MECHANICS OF SOLIDS LABORATORY

LAB MANUAL

Academic Year:		**2017 - 2018**
Course Code	**:**	**AAE101**
Regulations	**:**	**IARE - R16**
Semester	**:**	**III**
Branch	**:**	**AE**

Department of Aeronautical Engineering

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal – 500 043, Hyderabad

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Department of Aeronautical Engineering

VISION AND MISSION OF THE DEPARTMENT

VISION

To build a strong community of dedicated graduates with expertise in the field of aeronautical science and engineering suitable for industrial needs having a sense of responsibility, ethics and ready to participate in aerospace activities of national and global interest.

MISSION

To actively participate in the technological, economic and social development of the nation through academic and professional contributions to aerospace and aviation areas, fostering academic excellence and scholarly learning among students of aeronautical engineering.

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**

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
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.

MECHANICS OF SOLIDS LABORATORY INDEX

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp. No.	List of Experiments	Program Outcomes Attained	Program Specific Outcomes Attained
1	Izod impact test	PO1, PO2, PO5, PO9	PSO1, PSO3
2	Charpy impact test	PO1, PO2, PO5, PO9	PSO1, PSO3
3	Rockwell hardness test	PO1, PO9	PSO1, PSO3
4	Bernell hardness test	PO1, PO9	PSO1, PSO3
5	Torsion test	PO1, PO3, PO5, PO9, PO11	PSO1, PSO3, PSO4
6	Direct tension test	PO1, PO2, PO4, PO5, PO8, PO9, PO10, PO11	PSO1, PSO2, PSO3
7	Compression test on a cube	PO1, PO2, PO9	PSO1, PSO3
8	Spring test	PO1, PO4, PO9	PSO1, PSO3
9	Shear test on metals	PO1, PO2, PO3, PO9	PSO3

1. BRINELL HARDNESS TEST

AIM:

- To determine the Brinell hardness of the given test specimen.

APPARATUS:

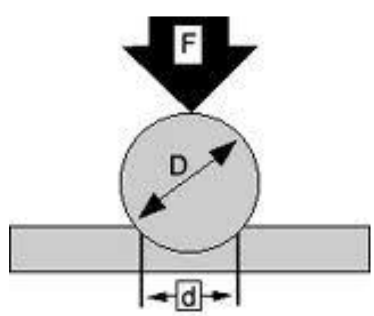
- Brinell hardness machine
- Test specimen
- Ball indenter
- Brinell microscope

THEORY:

Indentation hardness – a number related to the area or the depth of the impression made by a indenter or fixed geometry under a known fixed load.

This method consists of indenting the surface of the metal n\by a hardness steel ball of specimen diameter D mm under a given load F (kgf) and measuring the average diameter d mm of the impression with the help of the brinell microscope fitted with a scale. The brinell hardness HB is defined, as the quotient of the applied force F divided by the spherical area of the impression.

HB = Test load in kgf/ surface area of indentation



i.e., $$HB = \frac{2F}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

PROCEDURE:

1. Select the proper size of the ball and load top suit the material under test.
2. Clean the test specimen to be free from any dirt and defects or blemishes.
3. Mount the test piece surface at right angles o the axis of the ball indenter plunger.
4. Turn the platform so that the bal is lifted up.
5. By shifting the lever, apply the load and wait for some time.
6. Release the load by shifting the lever.
7. Take out the specimen and measure the diameter of the indentation by means of the brinell microscope.
8. Repeat the experiment at other positions of the piece.
9. Calculate the value of HB.

OBSERVATIONS:

Test piece material =

Diameter of Ball 'D' =

Laoad selection F/D^2 =

Test load F =

Load application time =

Least count of brinell microscope =

$$HB = \frac{2F}{\pi D \sqrt{D^2 - d^2}} \text{kg/mm}^2$$

Sl No.	Impression Diameter			F in kg	T in sec	D in mm	HB in kg/mm$_2$
	d_1	d_2	$(d_1+d_2)/2$				
1							
2							
3							
The average value of HB							

PRECUATIONS:

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.
4. Surface of the specimen is well polished, free from oxide scale and any foreign material.

RESULT:

The Brinell hardness number of the specimen is ………………….

2. ROCKWELL HARDNESS TEST

AIM:

- To determine the Rockwell hardness of a given specimen.

APPARATUS:

- Rockwell hardness testing machine.
- Black diamond cone indenter,
- Hard steel specimen.

THEORY:

Hardness: It is defined as the resistance of a metal to plastic deformation again indentation, scratching, abrasion of cutting. Rockwell test is developed by the Wilson instrument co U.S.A in 1920. This test is an indentation test used for smaller specimens and harder materials. The test is subject of IS: 1586. The hardness of a material by this Rockwell hardness test method is measured by the depth of penetration of the hardness. Both ball or diamond cone types of indenters are used in this test. There are three scales in the machine for taking hardness readings. Scale 'A' with load 60kgf or 588.4 N and diamond indenter is used for performing tests on thin steel and shallow case harnessed steel.

Scale 'B' with load 100kgf or 980.7N and 1.588mm dial ball indenter is used for performing tests on soft steel, malleable iron, copper and aluminum alloys.

First minor load is applied to overcome the film on the metal surface. Minor load also eliminates errors in the depth of measurements due to spring of the machine frame or setting down of the specimen and table attachments.

The Rockwell hardness is derived from the measurement of the depth of the impression

E_p = Depth of penetration due to minor load of 98.07N.

E_a = Increase in the depth of penetration due to major load.

E = Permanent increase of the depth of indentation under minor load at 98.07N even after removal of major load.

This method of test is suitable for finished or machine parts of simple shapes.

ROCKWELL HARDNESS SCALES:

Scale Designation	Indenter	Major Load (kg)	Minor Load (kg)	Application
REGULAR ROCKWELL SCALES				
A	Diamond	60	10	thin steel, thin case hardened steel
B	1/16" ball	100	10	Mid-range copper, aluminum, malleable iron
C	Diamond	15	10	Most steels, hard cast iron
D	Diamond	60	10	thin steel, thin case hardened steel, paralytic malleable iron
E	1/8" ball	100	10	cast iron, aluminum &magnesium alloys
F	1/16" ball	60	10	Softer copper, soft thin sheet metal
G	1/16" ball	150	10	Harder copper, malleable iron
H	1/8" ball	60	10	Zinc, lead, aluminum
K	1/8" ball	150	10	Thin soft metals or plastics
L	1/4" ball	60	10	
M	1/4" ball	100	10	
P	1/4" ball	150	10	
R	1/2" ball	60	10	
S	1/2" ball	100	10	
V	1/2" ball	150	10	
SUPERFICIAL ROCKWELL SCALES				
15N	Diamond	15	3	Thin metals, small diameter rounds like wire, or surface hardness testing on shallow case depth materials
30N	Diamond	30	3	
45N	Diamond	45	3	
15T	1/16" ball	15	3	
30T	1/16" ball	30	3	
45T	1/16" ball	45	3	

15W	**1/8" ball**	**15**	**3**	
30W	**1/8" ball**	**30**	**3**	
45W	**1/8" ball**	**45**	**3**	
15X	**1/4" ball**	**15**	**3**	
30X	**1/4" ball**	**30**	**3**	
45X	**1/4" ball**	**45**	**3**	
15Y	**1/2" ball**	**15**	**3**	
30Y	**1/2" ball**	**30**	**3**	
45Y	**1/2" ball**	**45**	**3**	

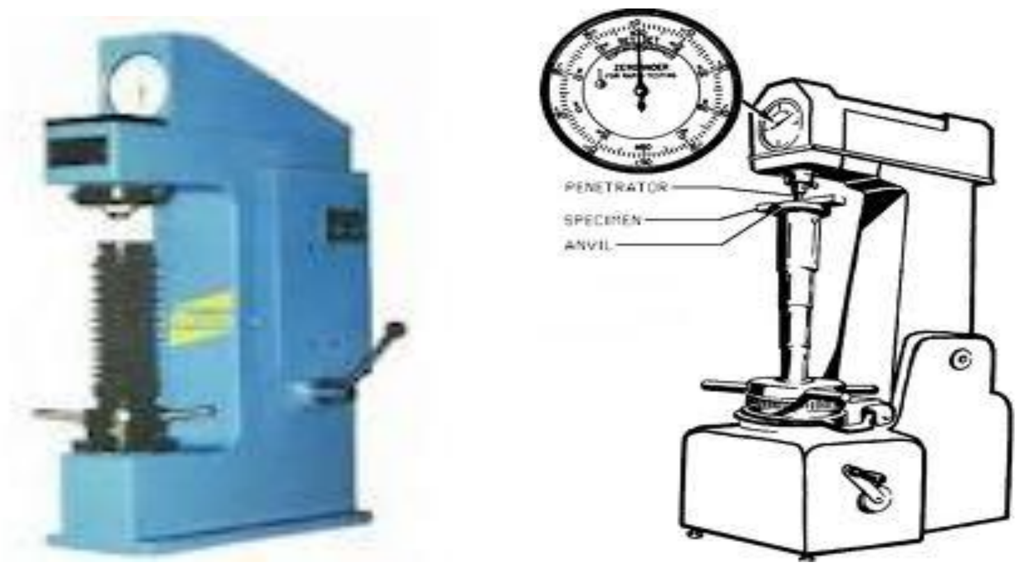


Fig.1 ROCKWELL HARDNESS TESTING MACHINE

PROCEDURE:

1. Select the load by rotating the knob and fix the suitable indenter.
2. Clean the test-piece on the special anvil or work table of the machine.
3. Turn the capstan wheel to elevate the test specimen into contact with the indenter point.
4. Further turn the wheel for three rotations forcing the test specimen against the indenter. This will ensure that the minor load of 98.07N has been applied.
5. Set the pointer on the scale dial at the appropriate position.

6. **6.** Push the lever to apply the major load. A dash pot provided in the loading mechanism to ensure that the load is applied gradually.
7. **7.** As soon as the pointer comes to rest pull the handle in the reverse direction slowly. This releases the major, but not minor load. The pointer will now rotate in the reverse direction.
8. **8.** The Rockwell hardness can be read off the scale dial, on the appropriate scale, after the pointer comes to rest.

OBSERVATIONS:

Material of test piece =

Thickness of the piece =

Hardness scale used =

Test No.	1.	2	3
Hardness value			

PRECAUTIONS:

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.

RESULT:

Rockwell hardness of given specimen is ………………

3. 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:

Fig.2 UTM

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:

Fig.3

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:

Fig.4

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:

Fig.5

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.

Stress (f) = Load (p)/area of cross section (A)

= P/A 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.

$$E = \text{Stress (f)} / \text{Strain (e)}$$

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

4. TORSION TEST

AIM:

- To conduct torsion on given specimen and to find the modulus of rigidity of the material.

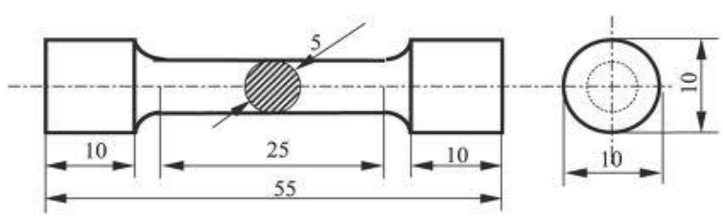
APARATUS:

- A torsion testing apparatus
- Standard specimen of mild steel or cast iron.
- A steel rule and
- Vernier caliper.

<u>THEORY:</u>

A torsion test is quite instrumental in determining the value of rigidity (ratio of shear stress to shear strain) of a metallic specimen. The value of modulus of rigidity can be found out through observations made during the experiment by using the torsion equation:

$$\frac{T}{I_p} = \frac{C\,\theta}{l} \qquad \text{or} \qquad C = \frac{T\,l}{I_p\,\theta}$$



<u>TORSION TESTING MACHINE</u> <u>TEST SPECIMEN</u>

Where,

T=torque applied,

I_p= polar moment of inertia,

C=modulus of rigidity,

θ= Angle of twist (radians), and

l= gauge length.

In the torque equipment. One end of the specimen is held by a fixed support and the other end to a pulley. The pulley provides the necessary torque to twist the rod by addition of weights (w). The twist meter attached to the rod gives the angle of twist.

Procedure:

1. Prepare the testing machine by fixing the two twist meters at some constant lengths from fixed support.
2. Measure the diameter of the pulley and the diameter of the rod.
3. Choose the appropriate loading range depending upon specimen.
4. Set the maximum\m load pointer to zero.
5. Load the member in suitable increments, observe and record strain readings.
6. Continue till failure of the specimen.
7. Calculate the modulus of rigidity C by using formulae within the elastic limit.
8. Plot the graph between C and θ.

OBSERVATIONS:

Gauge length(L) = ………..mm

Diameter of the specimen (D) = ……….mm.

Polar moment of inertia (I_p) = ………..mm^4.

Maximum angle of twist (θ_{max}) =………..rads.

Modulus of rigidity (C) = ………….N/mm^2

Sl No.	L (mm)	D (mm)	T (N-mm)	θ		I_p mm^4	C (N/mm^2)
1							
2							

RESULT:

Modulus of rigidity of the shaft…………

5. IZOD IMPACT TEST

AIM:

- To perform the Izod impact test on metals.

APARATUS:

- Izod impact testing machine
- Test specimen
- Vernier caliper
- Steel rule

THEORY:

In a impact test a specially prepared notched specimen is fractured by a single blow from a heavy hammer and energy required being a measure of resistance to impact.

Impact load is produced by a swinging of an impact weight W (hammer) from a height h. Release of the weight from the height h swings the weight through the a rcof a circle, which strikes the specimen to fracture at the notch.

Kinetic energy of the hammer at the time of impact is $mv^2/2$, which is equal to the relative potential energy of the hammer before its release.ie., P.E = mgh, where m is mass of the hammer and $v = \sqrt{2gh}$is its tangential velocity at impact, g isgravitational acceleration (9.806 m/s^2) and h is the height through which hammer falls. Impact velocity will be 5.126 m/s or slightly less.

Here it is interesting to note that height through which hammer drops determines the velocity and height and mass of a hammer combined determine the energy.

Energy used can be measured from the scale given. The difference between potential energies is the fracture energy. In test machine this value indicated by the pointer on the scale. If the scale is calibrated in energy units, marks on the scale should be drawn keeping in view angle of fall and angle of rise.

Height $h_1$and h_2 equals,h_1= R (1 – cosθ) and h_2= (1 - cosθ).

With the increase or decrease in values, gap between marks on scale showing energy also increase or decrease. This can be seen from the attached scale with any impact machine.

Energy used in fracturing the specimen can be obtained approximately asWh_1-Wh_2.

This energy value called impact toughness or impact value, which will be measured, per unit area at the notch.

Izod introduced Izod test in 1903. Test is as per the IS: 1598

Fig.6 IZOD IMPACT TESTING MACHINE

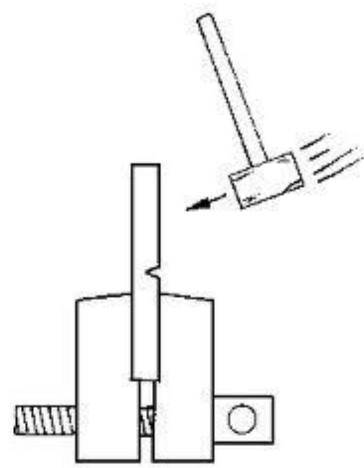


Fig.7 DIRECTION OF IMPACT

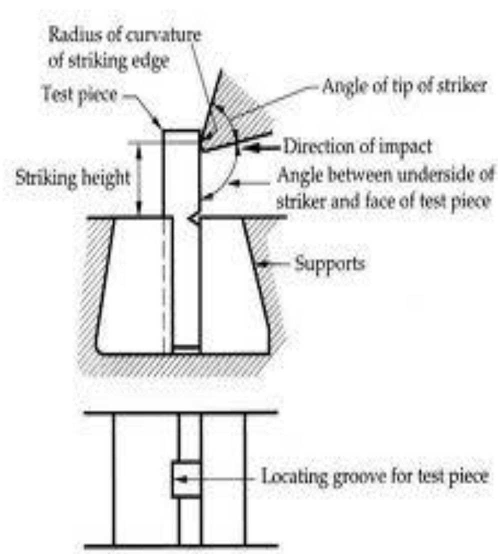


Fig.8

IMPACT ON THE SPECECIMEN

PROCEDURE:

1. Measure the dimensions of a specimen. Also, measure the dimensions of the notch.
2. Raise the hammer to 90 degrees position, fix it to the hook and note down initial reading from the dial, which will be energy to be used to fracture the specimen.
3. Place the specimen for test and see that it is placed center with respect to hammer. Check the position of notch.
4. Release the hammer and note the final reading. Difference between the initial and final reading will give the actual energy required to fracture the Specimen.
5. Compute the energy of rupture of the specimen.

OBSERVATIONS:

Sl No.	A Area of cross-section of specimen	K Impact energy absorbed	I impact strength

PRECAUTIONS:

1. Fix the specimen tightly.
2. After ascertaining the pendulum no person should be in the range of the pendulum oscillation.
3. Operate the pendulum hammer gently.
4. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.

RESULT:

- The strain energy in the test specimen is ……………..
- The impact strength of the given test specimen is ……………………..

6. CHARPY IMPACT TEST

AIM:

- To perform the Izod impact test on metals.

APARATUS:

- Izod impact testing machine
- Test specimen
- Vernier caliper
- Steel rule

THEORY:

In a impact test a specially prepared notched specimen is fractured by a single blow from a heavy hammer and energy required being a measure of resistance to impact.

Impact load is produced by a swinging of an impact weight W (hammer) from a height h. Release of the weight from the height h swings the weight through the a rcof a circle, which strikes the specimen to fracture at the notch.

Kinetic energy of the hammer at the time of impact is $mv^2/2$, which is equal to the relative potential energy of the hammer before its release.ie., P.E = mgh, where m is the mass of the hammer and $v = \sqrt{2gh}$is its tangential velocity at impact, g isgravitational acceleration (9.806 m/s^2) and h is the height through which hammer falls. Impact velocity will be 5.126 m/s or slightly less.

Here it is interesting to note that height through which hammer drops determines the velocity and height and mass of a hammer combined determine the energy.

Energy used can be measured from the scale given. The difference between potential energies is the fracture energy. In test machine this value indicated by the pointer on the scale. If the scale is calibrated in energy units, marks on the scale should be drawn keeping in view angle of fall and angle of rise.

Height $h_1$and h_2 equals,h_1= R (1 – cosθ) and h_2= (1 - cosθ).

With the increase or decrease in values, gap between marks on scale showing energy also increase or decrease. This can be seen from the attached scale with any impact machine.

Energy used in fracturing the specimen can be obtained approximately asWh_1-Wh_2.

This energy value called impact toughness or impact value, which will be measured, per unit area at the notch.

Charpy introduced Charpy test in 1909. Test is as per the IS: 1499.

Fig.8 CHARPY IMPACT TESTING MACHINE

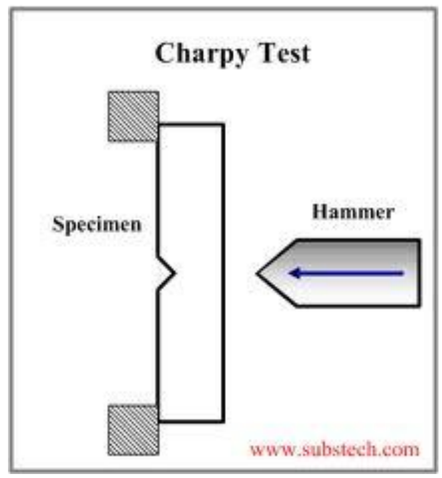


Fig.9 DIRECTION OF IMPACT

PROCEDURE:

1. Measure the dimensions of a specimen. Also, measure the dimensions of the notch.
2. Raise the hammer to 140 degrees position, fix it to the hook and note down initial reading from the dial, which will be energy to be used to fracture the specimen.
3. Place the specimen for test and see that it is placed center with respect to hammer. Check the position of notch.
4. Release the hammer and note the final reading. Difference between the initial and final reading will give the actual energy required to fracture the Specimen.

5. Compute the energy of rupture of the specimen.

OBSERVATIONS:

Sl No.	A Area of cross-section of specimen	K Impact energy absorbed	I impact strength

PRECAUTIONS:

1. Fix the specimen tightly.
2. After ascertaining the pendulum no person should be in the range of the pendulum oscillation.
3. Operate the pendulum hammer gently.
4. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.

RESULT:

- The strain energy in the test specimen is ……………..
- The impact strength of the given test specimen is ……………………..

7. COMPRESSION TEST ON SHORT COLUMNS

AIM:

To find buckling load of column using column test setup arrangement under one end hinged and one end fixed condition.

APPARATUS REQUIRED:

- Column test,
- Load indicator,
- Specimen rod and
- One hinged support & one fixed support.

FORMULA USED:

$$P = \frac{\pi^2 EI}{l_e^{\,2}}$$

P = Crippling load

E = Young's Modulus of Specimen

I = Moment of Inertia

l_e = Effective length

EULER'S COLUMN THEORY:

As per Euler's equation for buckling load of long column based on bending stress the effect of direct stress is neglected .This may be adjusted justified with the statement ,direct stress included in a column is negligible as compared to the bending stress.

ASSUMPTION:

- Initially the column is perfectly straight and the load is truly axial.
- The cross section of column is uniformed through its length.
- The column material is perfectly elastic homogenous and isotropic and obey hooks law.
- The length of is very large as compared with cross sectional dimensions and the failure occurs due to buckling load.

PROCEDURE:

1. Consider a column AB of length "*l*" with one end fixed other end hinged.
2. The column cannot be rotated because it is one end fixed end other end hinged.
3. It is positioned to have a complete supports.
4. The load is gradually applied by rotating the loading wheel connected to load cell intern to digital meter.
5. The load indicator is viewed simultaneously from the display of digital load indicator.

6. Now the column just starts buckling.
7. Till the deflection of column occurs as shown in figure mean while applied load value approximately coincides with the theoretical value.

TABULAR COLUMN:

When one end is hinged and other end is fixed before loading.

Sl. No	**Specimen**	**Young's modulus**	**Length (mm)**	**Diameter (mm)**	**Crippling load**
1)	Stainless steel				

Loading column is stopped at crippling load. This load is known as buckling load of column.

RESULT:

Thus buckling load of column was found and compared its value with theoretical values.

8. COMPRESSION TEST ON LONG COLUMNS

AIM:

To determine the Young's modulus of given long column.

APPARATUS REQUIRED:

1) Universal Testing Machine
2) Long Column
3) Steel Rule
4) Vernier caliper

SPECIFICATIONS:

Length of the column	400mm
Diameter of the column	20.2mm
Material of the Specimen	MS
Universal Testing Machine	
Number of Divisions	400
Load per division	0.25KN
Vernier Calipers	
Least count	0.02mm

THEORY:

A column can also be defined as a vertical member carrying compressive load with different end conditions. The maximum limiting load at which the column tends to have lateral displacement or tends to buckle is called buckling or crippling load. The buckling takes place about the axis having minimum radius of gyration or least moment of inertia.

Safe Load is the load at which a column is actually subjected to and is well below the buckling load. It is obtained by dividing the buckling load by a suitable factor of safety.

Classification of columns is done depending upon the slenderness ratio or length to diameter ratio.

Long columns have their lengths more than 30 times their respective diameters or slenderness ration more than 120 is called long columns. They are usually subjected to buckling stress only. Direct and compressive stresses are small compared to buckling stress and hence neglected.

The strength of a column depends upon the slenderness ratio. If the slenderness ratio is increased the compressive strength of a column decreases as the tendency to buckle is increased. The strength of the column also depends on the end conditions. The distance between the adjacent points of inflexion is called Equivalent length or effective length or simple column length. A point of inflexion is found at every column end that is free to rotate and at every point where there is a change of the axis.

i. Both ends hinged $L_e=L$
ii. One end fixed other end free $L_e=2L$
iii. One end fixed and other end pin jointed $L_e=L/\sqrt{2}$
iv. Both ends fixed $L_e=L/2$

EULER'S THEORY FOR LONG COLUMNS:

The following are the assumptions made while deriving the Euler's formula:

i. The column is initially straight and of uniform lateral dimension.
ii. The compressive load is exactly axial and it passes through the centroid of the column section.
iii. The material of the column is perfectly homogenous and isotropic.
iv. Pin joints are frictionless and fixed ends are perfectly rigid.
v. The weight of the column itself is neglected.
vi. The column fails by buckling alone.
vii. Limit of proportionality is not exceeded.

Euler's formula is used for calculating the critical load for a column

$$P_{euler} = \frac{\pi^2 EI}{l_e^2}$$

P=Critical load.

E=Modulus of elasticity.

I=Least moment of inertia of section of the column.

L_e= Equivalent length of the strut/column.

LIMITATIONS:

I. It is applicable to an ideal column and in practice there is always crookedness in the column and the load applied may not be exactly co-axial.
II. It takes no account of direct stress. It means that it may give a buckling load for columns, far in excess of the load which they can withstand under compression.

DERIVATION OF EULER'S FORMULA FOR BOTH ENDS FIXED:

Consider a column AB of length 'l' whose both ends A and B are fixed. Obviously there will be restraint moment M_o at each end. Let P be the crippling load.

Consider any section xx at the distance x from lower end B. the bending moment at the section xx, given by

$$EI\frac{d^2y}{dx^2} = M_o - Py$$

$$EI\frac{d^2y}{dx^2} + Py = M_o$$

$$\frac{d^2y}{dx^2} + \frac{Py}{EI} = \frac{M_O}{EI}$$

The solution to the above differential equation

$$y = c_1 Cos\left(x\sqrt{\frac{P}{EI}}\right) + \ c_2 \sin\left(x\sqrt{\frac{P}{EI}}\right) + \frac{M_O}{P}$$

where C_1 and C_2 are constants of integration.
The slope at any section is given by

$$\frac{dy}{dx} = -c_1\sqrt{\frac{P}{EI}}\sin\left(x\sqrt{\frac{P}{EI}}\right) + c_2\sqrt{\frac{P}{EI}}\cos\left(x\sqrt{\frac{P}{EI}}\right)$$

At B, the deflection is zero. Hence at x=0, y=0

$$y = c_1 Cos\left(x\sqrt{\frac{P}{EI}}\right) + \ c_2 \sin\left(x\sqrt{\frac{P}{EI}}\right) + \frac{M_O}{P}$$

$$0 = c_1 + \frac{M_O}{P} \qquad \text{or} \qquad c_1 = -\frac{M_O}{P}$$

At B, the slope is zero. Hence at x=0, $\frac{dy}{dx} = 0$

$$0 = \ c_2\sqrt{\frac{P}{EI}} \qquad \text{or} \qquad c_2 = \ 0$$

At A, the deflection is zero. At x=l, y=0

$$0 = -\frac{M_O}{P} Cos\left(l\sqrt{\frac{P}{EI}}\right) + \frac{M_O}{P}$$

$$\frac{M_O}{P}\left[Cos\left(l\sqrt{\frac{P}{EI}}\right) - 1\right] = 0$$

$$Cos\left(l\sqrt{\frac{P}{EI}}\right) = 1$$

$$l\sqrt{\frac{P}{EI}} = 0, 2\pi, 4\pi, 6\pi$$

Considering the first practical value

$$l\sqrt{\frac{P}{EI}} = 2\pi$$

$$P = \frac{4\pi^2 EI}{l^2}$$

PROCEDURE:

1. Measure the length of the long and short column using the scale.
2. Now measure the diameters of both the columns.
3. Place the long column in between the jaws provided for compression testing in a universal testing machine.
4. Now ensure that the pressure valve is closed and start applying the load by opening the load valve provided on the right side of a UTM.
5. At a particular value of a load, the long column tends to buckle, note the value of the load at that point which gives the critical load.
6. Now calculate the young's modulus E, of the column.
7. Now place the short column in the jaws of UTM.
8. Now, start applying loads as stated above. At a particular value of load the short column undergoes crushing. The load at that point gives the crushing load.
9. Using this value of load, calculate the young's modulus of the short column.

PRECAUTIONS:

1. Measure the dimensions accurately.
2. Ensure that the pressure valve is completely closed before applying load.
3. Take the readings without parallaxes error.

RESULT:

The young's modulus of the material is E=

Buckling load $P_{practical}$ =

$P_{theoretical}$ =

9. SPRING TEST

AIM:

To determine the stiffness of the spring and modulus of rigidity of the spring wire.

APARATUS:

i) Spring testing machine
ii) Springs for testing
iii) Micrometer
iv) Vernier caliper.

THEORY:

Springs are elastic members which distort under load and regain their original shape when load is removed. They are used in railway carriages, Motor cars, Scooters, Motor cycles, Rickshaws, Governors etc.

Types of springs:

1. Close-coiled helical springs & Tension helical springs with circular cross-section
2. Open-coiled springs & compression helical springs with square cross-section
3. Full-elliptical leaf springs.
4. Semi-elliptical laminated springs.
5. Cantilever lever springs.
6. Circular springs.

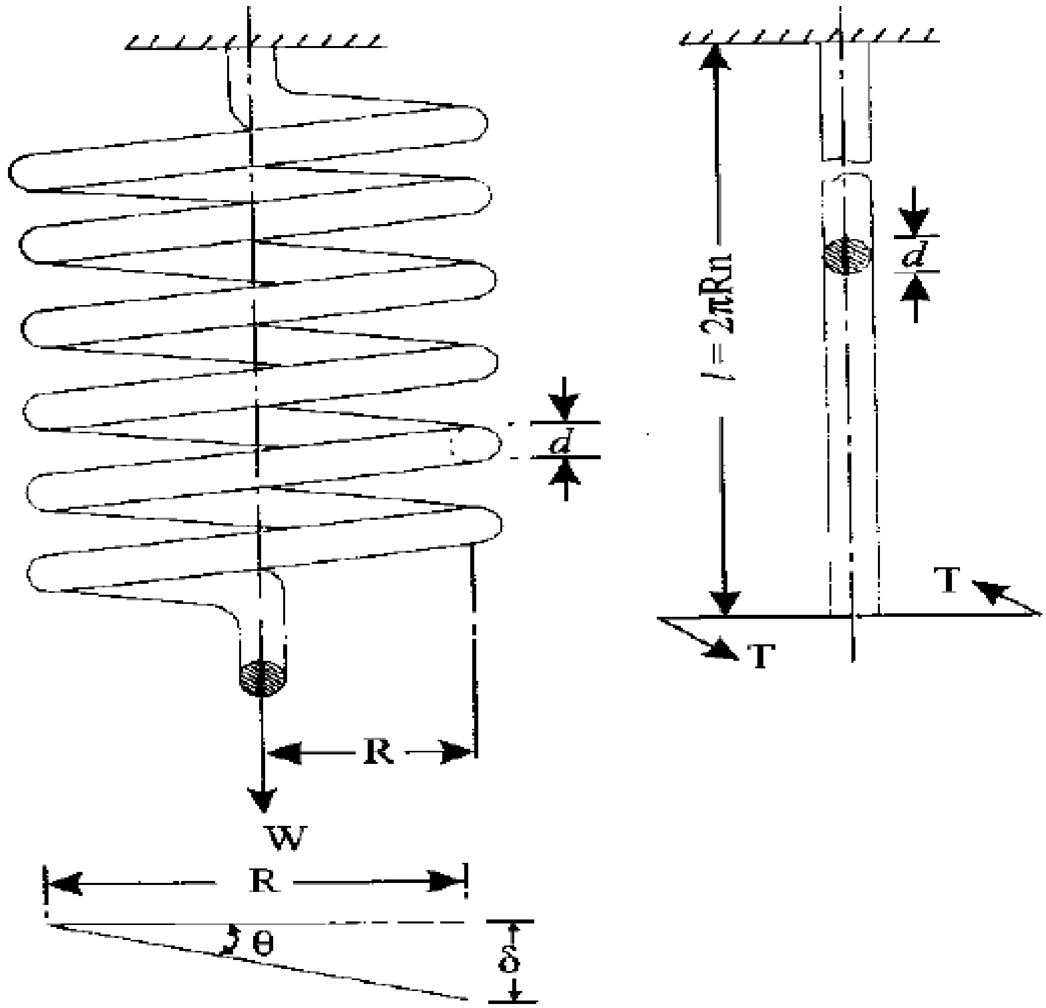
According to their uses, the springs perform the following function:

- To absorb shock or impact loading as in carriage springs.
- To store energy as in clock springs.
- To supply forces to and to controls motions as in brakes and clutches.
- To measure forces as in spring balances.
- To absorb the vibrations, characteristic of a member as in flexible mounting of motors.

- The springs are usually made of either high carbon steel (0.7% to 1.0%) or medium carbon alloy steels. Phosphor bronze, Brass and 18/8 stainless steel. Other metal alloys are used for corrosion resistance.

Analysis of close-coiled helical springs: (circular section wire)

- W Axial load applied(N)
- R_m Mean radius of the coil (mm)
- D_o Outer diameter of coil (mm)
- D_m (D_o -d) Mean diameter of the coil (mm)
- D Diameter of the wire of the coil (mm)
- δ Deflection of coil (m) under the load 'W'
- C Modulus of rigidity (N/mm^2)
- n Number of coils or turns.
- L Length of wire = $2\pi R_m n$ (mm)
- t shear stress(N/mm^2)
- T Torque (N-mm)
- I_p Polar Moment of Inertia of wire = $\pi d^4/32$ (mm^4)
- Spring index = D_m/d
- Modulus of rigidity **C =** $\frac{8WD_m{}^3 n}{\delta d^4}$



CLOSED COIL HELICAL SPRING

PROCEDURE:

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

OBSERVATIONS:

Sl No.	Load W, (N)	Deflection, δ, (mm)	Stiffness W/δ, (N/mm)
1			
2			

PRECAUTIONS:

1. The dimension of spring was measured accurately.
2. Deflection obtained in spring was measured accurately.

GRAPHS AND RESULTS:

- Load Vs deflection
- Stiffness Estimation.

10. (A) DEFLECTION TEST ON A CANTILEVER BEAM

AIM:

- To verify the theoretical deflection of the beam at when beam is subjected to point load at the free end.
- To find the effect on the deflection of the beam, when the beam is subjected to varying loads values.

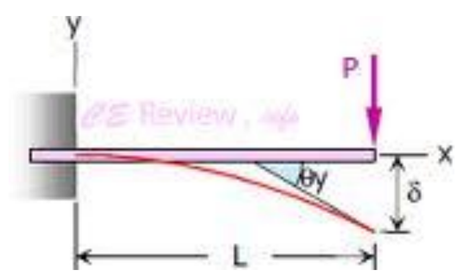
APPARATUS:

- Beam
- Dial gauge
- Weights
- Weight hanger

THEORY:

A cantilever is a beam one end of which is clamped and other end is free.

A cantilever beam with a length Lis fixed at one end and the other end is free. Let the moment of inertia of the beam is ‘I’ about its neutral axis and the young’s modulus be ‘E’.



CANTILEVER BEAM SUBJECTED TO POINT LOAD AT FREE END

Moment of inertia about the neutral axis I= bd^3 / 12,

Deflection at the centre (Max deflection) δ related to the load ‘W’. Span ‘L’ moment of Inertia ‘I’, and Young’s modulus ‘E’ through the equation.

$$\delta = \frac{WL^3}{3\ EI}$$

From the theory we can observe that, if the load is doubled, the deflection also will be doubled.

EXPERIMENTAL SET-UP:

The set up contains the following:

1. One rigid clamping support for fixing one end of the beam.
2. Rectangular cross sectional beam.
3. Loading arrangement along with different weights.
4. Dial gauge with magnetic stand.
5. Measuring tape.

PROCEDURE:

1. Clamp the beam horizontally and the clamped supported at one end.
2. Hang the loading pan at the free end of cantilever beam.
3. Fix the dial gauge at the point of loading and set the dial gauge reading to zero position.
4. Load the beam with different loads and note the corresponding dial gauge readings.

PRECAUTIONS:

1. The beam should be positioned horizontally.
2. The span of the beam should be measured properly.
3. Take the dial gauge readings with-out errors.

Theoretical Deflections:

Sl No:	LOAD (W)	Deflection(δ_{th})
1		
2		

Experimental Deflections:

Sl No:	LOAD (W)	Deflection (δ_{ex})
1		
2		

Conclusion:-

- The deflection of the beam is proportional to the load applied.

  The theoretical formula for the deflection is verified.

10. **(B) DEFLECTION TEST ON A SIMPLY SUPPORTED BEAM**

AIM:

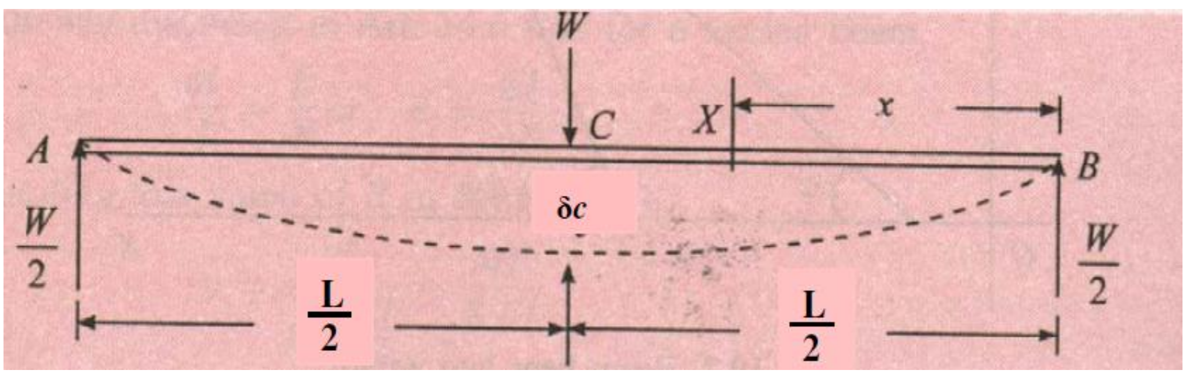
- To verify the theoretical deflection of the beam at when beam is subjected to point load at the mid span of the beam.
- To find the effect on the deflection of the beam, when the beam is subjected to varying loads values.

APPARATUS:

- Beam
- Dial gauge
- Weights
- Weight hanger

THEORY:

A beam with a span L & is supported at both ends knife edges. Let the moment of inertia of the beam is 'I' about its neutral axis and the young's modulus be 'E'.



Moment of inertia about the neutral axis I= $bd^3 / 12$,

Deflection at the centre (Max deflection) δ related to the load 'W'. Span 'L' moment of Inertia 'I', and Young's modulus 'E' through the equation.

$$\delta = \frac{WL^3}{48\,EI}$$

From the theory we can observe that, if the load is doubled, the deflection also will be doubled

EXPERIMENTAL SET-UP:

The set up contains the following:

1. Two knife edges & supported stands for beam.
2. Rectangular cross sectional beam.
3. Loading arrangement along with different weights.
4. Dial gauge with magnetic stand.
5. Measuring tape.

PROCEDURE:

1. Set the beam horizontally on the two knife edges.
2. Measure the span of the beam L.
3. Hang the loading pan at the mid-point of span.
4. Fix the dial gauge at the point of loading and set the dial gauge reading to zero position.
5. Load the beam with different loads and note the corresponding dial gauge readings.

PRECAUTIONS:

1. The beam should be positioned horizontally.
2. The span of the beam should be measured properly.
3. Take the dial gauge readings with-out errors.

Theoretical Deflections:

Sl No:	LOAD (W)	Deflection(δ_{th})
1		
2		

Experimental Deflections:

Sl No:	LOAD (W)	Deflection (δ)

Conclusion:-

- The deflection of the beam is proportional to the load applied.
- The theoretical formula for the deflection is verified

EXPERIMENT 1

1.1 PRE-LAB QUESTIONS

1. If the sharpness of V-notch is more in one specimen than the other, what will be its effect on the test result?
2. What is the principle involved in charpy impact test?
3. What type of material is used as an impact test specimen?
4. What is the difference between charpy impact test and izoid impact test?

1.2 POST-LAB QUESTIONS

1. What is resilience? How is it different from proof resilience and toughness?
2. What is the necessity of making a notch in impact test specimen?
3. What precautions could be taken in charpy impact test?

1.3 ASSIGNMENT QUESTIONS

1. In what way the values of impact energy will be influenced if the impact tests are conducted on two specimens, one having smooth surface and the other having scratches on the surface?
2. What is the effect of temperature on the values of rupture energy and notch impact strength?

EXPERIMENT 2

2.1 PRE-LAB QUESTIONS

1. If the sharpness of V-notch is more in one specimen than the other, what will be its effect on the test result?
2. What is the principle involved in charpy impact test?
3. What type of material is used as an impact test specimen?
4. What is the difference between charpy impact test and izoid impact test?

2.2 POST-LAB QUESTIONS

1. What is resilience? How is it different from proof resilience and toughness?
2. What is the necessity of making a notch in impact test specimen?
3. What precautions could be taken in charpy impact test?

2.3 ASSIGNMENT QUESTIONS

1. In what way the values of impact energy will be influenced if the impact tests are conducted on two specimens, one having smooth surface and the other having scratches on the surface?

2. What is the effect of temperature on the values of rupture energy and notch impact strength?

EXPERIMENT 3

3.1 PRE-LAB QUESTIONS

1. Define hardness?
2. What is the principle involved in Rockwell hardness test?
3. What are the shapes of Indenters usually used for hardness tests?

3.2 POST-LAB QUESTIONS

1. What are the materials generally used for indenter?
2. What does HRB mean?
3. What types of materials are used for test specimens in Hardness tests?

3.3 ASSIGNMENT QUESTIONS

1. What precautions should be taken in case of Rockwell hardness test?
2. What is the minimum distance between the centres of the two adjacent indentations?
3. What is the minimum thickness of the test piece in case of Rockwell hardness test?

EXPERIMENT 4

4.1 PRE-LAB QUESTIONS

1. What is the unit of B.H.N?
2. Which ball size is recommended for Brinell test?
3. What are the equipment and materials required for Brinell hardness test?

4.2 POST-LAB QUESTIONS

1. What is the purpose of microscope used in Brinell hardness test?
2. The surface area of indentation 'A' is dependent upon---?
3. What is the range of the size of ball indenter in case of Brinell hardness test?
4. What are the units for BHN?
5. While mounting the test specimen the surface of the test specimen should be at to the axis of the ball indenter plunger?

4.3 ASSIGNMENT QUESTIONS

1. What is the limitation of Brinell hardness test and why?
2. Which is the hardest material? And why?
3. Can we predict the tensile strength of a material if its hardness in known?

EXPERIMENT 5

5.1 PRE-LAB QUESTIONS

1. What do you mean by modulus of rigidity?
2. What is shear strain?
3. Give the expression for the basic torsion equation?

5.2 POST-LAB QUESTIONS

1. What do you mean by polar moment of inertia?
2. What is polar modulus? What is the expression for polar modulus of a circular shaft?
3. What do you mean by torsional rigidity?

5.3 ASSIGNMENT QUESTIONS

1. Give the expression for power transmitted by a shaft?
2. What are the precautions that should be taken during torsion test?
3. Between which parameters a graph is plotted in case of torsion test?

EXPERIMENT 6

6.1 PRE-LAB QUESTIONS

1. Which steel have you tested?
2. In what region of a stress vs. strain graph do you find Young's Modulus?
3. Why do we remove the extensometer after yielding occurs?
4. What is Elasticity?
5. Define Hook's law?
6. What do you mean by percentage elongation?
7. What do you mean by percentage reduction in area?

6.2 POST-LAB QUESTIONS

1. Which stress have you calculated: Nominal stress or true stress?
2. Which is the most ductile material? What is its elongation?
3. Which stress have you calculated : nominal stress or true stress ?
4. What kind of fracture has occurred in the tensile specimen and why ?

6.3 ASSIGNMENT QUESTIONS

1. What general information is obtained from the tensile test regarding the properties of the material?
2. What kind of fracture has occurred in the tensile specimen and why ?
3. Which is the most ductile metal ?How much is its elongation?

EXPERIMENT 7

7.1 PRE-LAB QUESTIONS

1. What do you mean by a spring?
2. What are the important functions of a spring?
3. What are the common materials by which springs are made?

7.2 POST-LAB QUESTIONS

1. List out types of springs?
2. What do you understand by a helical spring?
3. What is the difference between a closed coil helical spring and open coil helical spring?

7.3 ASSIGNMENT QUESTIONS

1. What types of stresses are involved in leaf springs?
2. What type of spring is used to transmit a small torque?

EXPERIMENT 8

8.1 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.

8.2 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?

8.3 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 ste

EXPERIMENT 9

9.1 PRE – LAB QUESTIONS

1. What is long column
2. How you apply compressive load on column
3. What for you are applying compressive load

9.2 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

9.3 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 10

10.1 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

10.2 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

10.3 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