EXPERIMENTS IN MECHANICS OF SOLIDS

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DEPARTMENT OF CIVIL ENGINEERING

SUBJECT : MECHANICS OF SOLIDS
SUBJECT CODE: 110010
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LAW OF POLYGON OF FORCES

OBJECTIVE

To find the magnitude and direction of unknown forces by using law of polygon of forces acting on a particle in equilibrium.

APPARATUS

Universal force table with four pulleys Fig. 1.1, piece of string, standard weights.

ASSUMPTIONS

1. Pulleys are assumed to be frictionless.
2. Self weight of thread is neglected.

THEORETICAL BACKGROUND

The state of equilibrium of particle refers to the state of uniform velocity or of rest. A particle is set to be in equilibrium under the action of forces if the vectorial summation of the forces is zero.

This experiment pertains to the study of the system of coplanar and concurrent forces acting on a particle with the help of universal force table.

Technical terms:

- **Coplanar forces**: forces acting in a plane.
- **Concurrent forces**: force meeting at a point.
- **Resultant**: A force capable of producing same effect as that of given force system.
- **Equilibrium of forces**: When resultant of a force system acting on a particle is zero, the particle is set to be in equilibrium under the action of forces.

Analytical method

Let $P_1$, $P_2$, $P_3$, $P_4$ are four forces acting simultaneously on a particle “O” (fig. 1.2 A) at an inclination of $\theta_1$, $\theta_2$, $\theta_3$, $\theta_4$ with positive X-axis measured in clockwise direction. The particle is said to be in equilibrium if their vectorial summation is zero i.e. $\sum F=0$. In terms of components along Cartesian X and Y directions, it is further expressed as $\sum F_x=0$ and $\sum F_y=0$.

Where, 

$$\sum F_x = P_1 \cos \theta_1 + P_2 \cos \theta_2 + P_3 \cos \theta_3 + P_4 \cos \theta_4 \quad \ldots \quad 1$$
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\[ \sum F_y = P_1 \sin \theta_1 + P_2 \sin \theta_2 + P_3 \sin \theta_3 + P_4 \sin \theta_4 \quad \ldots \quad 2 \]

Considering magnitude of two of the forces unknown, their value is obtained by solving equation 1 and 2 simultaneously.

**Graphical Method**

Law of polygon is used to find magnitude and or direction of unknown forces graphically, it states that “When a system of forces are in equilibrium, the polygon drawn by considering them in order, in direction and magnitude, results in close polygon”. Thus, to find the unknown forces, following procedure is adopted.

A space diagram is drawn and Bow’s notations are assigned Fig. 1.2 A, B, C and D are Bow’s notation and AB represents force \( P_1 \). A point in space is selected and lines parallel to the forces are extended from their respective points (say c & a, If \( P_3 \) and \( P_4 \) are unknown) and whenever they meet, defines the magnitude of each force to the selected scale. Their inclination w.r.t. X – axis is measured from the force polygon itself.

**PROCEDURE**

- Level force table with the help of spirit level and adjusting foot screws.
- Apply weights and/or adjust pulleys such that the center of knot coincides with central pivot.
- Note the angle made by strings through which weights are hanging.
- Find the unknown forces by solving problem, first analytically and graphically.
- Find their absolute percentage of error in the values unknown forces obtained graphically and experimentally w.r.t. then analytical results.

**PRECAUTIONS**

- Threads should be free of knots.
- Rotations of pulley should be smooth.

**OBSERVATION TABLE**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>MAGNITUDE OF FORCES</th>
<th>ANGLE W.R.T. X AXIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( P_1 ) (N)</td>
<td>( \theta_1 ) °</td>
</tr>
<tr>
<td></td>
<td>( P_2 ) (N)</td>
<td>( \theta_2 ) °</td>
</tr>
<tr>
<td></td>
<td>( P_3 ) (N)</td>
<td>( \theta_3 ) °</td>
</tr>
<tr>
<td></td>
<td>( P_4 ) (N)</td>
<td>( \theta_4 ) °</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CALCULATIONS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>FORCE (N)</th>
<th>ANGLE (deg)</th>
<th>VALUE OF P (N)</th>
<th>$\theta^\circ$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ANALYTICAL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GRAPHICAL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EXPERIMENTAL</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% AGE ERROR FOR FORCE P</th>
<th>GRAPHICALLY MAGNITUDE</th>
<th>EXPERIMENTALLY MAGNITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$[P_{(ANA)} - P_{(GRA)}]/P_{(ANA)}$</td>
<td>$[P_{(ANA)} - P_{(EXP)}]/P_{(ANA)}$</td>
</tr>
</tbody>
</table>

CONCLUSIONS

QUIZ

1. What is meant by polygon?


3. Distinguish between closed polygon and open polygon.
4. What is the function served by the pulleys used in the experiment?

5. Draw a free body diagram for the weight hanging with thread.

6. What are the equations used for solving a problem of coplanar concurrent forces?

7. What is meant by resultant of forces?

8. Draw the polygon of forces for following cases:
   (a) Four forces (pull type) of 5 kN each, acting on a particle in the North, East, West and South directions.
   (b) Three forces (push type) of 2 kN, 3kN and 4 kN acting at an angle of 120° with one another.
WHEEL AND DIFFERENTIAL AXLE

OBJECTIVE

To determine the mechanical Advantage, Velocity Ratio, Idle Effort, Frictional effort, Ideal load, Frictional load and Efficiency of a given Wheel and Differential axle.

APPARATUS

Wheel and differential axle, standard weights, vernier-caliper and meter rule.

CONSTRUCTION

This simple machine mainly consists of two parts as shown in Fig. 5.1
(a) Load axle (b) Effort axle
The load-axle assembly consists of two axles of different parameter; let their diameter be \( d_1 \) and \( d_2 \). The larger diameter wheel is used as an effort wheel of diameter \( D \) such that when effort is applied to rotate the assembly, the string gets wound over the larger diameter axle \( (d_1) \) and gets unwound from the smaller axle \( (d_2) \).

THEORETICAL BACKGROUND

In Wheel and differential axle, a very high velocity ratio is achieved by varying size of diameters of differential axle. Some of the technical terms related to this experiment are as follow:

1. Mechanical Advantage (M.A.)
   It is the ratio of load (\( W \)) lifted by the machine to the effort (\( P \)) applied to the machine.

2. Velocity Ratio (V.R.)
   It is ratio of distance moved by the effort (\( Y \)) to the distance moved by the load (\( X \)). This value is constant for a given machine.

   \[
   V.R. = \frac{\text{Distance moved by effort (Y)}}{\text{Distance moved by load (X)}}
   \]

   \[
   V.R. = \frac{\pi D}{\{(\pi d_1-d_2)/2\}}
   \]

   \[
   V.R. = \frac{2D}{(d_1-d_2)}
   \]

3. Ideal Effort (\( P_i \))
   Maximum effort required to lift a given load by the machine assuming it to be ideal.
   \[
   P_i = \frac{W}{V.R.}
   \]
4. **Frictional Effort** ($P_f$)
Effort lost in overcoming frictional force developed between the surfaces of the machine.

\[
\text{Output} = \text{Input} - \text{Losses} \\
\text{W}.X. = (P - P_f) Y \\
\text{Or, } P - P_f = \frac{W}{(Y/X)} \\
\text{Or, } P_f = P - P_i
\]

5. **Ideal Load** ($W_i$)
Loads that can be lifted using a given effort by the machine assuming it to be the ideal.

\[
W_i = P. (V.R.)
\]

6. **Frictional Load** ($W_f$)
It is the apparent increase in load due to friction.

\[
\text{Output} + \text{Losses} = \text{Input} \\
(W + W_f) X = P.Y \\
(W + W_f) = P.Y/X \\
\text{Frictional Load, } W_f = P.(V.R.) - W \\
= W_i - W
\]

7. **Ideal machines**
The machine in which there are no losses and gives output equal to the input supplied. The efficiency of such machine is 100%. These are also called as frictionless machines.

\[
\text{Or} \quad \text{M.A.} = \frac{\text{V.R.}}{1} = 100 \%
\]

8. **Ideal machines**
The actual efficiency of the machine is less than unity because losses are mainly due to friction.

9. **Efficiency** ($\eta$)
It is the ratio of output obtained from the machine to be input supplied to the machine. In other words, it is defined as the ratio of the mechanical Advantage to Velocity Ratio.

\[
\eta = (\text{Output} / \text{Input}) = \frac{W.X}{P.Y} = \frac{(W/P)/(Y/X)}{\text{M.A.}/\text{V.R.}} \times 100
\]

10. **Maximum efficiency** ($\eta_{\text{max}}$)
It is the maximum theoretical efficiency which can be achieved when machine is subjected to load of infinite magnitude

\[
\eta_{\text{max}} = \frac{1}{m. \text{ VR}} \quad \text{Where } m \text{ is the slope of } P \text{ v/s } W \text{ graph.}
\]
11. **Reversibility of machine**

A machine is said to be reversible, if its efficiency is greater than 50 % and irreversible if its efficiency is less than or equal to 50 %.

**PROCEDURE**

1. Measure the initial position of the load (say X1) and effort pan (say Y1) from a reference level.
2. Apply effort on effort pan so that it moves downward and note the final position of the load (X2) and effort pan (Y2) with the same reference level.
3. Calculate the distance moved by the effort (Y) and (X) by subtracting reading of step 1 (X1, Y1) and 1 (X2, Y2), which is the difference of final and initial position of the load pan and effort pan. Find the V.R. of the machine. It should be taken as average of velocity ratios, so obtained.
4. Measure diameters D, d1 and d2 and final theoretical value of velocity ratio so as to check the V.R. obtained in step 3.
5. Apply incremental loads on the load pan and find out minimum effort on the effort pan required to raise the load with slow uniform motion without any jerk.
6. Plot the graphs
   a) Actual effort v/s load
   b) Ideal effort v/s load
   c) Frictional effort v/s load
   d) M.A. (show max efficiency also) /s load
   e) Efficiency (show max efficiency also) v/s load

(Sample graphs are shown in figure 5.2, 5.3 and 5.4)

7. Work out the law of machine \( P = mW + C \) from the graph of load v/s actual effort. Where,
   \[ P = \text{Actual effort} \]
   \[ W = \text{Load applied} \]
   \[ C = \text{Initial friction, (constant)} \]
   \[ m = \text{Slope of P versus W graph} \]

**OBSERVATION**

1. Diameter of the effort wheel (D) =
2. Diameter of the bigger axle (d1) =
3. Diameter of the smaller axle (d2) =
4. Velocity ratio of the machine = \( \frac{2D}{(d1 - d2)} \)

**OBSERVATION TABLE**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Total Load(N)</th>
<th>Total Effort (N)</th>
<th>Velocity Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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</tbody>
</table>
### CALCULATIONS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>M.A = W/P</th>
<th>Ideal Effort ( P_i = \frac{W}{(VR)} ) (N)</th>
<th>Frictional Effort ( P = P - \frac{W}{(VR)} ) (N)</th>
<th>Ideal Load ( W_1 = P \cdot (VR) ) (N)</th>
<th>Frictional Load ( W_1 = P \cdot (VR) - W ) (N)</th>
<th>Efficiency ( n = \frac{M.A}{V.R} \cdot 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>3</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
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</tbody>
</table>

Maximum M.A = \( \frac{1}{m} \) =

Maximum Efficiency = \( (\frac{1}{m} V.R) \cdot 100 \) =

### CONCLUSIONS

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### QUIZ

1. Explain the condition for self locking of a machine.

2. How does the effort vary with the load for an ideal machine.
3. Assuming the law of the machine is linear device equations for the maximum mechanical advantage and efficiency of the machine

4. Mention the lifting machine suited, in your opinion for the following jobs
   a) lifting a drum of water from a well
   b) lifting a heavy consignment from a ship
   c) lifting a body of a truck for the purpose of changing a wheel
SINGLE PURCHASE WINCH CRAB

DATE:

OBJECTIVE

To determine the mechanical advantage, Velocity Ratio, ideal effort, Friction effort, ideal load, friction load and efficiency of a given single purchase winch crab.

APPARATUS

Single winch crab, caliper, weights and meter rule etc.

THEORETICAL BACKGROUND

The single winch crab is a mechanical device to achieve velocity ratio to achieve velocity ratio for lifting machine using gears. (Draw fig of this machine and write the working phenomenon).

PROCEDURE

Note the total load applied and the corresponding effort required to raise the load with uniform slow motion. Take five Reading with uniform load and corresponding efforts required. Plot the graphs with i) actual efforts ii) ideal effort iii) Frictional effort and iv) efficiency on Y-axis and efficiency on X-axis.
Work out the law of machine $P = mW + C$. Where $P$ is actual effort required to raise load $W$. ($m$ & $c$ are the constants of a given machine) Where $m$ is the slope of the graph and $C$ is the initial required to start the machine.

Work out the law of the machine $P = mW + C$, Where $P$ is actual effort required to raise Load $W$;” $m$” and $C$ are the constants of a given machine

**OBSERVATIONS:**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diameter of the Wheel (D)</td>
<td>cm.</td>
</tr>
<tr>
<td>2</td>
<td>Diameter of the axle (d)</td>
<td>cm.</td>
</tr>
<tr>
<td>3</td>
<td>No. of teeth on spur wheel (TS)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>No. of teeth on pinion wheel (TP)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Velocity ratio $VR=(D.TS)/(d.TP)$</td>
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**OBSERVATION TABLE:**

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<td>3</td>
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<td>4</td>
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<tr>
<td>5</td>
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</tbody>
</table>

**CALCULATION:**

1. Give sample calculation for all quantities for any reading of observation table.
2. For law of machine, $P = mW + C$ from the graph of actual effort, determine the value of $m$ & $c$.
3. Maximum mechanical advantage (MA) = $1/m = \underline{\quad}$
4. Maximum Efficiency $= 1(m.VR) = \underline{\quad}$

**CONCULSION:**

1. Nature of graphs.
2. Which graph passes from origin and why?
(3) Reversibility of this machine.

(4) Law of machine \( P = mW + C \) (Write value of \( m \) and \( c \))

QUIZ

(1) What is velocity ratio equation for double purchase crab?

(2) Velocity ratio is dependent on which parameters of machine?
BRINELL HARDNESS TEST

OBJECTIVE

To determine the Brinell hardness number of given metal specimen by Brinell hardness test.

EQUIPMENT

Brinell hardness testing machine

APPARATUS

Microscope

MATERIALS

Steel, Brass, Aluminum, Copper, Cast Iron.

RELATED I.S.CODES


SALIENT FEATURES

Hardness is basically an important property of the metals and is defined as the resistance given by the metal specimen to indentation scratching or abrasion on its surface. Brinell hardness is a method of finding hardness of given specimen by indentation and was introduced by J.A Brinell in 1900. This method uses a steel ball (or indenter) of standard known diameter (D) on which a standard load (F) is applied gradually. The hardness tester is shown in figure 1.1

The hardness number is then calculated from the depth of the indentation (of Diameter d) produced by the load applied. Thus it is an indirect method of finding hardness. Brinell hardness is defined as the ratio of the load applied to the spherical area of the indentation formed on the specimen surface and is equivalent to kgf/mm$^2$

Figure 1.2 shows the indentation on the metal surface.

BHN=Test load (kgf)/surface area of indentation (sq.mm)
Where,

\[ F = \text{force applied in kgf} \]
\[ D = \text{diameter of ball in mm (generally 1, 2, 2.5, 5 & 10mm)} \]
\[ D = \text{diameter of indentation in mm} \]

The distance between the centre of any indentation and the edge of the test piece shall be at least 2.5 times the mean diameter of the indentation in case of steel, cast iron, copper & copper alloys and at least three times the mean of the dentition in the case of light metals, lead, tin and their alloys.

The distance between the centers of the two adjacent indentations shall be at least four times the mean diameter of the indentation in the case of steel, cast iron, copper & copper alloys, and at least six times the mean diameter of the indentation in case of light metals, lead, tin & their alloys.

**LIMITATIONS:**

1. Specimens with lesser thickness blades. If tested by this method, would not give accurate results as the usual indentation might be greater than the thickness of the specimen and lesser thickness inhibits the generation. As general rule, the thickness of the specimen shall be at least eight times the depth of the indentation.

2. It is recommended that the steel ball med enter should be used for materials with a brinell hardness not exceeding 350. For higher hardness up to 630 indenter of carbide metal should be used.

**APPLICATIONS:**

This property of the metal has a very large application in the industry right from a small needle to gigantic aircrafts. The quality of the metal to be used for a specific purpose is controlled by this test e.g. the drill shall have hardness greater than the material to be worked on. Similarly strength of jobs like forging, alloying or casehardening is determined with this test.

**OBSERVATION TABLE:**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Metal</th>
<th>Ball Diameter (D) in mm</th>
<th>Test Load (P) in kgf</th>
<th>Diameter of Inventor (d) in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C.I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Brass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Aluminum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Load to be applied in kgf is chosen as follows according to the provisions of Indian standards I.S. limit for Brinell hardness test on steel is HB 450 and balls of diameter 2.5 mm, 2 mm & 1 mm should not be used for conducting hardness test on cast metal.

<table>
<thead>
<tr>
<th>LOAD (kgf)</th>
<th>MATERIAL</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>30D²</td>
<td>Steel</td>
<td></td>
</tr>
<tr>
<td>30D²</td>
<td>Grey C.I</td>
<td></td>
</tr>
<tr>
<td>30D²</td>
<td>Grey C.I el</td>
<td>For HB less than 140</td>
</tr>
<tr>
<td>5D² 10D² 150D²</td>
<td>Grey C.I</td>
<td>5D² for HB less than 55</td>
</tr>
<tr>
<td>30D²</td>
<td>Copper &amp; its Alloys</td>
<td>For HB less than 40</td>
</tr>
<tr>
<td>30D²</td>
<td>Copper &amp; its Alloy</td>
<td>For HB 35 to 200</td>
</tr>
<tr>
<td>30D²</td>
<td>Copper &amp; its Alloy</td>
<td>For HB greater than 190</td>
</tr>
</tbody>
</table>

**PROCEDURE:**

1. Check the specimen as per Is code specifications and steps mentioned in the subhead precautions.
2. Select the appropriate ball indenter and the corresponding load to be applied on the specimen selected.
3. Place the specimen on the anvil and bring the indenter in the contact with the surface of the specimen.
4. Apply the load at a gradual rate up to the test load F is attained. The time from the initial application of force until the full test load reached shall not be less that two seconds nor greater than eight seconds. The test load shall be maintained for ten to fifteen seconds for steel, 30 +2 seconds for light metals and their alloys and 15 to 20 seconds for grey cast iron.
5. Unload the specimen by releasing the lever.
6. Measure the diameter of the indentation at right angles with the help of the microscope. The average of these readings gives the diameter of the indentation.
7. Calculate the BHN of the given specimen by the formula given in the theory.

**PRECAUTIONS:**

1. The surface of the test specimen shall be smooth and even, free from oxide scale, foreign matter and, in particular, completely free form lubricants.
2. Preparation of the test specimen shall be carried out in such a say that any alteration of the surface due to heat or cold working is minimized. Ambient temperature for carrying out the test is 100°C to 350°C.
CALCULATIONS:

<table>
<thead>
<tr>
<th>SR.NO.</th>
<th>METAL</th>
<th>BHN</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C.I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Brass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Copper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Aluminum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION:

QUIZ

1. Define Hardness and state types of hardness test.
2.

3. How would the results be affected, if
   a) the indentation is made nearer to the edge of the specimen.
   b) the indentation is made close to the previous indentation.
3. What will be the effect in hardness number, if
   a) rate of loading is rapid
   b) load is removed immediately.

4. If material is harder than BHN 630, what happens if Brinell Hardness Test is Conducted on the material?
ROCKWELL HARDNESS TEST

DATE:

OBJECTIVE

To determine the hardness number of given metal specimen by Rockwell hardness test.

EQUIPMENT

Rockwell hardness testing machine with direct reading dial

APPARATUS

Microscope

MATERIALS

Mild Steel, Brass, Aluminum, Copper, Cast Iron.

RELATED I.S.CODES

I.S 1586-1988: Method for Rockwell hardness test (B & C scales for steel)

SALIENT FEATURES

Hardness is basically an important property of the metals and is defined as the resistance given by the metal specimen to indentation scratching or abrasion on its surface.

This experiment pertains to indentation hardness under a given static load. Standard values of indenting forces is applied on the specimen and the impression formed on the surface of the specimen is measured. Depending upon the impression, the Rockwell hardness number is assigned. The prefix HR with dial reading is used to designate the Rockwell number. The line diagram of the machine is shown in fig. below.

Rockwell hardness number is directly read from dial having B & C scales and used to test the hardness of the steel. B scale is meant for materials of medium hardness where as C scale is used for the material harder than 100. This scale C should not be used for range below HRC 20.

This test differs from brinell test in the sense that the penetration and the loads are smaller, and hence the resulting indentation shallower, so it is applicable to the testing of materials having hardness beyond the scope of Brinell test. Rockwell hardness number is inversely proportional to the depth of the indentation. Fig.1 below shows the indentation caused by steel ball and Fig.2 shows the indentation caused by diamond cone on metal surfaces.

A minor load of 10 kg is applied first for proper fixing of the specimen, which causes initial indentation that sets the indentor and hold the specimen in position. This is followed by the application of major load, which leaves an indentation on the surface of the specimen. The depth of indentation is derived from the dimension of the indentation.
Rockwell B number (HRB) = 130 – [ depth of penetration h (mm) / 0.002]

Rockwell C number (HRC) = 100 – [ depth of penetration h (mm) / 0.002]

Following table give the tabulated details of the load to be applied and the scale to be referred for particular materials.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Indenter Type</th>
<th>Major Load in Kg</th>
<th>Dial</th>
<th>Typical Application of scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Hardness steel ball of diameter 1.5875 mm</td>
<td>100</td>
<td>Red</td>
<td>Cooper alloys, Aluminum alloys, Soft steel, etc.</td>
</tr>
<tr>
<td>C</td>
<td>Diamond cone, angle at tip (120±0.5)° (Tip of diamond cone is rounded to radius of 0.2mm)</td>
<td>150</td>
<td>Black</td>
<td>Steel, Hard C.I, Deep case hardened steel, etc.</td>
</tr>
</tbody>
</table>

**PROCEDURE**

- Place the specimen on the anvil.
- Apply minor load of 10 kg gradually so as to ensure proper holding of the load to the specimen.
- Select proper value of load with the help of the load selector.
- Adjust the pointer at “set” position and set the dial to zero-position.
- Apply major load by operating handle without any interference.
- Bring the lever back to its catch position to take off the load from the position.
- Read the position of the pointer on the pointer on the appropriate dial, Which gives Rockwell hardness number.
- Measure the diameter of the impression with the help of microscope and determine the depth of the indentation using simple geometry. Using this diameter and formula, find Rockwell Hardness number.

**PRECAUTIONS**

The minimum distance between two indentations should be at least 2d and the distance of the indentation from the edge of specimen should be at least 3d, where d is the distance of the indentation.

**APPLICATIONS**

On the basis of hardness, material are graded for their commercial use. The quality of material and products is maintained or controlled by hardness test. Also, the strength of this job like
forming, alloying, case hardening etc. is determined with the help of this test. Some correlation of hardness with other parameters like tensile strength is established which is useful in estimating the tensile strength of the material.

**OBSERVATION TABLE**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Specimen</th>
<th>Indenter Type</th>
<th>Major Load (kgf)</th>
<th>Dial Colour</th>
<th>Dia. of Indentation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C.I.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Aluminum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Brass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATIONS**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Specimen</th>
<th>Harness Number.</th>
<th>Remarks From Dial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C.I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Copper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Aluminum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Brass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSION**

**HOME-ASSIGNMENT:**
Students are required to find some examples where hardness governs the design of machine components.

**QUIZ**

1. Why the minor load is applied before test load?
2. Distinguish this test from the other tests for measuring hardness, based on the principle of indentation.

3. What is meant by Calibration of machine?

4. If Rockwell hardness Test is done on too thin a specimen, how would the observed hardness be affected?

5. Is there any relation between the hardness obtained by different method? If yes, give the I.S. Code Number Formulae.
IZOD IMPACT TEST

DATE:

OBJECTIVE

To study the behavior of metals under impact loads.

EQUIPMENT

Izod Impact Testing machine with direct reading dial

MATERIALS

Mild Steel, Brass, Aluminum, Cast Iron.

RELATED I.S.CODES


SALIENT FEATURES

Components of many structures or machines have to resist dynamic loads, which are either impact loads or rapid fluctuating loads are applied suddenly and this test provides information about the behavior of materials under such loads. The predominant consideration in impact resistance is the capacity of material to absorb energy, which depends on toughness of material (energy required to rupture a material). In this test, toughness is not measured through strain or deflection measurement but this is ascertained by measuring energy to rupture a specimen. Fig below shows the line diagram of the machine.

In such tests, the load may be applied in flexure, tension, compression or torsion and impact may be delivered through dropping weight, swinging pendulum of rotating flywheel. In this test, the specified cantilevering length of the specimen is projecting out from vise with notch at the base as shown in Fig. below and swinging pendulum strikes on the edges of the specimen giving a flexural type of loading.

Indian standards lay down the following major requirements for the impact testing machines.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Izod Impact Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance between the base of notch and point of specimen hit by hammer</td>
<td>22 ± 0.5 mm</td>
</tr>
<tr>
<td>Angle at tip of hammer</td>
<td>75°</td>
</tr>
<tr>
<td>Speed of Hammer</td>
<td>3 to 4 m/s</td>
</tr>
<tr>
<td>Accuracy of graduation of scale</td>
<td>± 0.14 kg-m</td>
</tr>
</tbody>
</table>

Change in Temperature has a marked effect on the impact resistance of notched bars. Fig. below illustrates in a much generalized form of the nature of the variation of the energy top produce rupture in the impact test over a considerable range of temperature.
Specimens used in this test are notched type, which causes high- localized stress concentration, artificially reduces ductility and tends to induce a brittle type of fracture.

**SPECIMEN**

Specimen with at suitable position is used for carrying out the impact test on the impact. For steel specimen. Requirement is as follows:

<table>
<thead>
<tr>
<th>Shape of the Specimen</th>
<th>Type</th>
<th>Type of Notch</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square or Round</td>
<td>Cantilever beam fixed at notch</td>
<td>V notch at base</td>
<td>Fig below</td>
</tr>
</tbody>
</table>

**PROCEDURE**

1. Check the specimen, its dimensions and ascertain that the IS requirements are satisfied.
2. Fix the specimen tightly in the vise and ascertain that the longitudinal axis of the specimen lies in the plane of swinging of the hammer.
3. Plane of symmetry of notch should coincide with the top surface of the grips. The hammer.
4. Set the pointer to read the energy of the blow of the pendulum.
5. Release the pendulum and allow it to strike the test specimen.
6. Read the indicator and obtain impact value of the specimen by deducting the energy losses from the reading.
7. Study the type of fracture and correlated it with fracture of specimen of different material.
8. Repeat steps 4 to 7 without specimen, the indicator reading shows the energy losses due to friction. Note down the value.
9. The impact values of material is obtained by subtracting reading obtained in step 8 from step 6.

**LIMITATION**

To determine the impact resistance, temperature should be 32º to 38º because it has a very marked effect on impact resistance of notched bar.

**PRECAUTIONS**

It is not advisable to stand near or in fromt of machine when the pendulum is to be released. Notch should be exactly in the line of action of the pendulum.

When specimen is being fitted, care should be taken that pendulum does not released.

**APPLICATIONS**

As mentioned in the therotical background. This test is basically designed to checked the suitability of material subjected to dynamic loads e. g. wave or hammer falling on mail. The ductile material like steel has more impact value and therefore has wide acceptability in structural and other mechanical applications.
OBSERVATION TABLE

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Specimen</th>
<th>Gross Energy (kg-m)</th>
<th>Energy Loss (kg-m)</th>
<th>Impact Value (kg-m)</th>
<th>Mode of Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.S.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>C.I.</td>
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<tr>
<td>3</td>
<td>Copper</td>
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</tr>
<tr>
<td>4</td>
<td>Aluminum</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>Brass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

HOME ASSIGNMENT

Student should observe the system, which are subjected to impact loads and try to list them with brief description of each.

QUIZ

1. Why are impact flexure specimens notched?

2. Discuss the effect of following factors upon the results of impact test.
   (a) Characteristics of the notch (b) Velocity of the hammer (c) Types of testing machine (d) Temperature of the specimen
3. What physical property of a material is determined by means of impact test?

4. Tick the mode of applying load in this test. (Flexure/Compression/Tension/Torsion)

5. Tick the specimen type used in this test. (Flexure/Compression/Tension/Torsion)
EQUILIBRIUM OF PARALLEL FORCE SYSTEM - SIMPLY SUPPORTED BEAM

OBJECTIVE

To verify the conditions of equilibrium of a system of coplanar-parallel forces with the help of a simply supported beam and an overhang beam apparatus.

APPRATUS

Simply supported and overhang beam set, standard weights and a metre rule.

THEORETICAL BACKGROUND

Beam is a structural member having cross-sectional dimensions very smaller than its length and is subjected to transverse loads (load acting perpendicular to the longitudinal axis of the beam). Fig. 2.1 shows simply supported beam and fig. 2.2 shows an overhang beam. In equilibrium condition, when a system of coplanar and non-concurrent forces acts on a beam, following statistical conditions should be satisfied for the system.

\[ \sum H = 0, \text{ i.e. Algebraic sum of forces along X axis must be zero.} \]

\[ \sum V = 0, \text{ i.e. Algebraic sum of forces along Y axis must be zero.} \]

\[ \sum M = 0, \text{ i.e. Algebraic sum of moments of forces along any point must be zero.} \]

\[ \sum H \text{ and } \sum V \text{ takes into account the action of the forces on the beam and } \sum M \text{ takes into account the action of the forces due to their eccentricity from the point about which moment is to be taken.} \]

PROCEDURE

1. Place the beam in its position on a selected value of the span.
2. Note down the initial reading shown by the spring balance at the reaction points. These reactions are due to self-weight of the beam.
3. Suspended several weights from the beam and note the magnitude of the loads and their distance from the self support.
4. Observe the final readings shown by the spring balances at the reaction points.
5. Calculate the experimental value of the reaction by deducting initial reading from the final reading.
6. Calculate the percentage error in equilibrium of forces and moments (refer Table I and II of calculation)
7. Find the value of unknown Load ‘P’ considering the system to be in equilibrium (refer Table III of calculation)
8. Repeat the steps 1 to 7 for an overhang beam.

**OBSERVATION**

Span of the beam = ________________ mm

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Load on beam (gms)</th>
<th>Total Load (W)</th>
<th>Distance from support A</th>
<th>Span (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W1(gms)</td>
<td>W2(gms)</td>
<td>X1(cm)</td>
<td>X2(cm)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>3</td>
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<td>4</td>
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<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Support readings**

<table>
<thead>
<tr>
<th>Ra (gms)</th>
<th>Rb(gms)</th>
<th>Ra(gms)</th>
<th>Rb(gms)</th>
<th>Total reaction (R)</th>
<th>Difference (W-R) (gms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**CONCLUSION**

**QUIZ**

1. What type of force system does this experiment represent?
2. What is the difference between the force system of this experiment and of the previous experiment?

3. How can the percentage error obtained in the experiment be reduced?

4. Refer the figure of overhanging beam, if $X_2 = 1.5 \, \text{L}$ and $W_1=W_2$, what should be the value of $x_1$, so that $R_L=0$.

5. How should the load be placed on the simply supported beam theoretically so that $R_L$ becomes Zero?
COEFFICIENT OF STATIC FRICTION

OBJECTIVE

To determine the coefficient of static friction between given two surfaces with the help of an inclined plane.

APPARATUS

An adjustable inclined wooden plane with pulley at one end (Fig. 4.1 A and 4.2 A), wooden block, inextensible string and standard weights

THEORETICAL BACKGROUND

When a body moves or tends to move or another body, a force opposing the motion develops at the contact surfaces; This force which opposes the movement is called friction or frictional force. If the contact surfaces are perfectly smooth, there is no friction. In mechanics, friction is both desirable or undesirable where it causes loss of cover and/or wear, it is undesirable. On the other hand, friction is essential for various holding and fastening devices, brakes, belt drives, driving an automobile etc. Following are technical terms related to the theory of friction.

Coefficient of Friction ($\mu_s$)

Ratio maximum frictional force ($F$) developed to the normal reaction ($N$) developed between two bodies in contact.

$$\mu_s = \frac{F}{N}$$

Angle of Friction ($\phi$)

Angle made by resultant of the normal reaction ($N$) and frictional force ($F$) developed at the surface to the normal when the body is in impending condition is called angle of friction. The tangent of this angle is equal to coefficient of friction.

$$\mu = \tan\phi = \frac{F}{N}$$

Angle of Repose ($\lambda$)

The maximum angle of an inclination with horizontal at which a point mass resting on it rest on it is just on verge of sliding is called the angle of repose.

Law of Dry Friction

- If friction is neglected, the reaction developed is always normal to surface in contact.
Experiments in Mechanics of Solids: Semester I & II

✓ Friction always acts in direction opposite to motion or tendency to move. It is tangent to the surface in contact.
✓ In the case of static friction, the value of friction force may vary from zero to its limiting value. The body impends after this value.
✓ The maximum available static friction is equal to \( \mu_s N \).
✓ When the motion occurs, the kinetic friction always acts in the direction opposite to the motion and is given by \( \mu_k N \), where \( \mu_k \) is the coefficient of kinetic friction and \( \mu_k < \mu_s \) (Fig. 4.3)

PROCEDURE

- Set the working plan at zero inclination to horizontal.
- Place the given block and known weight from the working surface.
- Connect the block to effort pan by a string passing over a frictionless pulley.
- Apply effort in small increments such that the block impends. Note down the corresponding value of effort. Calculate the coefficient of friction between the surfaces.
- Find the angle of repose by keeping the block on the surface and gradually tilting the incline such that the block starts slipping down corresponding angle with the horizontal is angle of repose.
- Set the incline at an angle greater than angle of repose and take a reading for motion impending upwards as well as downwards.
- Set the incline at an angle smaller than angle of repose and take a reading for motion impending upwards.
- Calculate the average coefficient of static friction.

OBSERVATION TABLE

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>SURFACES IN CONTACT</th>
<th>ANGLE OF INCLINATION (deg)</th>
<th>LOAD (N) (W)</th>
<th>EFFORT (N) (P)</th>
<th>COEFFICIENT OF FRICTION (( \mu_s ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zero</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANGLE OF REPOSE (\( \gamma \)) =
MOTION UP THE PLANE (\( \theta > \gamma \))

| Reading 1 | (Fig. 4.1 B) | \( \mu_s = \frac{P}{W} \) |
Experiments in Mechanics of Solids: Semester I & II

Reading 2  (Fig. 4.2 B) \[ \mu_s = \frac{(P \text{ Sec } \theta)}{W} - \tan \theta = \]

Reading 3 \[ \mu_s = \tan \theta - \left( \frac{P \text{ Sec } \theta}{W} \right) = \]

Reading 4 \[ \mu_s = \left( \frac{P \text{ Sec } \theta}{W} \right) - \tan \theta = \]

CONCLUSION

QUIZ

2. Distinguished between static and kinematic friction.

3. Weather the kinematic friction is more than static friction? Comment.

4. If the area of contact is increased twice, will the friction force is double?

5. The coefficient of friction between two surfaces is constant of proportionality between the applied tangential force and the normal reaction at the instant of _________.
   (Application of force, Body at rest, Impending motion)

6. The force of action acts in the _________direction of that motion and in _________ direction to the surface of friction. (Normal, Tangential, Same, Opposite).
7. What is the effect of following on coefficient of friction and angle of friction?
   (a) Weight of body, Shape, Area.
   (b) Angle of inclination of the applied force, smoothness or roughness of contact surface.
COMPRESSION TEST ON TIMBER AND METAL

DATE:

OBJECTIVE

To determine the compression strength of various materials such as Mild Steel (M.S) cast Iron (C.I), Timber and study their behavior when subjected compressive load up to fracture.

MATERIALS

Mild steel, Cast Iron, Timber

APPARATUS

Universal Testing Machine with the arrangement of extensometer to test Specimen in tension and compression, venire calipers.

THEORETICAL BACKGROUND

Specimen for compression test usually fails by buckling they are slender. So to avoid buckling failure the length of the specimen should be about the same order with the minimum dimension in cross section.

For ductile material like M.S. or copper the Specimen bulges laterally under compressive load and takes a barrel shape. Finally occurs by appearance of cracks on the circumferential surface with spread invert.

Brittle material such a C.I usually fails by Shearing plan inclined 50 to 70 with longitudinal axis. But sometime a normal failure plane is not fully developed within the length of the specimen and in such case apparent strength is appreciably increased and crushing may occurs. When there is a combination of high compression strength and unrestrained lateral expansion at the ends the specimen fails by separation in to columnar fragment known as columnar fracture.

Wood is not an isotropic materials means it has different strength in different direction. It is a composed of series of parallel tubes along the grain. For load normal to the grain the load that causes lateral collapse of tubes is the significant load.

SPECIMEN

For uniform stressing of compression metal specimen, a circular section is to be preferred over other shapes. Slenderness ratio of 2 is generally adopted to avoid buckling of specimen.

In this test specimen with slenderness ratio 2 to 5 is adopted to understand effect of slenderness of specimen when subjected to compression force.

I case of timber specimen size should be mentioned (50.50.200) mm for parallel to grains and (50.50.200) mm for perpendicular to grains.
PROCEDURE

1. Measure all dimension given specimens carefully with help to venire calipers.
2. Put the specimen of the mild steel in the machine and apply the load gradually on to it. Stop the loading when first crack observed on the specimen or it break.
3. Repeat the step (1) for cast iron and for timber (parallel to grain and perpendicular to grain)
4. Find out the stress on each specimen

LIMITATIONS

1. Difficulty of applying truly axial load.
2. Friction between the heads of testing machine or bearing plates and the surface of the specimen due to the lateral expansion. This may alter considerably the result with compare to those obtained in absence of such lateral resistant.
3. To obtain a proper degree of stability of the piece, the cross section area should be large compare to its lengthy It is possible in two ways.
   a. Proving large area for the same length, but this may require large amount for Loading and large machine capacity.
   b. Proving smaller specimen length for the same c/s area, but this creates difficulty In measuring strain accurately.

FIGURES

Fig. 1.1 Universal Testing Machine
OBSERVATION TABLE (For compression Test on Timber):

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of specimen</th>
<th>Cross sectional area (mm²)</th>
<th>Load applied parallel to grain</th>
<th>Load applied perpendicular grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load at failure (N)</td>
<td>Mild Steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load at failure (N)</td>
<td>Cast Iron</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OBSERVATION TABLE BEFORE FAILURE (For compression Test on Metals):

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of specimen</th>
<th>Diameter</th>
<th>Height</th>
<th>Aspect Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mild Steel</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cast Iron</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### OBSERVATION TABLE AFTER FAILURE (For compression Test on Metals):

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of Specimen</th>
<th>Height after Test</th>
<th>Mean Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mild Steel</td>
<td>TOP</td>
<td>MIDDLE    BOTTOM</td>
</tr>
<tr>
<td>2</td>
<td>Cast Iron</td>
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</tbody>
</table>

### CALCULATION:

### CONCLUSION:

### QUIZ

1. What Failure plane in brittle are not exactly 45?

2. What do you mean by Slenderness ratio?
3. How do you will differentiate M.S and Cast Iron specimen?

4. What the Function of compress meter?

5. In which failure position strength of timber is higher? Parallel to grain and perpendicular to gains? Why?
TENSION TEST

OBJECTIVE

To study stress-strain curve & its characteristics with the help of tensile test on ductile and brittle materials.

MATERIALS
Ductile material mild-steel, brittle -Cast iron.

APPARATUS
Universal Testing Machine with the arrangement of specimen in tension, venire calipers and extensometer.

RELATED I.S. CODES

THEORETICAL BACKGROUND:
Tensile test is required for test in which a standard specimen is subjected to gradually increasing static (i.e. not changing a time) uni axial load until failure occurs. Deformation is measured over the gauge length.
Gauge length is the prescribed part of the cylindrical on prismatic portion of the test piece on which elongation is measured any moment during the test.

SCOPE:
Tension test are generally conducted on rolled or forged ferrous and ferrous materials and alloys, which are required to resist tensile forces. The static tension as also compression test is the simplest and most common of all the mechanical tests. These tests help us in evaluation of fundamental properties for use in design like;

1. Elastic or Plastic behavior.
2. Limits of proportionality and elasticity.
6. Toughness.
7. Percentage elongation.
8. Percentage reduction in area.
9. Ductile and brittle characteristics based on type of fracture surface.

PROCEDURE:

1. Check weather the specimen fulfills I.S. requirements.
2. See that the specimen is symmetrical with respect to its longitudinal axis throughout the length.
3. Mark the Gauge length at 5.65 A=5.d
4. Measure diameter and its length before applying the load.
5. Fix extensometer on the specimen and fix the specimen in universal testing machine.
6. Apply tensile load.
7. Measure elongation with the help of extensometer up to yield point. Note down the ultimate load & braking load.
8. Measure the reduced diameter & increased length & note down the type of fracture.
9. See whether the fracture lies within gauge length or out side. If it is out side comment on validity test.
10. Plot a graph of load V/s deformation and stress and V/s strain. Determine the stress characteristics and form fracture comment on the type of material.

LIMITATION
These tests are not sufficient to provide information about the performance of material under all loading conduction like impact load and fatigue load.

Note:
After yield load, extensometer should be removed to avoid damage to the same.

OBSERVATION

1. Original diameter of cross section (mm) d :________________________
2. Original gauge length (mm) L :________________________
3. Final gauge length (mm) Lf :________________________
4. Diameter after fracture df :________________________
5. Load at yield point (kN) Py :________________________
6. Ultimate load (kN) pu :________________________
7. Breaking load (kN) Pu :________________________
8. Type of fracture :________________________
9. Original area (A) :________________________
10. Final area (Af) :________________________
OBSERVATION TABLE

<table>
<thead>
<tr>
<th>Load (kN)</th>
<th>Extension (mm)</th>
<th>Load (kN)</th>
<th>Extension (mm)</th>
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CALCULATIONS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameter</th>
<th>Calculation</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yield stress</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>Ultimate stress</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>Breaking stress</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>Actual breaking stress</td>
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<tr>
<td>5</td>
<td>Percentage elongation in the gauge length</td>
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<tr>
<td>6</td>
<td>Percentage reeducation in area</td>
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Form Graph:

1. Stress= ____________
2. Strain= ____________
3. Modulus of elasticity $E = \frac{\text{Stress}}{\text{Strain}}$: ________________

CONCLUSION:
FIGURES:

![Fillet and gauge point diagram](image1)

**Fig. 2.1** Typical specimen for tensile test

![Failure patterns](image2)

**Fig. 2.2** Typical failure patterns

![Stress-strain diagrams](image3)

**Fig. 2.3** Stress-strain diagrams for ductile and brittle materials

![Proof stress diagram](image4)

**Fig. 2.4** Proof stress
QUIZ

1. What do you mean by yield point?

2. What do you mean by Yield of proportionality?

3. Draw a shape of stress-strain curve for ductile materials.

4. What is the function of extensometer?