other (see Figure), it is not possible to predict its effective length precisely by looking at it, but bending theory shows mathematically that it is approximately 0.7*L*, so that its buckling load is slightly greater than twice (2.04 times, more accurately) the buckling load of the pinned-end strut. It's shape is approximately 1/2 of a sine wave.

From this theory, if the pinned ends condition has a buckling load of 1 kN, the fixed and pinned end condition has a buckling load twice this (2 kN). The fixed ends condition has a buckling load of four times this (4 kN).



Buckled Shape of an Initially Curved Strut

Figure shows the buckled shape of a strut that already has a displacement at its central position. This curve is symmetrical (a half cycle of a sine wave). The deflection equation for any point along the initial curve is:

$$y_o = y_{co}\sin\left(\frac{\pi x}{L}\right)$$

The bending equation becomes:

$$EI\frac{d^2y}{dx^2} = -P(y + y_o) \quad \textbf{OR} \quad \frac{d^2y}{dx^2} + \frac{P}{EI}y = -\frac{P}{EI}y_{co}\sin\frac{\pi x}{L}$$

The solution to this equation is:

$$y = A\cos\mu x + B\sin\mu x + \frac{\mu^2 y_{co}}{\frac{\pi^2}{L^2} - \mu^2}\sin\frac{\pi x}{L}$$

Where $\mu^2 = P/EI$

At the conditions x=0, y=0, L gives A=0 and B=0 so:

$$y = \frac{\mu^2 y_{co}}{\frac{\pi^2}{L^2} - \mu^2}\sin\frac{\pi x}{L} \quad \textbf{OR} \quad y_c = \frac{y_{co}}{\frac{\pi^2 EI}{PL^2} - 1}$$

So

$$y_c = \frac{y_{co}}{\frac{P_{cr}}{P} - 1}$$

Slenderness Ratio and Buckling Stress

The radius of gyration, *r*, of a section is the distance from its centroid at which its area may be effectively considered to be concentrated.

As stated earlier, the second moment of area (*I*) links with the cross-sectional shape and area of a beam or strut. It also links with the area and the radius of gyration, so that:

$I = Ar^2$

Substituting this in the Euler buckling equation gives:

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2} = \frac{\pi^2 EAr}{(KL)^2}$$

As shown earlier, stress is the force divided by the area (F/A). From this, the critical stress at the buckling load is

$$\sigma_{cr} = \frac{P_{cr}}{A}$$

Substituting this in equation :

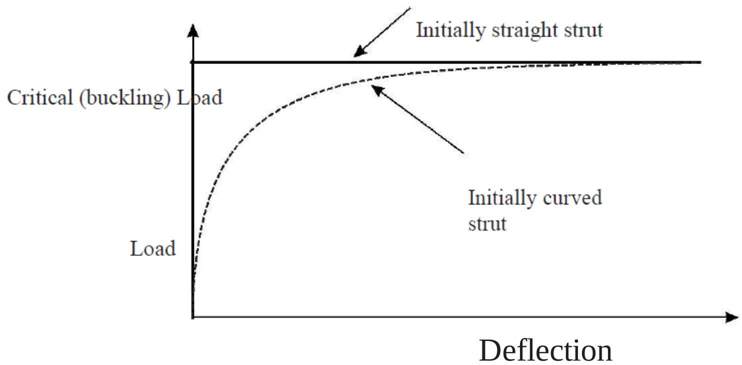
$$\sigma_{cr} = \frac{\pi^2 E r^2}{(KL)^2}$$

And

$$\sigma_{cr} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

KL/r (or l/r in this theory) is the **slenderness ratio** of the strut. It is a measure of buckling resistance. Equation shows that buckling stress is inversely related to the square of the ratio. From this, you should always use the minimum dimensions of your strut (for example - if you have a non-symmetric strut), to calculate the slenderness ratio. This is because a strut always buckles in the direction that matches the weakest dimension of the strut. However, of course the end fixings affect this as well.

Effects of Imperfections



Comparison of Straight and Curved Strut

Equation depends on three assumptions:

- The strut has constant values of E and I, so that it is homogeneous (has constant material properties).
- The strut is prismatic (has constant cross-section and therefore I value).
- The strut is perfectly straight.

In reality, none of these assumptions can be perfectly true, especially straightness. This is important. Remember that Figure (an already curved strut) and its theory shows a strut with a known lack of initial straightness. It also shows that deflection increases rapidly as the compressive load approaches its critical value.

PROCEDURE:

1. Create a blank results table, similar to Table. If you are to use VDAS®, select the Strut Experiments. The software will create a table of results for you automatically.

2. Connect and switch on the Load Display. Allow a few minutes for the display and the load cell of the measuring end to warm up. Tap the load measuring end to remove any effects of friction, and then zero the display.

3. Find the 750 mm steel strut. Use a micrometer or vernier and carefully measure its dimensions, and calculate its second moment of area.

4. Fit the strut in the pinned ends condition, but remove the deflection indicator.

NOTE:

You must now buckle the strut, and then buckle it again, in the opposite direction. This gives you two test results, and you find the average peak (buckling) load to get a good result

The first time the strut buckles, it buckles in its 'natural' direction.

1. Use the large hand wheel to load the strut slowly. As you turn the hand wheel, watch the load reading and the deflection of the strut. When you see that the load does not increase, but the strut is still deflecting, the strut has buckled. Record the 'peak load', shown in the Load Display. Release the load.

2. Apply a light load, and gently push the strut to make it buckle the opposite way to your last test. Increase the load until the strut buckles, and record the peak load.

3. Repeat the test for other struts of the same cross-section and second moment of area, but different lengths.

TABULATION:

	Strut Details					
Length	**Material**	**Second Moment of Area**	**Peak (Buckling) Load 1**	**Peak (Buckling) Load 2**	**Average Peak (Buckling) Load**	**Theoretical Buckling Load**

PRECAUTIONS:

1. Ensure zero reading on the dial gauge before loading the beam.
2. Note down the readings with parallax error.
3. Do not disturb the apparatus during the experiment.

RESULT:

For each strut, calculate the average peak (buckling) load.

Plot a curve of the length (vertical axis) against the buckling load. Use the second moment of area to calculate the theoretical buckling load for each length and plot it on the same chart.

NOTE:

As with all your results, use suitable units. SI units are best, but can give numbers with many decimal places

Does the Euler theory predict the buckling load well? You will notice that when the strut buckles in its natural direction that the load is lower. Why is that? (Hint - see to the assumptions made in the Euler theory).

Your curve will be non-linear, so it is difficult to see errors. The Euler Buckling Formula shows that you can plot $1/L^2$ against buckling load to give a linear plot that makes it easier to compare results. This also shows that bucking load is proportional to $1/L^2$.

EXPERIMENT NO: 4

BUCKLING TEST

(Southwell Plot and Buckling Load of Column)

AIM:

To show how to use the Southwell plot to find the buckling load of a strut, and prove its usefulness.

APPARATUS REQUIRED:

1. Load measuring end
2. Knife edge support
3. Loading end with handle
4. Weights
5. Weight Hanger
6. Load meter

SPECIFICATIONS:

Item	Details
Nett Dimensions	Main Unit: 1350 mm long x 500 mm front to back x 500 mm highDigital Load Display: 170 mm x 60 mm x 200 mm
Nett Weight	Main Unit: 24 kg Digital Load Display: 1.4 kg
Electrical Supply (for the Digital Load Display Power Supply	Input 90 VAC to 264 VAC 50 Hz to 60 Hz at 1A Output 12 VDC at 5 A Centre Positive
Fuse	No fuses fitted.
Operating Environment	Indoor (laboratory) Altitude up to 2000 m Overvoltage category 2 (as specified in EN61010-1). Pollution degree 2 (as specified in EN61010-1).
Maximum Load Capacity of Load Measurement Unit	2000 N
Maximum strut length	Approximately 800 mm in fixed - fixed ends.
allowable	
Eccentric End Fittings	Offset the loading centre of a 3 mm strut by 5 mm and 7.5 mm.

Standard Struts **Nominal Dimensions**	Strut 1 - Steel, 20 mm x 3 mm x 750 mm Strut 2 - Steel, 20 mm x 3 mm x 700 mm Strut 3 - Steel, 20 mm x 3 mm x 650 mm Strut 4 - Steel, 20 mm x 3 mm x 625 mm Strut 5 - Steel, 20 mm x 3 mm x 600 mm Strut 6 - Steel, 20 mm x 3 mm x 550 mm Strut 7 - Brass, 19 mm x 4.8 mm x 750 mm Strut 8 - Aluminum, 19 mm x 4.8 mm x 750 mm Strut 9 - Steel, 15 mm x 4 mm x 750 mm Strut 10 - Steel, 10 mm x 5 mm x 750 mm

Item	Details
Optional Struts **Nominal Dimensions**	Strut A - Hardwood (Mahogany), 20 mm x 6 mm x 550 mm with steel knife edge inserts. Strut B - Plywood (Marine Ply), 20 mm x 6 mm x 550 mm with steel knife edge inserts. Strut C - Glass Fibre, 20 mm x 5.5 mm x 550 mm with steel knife edge inserts. Strut D - Moulded Brass (Extruded brass), D shape, 19 mm x 4.5 mm x 550 mm Strut E - Steel Compound, Two steel struts, bolted together. Both 13 mm x3 mm. One longer (650 mm) with knife edge ends, the other 640 mm. Strut F - Aluminium channel, 13 mm x 13 mm and 1.5 mm thick wall x 750 mm with steel end fittings. Strut G - Aluminium angle, 13 mm x 13 mm and 1.5 mm thick wall x 750 mm with steel end fittings. Strut H - Aluminum angle, 13 mm x 13 mm and 1.5 mm thick wall x 750 mm with steel end fittings. Strut I - Steel Rectangular, 13 mm x 6.4 mm x 650 mm. Strut J - Steel Round, 6.4 mm diameter x 650 mm.

Material	Young's Modulus (Nominal)
Steel	207 $GN.m^{-2}$(207 GPa)
Aluminum	69 $GN.m^{-2}$ (69 GPa)
Brass	105 $GN.m^{-2}$(105 GPa)

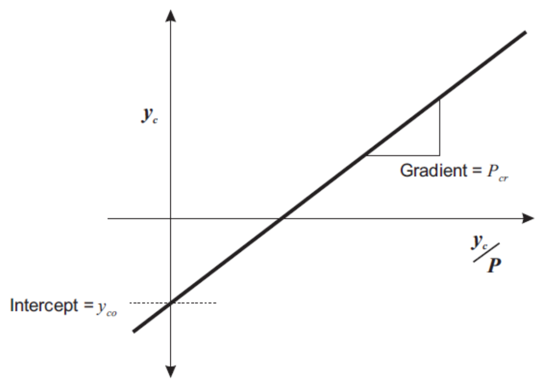
THEORY:

The Southwell Plot and 'Eccentricity of Loading'

Figure shows a comparison of the deflection under load of initially straight and curved struts. With the initially straight strut under perfect conditions, it only deflects when the load reaches the critical value. This gives a clear visual display of the point of buckling. For the initially curved strut, the gradual increase in deflection makes it difficult to see the point of buckling. In reality, struts are not perfect and most will gradually deflect as you apply load.

To help with this, you can use a **Southwell Plot**. A rearranged version of Equation 6 gives this plot, so:

$$y_c = P_{cr}\left(\frac{y_c}{P}\right) - y_{co}$$



Southwell Plot

Equation 6 shows that a plot of y_c against y_c/P will be linear (see Figure 24) and that its slope gives an approximate value of the critical load. Also, the intercept on the y-axis gives an approximate value for the original central out-of-straightness or '**eccentricity of loading'** (y_{co}). This helps you to see how imperfect the strut is.

The Southwell Plot and Testing Struts

During the experiments, you will find two important factors that make the Southwell Plot a useful tool for predicting the properties of a strut.

1. You do not need to test a real strut to its critical (buckling) load to create the Southwell Plot. This allows you to do tests without risk of damaging the struts.

2. For accurate results in some experiment, you need to do two tests and work out the average buckling load (due to the struts natural buckling direction). This is not necessary for the Southwell Plot.

PROCEDURE:

1. Create a blank table of results, similar to Table 6.
2. Connect and switch on the Load Display. Allow a few minutes for the display and the load cell of the measuring end to warm up. Tap the load measuring end to remove any effects of friction, and then zero the display.
3. Find the 600 mm steel strut (strut number 5).
4. Fit the strut in the pinned ends condition as described in Experiment 3 - The Deflected Shape of a Strut.
5. Use the large hand wheel to load the strut slowly to get a deflection of 0.5 mm. As you turn the hand wheel, gently tap the base to help remove any friction in the deflection indicator. Watch the load reading and the deflection of the strut. Record the deflection and load at approximately 0.5 mm intervals until you reach 4 mm deflection. Release the load.

TABULATION:

Load (N)	Deflection (mm)	Deflection /Load
0	0	

PRECAUTIONS:

1. Ensure zero reading on the dial gauge before loading the beam.
4. Note down the readings with parallax error.
5. Do not disturb the apparatus during the experiment.

RESULT:

Divide your central deflection (y_c) results by the load (P) at each deflection to complete your table.

Create a Southwell Plot of central deflection (y_c) against (y_c/P), in fundamental units. From this, note the gradient, to give you the buckling load of the strut. If you have done the earlier experiments, does the gradient agree with the theoretical and actual buckling loads for this strut.

EXPERIMENT NO: 5

BENDING TEST

AIM:

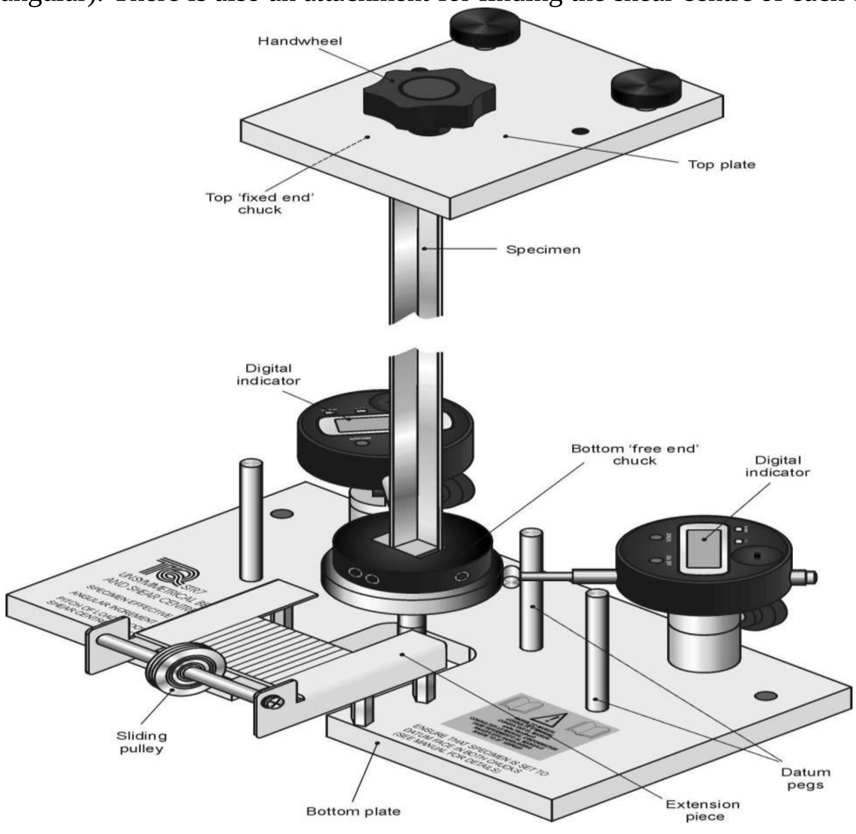
To perform Unsymmetrical Bending of cantilever beam.

APPARATUS REQUIRED:

1. Unsymmetrical bending structure frame
2. Digital indicator
3. Hanger and mass
4. Angle specimen
5. U section specimen
6. Rectangular specimen

THEORY:

Figure shows the Unsymmetrical Bending and shear Centre experiment. It consists of a top plate and chuck, a bottom plate with two digital indicators, a 'free end' chuck and three specimens ('U','L' and rectangular). There is also an attachment for finding the shear centre of each beam.



The top plate fastens to the top member of the Test Frame, and the bottom plate on the bottom member. The specimen beams secure into the top plate chuck, which indexes around in 22.5° steps (giving 16 angular increments). The bottom plate has two digital indicators than can be arranged at 90° to each other for the unsymmetrical bending experiment or parallel to each other for the shear centre experiment. The bottom chuck secures to the 'free' end of the specimen and contacts the two indicators. This arrangement allows measurement of the end deflection of the specimen in two directions. The force is applied to a peg on the bottom chuck. For the shear centre experiment the indicators swing round and the shear beam attachment fixes to the bottom chuck.

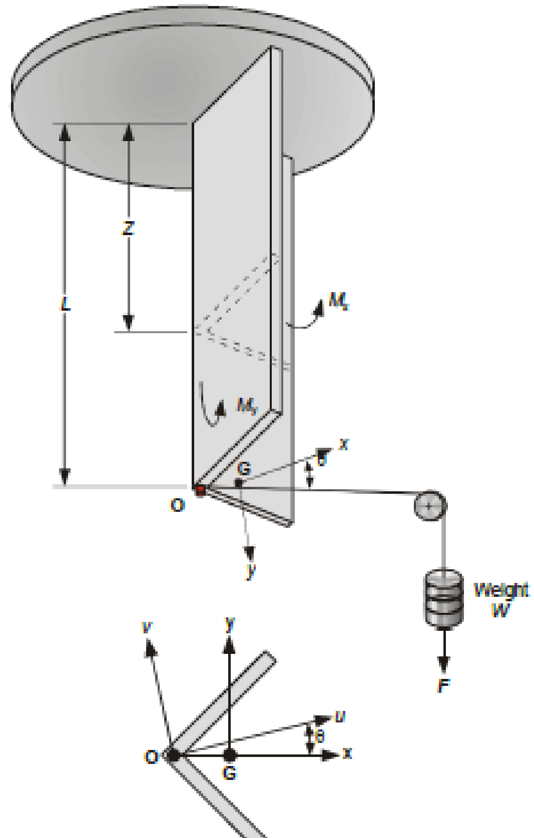


Figure3 Cantileverschematic andnotation

Figure shows a cantilever beam with a load applied at the free end. The beam has two **principal axe**s, x and y, about which pure bending can take place. The principal axes pass through the centroid of the section but do not necessarily coincide with the arbitrary geometrical axes of the section.

If applying a moment about one of the principal axis then the beam will deflectionn that direction only and the simple bending formula can predict the deflection.

However, if the moment is at an angle to either of the axes then the beam will bend about both of the axes. The free end deflection will have two components one in the direction of pull (U)and at right angles(V).

If we were interested in predicting them agnitude of the deflections,we would need to resolve the moment into components acting about theprincipal axes.This leads to the following formulae (standard texts out line the derivation.

$$U = \frac{FL^3}{6E}\left[\left(\frac{1}{I_x}+\frac{1}{I_y}\right)+\cos 2\theta\left(\frac{1}{I_y}-\frac{1}{I_x}\right)\right]$$

$$V = \frac{FL^3}{6E}\sin 2\theta\left[\frac{1}{I_x}-\frac{1}{I_y}\right]$$

where:

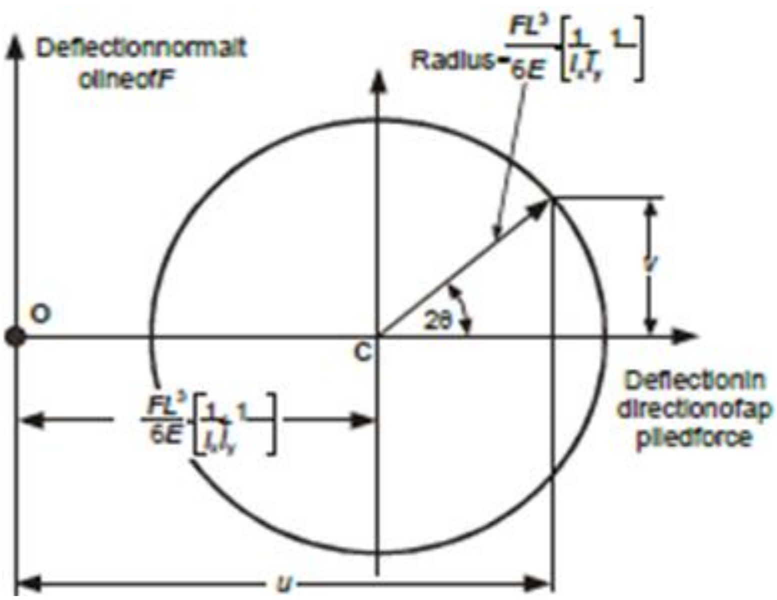
- F = Force
- L = Effective length of the specimen(m),
- E = Young’s modulus (GNm^{-2}),
- U = Deflection in the direction of pull (m),

V = Deflection at right angles to the pull (m),

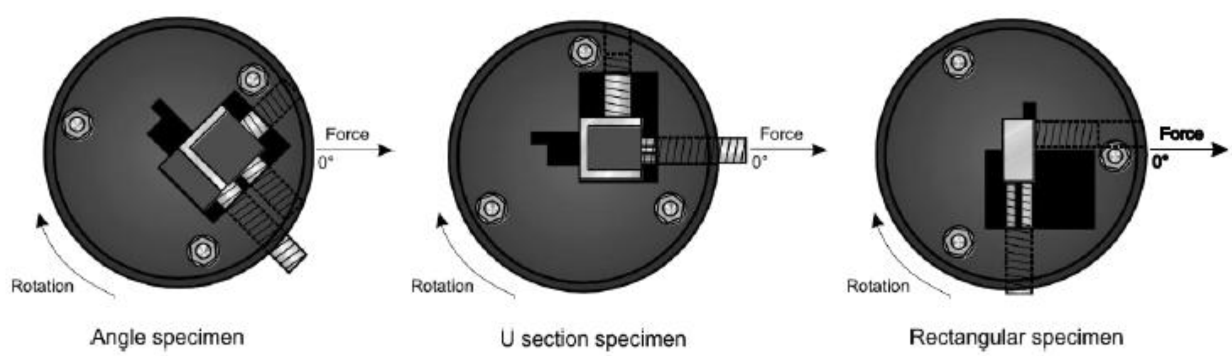
θ = Angle of pull (°),

I_X, I_Y = Principal second moments of area (m^4).

A good way of reading off the cantilever deflections forvarious angles is to construct a Mohr's Circle. The Mohr's Circle is an excellent graphical method, which you may have come across before in stress analysis. To construct a Mohr's Circle of deflections you would need to know at least the principal second moments of area ($I_X$andI_Y). In this experiment we will use the Mohr's Circle in reverse to establish values of the principal second moments of area from deflections measured off the equipment in each direction (U and V). We can then compare the principal second moments to theoretical values.



Morh's circle of deflection to find out principle second moment of area



Place an assembled Test Frame (refer to the separate instructions supplied with the Test Frame if necessary) on a work bench. Make sure the 'window' of the Test Frame is easily accessible Referring to Figure,ensure there are two securing nuts in each of the top and bottom members in the top slot. If none are present, move them from other positions on the frame (seeSTR1instructionsheet). When fitted slide them to approximately the positions shown in Figure. Position the top and bottom plates onto the frame as shown, and fix using the thumb screws.

PROCEDURE:

1. Ensure that the equipment is setup as following steps 1 and 2 on page 2. Loosen the two rear ward facing thumb screws on the indicator bosses, turn the indicators inward to contact the inner two datum pegs and lock off the thumb screws. This sets the 90° angle between the two indicators.
2. Select one of the three specimens and fit it into the bottom chuck referring to Figure for correct positions. Fit the top of the specimen into the top chuck in the same relative position, ensure that the specimens are set squarely and all of the screws are tight .Fit the extension piece to the bottom chuck ,hook the cord on to the groove and pass it over the sliding pulley.
3. Undo the top chuck hand wheel and rotate the specimen so it is orientated at 0° as per Figure. When you feel the chuck 'click' into the correct position tighten the hand wheel.
4. Ensure that the indicators have about 10-11mm forward and 2-3mm backward travel in this position; if not loosen the indicator top screw and slide the indicator to the correct position, retighten the screw.
5. Tap the frame sharply to reduce the effect of friction and zero the indicators. Apply loads in 100 gincrements, up to a maximum of 500 g on the end of the cord. Ensure the cord remains parallel to the lines on the plate below. Tap the frame sharply after adding each load. Record the resulting deflections (left and right) in Table under the 'Head angle: 0°' title.
6. You may find the following table useful in converting the masses used in the experiments to loads.
7. Undo the top chuck hand wheel, rotate the specimen clock wise 22.5° (i.e. to then ext location) and tighten.
8. Zero the indicators, if required, and the n repeat the loading procedure, recording the results under 'Headangle:22.5°'in Table. Continue taking results until the specimen has rotated 180°.
9. With all the tables complete, resolve the left and right indicator readings into the *U* and *V* directions using the following formulae:

$$U = \frac{(\text{left} + \text{right})}{\sqrt{2}} \qquad V = \frac{(\text{left} - \text{right})}{\sqrt{2}}$$

10. Be careful with your signs as these values can be negative. Plot graphs of U and V (mm) versus the pulling mass, P (in grams) for each head angle. Establish gradients of dU/dP and dV/dP on each graph noting the results in Table (in mmg-1). Convert these values into fundamental units of N/m.

11. Use this data to construct a Mohr's Circle by plotting the values of dV/dP versus dU/dP for each head angle. The points should form a circle; if distorted draw a circle that encompasses most of the points or draw two circles and average them.

12. Calculate the principal second moments of area using the Mohr's Circle and the following formulae:

$$I_y = \frac{L^3}{3E(OC + R)}$$

$$I_x = \frac{L^3}{3E(OC - R)}$$

Where:

L = Effective length of the specimen (m),

E = Young's Modulus (69 GNm^{-2} For aluminum),

OC = Distance from origin to centre of Mohr's Circle (mN^{-1}),
R = Radius of Mohr's Circle (mN^{-1}).

TABULATION:

Mass (Grams)	Load (Newton's)
100	0.98
200	1.96
300	2.94
400	3.92
500	4.90

Grams to Newton's conversion table

Loading angle (°)	dU/dP (mmg^{-1})	dV/dP (mmg^{-1})	dU/dP ($x10^{-6} mN^{-1}$)	dV/dP ($x\ 10^{-6} mN^{-1}$)
0				
22.5				
45				
67.5				
90				
112.5				
135				
157.5				
180				

dU/dP and dV/dP for each angle

Experimental results for unsymmetrical bending of an angle section

Headangle:0^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

Headangle:67.5^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

Headangle:135^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

Headangle:22.5^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

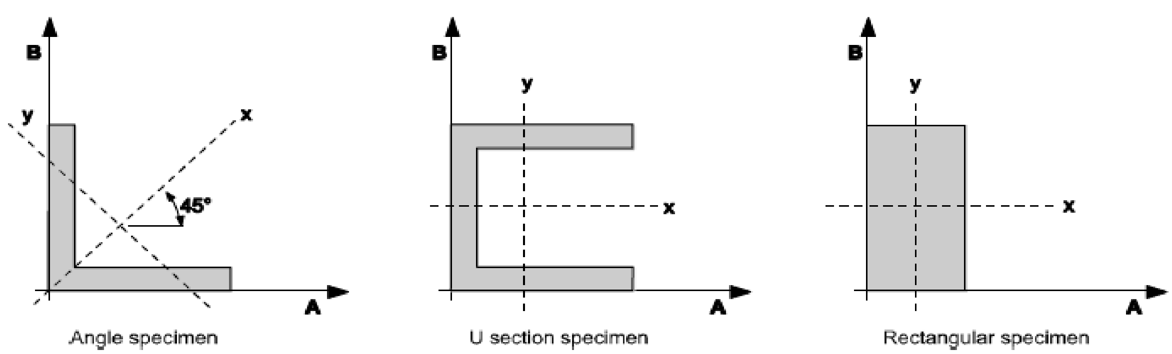
Headangle:90^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

Headangle:157.5^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

Headangle:45^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

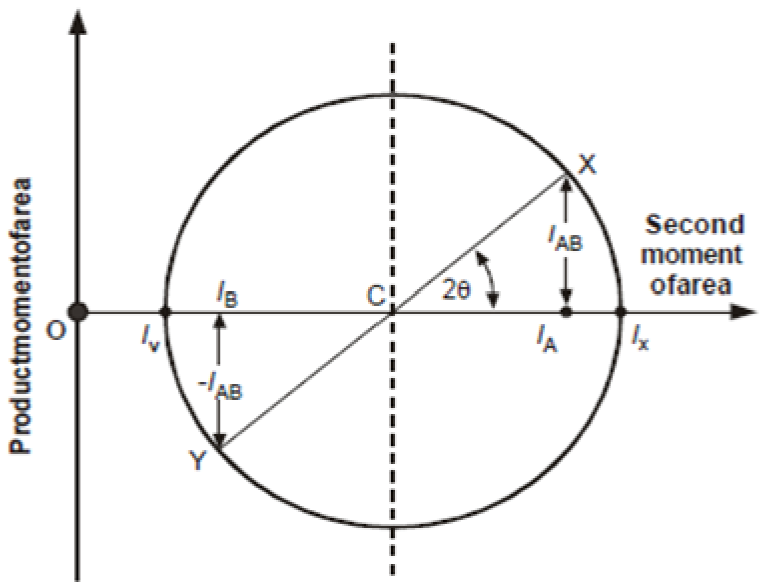
Headangle:112.5^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				

Headangle:180^{o}				
Load (g)	Left dial	Right dial	*U*	*V*
0				
100				
200				
300				
400				
500				



Orientation of the arbitrary and principal axes for the three test sections

To find the theoretical principal second moments of area in some cases is quite easy. In others it can be a little more involved. For symmetrical sections, axes of symmetry areal ways principal axes. The rectangular section has two axes of symmetry and therefore the principal axes are easily obtained, refer to Figure. When the location and orientation of the principal axes is not obvious, we can determine these by firsts electing arbitrary axes A and B, we then use an appropriate method to calculate *IA* and *IB* (the second moment of area about the axes A and B) and *IA B* (the product moment).We then use a Mohr's Circle to find the principal second moments of area and the position of their axis in relation to. The arbitrary axes A and B. To construct a Mohr's Circle follow the steps below and refer to Figure. Set up horizontal and vertical axes for the second moments and product moments respectively. Plot *I*A and *I*A B to give A point X and I_B and–I_{AB} to give a Point Y. Join points X and Y to give the point C. With the centre C and the radius CY draw a circle.



Mohr's for second moment of area

The two points where the circle crosses the horizontal axis are the values of the principal second moments of area Ix and Iy. Join up the points X and Y and measure the angle from the horizontal axis (in the case of an equal 'L' section, this Should be a vertical linei.e.90°). The position of the principal axes in relation to the axes A and B = measuredangle/2(i.e.45°f
Or an equal 'L' section). This method applies to any section regardless of complexity as long as the IA , IB and IAB values can be calculated. Compare the theoretical values to the e xperimental values and comment on the accuracy of your results. Give possible reasons for any discrepancy between the theoretical and experimental value se their in terms of the analysis or
In the equipment. Is the graphical Mohr's Circle method truly accurate? If not how could it be made more so.

PRECAUTIONS:

1. Ensure zero reading on the dial gauge before loading the beam.
2. Note down the readings with parallax error.
3. Do not disturb the apparatus during the experiment.

RESULT:

EXPERIMENT NO: 6/7

SHEAR CENTRE FOR OPEN/CLOSED SECTION

AIM:

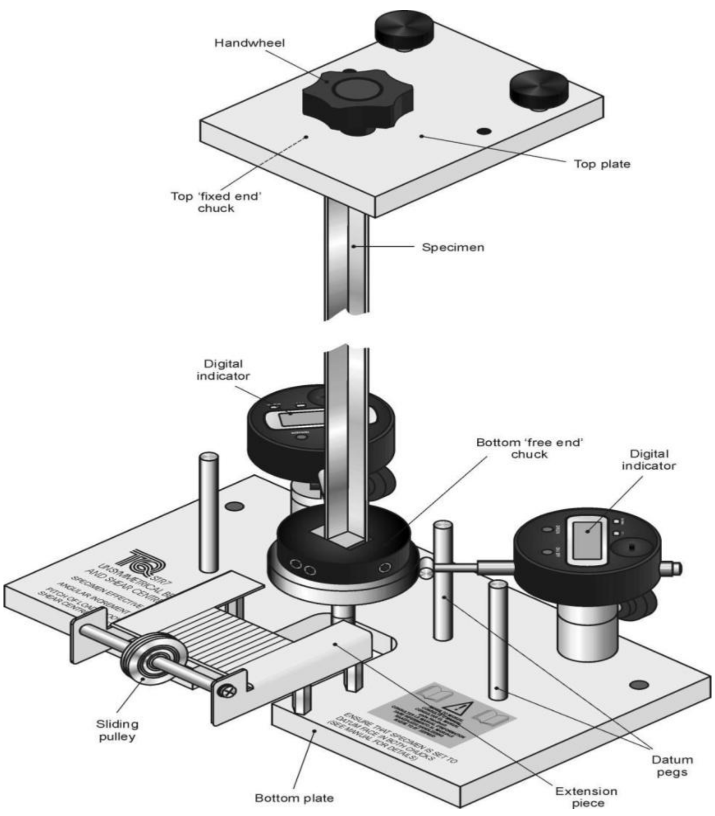
To find shear centre of an open section.

APPARATUS REQUIRED:

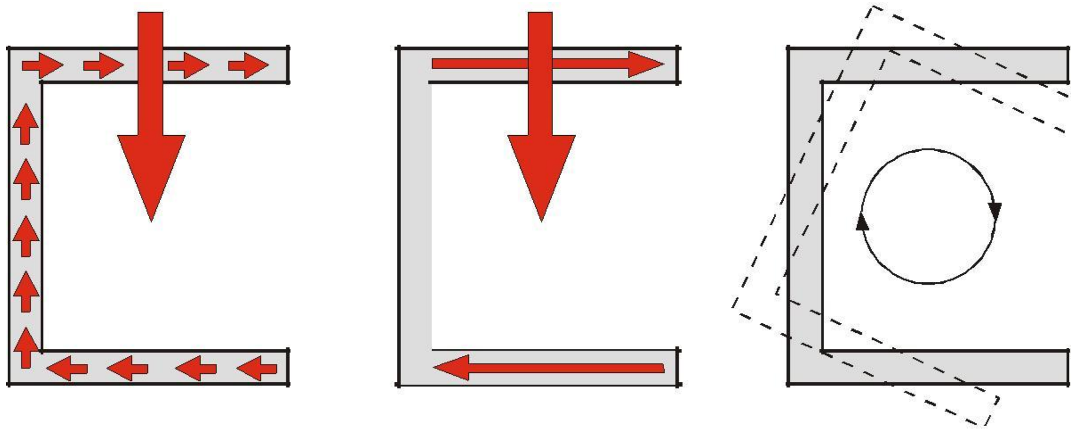
1. Unsymmetrical bending structure frame
2. Digital indicator
3. Hanger and mass
4. Channel section specimen
5. U section specimen
6. Rectangular specimen

THEORY:

Figure shows the Unsymmetrical Bending and Shear Centre experiment. It consists of a top plate and chuck, a bottom plate with two digit al indicators, a 'free end' chuck and three specimens ('U', 'L' and rectangular). There is also an attachment for finding the shear centre of each beam.



The top plate fastens to the top member of the Test Frame, and the bottom plate on the bottom member. The specimen beams secure into the top plate chuck, which indexes around in 22.5° steps (giving 16 angular increments). The bottom plate has two digital indicators than can be arranged at 90° to each other for the unsymmetrical bending experiment or parallel to each other for the shear centre experiment. The bottom chuck secures to the 'free' end of the specimen and contacts the two indicators. This arrangement allows measurement of the end deflection of the specimen in two directions. The force is applied to a peg on the bottom chuck. For the shear centre experimentthe indicators swing round and the shear beam attachment fixes to the bottom chuck



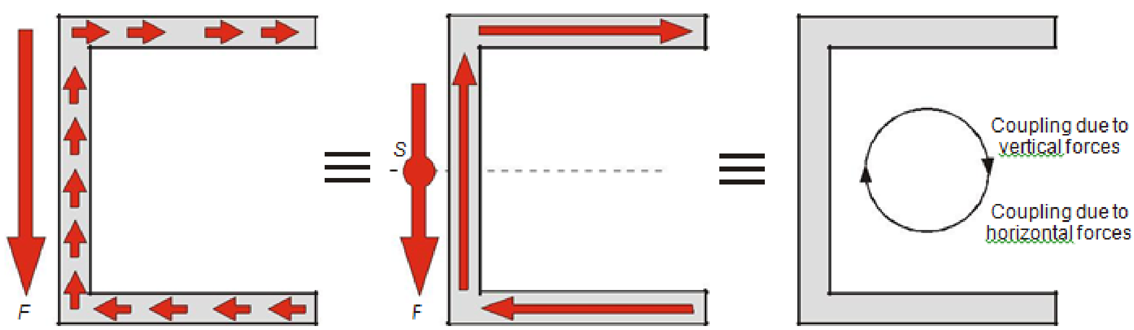
The applied force induces shearing stress in the section.

Shearing stresses give rise to Shearing forces. For equilibrium, The vertical shear force is equal to *F*; the two horizontal shearing forces are equal.

The coupling due to the vertical and horizontal forces are in the same direction, so the section twists.

Beams will always bend when loaded but unless the load is applied at a position known as the **ShearCentre** the bending will be accompanied by a twistingaction. Figure shows the 'U' section loaded with a force *F* (on its side). The load sets up shearing stresses in the section caused by the shear force.

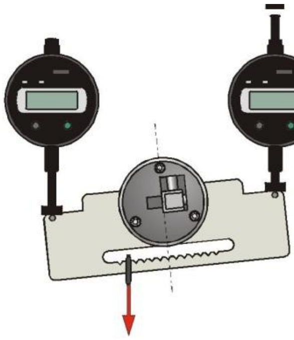
For equilibrium the vertical force must balance the applied load and the two horizontal shearing forces must be equal and opposite. The two horizontal forces form two moments, which combine to twist the section.

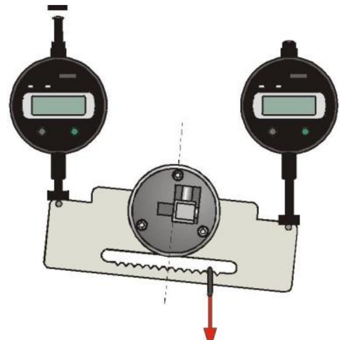


The 'U' section under load through its shear centre

However, if the beam is loaded at its shear centre, S as shown in Figure then the two moments cancel out. The beam then bends but does not twist.

In this experiment we will purposely load the 'U' section eccentrically, that is at positions each side of the shear centre and measure the twisting action with the indicators each side of the section. We can then ascertain the position of the shear centre, since it is the point of zero twist (i.e. when the two indicator readings are identical).





Load to the left of shear centre   Load to the right of shear centre   Load at shear centre

PROCEDURE:

1. Ensure that the equipment is set up as following steps 1 and 2 on page 2. Loosen the two rearward facing thumbscrews on the indicator bosses, turn the indicators outward to contact the outer two datum pegs and lock off the thumbscrews. This sets the two indicators parallel.
2. Fit the ‘U’ section into the bottom chuck, referring to Figure for correct positions. Fit the top of the specimen into the top chuck in the same relative position, ensuring that the specimen is set squarely and all of the screws are tight.
3. Undo the top chuck hand wheel and rotate the specimen so it is orientated as per Figure. When you feel and hear the chuck ‘click’ into the correct position, tighten the hand wheel.
4. Fit the shear centre beam to the bottom chuck as shown in Figure and secure with the extension piece.
5. Ensure that the indicators have roughly equal travel forward and backward on the shear arm pegs. If not, loosen the indicator top screw, slide the indicator to the correct position and tighten the screw.
6. Tap the frame sharply to reduce the effect of friction and zero the indicators. Apply a load of 500 g to the left-hand notch □25 mm). With the cord over the pulley, ensure that the pulley and cord remain parallel to the lines on the plate below.
7. Record the resulting indicator readings in Table. Repeat with the same load at the other notch positions ensuring the cord remains parallel at all times.

TABULATION:

Eccentricity of load (mm)	Left-hand indicator reading (mm)	Right-hand indicator reading (mm)
-25		
-20		
-15		
-10		
-5		
0		
5		
10		
15		
20		
25		

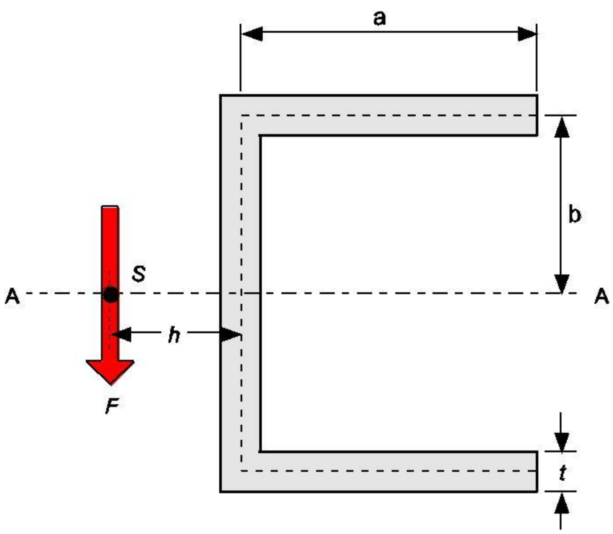
PRECAUTIONS:

1. Ensure zero reading on the dial gauge before loading the beam.
2. Note down the readings with parallax error.
3. Do not disturb the apparatus during the experiment.

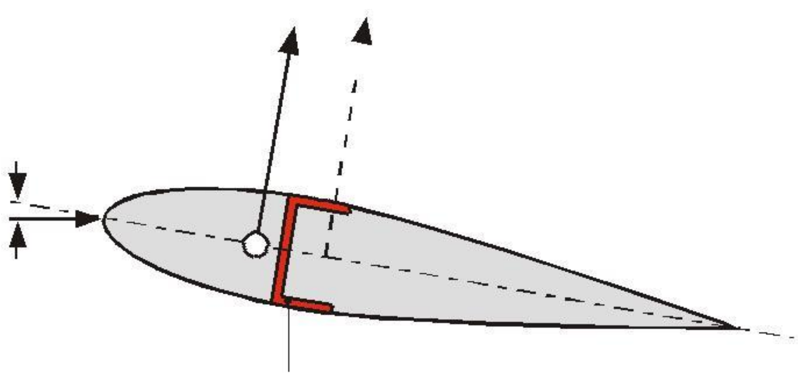
RESULT:

Plot a graph of the indicator readings in mm (y-axis) versus the eccentricity of the load in mm (x-axis). Where the two lines intersect is the position of the shear centre. It is helpful to visualise the position of the shear centre by sketching the section to the x-axis scale on your graph. The theoretical shear centre is given by:

$$h=\frac{b^2 a^2 t}{I_A}$$



Notation for shear centre calculation



An aircraft wing section

Figure shows a section through an aircraft wing. Comment on the possible effects of the aircraft flying at supersonic speeds.

EXPERIMENT NO: 8

WAGNER'S THEOREM

AIM:

The objective of this experiment is to determine the constant K of Wagner beam.

APPARATUS:

1. Wagner's beam setup

THEORY:

In this analysis of wing beams of airplanes the designer is faced with several problems which, in general are present in Aeronautical engineering structural design. The Aeronautical engineering Endeavour's to make the web sheet of all beams thickness enough so that the web will not buckle before the design load is reacted on the structure.

Buckling in a case of failure and the shearing stress causing buckling determines the allowable shear that can be applied. The critical buckling shear stress is given by

$$\tau_{cr} = \frac{\pi^2 E}{12(1-m^2)}\{\frac{t}{b}\}^2,$$

$$\sigma_{cr} = \frac{k\pi^2 E}{12(1-\vartheta^2)}\{\frac{t}{b}\}^2$$

The basic assumption of this theory is that total shear force in the web can be divided into a shear in the sheet and the shear force carried by diagonal tension

$$k = (1-\frac{\tau_{cr}}{\tau})^n$$

If the sheet is very thin, buckling stress given by equation is extremely low and in the interest of making, efficient use of all available material. The aircraft engineer raises the question as too much additional shear can be carried by such a buckled plate before.

- Some portion of the shear has a total stress equal to the yield point of the material. Thus giving rise to permanent deformation or
- The ultimate strength is reached.

OBSERVATIONS:

The thickness of plate :

Distance between the webs :

Distance between the supports :

Channel – 1 – red - white

Channel – 2 – blue - black

Channel – 3 – yellow - green

The Wagner beam constant for a given Wagner is beam to be positive value,

$$\sigma_x = \left(\frac{E}{1-\vartheta 2}\right)(\epsilon_x + \vartheta_{xy})$$

$$\sigma_y = \left(\frac{E}{1-\vartheta 2}\right)(\epsilon_y + \vartheta_{xy})$$

$$C_{xy} = \frac{E}{2(1+\vartheta)}\vartheta_{xy}$$

$$\sigma_1 = \frac{\sigma_x - \sigma_y}{2} + \frac{1}{2}\sqrt{\sigma_x - \sigma_y^2} + 4C_{xy}^2$$

$$\sigma_1 = \frac{\sigma_x - \sigma_y}{2} - \frac{1}{2}\sqrt{\sigma_x - \sigma_y^2} + 4C_{xy}^2$$

To find the Euler's critical buckling shear stress

$$\tau_{cr} = \frac{\pi^2 E}{12(1-m^2)}\{\frac{t}{b}\}^2$$

To find the shear buckling co-efficient K

$$k = (1 - \frac{\tau_{cr}}{\tau})^n,$$

N=1 for linear materials

Where,

$$c = \frac{F}{bt(A)}$$

Shear load/ Area (thickness of plate * width of plate)

TABLE OF READING:

SL.No	Load in kg	ε_A	ε_C	ε_B	σ_x Mpa	σ_y Mpa	C_{xy} Mpa	σ_1 Mpa	σ_2 Mpa

Result:

Thus the constant K of Wagner beam is calculated.

EXPERIMENT NO: 9

SANDWICH PANEL TENSION TEST

AIM:

To find the young's modulus for the given sandwich structures.

APPARATUS:

2. Measuring scale
3. Aluminum sheet of required dimensions
4. Marker
5. Metal sheet cutter
6. Wooden piece
7. UTM
8. Adhesive

SPECIFICATIONS:

Dimensions of wood = 185*65 mm^2
Thickness of wood = 9mm
Young's modulus of wood = 11GPa
Thickness of aluminum sheet = 3mm
Young's modulus of aluminum = 70GPa

THEORY:

The word composite material signifies that two or more materials are combined at a macroscopic level. The advantage of composite material is that, if it is well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent nor possesses.

In common aerospace terminology the term composite structure refers to fiber a reinforced composite which is fiber embedded in resin commonly known as matrix. Here the fiber provides strength and stiffness to carry tension loads and matrix provides support for the fibers and assists the fibers in carrying compressive loads.

CLASSIFICATION OF COMPOSITE MATERIALS:

These are mainly classified into four categories:

1. Fibrous Composite Materials
2. Particulate Composite Materials
3. Laminated Composite Materials
4. Combinations of above.

FIBROUS COMPOSITE MATERIALS:

Long fibers in various forms are inherently much stiffer and stronger than the same material in bulk form. The paradox of fiber having the different properties from the bulk is due to more perfect structure of a fiber. In fiber, the crystals are aligned along the fiber axis. More over there are fewer internal defects in fibers than in bulk material. For example in the materials that have dislocations, the fiber form has fewer dislocations than in bulk form. If we consider ordinary plate glass fractures at stresses below 20MPa, at glass fibers have strength of 2800 to 4800MPa.

A typical fibrous composite material consist of

1. A reinforcement which is of two types

2. Continuous (fibers)
3. Discontinuous (whiskers)
4. Matrix can be divided into
5. Metallic matrices
6. Ceramic matrices
7. Polymer matrices

Particulate Composite Matrix:

Particulate composite materials consist of particles of one or more materials suspended in a matrix of another material. The particles may be either metallic or non-metallic as can the matrix. The four possible combinations of these constituent are as follows.

1. Non-metallic particles in the non-metallic matrix composite materials.
2. Metallic particles in metallic matrix composite materials.
3. Metallic particles in non-metallic matrix composite materials.
4. Non- metallic particles in metallic matrix composite materials.

LAMINATED COMPOSITE MATERIALS:

Laminated composite materials consist of layers of at least two different materials that are bonded together. Lamination is used to combine the best aspects of the constituent layers and bonding material in order to achieve a more useful material. The properties that can be emphasized by lamination are strength, stiffness, low weight, corrosion resistance, wear resistance, beauty or attractiveness, thermal insulation, acoustical insulation etc. such claims are best represented by the examples in which bimetals, clad metals, laminated glass, plastic based laminates and laminated fibrous composite materials are described.

COMBINATIONS OF COMPOSITE MATERIALS:

Numerous multiphase composite material exhibit more than one characteristic of the various classes, fibrous, laminated or particulate composite materials. For example, reinforced concrete is both particulate (because the concrete is composed of gravel in a cement paste binder) and fibrous (because of the steel reinforcement). Also laminated fiber reinforcement composite materials are obviously both laminated and fibrous composite materials. Thus, any classification system is arbitrary and imperfect.

FLITCH BEAMS:

It is common to reinforce beams to withstand loads greater than normally allowable and in some cases different materials may be used to provide the reinforcement symmetrically disposed about the neutral axis.

SIMPLY SUPPORTED BEAMS:

The figure shows a simply supported beam AB of span L carrying a point load W at the mid span C. Since the load is symmetrically applied the maximum deflection y_{max} will occur at the mid span. Each vertical reaction equals W/2.

Consider the left half AC of the span. The bending moment at any section XX in AC at distance x from A is given by

$$EI\frac{d^2y}{dx^2} = \frac{W}{2}x$$

On Integrating, we get

$$EI\frac{d^2y}{dx^2} = \frac{W}{2}x^2 + C_1$$

Where, C_1= constant of integration.

When x=L/2, $\frac{dy}{dx} = 0$

$0=\frac{W}{4}\left(\frac{L}{2}\right)^2 + C_1$

$$C_1 = \frac{-WL^2}{16}$$

Hence, $EI\frac{dy}{dx} = \frac{W}{4}x^2 - \frac{WL^2}{16}$ -------------------- (1) slope equation.

Slope at A: putting x=0, we get $\theta_A = \frac{dy}{dx} = \frac{-WL^2}{16EI}$

Integrating the slope equation, we get

$$EIy = \frac{W}{12}x^3 - \frac{WL^2}{16}x + C_2$$

When x=0, y=0 therefore C_2=0

Hence, $EIy = \frac{W}{12}x^3 - \frac{WL^2}{16}x$--------------------- (2) deflection equation.

Deflection at C:

Putting x=L/2 we get,

$$EIy_c = \frac{W}{12}\left(\frac{L}{2}\right)^3 - \frac{WL^2}{16}\left(\frac{L}{2}\right)$$

$$EIy_c = \frac{WL^3}{96} - \frac{WL^3}{32}$$

$$EIy_c = -\frac{WL^3}{48}$$

$$y_c = -\frac{WL^3}{48EI}$$

BEAM OF HETEROGENEOUS MATERIALS:

It is common to reinforce beams to withstand loads greater than normally allowable and in some cases different materials may be used to provide the reinforcement symmetrically disposed about the neutral axis.

The following expressions hold in all cases:

1. The total resisting moment at any section is the sum of resisting moments caused by the individual material making up the section.
2. Thus, if M_1 and M_2 are resisting moments then the total resisting moment M is given by

   $M = M_1+M_2$
3. For each material, the radius of curvature is same that of the neutral axis apply. Thus, for bending equation becomes

Material 1: $\frac{M_1}{I_1} = \frac{\sigma_1}{y_1} = \frac{E_1}{R_1}$

Material 2: $\frac{M_2}{I_2} = \frac{\sigma_2}{y_2} = \frac{E_2}{R_2}$

On equating radius of curvature we get,

$$\frac{M_1}{E_1 I_1} = \frac{M_2}{I_2 E_2}$$

Procedure:

1. Consider a wooden plate having the dimensions of 185*65*9 mm and two aluminum sheets of 3mm.
2. Prepare epoxy system using araldite resin and hardener with proper mixing ration.
3. Using hand layup technique applying epoxy system on both side of the wooden piece.
4. Attaching the two aluminum sheets on both sides of the wood piece where we epoxy system is applied.
5. The prepared specimen is kept under curing at room temperature for 24 hours.
6. The cured specimen is tested in UTM under 3-point bending test.

Precautions:

1. Use glosses for mixing the epoxy system.
2. Carefully switch ‘ON’ the machine
3. Hold the loads carefully, so that it doesn’t fall on your feet and gets you injured.
4. Set the dial corresponding to the load applied.
5. Be careful while fixing the specimen between the jaws of the UTM
6. Keep your hands away from the parts of the UTM, after the specimen is fixed between the jaws of the machine.

Result:

Thus young’s modulus of sandwich structure is calculated.

EXPERIMENT NO: 10

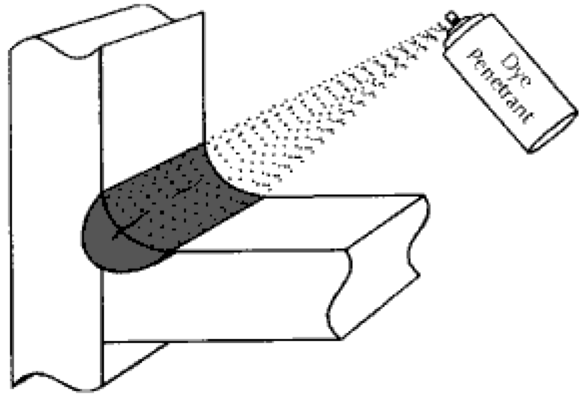
NON-DESTRUCTIVE TESTING
(Dye-Penetration Method)

AIM:
To detect the flaws in the given specimen by conducting Non-Destructive test called Dye-Penetration method.

APPARATUS:
1. Test specimen
2. Cleaner
3. Penetrant
4. Developer

DESCRIPTION:
Dye penetrant inspection (DPI), also called liquid penetrant inspection (LPI) or penetrant testing (PT), and is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials. It can be used for finding discontinuities that are open to surface of solid and non-porous materials. Indications of flaws can be found regardless of size, configuration, internal structure, chemical composition and flaw orientation. Liquid penetrants can seep into the various types of minute surface openings by capillary action. Because of this, the process is well suited for the detection of all types of surface cracks, laps, porosity, shrinkage areas, laminations and similar discontinuities. It is used extensively for inspection of wrought and cast products of both ferrous and non-ferrous metals, powder metallurgy parts, ceramics, plastics and glass.

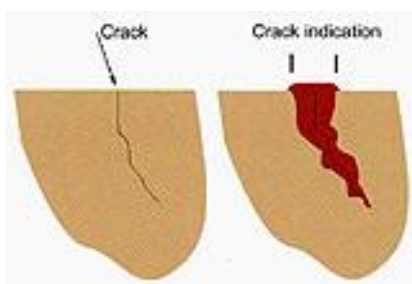
PRINCIPLE OF OPERATION:
DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed, a developer is applied. The developer helps to draw penetrant out of the flaw where a visible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending upon the type of dye used - fluorescent or non-fluorescent (visible).



PENETRANTS:

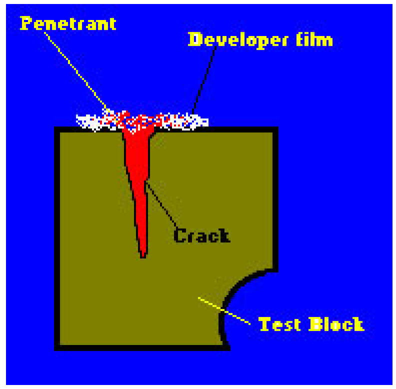
Penetrants are classified into sensitivity levels. Visible penetrants are typically red in color, and represent the lowest sensitivity. Fluorescent penetrants contain two or more dyes that fluoresce when excited by ultraviolet (UV-A) radiation (also known as black light). Since Fluorescent penetrant inspection is performed in a darkened environment, and the excited dyes emit brilliant yellow-green light that contrasts strongly against the dark background, this material is more sensitive to small defects.

When selecting a sensitivity level one must consider many factors, including the environment under which the test will be performed, the surface finish of the specimen, and the size of defects sought. One must also assure that the test chemicals are compatible with the sample so that the examination will not cause permanent staining, or degradation. This technique can be quite portable, because in its simplest form the inspection requires only 3 aerosol spray cans, some lint free clothes, and adequate visible light. Stationary systems with dedicated application, wash, and development stations, are more costly and complicated, but result in better sensitivity and higher samples through-put.



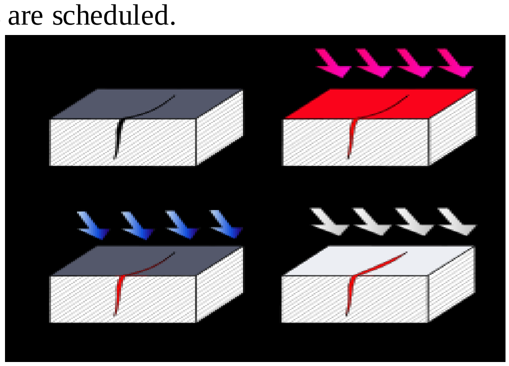
DEVELOPERS:

Several developer types are available, including: non-aqueous wet developer, dry powder, water suspendable, and water soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or suspendable developer with water-washable penetrant), and by inspection conditions. When using non-aqueous wet developer (NAWD) or dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step. NAWD is commercially available in aerosol spray cans, and may employ acetone, isopropyl alcohol, or a propellant that is a combination of the two. Developer should form a semi-transparent, even coating on the surface.



PROCEDURE:

1. The test surface is cleaned with solvents, alkaline cleaning steps, vapor degreasing to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications.
2. The penetrant is then applied to the surface and is allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes).
3. The excess penetrant is then removed from the surface. When using solvent remover and lint-free cloth it is important to not spray the solvent on the test surface directly, because this can remove the penetrant from the flaws.
4. If excess penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that can mask indications or defects. In addition, this may also produce false indications severely hindering your ability to do a proper inspection.
5. After excess penetrant has been removed a white developer is applied to the sample. The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out.
6. Any areas that bleed-out can indicate the location, orientation and possible types of defects on the surface. The indication size is not the actual size of the defect.
7. Inspection of the test surface should take place after a 10 minute development time. This time delay allows the blotting action to occur.
8. The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.



ADVANTAGES:

1. The main advantages of DPI are the speed of the test and the low cost.
2. It can indicate the flaws both in ferrous and non-ferrous metals, plastic object parts and glass object parts.

LIMITATIONS:

1. The main disadvantages are that it only detects surface flaws and it does not work on very rough surfaces.

2. Also, on certain surfaces a great enough color contrast cannot be achieved or the dye will stain the work piece.

RESULT:

Thus the given test specimen is inspected by dye-penetrant method.

EXPERIMENT NO: 11

NON-DESTRUCTIVE TESTING

(Magnetic Particle Inspection)

AIM:

To detect the flaws in the given specimen by conducting Non-Destructive test called magnetic particle inspection.

APPARATUS:

1. Magnetic Yoke
2. Magnetic powder
3. Metal specimen
4. Sprayer

TECHNICAL SPECIFICATIONS:

Input	:	AC 220 volts; 50Hz; single phase supply
Load current	:	2.5 amps
Pull force	:	24kgs in HWDC and 7kgs in AC
Electronics	:	Solid state circuitry Housed in the moulded casings
Features	:	AC current with fixed magnetization level HWDC current with variable magnetization levels Mag button press to ON & release to OFF
Duty Cycle	:	Two minutes ON; Two minutes OFF
Pole adjustment	:	0-300mm
Weight	:	4.0kgs maximum.

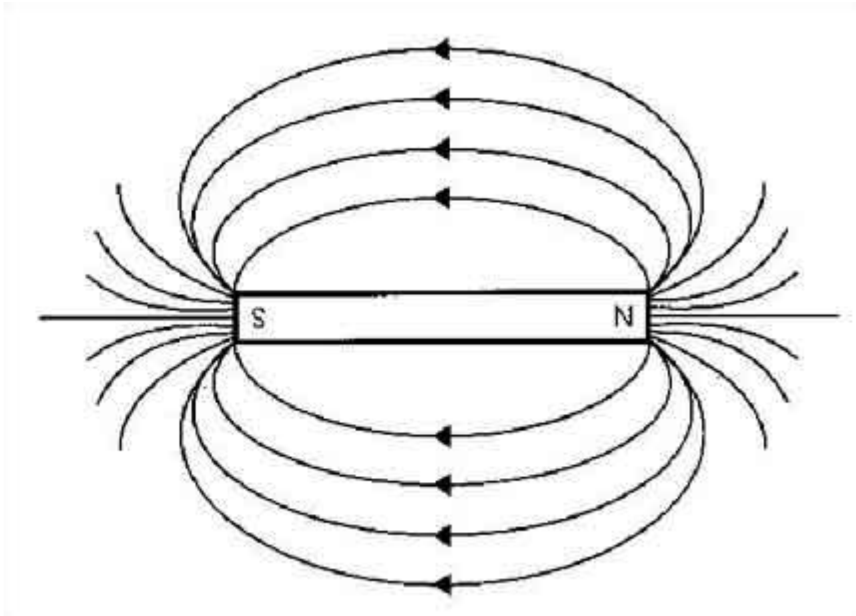
THEORY:

The Magnetic particle method of Non-Destructive Testing is a method for locating surface and subsurface discontinuities in ferromagnetic materials. The basic principle of the magnetic particle technique is to magnetize an object to a flux density that causes Magnetic flux leakage from a discontinuity. Powered ferromagnetic material is then passed through leakage field and those held over discontinuity form an outline of the discontinuity indicating its location, size, shape and extent.

MPI method can be used on any ferromagnetic material. It works best on steel and alloys having high permeability, Gray or malleable iron castings as well as on metallic nickel and cobalt. Stainless steel and other alloys in austenitic state cannot be tested since iron in this state is non-magnetic.

PRINCIPLE OF OPERATION:

This equipment produces longitudinal magnetic field between the legs when energized by pressing the Mag on push button in any model i.e., AC or HWDC. The field is a multiple invisible magnetic flux lines of force across the gap between the legs. When the yoke is brought in contact with Ferro-magnetic material, the generated field takes a path from one leg to the other. Any discontinuity or crack across the field i.e., perpendicular to the line of legs, will cut the flux lines and at the cut area, there will be opposite pole formation. Because of this poles, there will be leakage field in the air above the crack in the same shape. Iron particles sprinkled over this field will get attracted to this field in the shape of the discontinuity.



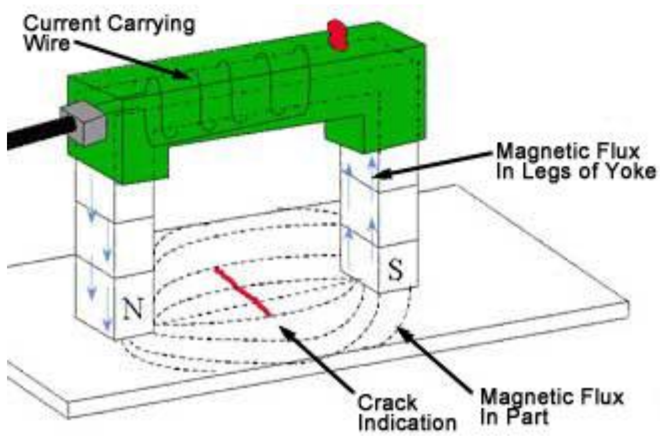
DESCRIPTION OF YOKE:

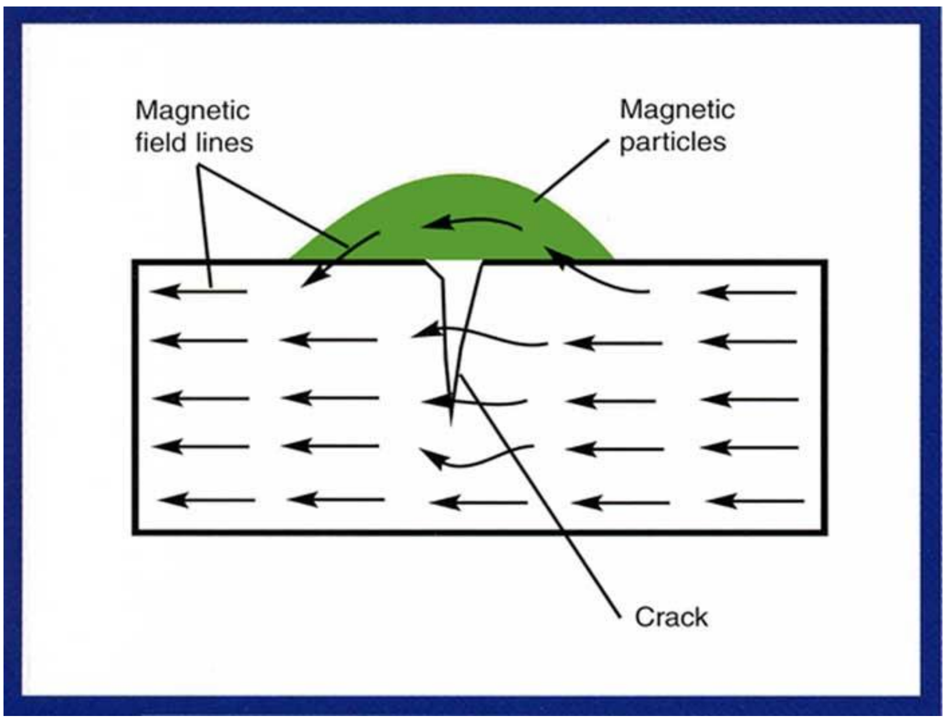
The magnetic yoke is handy, rugged and compact in consstruction and all the components are housed in a moduled casing which the shock and wear resistant. This equipment has a provision of both AC and Half Wave DC currents thus providing corresponding magnetic fields. This equipment can detect both crack surface and sub surface in ferro magnetic materials with limitations. Articulated legs are provided for adjustment of inter pole distance. The maximum distance between the legs can be adjusted upto 300mm maximum. This equipment offers demagnetization with some limitations in AC mode.

The yoke comprises of the U-shape soft iron core. When a current is passed through the coil, the core becomes an electromagnet with strong magnetic poles at the tips. Surface and near surface cracks lying transeverse to this field and also those up to 45 degrees on either side cause a leakage field to be developed at the crack. When sprayed with the dry magnetic powder or wet magnetic bath, the leakage field to form an indication of the cracks attracts the fine particles.

The electro magnetic yoke is “ plug in and use” type and check the following

1. Attach the adaptor to the yoke. Attach legs by tightening the wing key, if required.
2. Ensure that the power supply is 230V on the mains supplyand check operation of the yoke on DC as well as on AC mode.
3. Adjust the AC current with the help of the knob provided and feel it is operating.
4. If the yoke is working properly without any heating or sparking etc then the yoke is installed properly.





ADVANTAGES OF MAGNETIC PARTICLE INSPECTION (MPI):

1. Simple and reliable method for finding surface and sub surface cracks.
2. Indications are produced directly on surface and skilled operatores can judge crack depth quite accurately.
3. There is little or no limitation to size and shape of part being tested.
4. No elaborate pre-cleaning is required.
5. Easy to learn the method, quick and simple to operate.
6. Can be made fully automatic for bulk testing of materials for the industry.

LIMITATIONS FOR MAGNETIC PARTICLE INSPECTION (MPI):

1. Works only on ferromagnetic materials.
2. Direction of mgnetic field must intercept plane of discontinuity, which should be taken care of.
3. Exceedingly heavy currents are sometimes required for testing very large casting and forging.
4. Care should be taken to avoid local heating and burning at the point of electrical contact.

5. Most components need demagnetization after crack detection. It creates problem in case of DC current used for magnetization. Excessive magnetizing current or structural design of the article can create non-relevant indications.

PROCEDURE:

1. The surface of the test specimen should be clean, free from dirt, rust, oil or grease. This can be done with wire brush or by other means.
2. Then the specimen is magnetized both in circular and longitudinal direction by magnetic yoke.
3. Dry magnetic powder can be applied by sprinkling or dusting on the surface of the part.
4. The excess powder on the surface of the suspension should be blown off or removed.
5. If wet powder bath is appled on the specimen then it should be magnetized in longitudinal, circular and multi-directions.
6. Water or kerosene can be used as vehicle for wet bath. Wet powder can also be in paste or liquid concentrate.
7. We can examine the suface for powder patterns or indications in the region where there are defects in the specimen.
8. After inspecting the specimen, it should be cleaned as the film of the powder or wet bath may remain on the surface.

PRECAUTIONS:

1. Ensure the proper input power supply.
2. Ensure that the contact of leg is based on the job is firm and full.
3. Do not connect battery or power source to this unit.
4. Do not over enrgise the yoke beyond specified duty cycle.
5. Do not handle carelessly and make the unit fall from heights.
6. Do not change the mode AC-DC while pressing the Mag push Button.

RESULT:

Thus the given specimen is inspected for defects by magnetic particle inspection method.

EXPERIMENT NO: 12

VIBRATION TEST FOR BEAM

AIM:

To estimate the fundamental frequencies and the damping ratio of the given specimen by performing vibration testing under the action of impact load.

APPARATUS:

The equipment required for carrying out this experiment is described below.

1. A source for excitation signal
2. Power Amplifier
3. Exciter
4. Transducers
5. Conditional Amplifiers
6. Analyzer or Data Acquisition System(DAS)

TECHNICAL SPECIFICATIONS:

i. A source or excitation signal

This will depend on the type of test being undertaken. In this experiment, a transient excitation signal is generated by applying an impact with a hammer.

ii. Power Amplifier

This component will be necessary in order to drive the actual device used to vibrate the structure which, in turn, will take one of a number of different forms, as discussed below. The power amplifier will necessarily be selected to match the excitation device.

Fig 1: Showing Power Oscillator

iii. Exciter

The structure can be excited into vibration in several ways, here by a hammer blow. **

Impact Hammer Specifications:
MAKE : PCB
MODEL NO : 086C03
SENSITIVITY (+/-15%) : 2.25mV/N
MEASUREMENT RANGE: 2224N pk

** (Figure of hammer be enclosed)

iv. Transducers

They are devices available to measure the excitation forces and the various responses of interest. Here, we make use of piezoelectric acceleration transducers to measure acceleration response.

Accelerometer Specifications:
Sensitivity (+/-10%) : 10mV/g
Measurement Range : +/-50 g pk
Frequency Range(+/- 5%) : 0.5 to 10000 Hz

Fig 2: Showing Acceleration Transducer

v. Conditioning Amplifiers

The choice of amplifier depends heavily on the type of transducer used and should, in effect, be regarded as part of it. In all cases, its role is to strengthen the (usually) small signals generated by the transducers so that they can be fed to the analyzer for measurement.

Here, we make use of two accelerometer amplifiers.

Fig 3: Showing Accelerometer Amplifier

vi. Analyzer or Data Acquisition System (DAS)

The function of an analyzer is simply to measure the various signals developed by the transducers in order to ascertain the magnitudes of the excitation force(s) and responses. In essence, it is a voltmeter but in practice it is a very sophisticated one.

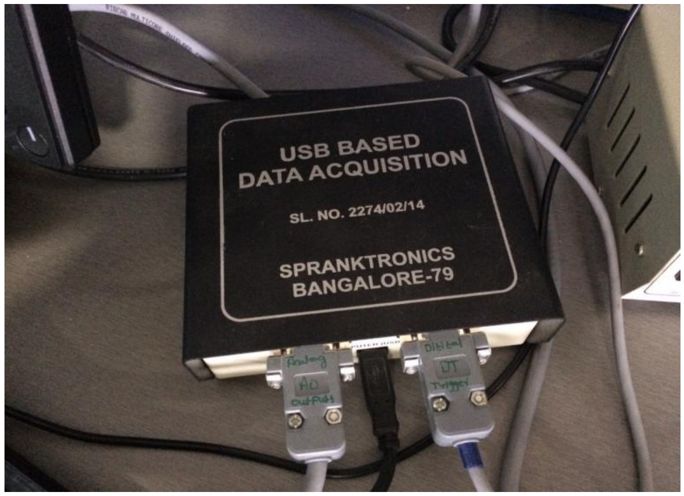


Fig 4: Showing Data Acquisition System

THEORY:

MODAL DATA ACQUISITION

Acquisition of data that is used in the formulation of a modal model involves many important technical concerns. The primary concern is the digital signal processing or the converting of analog signals into a corresponding sequence of digital values that accurately describe the time-varying characteristics of the inputs to and responses from a system. Once the data is available in digital form, the most common approach is to transform the data from the time domain to the frequency domain by use of a discrete Fourier transform algorithm. Since this algorithm involves discrete data over a limited time period, there are large potential problems with this approach that must be well understood.

ANALYSIS OF MEASURED RESPONSE FUNCTIONS

The next stage in the modal test procedure is the analysis which is applied to the measured response functions in order to reveal the properties of the mathematical model which closely describes the behavior of the measured structure. The first part of this stage comprises a process of `modal parameter extraction' or `modal analysis' in which the measured response functions are scrutinized in some detail in order to determine the underlying formulas which can be used to characterize their form. This is usually achieved by using curve-fitting procedures, where the basis of each curve is a theoretically-generated formula developed for an MDOF system with, at the outset, unknown parameters. By applying curve-fitting procedures, least-squares or other criteria can be applied in order to determine the best-fit coefficients in these expressions such that a theoretically-regenerated curve can be constructed to pass through the measured data points with the minimum of discrepancy

PROCEDURE:

1. The general layout for carrying out this experiment is shown below.

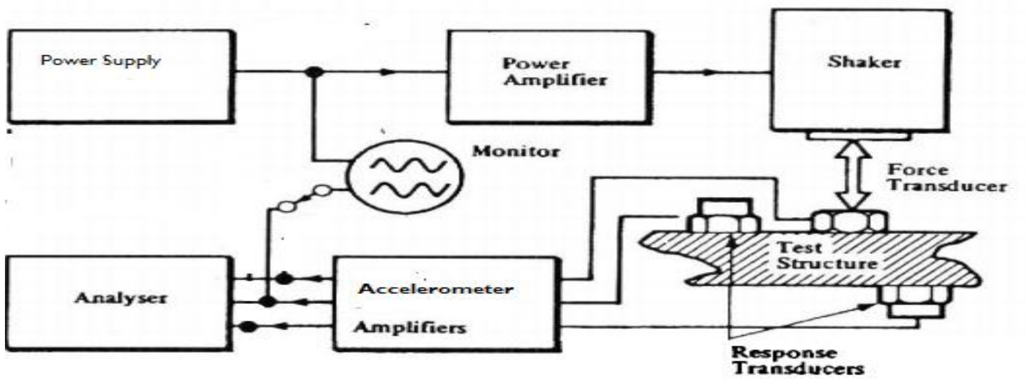


Fig 5: Showing layout of the Vibration Testing system (Source: Ewins D.J, Modal Testing Theory and Analysis)

2. The specimen is clamped to the cantilever beam fixture as shown in Fig 6.
3. The rubber tip to the impact hammer is connected by first inserting it at the required tip and rotating it tight as shown in Fig 7.

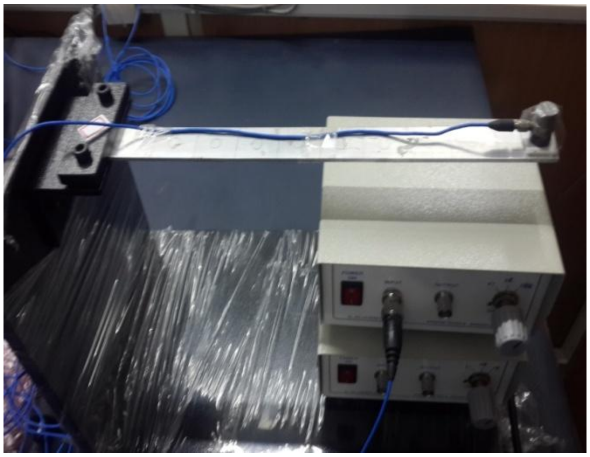


Fig 6: Showing Initial Set-Up

4. Next, connect 1:1 B&C cable,-one end to the hammer and the other end to the amplifier input. As shown in Fig 8. Here, Accelerometer Amplifier, with the gain selector switch of 20 to be used for Impulse hammer excitation
5. Next, connect output port with the cable marked IH for data acquisition of Impulse hammer signal as shown in Fig 9.
6. Connect the data acquisition system cables as shown in Fig 10.

Fig 7: Showing the rubber tip being fixed to one end of the impact hammer

Fig 8: Showing one end of 1:1 B&C cable being connected to impact hammer and the other end to the Input port of Accelerometer Amplifier

Fig 9: Showing IH cable being connected to output port

Fig 10: Showing Connections to the DAS

7. Next, acquire the impulse response data without digital trigger by just clicking the start data acquisition button from the software menu, immediately followed by a gentle tap from the impulse hammer tip as shown in Fig 11. Hammer tip should be perpendicular to the beam. Based on the sampling interval and number of data points to be stored input in the software, impulse hammer and accelerometer data will be stored in the user defined file.
8. Or, for acquiring the impulse response data with digital trigger, just click and release the switch two times as shown, immediately followed by a gentle tap from the impulse hammer tip as shown in Fig 12. Hammer tip should be perpendicular to the beam. Based on the sampling interval and number of data points to be stored input in the software, impulse hammer and accelerometer data will be stored in the user defined file.

Fig 11: Showing Impact loading with hammer without using trigger

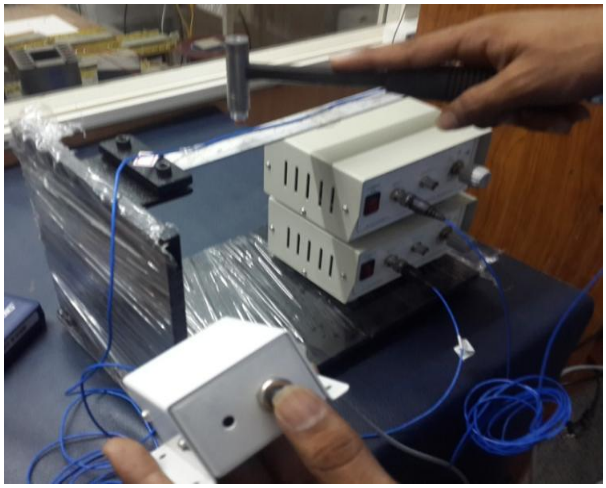


Fig 12: Showing Impact loading with hammer using trigger

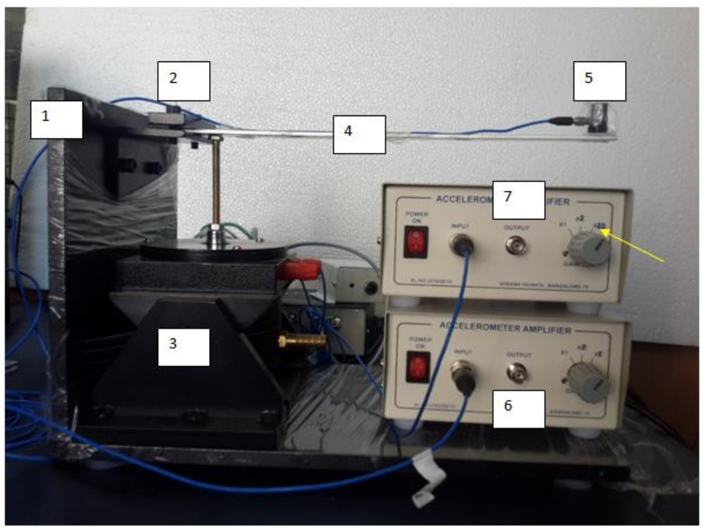


Fig 13: Showing Impact loading with hammer using trigger

PRECAUTIONS:

1. Check the connection properly connected or not
2. Readings should be regular taken note.
3. See that the equipement is far from the other vibrating sources.

RESULT:

The natural frequency of the beam is

EXPERIMENT 1

1.1 PRE – LAB QUESTIONS
1. What do you mean by tension test?
2. What physical properties you are going to identify using tension test.
3. Draw and explain stress strain diagram of mild steel.

1.2 POST – LAB QUESTIONS
1. What is the critical load of the specimen?
2. What do you observe in the graph obtained?
3. What do you know about universal testing machine?

1.3 ASSIGNMENT QUESTIONS
1. Explain briefly about the longitudinal characteristics of the mild steel.
2. Explain about various tensile loads acting on an aircraft when it is in the cruise.
3. Write the mechanical properties of the mild steel.

EXPERIMENT 2

2.1 PRE – LAB QUESTIONS
1. What are types of beams
2. What is plasticity?
3. Write the bending moment equation for a beam.

2.2 POST – LAB QUESTIONS
1. What is the difference between plastic bending and elastic bending?
2. how you calculate the maximum deflection of beam.
3. Draw the bending moment diagram for a beam.

2.3 ASSIGNMENT QUESTIONS
1. Explain the behavior of a beam under the three point bending.
2. What are the different types of beams with sketch?
3. Write the deflection formula for all the types of beams.

EXPERIMENT 3

3.1 PRE – LAB QUESTIONS
1. What is long column
2. How you apply compressive load on column
3. What for you are applying compressive load

3.2 POST – LAB QUESTIONS
1. What is slenderness ratio
2. What do you mean by effective length of the column
3. What is the meaning of critical load

3.3 ASSIGNMENT QUESTIONS
1. Derive an equation for critical load

2. Explain briefly about the different types of columns
3. What is the different between beam and column

EXPERIMENT 4

4.1 PRE – LAB QUESTIONS

1. What is the difference between short and long columns
2. what are the applications of short columns
3. what do you mean by buckling of a column

4.2 POST – LAB QUESTIONS

1. which column bear more compressive load
2. is effective length play a critical role in calculating critical load
3. what are the assumptions of Euler buckling theory

4.3 ASSIGNMENT QUESTIONS

1. Derive the formula for effective length of both ends fixed
2. Explain briefly about the different end conditions
3. Compute the eccentricity for the respective column

EXPERIMENT 5

5.1 PRE – LAB QUESTIONS

1. What is unsymmetrical bending?
2. What is plane stress?
3. What is plane strain?

5.2 POST – LAB QUESTIONS

1. Write the equation for principle stresses.
2. Write the equation for principle strain.
3. What are the equilibrium equations?

5.3 ASSIGNMENT QUESTIONS

1. How to calculate the principal second moments of area using the Mohr's Circle.
2. Derive the equation for maximum principle stress.
3. Derive the second moment of inertia of a angle section.

EXPERIMENT 6/7

6.1 PRE – LAB QUESTIONS

1. What is shear centre?
2. Where shear centre lie for symmetrical bodies.
3. Where shear centre lie for open and closed section beams.

6.2 POST – LAB QUESTIONS

1. What is the formula for calculating the shear centre theoretically?
2. What is the importance of finding shear centre?
3. Where the shear centre lie for L, C and Z sections.

6.3 ASSIGNMENT QUESTIONS

1. Find out the distance of shear centre for L section from the origin.
2. Find out the distance of shear centre for C section from the origin.
3. Find out the distance of shear centre for Z section from the origin.

EXPERIMENT 8

8.1 PRE – LAB QUESTIONS

1. What is Wagner's beam?
2. What is epoxy?
3. What is composite?

8.2 POST – LAB QUESTIONS

1. What are the different techniques used for the preparation of laminate
2. How to find the young's modulus of a composite.
3. Mention the methods of testing the composite.

8.3 ASSIGNMENT QUESTIONS

1. Explain the autoclave method of preparing the laminate.
2. Differentiate between the lamina and laminate
3. Explain the procedure of mixing the epoxy, with example.

EXPERIMENT 9

9.1 PRE – LAB QUESTIONS

1. What is composite?
2. State the mixture rule.
3. What is epoxy?

9.2 POST – LAB QUESTIONS

1. What are the different techniques used for the preparation of laminate
2. How to find the young's modulus of a composite.
3. Mention the methods of testing the composite.

9.3 ASSIGNMENT QUESTIONS

1. Explain the autoclave method of preparing the laminate.
2. Differentiate between the lamina and laminate
3. Explain the procedure of mixing the epoxy, with example.

EXPERIMENT 10

10.1 PRE – LAB QUESTIONS

1. What do you mean by dye?
2. What do you mean by penetration?
3. What are the sprays we are going to apply on the body?

10.2 POST – LAB QUESTIONS

1. Explain the procedure of finding a crack using dye penetration technique.
2. Which one is effective when you compare magnetic particle and dye penetration. technique
3. What are the other penetration sprays you can use for cleaning the surface of the body.

10.3 ASSIGNMENT QUESTIONS

1. Explain different types sprays we can use in dye penetration technique and their purposes.

2. Where dye penetration inspection stands among all types of NDT.
3. What kind of structures is inspected using dye penetration technique?

EXPERIMENT 11

11.1PRE – LAB QUESTIONS

1. What do you mean by non destructive testing techniques
2. How important is to identify the crack inside the body
3. How NDT's differ from destructive tests

11.2 POST – LAB QUESTIONS

1. How you identify the crack inside the body using Magnetic particle inspection
2. What is the effectiveness of magnetic particle inspection
3. How important is magnetic particle inspection in aircraft inspection techniques

11.3 ASSIGNMENT QUESTIONS

1. Where magnetic particle inspection stands among all types of NDT
2. Even though it is very easy to inspect given specimen where it is difficult for certain bodies
3. How the magnetism created inside the apparatus

EXPERIMENT 12

12.1 PRE – LAB QUESTIONS

1. What is natural frequency?
2. What is vibrating system?
3. Define the DOF of a system.

12.2 POST – LAB QUESTIONS

1. Explain the vibrating system with sketch.
2. What are the different types of damper?
3. What are methods to reduce the vibration in the system?

12.3 ASSIGNMENT QUESTIONS

1. Derive the equation for a natural frequency.
2. Explain the different parts of a vibration system
3. How the damping coefficient varies, explain.