*LAB MANUAL*

# *Strength of Material Lab*

## *(LC-ME-214G)*

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CONTENTS

**Objective**: **To study the Brinell hardness testing machine & perform the Brinell hardness test.**

**Apparatus used:**

1. Brinell Hardness Tester
2. Test Piece
3. Hardened steel ball 10mm diameter
4. Microscope

**Theory**:

Hardness represents the resistance of a material to indentation, and involves the measurement of plastic deformation caused when a loaded ball or diamond is applied to the surface of material.

Brinell Method: In this a hardened steel ball is pressed into the surface under a specified load which is held on for a fixed period and then released.

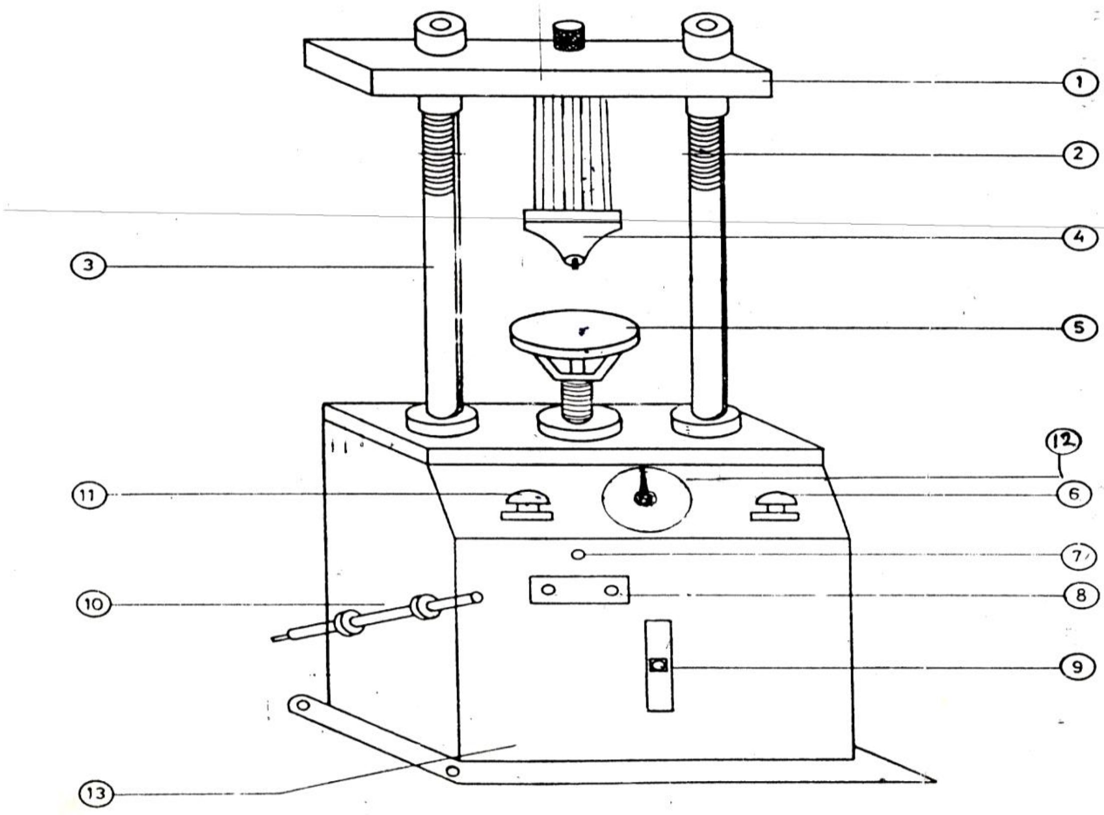
Brinell Hardness is defined as the quotient of the applied force F, divided by the spherical area of impression.
From fig. we find that:

Brinell Hardness, HB = Test load/Surface area of indentation

$$= 2F/\pi D(D-\sqrt{D^2-d^2}) \ \ N/mm^2$$

**Procedure:**

1. Place the test specimen and the test table of the testing machine.
2. Apply load slowly and progressively to the specimen at right angle to the surface and maintain full load for 15 seconds.
3. Release the load and remove the specimen from the table.
4. Measure the diameter of impression on the test specimen by microscope fitted with a scale.




**Brinell Hardness Testing Machine**

**<u>Observations</u>:**

Material of test piece =
Diameter of ball =
Load 'F' =
Load application time =
Diameter of Impression'd' =

**<u>Calculations</u>:**
**Brinell Hardness HB =Test load\Surface area of indentation**

$$= 2F/\pi D(D-\sqrt{D^2-d^2}) \ \ N/mm^2$$

| Sr. No | DESCRIPTIONS |
|---|---|
| 1 | ADJUSTABLE CROSS HEAD |
| 2 | PROVING RING DYNAMOMETER |
| 3 | CRROMIUM PLATED PILLARS |
| 4 | BALL INDENTOR |
| 5 | BASE PLATE |
| 6 | CONTROL VALVE |
| 7 | INDCATOR |
| 8 | ON/OFF PUSH BUTTON |
| 9 | PROVISION FOR HAND OPERATION |
| 10 | HANDLE FOR MANUAL OPERATION |
| 11 | RELASE VALVE |
| 12 | DIAL GAUGE |
| 13 | DUST PROOF CABINET |

**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.
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 -------

**OBJECTIVE: To study the Rockwell hardness testing machine & perform the Rockwell hardness test.**

**APPARATUS REQUIRED:**
Rockwell hardness testing machine.
Black diamond cone indenter,
Hard steel specimen.

**THOERY:**

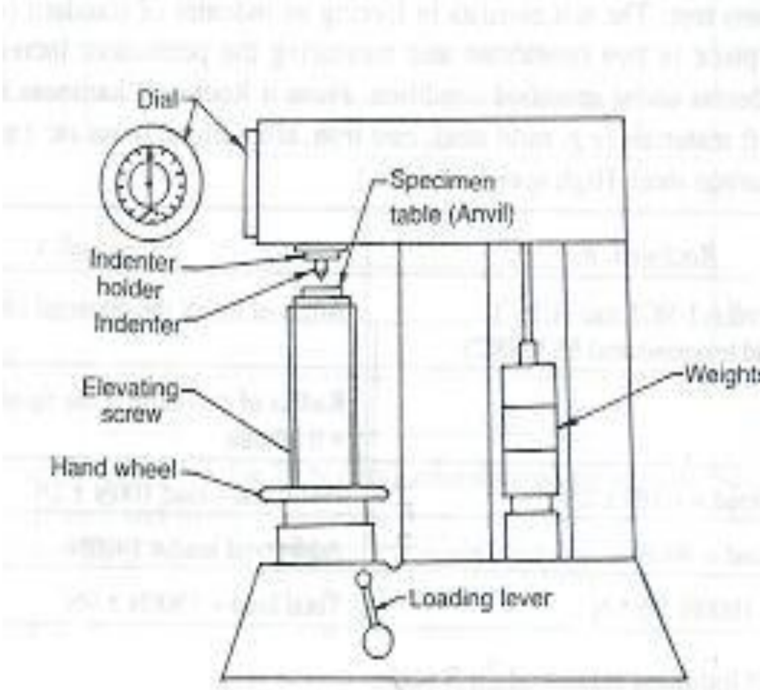
Rockwell test is developed by the Wilson instrument co U.S.A in 1920. In this test consists in touching an indenter of standard cone or ball into the surface of a test piece in two operations and measuring the permanent increase of depth of indentation of this indenter under specified condition. From it Rockwell hardness is deduced. The ball (B) is used for soft materials (e.g. mild steel, cast iron, Aluminum, brass.etc.) and the cone (C) for hard ones (High carbon steel. etc.).

HRB means Rockwell hardness measured on B scale
HRC means Rock well hardness measured on C scale.

**PROCEDURE:**

1. Clean the surface of the specimen with an emery sheet.
2. Place the specimen on the testing platform.
3. Raise the platform until the longer needle comes to rest.
4. Release the load.
5. Apply the load and maintain until the longer needle comes to rest.
6. After releasing the load, note down the dial reading.
7. The dial reading gives the Rockwell hardness number of the specimen.
8. Repeat the same procedure three times with specimen.
9. Find the average. This gives the Rockwell hardness number of the given specimen.

**LAYOUT DIAGRAM:**




**Rockwell hardness test equipment**

**OBSERVATION TABLE:**

| S.No. | Material | Scale | Load (kgf) | Rockwell hardness Number | | | Rockwell hardness Number(Mean) |
|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**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 number of the given material is _________

**Objective**: **To study the Erichsen sheet metal testing machine & perform the Erichsen sheet metal test.**

**Apparatus used:** Cupping test machine, test specimen, vernier calliper, steel rule.

**Theory:**

This is a mechanical test used to determine the ductility and drawing properties of sheet metal. It consists in measuring the maximum depth of bulge or cup which can be formed before fracture. Cupping number is the depth of impression at fracture, in the cupping test, usually expressed in millimeters.

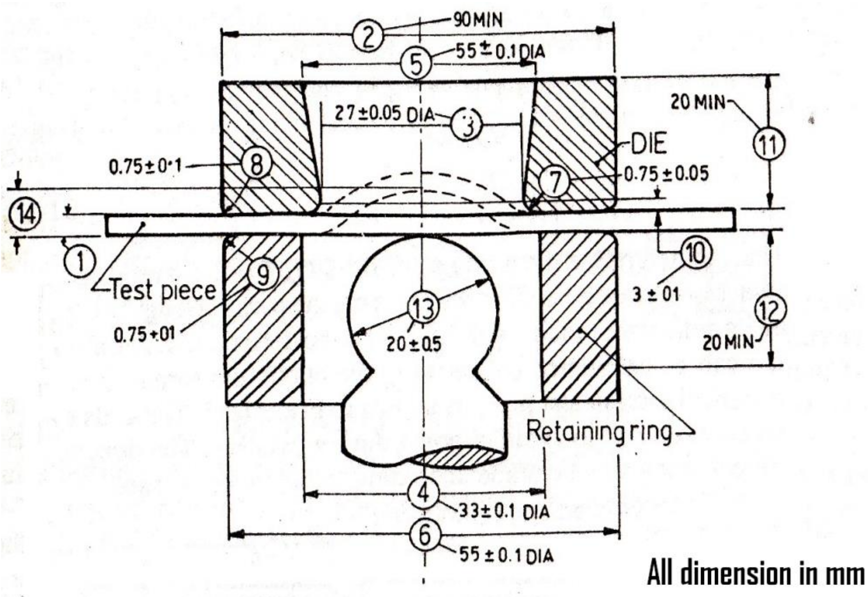



FIG.-MODIFIED ERICHSEN CUPPING TEST

**Procedure:**

1. Measure the dimension of the test piece.
2. Place the test piece in the machine dies and touch the penetrator.
3. Rotate the handle of the machine to penetrate the penetrator in the test piece by pressing the retaining ring.
4. As soon as crack appears in the test piece stop rotating the handle.
5. Determine the depth of cup from med, which is the cupping number.

**Observations:**

1. Thickness of test piece: 0.5 to 2 mm.
2. Rotation speed: 5 to 20 mm per minute.
3. Diameter of ball: 20 mm

**Observation table:**

| **Sr.No.** | **Test piece thickness in mm** | **Reading** | | **Cupping Number** |
|---|---|---|---|---|
| | | **Initial** | **Final** | |
| **1** | | | | |
| **2** | | | | |

**Precaution:**

1. Test piece should be perfectly flat.
2. Testpiece should be free from foreign matter.
3. The cup formed should be continuously watehed.
4. The handleshould be rotated uniformly and continuously.

Sources of error':

1. Handle being rotated with jerks.
2. Test piece not perfectly flat.

**Conclusion:** The study of Erichsen sheet metal testing has been successfully done.

**(A)**

**OBJECTIVE: To determine the impact strength of a given specimen by Izod test.**

**Apparatus Used**: Mild Steel Specimen, Impact testing machine

**Theory:-**

In 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 arc of a circle, which strikes the specimen to fracture at the notch.

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.

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.

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

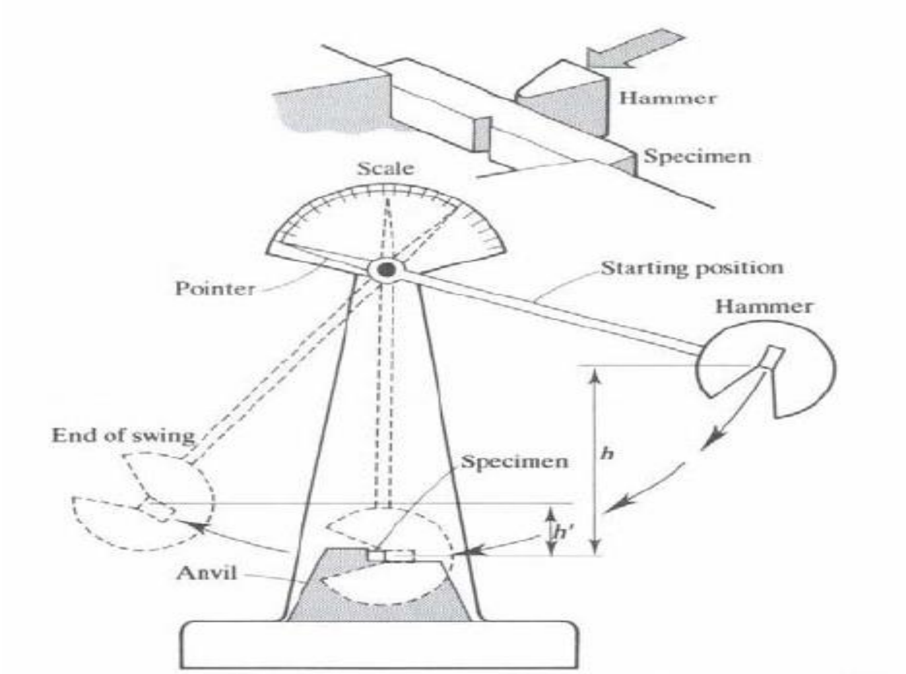
Charpy introduced Charpy test in 1909. Test is as per the IS: 1499.

**Impact:** The capacity of a material to resist or absorb shock energy before it fractures is called Impact.

**Strength:** The strength of material is ability to resist the action of an external force without breaking. It is usually defined as tensile strength, Compressive strength, Shear strength etc. Energy absorbed by specimen during impact test is known as impact strength.

**Izod Impact Test:** In the Izod impact test, the surface of the specimen should be smooth and free from grooves running parallel to the plane of symmetry of notch. The centre of percussion shall be at the point of Impact of the hammer.

**Layout Diagram:**




**Izod Impact testing equipment**

**The machine should have following specification:**

Angle between top of grip and face holding the specimen vertical: 90°

Angle of tip of hammer: 75°

Angle between normal to the specimen and the underside of the hammer at striking point: 10°

Speed of hammer Impact: 3 to 4 m/s.

Striking energy: 165.6 ± 3.4 N-m

The longitudinal axis of the test piece should lie in the plane of swing of the centre of gravity of the hammer. The notch shall be positioned so that its plane of symmetry coincides with the top face of the grips. The notch shall be at right angle to the plane of swing of centre of gravity of hammer.

**Procedure:**

1. Measure the dimensions of a specimen. Also, measure the dimensions of the notch.

2. Raise the hammer 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. Repeat the test for specimens of other materials.

6. Compute the energy of rupture of each specimen.

**Observation Table:**

| S.No. | Initial Reading | Final Reading | No. of division (Initial-Final Reading) | Observed Energy (2× No. of division) | Mean Energy Stored |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

**Result: Mean energy stored by the specimen = ……**

**(B)**

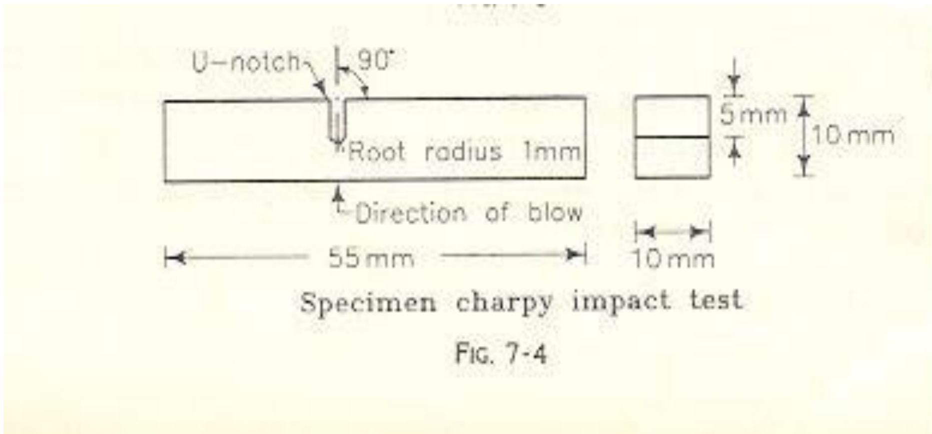
**OBJECTIVE: To determine the impact strength of a given specimen by charpy test.**

**Apparatus Used**: Mild Steel Specimen, Impact testing machine.

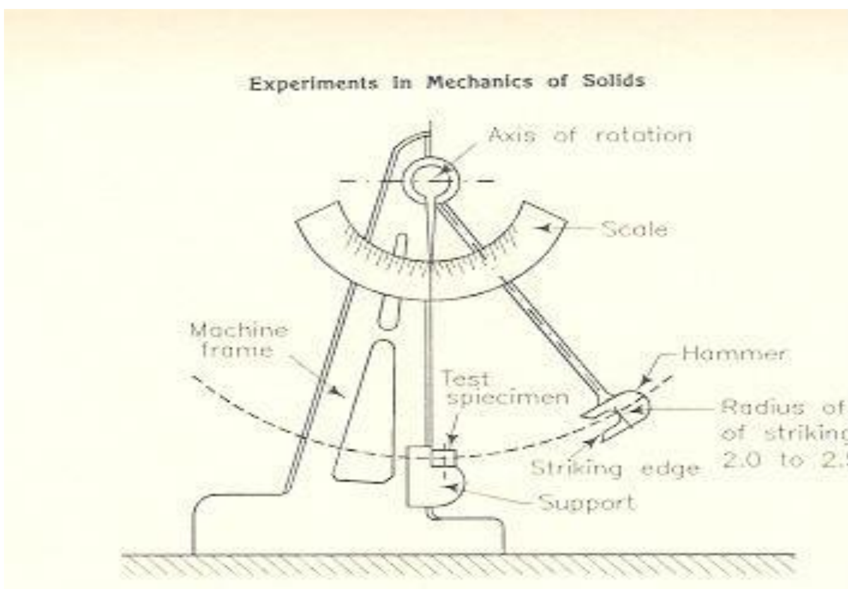
1. V-Notch 2. U-Notch 3.Keyhole Notch

**Charpy Impact Test:** It is single blow Impact test, in which the notched specimen is supported at both ends, as a simple beam & broken by a falling pendulum on face opposite to and immediately behind the notch. The energy absorbed as determined by the subsequent rise of pendulum is a measure of impact strength or notch toughness and is expressed as N-m/$m^3$.

**Layout Diagram:**




**Specimen for Charpy test**




**Charpy impact testing equipment**

**Charpy Notched Impact test:** The test piece should be machined all over at 55 mm long and off square cross-section with 10 mm side. The notch is made at the centre of the test specimen.

The notch should be prepared carefully by any machining method like milling, shaping. The test piece should lie squarely against the supports with the plane of the notch with in 0.5 mm at the plane midway between them.
**Specimen:** A standard mild steel specimen of square section 10×10×55 mm, with a 45° V-Notch of 2 mm depth, provided at the centre of one side and is supported horizontally.

**Procedure:**

1. Measure the dimensions of a specimen. Also, measure the dimensions of the notch.

2. Raise the hammer 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. Repeat the test for specimens of other materials.

6. Compute the energy of rupture of each specimen.

**Observation:**

| S.No. | Initial Reading | Final Reading | No. of division (Initial-Final Reading) | Observed Energy (2× No. of division) | Mean Energy Stored |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

**Result:** Strain energy of given specimen is ---------

**OBJECTIVE: To study the Universal Testing Machine & perform the Tensile Test.**

**Requirements:**

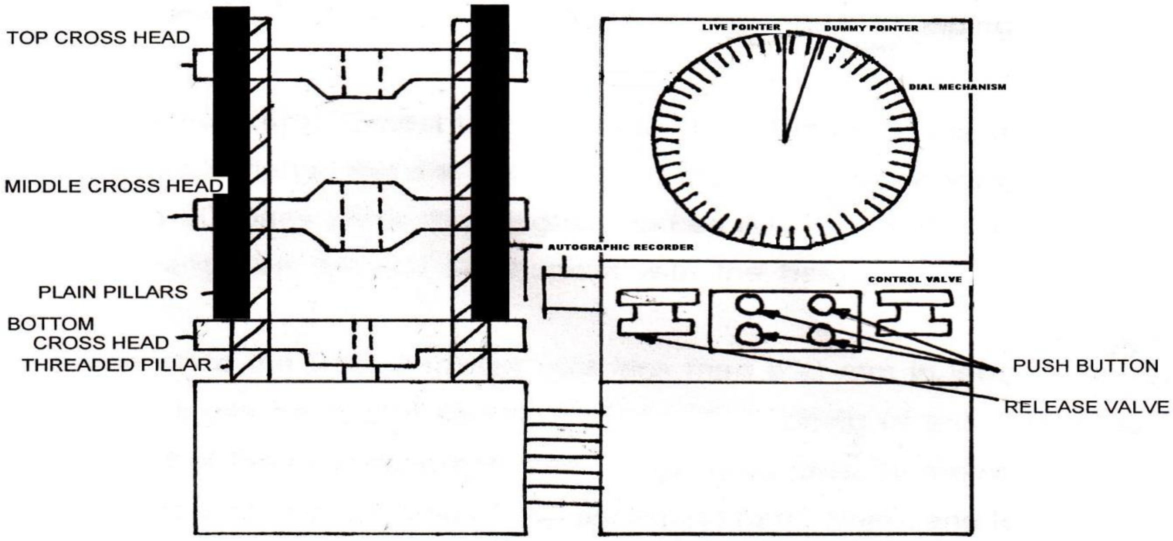
1. Universal Testing Machine
2. Test specimen
3. Micrometer
4. Steel scale

**Theory:**

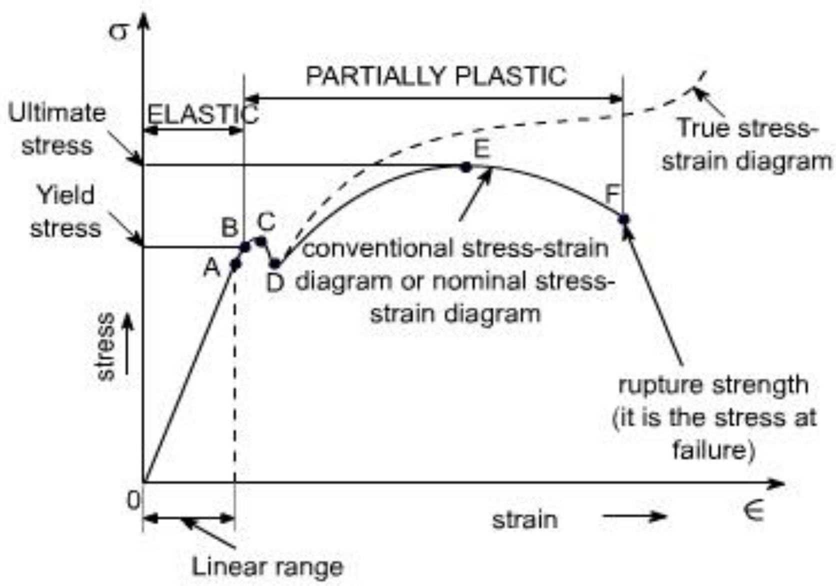
The tensile test is most applied one, of all mechanical tests. In this test ends of a test piece are fixed into grips connected to a straining device and to a load- measuring device. If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original position as soon as load is removed. However, if the load is too large, the material can be deformed permanently. The initial part of the tension curve (fig.8), which is recoverable immediately after unloading, is termed as elastic and rest of the curve, which represents the manner in which solid undergoes plastic deformation is termed plastic. The stress below which the deformation is essentially entirely elastic is known as the yield strength of material. In some materials (like mild steel) the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and lower yield point. However, some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions strain hardening cannot compensate for the decrease in section and thus the load passes trough a maximum and then begins to decrease. As this stage the' Ultimate strength ', which is defined as the ratio of the specimen to original cross –sectional area, reaches a maximum value. Further loading will eventually cause 'neck' formation and rupture.

Usually a tension test is conducted at room temperature and the tensile load is applied slowly. During this test either round or flat specimens may be used. The round specimens may have smooth, shouldered or threaded ends. The load on the specimen is applied mechanically or hydraulically depending on the type of testing machine.

**Layout Diagram:**




UNIVERSAL TESTING MACHINE




**Stress-strain diagram**

**<u>Procedure</u>:**

1. The diameter of the test piece is measured by means of a micrometer at least at three plane and determine the mean value. The gauge length is marked.
2. Suitable scale is selected.

3. The test specimen in the grips is inserted by adjusting the cross-heads of the machine.
4. The extensometer on the test piece and set its scale dials to zero position.
5. Graph recording system is activated.
6. Machine is started and readings of dials on the extensometer are taken for a particular value of load.
7. The rate of loading may be 10 mpc/sec initially and should be reduced to 7.5mpc/sec. when the yield point is reached.
8. Load is applied continuously till the specimen breaks and then stops the machine.
9. Plot load extension diagram.

**Observation**:

L.C. of micrometer =
Original dia. of specimen (d) =
Dia after fracture (du) =
Gauge length (Lo) =
Total length after fracture (Lu) =
L.C. of extensometer =

**Observation Table:**

Observation table 1

| Sr. No | Load applied (N) (p) | Area of a specimen ($A_o$) | Stress $N/mm^2$ | Modulus of elasticity (E) $N/mm^2$ |
|---|---|---|---|---|
| | | | | |

Observation table 2

| Sr. No | Contraction in diameter ($d_d$) (mm) | Deformation in length (mm) | Lateral strain | Linear strain | Poisson ratio |
|---|---|---|---|---|---|
| | | | | | |

Note:

1. Use Vernier Caliper to measure diameter, gage length etc. for the specimen.
2. If C.I. specimen is to be tested only one observation will be taken at failure.

**Calculations**:

Stress (Strength) = Load/Area
Percentage elongation = 100(Lu-Lo)/Lo
Percentage reduction in area = 100(Su-So)/So

**Results:**

| | |
|---|---|
| Proportional limit, MPa | = |
| Yield strength, Mpa | = |
| Percentage elongation | = |
| Ultimate Strength, MPa | = |
| Percentage reduction in area | = |
| Breaking strength, MPa | = |
| Modulus of elasticity | = |

**Conclusion:**

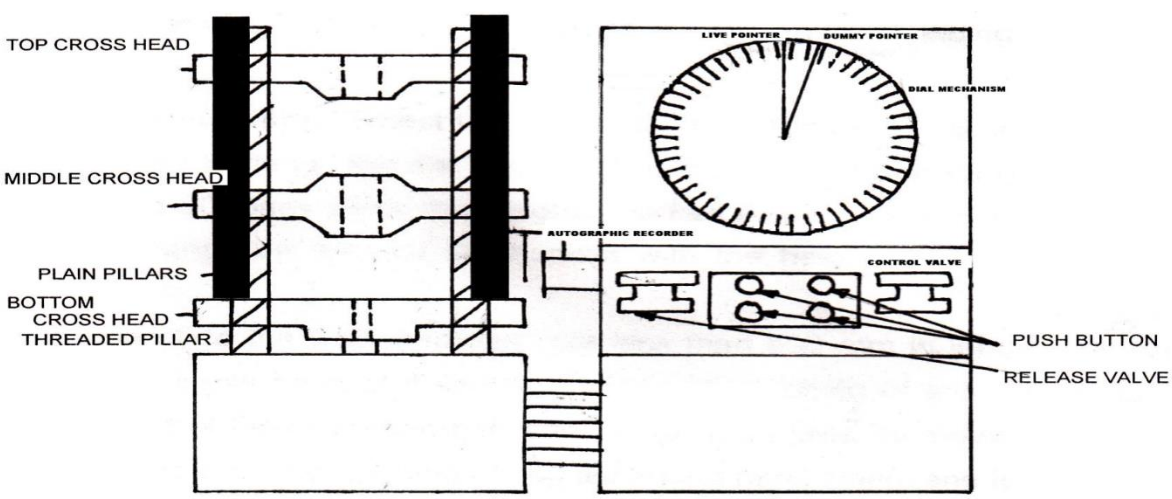
The tensile test on UTM has successfully done.

**Objective: To perform Compression test & find out the compressive strength of test piece.**
**Apparatus Used:**

1. Universal Testing Machine
2. Test piece

**Theory:**
Compression Test consists in straining a test piece by compression loading. Specimen for compression test on metal are usually circular, and for concrete square, in-section. To prevent failure by bulking, the length should be of about the same order as the minimum width. In the ductile material distortion takes place while in case of brittle materials, usually fail by shearing.

**Layout Diagram:**




UNIVERSAL TESTING MACHINE

**Procedure:**

1. Measure the diameter of the test piece at three different planes and take the average value.
2. Place the specimen between middle and lower cross heads and apply the compressive load.
3. Increase the load gradually until the specimen fails.

**Observations:**

Ultimate load =
Average diameter of test piece (D) =

**Calculations:**

Cross-sectional area =
Ultimate compressive strength =

**Precautions:**

1. The specimen should be straight and ends of specimen must be at right angle to the axis of specimen.
2. The length of specimen has to be kept small to avoid the buckling of the specimen.

**Result:**

Ultimate Compressive Strength =

**(B)**

**Objective:** To perform bend test on universal testing machine

**Apparatus Used:** UTM machine, wooden specimen of rectangular section, bending dogs, scale.

**Theory:**

If a beam is simply supported at the ends and carries a concentrated load at the center, the beam bends concave upwards. The distance between the original position of the beam and its position after bending is different at different points (fig) along the length if the beam, being maximum at the center in this case. This difference is called 'deflection'.

**Assumptions:**

1) Small deflections
2) Linear-elastic behavior

3) Plane sections remain plane - line ab straight before and after bending

4) Pure bending - no shear or axial forces - in practice stress and deflections due to shear and axial forces can be calculated separately and added on using superposition.

**Overall simple bending equation** $M/I = E/R = \sigma/y$

**Procedure:**

(i) Measure the dimensions of the specimen of wood.

(ii) Note the zero error on UTM if any.

(iii) Place the wooden specimen in the lower zone (compression zone) of UTM

(iv) Fix the bending dogs in UTM.

(v) Lower the moveable arm of the UTM so that bending dog touches the specimen firmly.

(vi) Read the load on the machine if any.

(vii) Now apply load on the specimen with the help of loading wheel slowly till the wooden beam breaks.

(viii) Note the load on the UTM.

(ix) Calculate moment of inertia ' I ' of the specimen.

(x) Measure y of the beam.

(xi) Calculate the stress at rupture by using the simple bending equation.

(xii) Find the standard value of rupture stress from the handbook.

(xiii) Compare the determined and standard value and write the possible reasons of deviations.

**Precautions:**

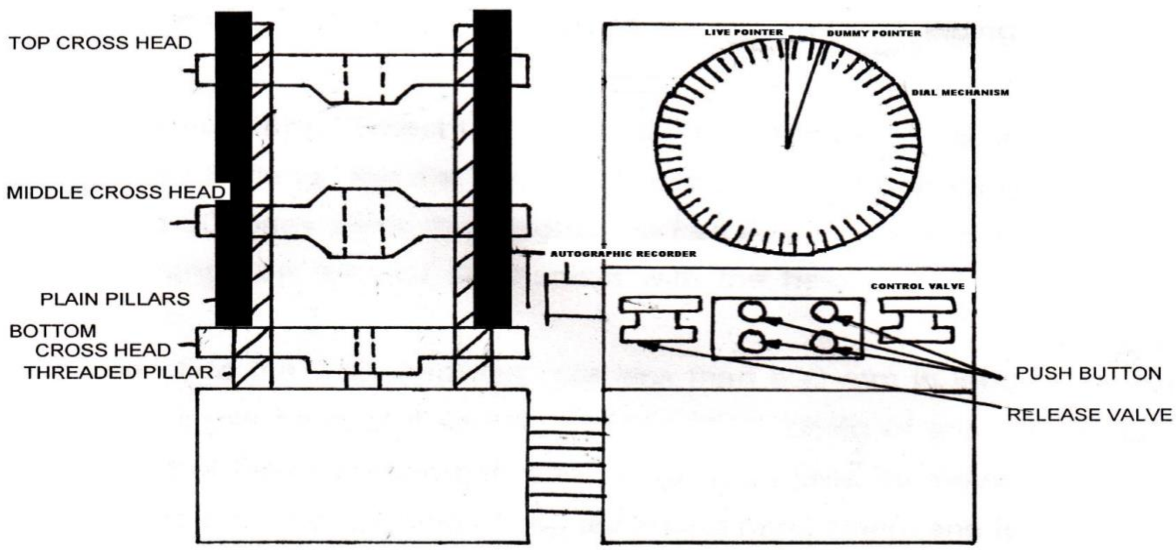
1. The specimen should be straight and ends of specimen must be at right angle to the axis of specimen.
2. The length of specimen has to be kept small to avoid the buckling of the specimen.

**Objective:** To perform the shear test on UTM.

**Apparatus Used:** A UTM, Specimen, shearing attachment, vernier caliper etc.

**Theory:** A type of force which causes or tends to cause two contiguous parts of the body to slide relative to each other in a direction parallel to their plane of contact is called the shear force. The stress required to produce fracture in the plane of cross-section, acted on by the shear force is called shear strength.

**Layout Diagram:**




UNIVERSAL TESTING MACHINE

**Procedure:**

1. Insert the specimen in position and grip one end of the attachment in the upper portion and one end in the lower position

2. Switch on the UTM
3. Bring the drag indicator in contact with the main indicator.
4. Select the suitable range of loads and space the corresponding weight in the pendulum and balance it if necessary with the help of small balancing weights
5. Operate (push) the button for driving the motor to drive the pump.
6. Gradually move the head control ever in left hand direction till the specimen shears.
7. Note down the load at which the specimen shears.
8. Stop the machine and remove the specimen.
9.

**Observation:**

- Applied compressive force (F) = ---------kgf.
- Diameter of specimen = ---------mm.

**Calculations:**

The shear strength shall be calculated from the following formulae:

$\tau_s = (F/2) / (\pi d^2/4) = 2F / \pi d^2$

where 'd' is the actual diameter of the specimen.

**Precautions:**

1. The measuring range should not be changed at any stage during the test.
2. The inner diameter of the hole in the shear stress attachment should be slightly grater than the specimen.
3. Measure the diameter of the specimen accurately.

**Conclusion:** Shear strength of specimen = --------

<table>
<tr><td rowspan="1"></td><td>BRCM COLLEGE OF<br>ENGINEERING & TECHNOLOGY<br>BAHAL, BHIWANI<br><br>Practical Experiment Instructions Sheet</td><td>Lab Manual</td></tr>
<tr><td>Exp. Title</td><td>To study the torsion testing machine and perform the torsion test.</td><td>EXP. NO. 8</td></tr>
<tr><td>SOM Lab</td><td>Semester-4th</td><td>Page No. 24-26</td></tr>
</table>

**Objective:** To study the Torsion Testing Machine & perform torsion test.

**Apparatus Used:**
1. Torsion Testing Machine
2. Specimen
3. Micrometer
4. Steel Scale

**Theory:**
A circular cylindrical shaft is said to be subjected to pure torsion when the torsion is caused by a couple, so that the axis of the applied couple coincides with the axis of the shaft. In such a case the state of stress at any point in the cross-section of the shaft is pure shear.

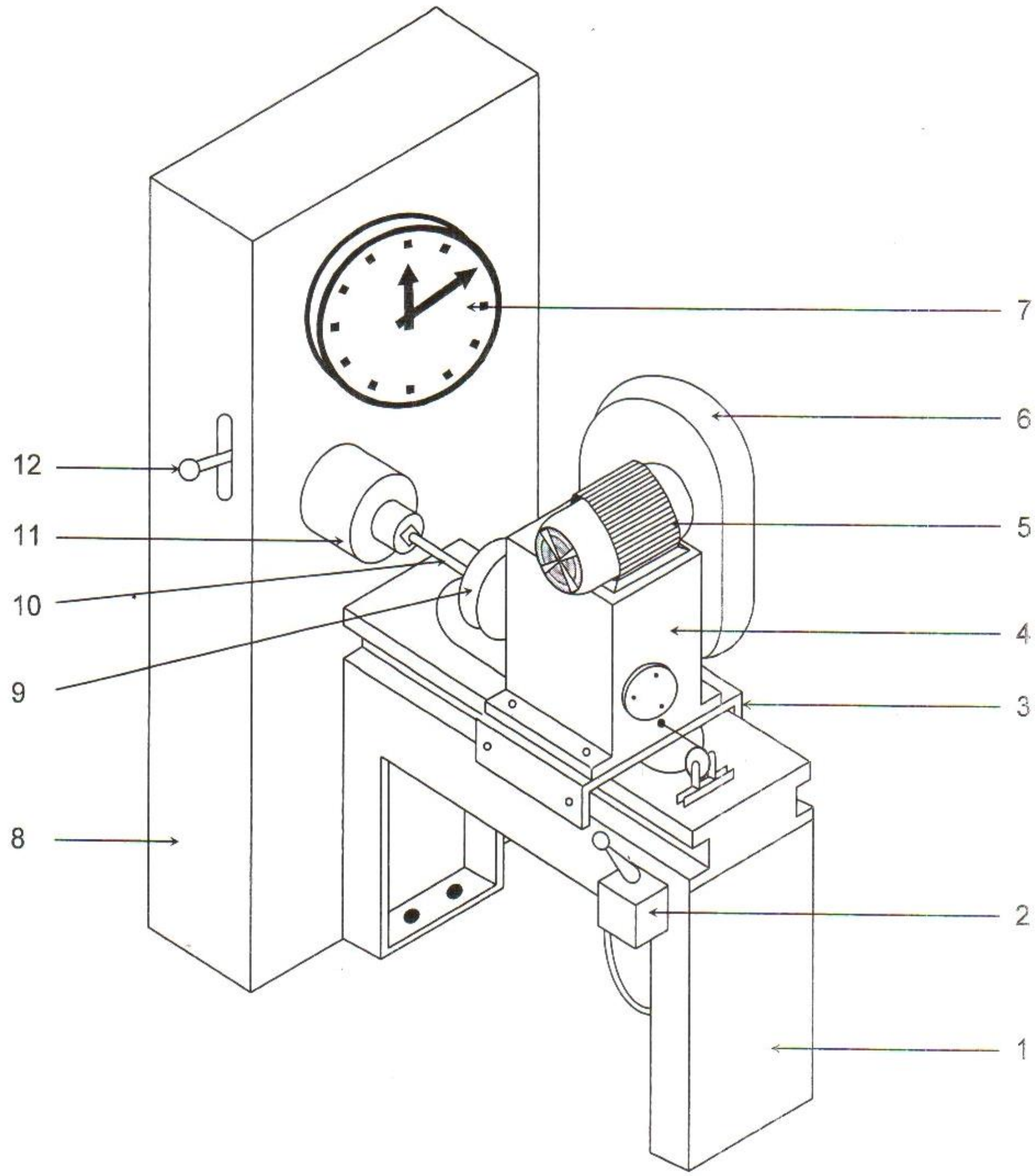
Torsional formula is given by:

$$T/J = t/r = G\theta/L$$

Where,

T= Twisting Moment
J= Polar M.O.I. of original cross-section
t= Shear Stress induced in specimen
r= Radius of original cross-section
G= Modulus of Rigidity
θ= Angle of Twist
L= Parallel length of initial specimen

**Layout Diagram:**




## TORSION TESTING M/C
(FOR RODS)

| S. No. | DESCRIPTION | S. No. | DESCRIPTION |
|---|---|---|---|
| 1 | Base Frame | 7 | Dial Gauge |
| 2 | On – Off Switch | 8 | Measuring Panel |
| 3 | Trolley | 9 | Drive Chuck |
| 4 | Gear Box | 10 | Test Piece |
| 5 | Motor | 11 | Driven Chuck |
| 6 | Chain Guard | 12 | Rack |

**Procedure**:

1. Measure the diameter of the test piece of four different planes on its parallel length by using a Micrometer. At each plane measure the diameter at right angle to each other.
2. Measure the parallel length of the test piece.
3. Insert the test piece in the grips of the machine.
4. Select a suitable scale on the digital indicator and adjust the initial torque and angle of twist reading to zero position.
5. Apply the torque on specimen with the driving chuck. To activate the driving chuck, switch on the. Electrical lever control, with this, the test specimen start twisting and with the increased load, the digital display on the digital indicator unit progressed.
6. Torque is applied until specimen breaks and maximum torque that sample has taken is read out from Digital Indicator unit by pressing the peak push button.
7. Angle of twist is noted from Angle of twist measuring wheel after the specimen has failed.
8. Initially a line may be marked parallel to the length of the test piece to visually see the helix formation.

**Observations:-**

1. Material of test specimen=
2. Least count of micrometer=
3. Parallel length of test specimen=
4. Diameter:
5. Maximum torque (N-m) =
6. Breaking torque (N-m) =
7. Angle of twist Ø =

**<u>Calculations</u>:-**

Modulus of rupture ts = Tr/J

Modulus of rigidity G = Tl/Jθ

Where:

T= Maximum twisting moment.

r= Original outer radius of specimen

J= Polar moment of inertia of the original cross-section

θ= Angle of twist

l= Parallel length of specimen.

**<u>Results</u>:-**

1.Maximum torque=

2.Breaking torque=

3.Total angle of twist to fracture

4.Modulus of rupture=

5.Modulus of rigidity=

**Conclusion:**

Hence the study of Torsion test is completed.

**Objective: To determine Mechanical Advantage and Efficiency of Single and Double Purchase Winch Crab**.

**Apparatus used:** Single and Double purchase winch crab apparatus, weights, hangers, rope etc.

**Theory:** Winch crab is a kind of lifting m/c in which velocity ratio obtained by employing spur gears. This m/c. is basically used on boats ships to raise starboard or tightening rope and on bridges and dam to operate lockage. These are classified as:

1. Single purchase Winch crab.
2. Double purchase Winch Crab

**Single Purchase Winch Crab**: - It consists of a load drum of radius r connected to an axle by gears. The toothed wheel on load drum is called Spur wheel and the small toothed wheel on axle is called Pinion. The axle is provided with an effort pulley of diameter D.

Let, number of teeth on spur wheel and pinion is $T_1$ and $T_2$ respectively.

The effort P be applied at the effort pulley.

When one revolution is made by the pulley, the distance moved by the effort = $2\pi R = \pi D$

When the axle makes one revolution, due to gear arrangement the load drum also moves $T_2$ number of teeth, which means it makes $T_2 / T_1$ revolutions.

The distance over which the load moves = $2\pi r (T_2 / T_1)$

Velocity Ratio = distance moved by effort / distance moved by the load

$= 2\pi R / 2\pi r (T_2 / T_1)$

$= D / d (T_1 / T_2)$

Mechanical Advantage (M.A.) = W / P

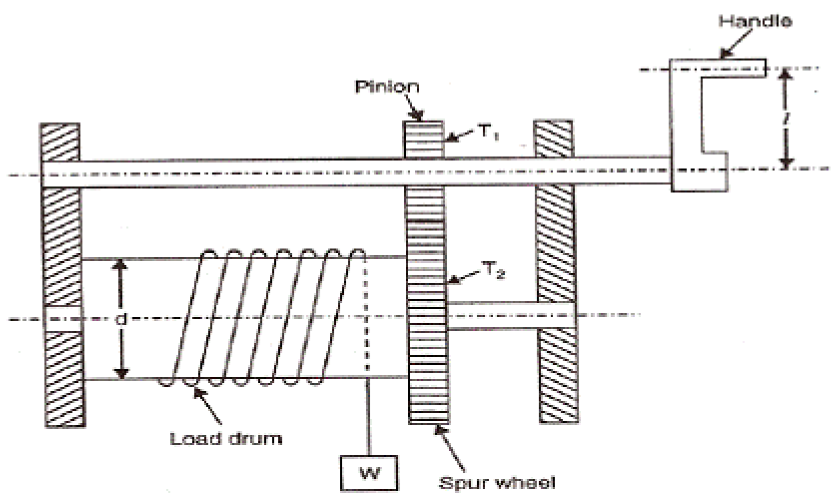
Efficiency, $\eta$ = M.A. / V.R.

**Double Purchase Winch Crab**: - Velocity Ratio of a Winch Crab can be increased by providing another axle with a pair of pinion and gear. Since two pairs of pinion and gear are used it is called Double purchase winch crab. It is used for lifting heavier loads.

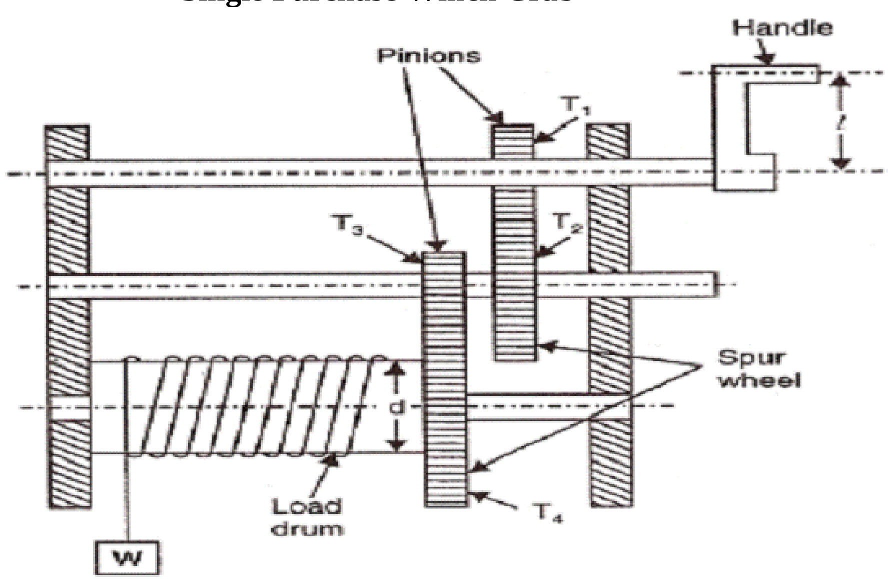
Let, the number of teeth on the two spur wheels is $T_1$ and $T_3$ and number of teeth on the two pinions are $T_2$ and $T_4$ respectively. The effort P is applied at the effort pulley.
When one revolution is made by the pulley, the distance moved by the effort = $2\pi R = \pi D$

When axle A makes one revolution, axle B is moved by $T_2$ teeth i.e., it makes $T_2 / T_1$ revolutions and the load axle moves by $(T_2 / T_1) / (T_4 / T_3)$ revolutions.
Therefore, the distance moved by the load = $2\pi r (T_2 / T_1) / (T_4 / T_3)$
Velocity Ratio = distance moved by effort / distance moved by the load
= $2\pi R / 2\pi r (T_2 / T_1) / (T_4 / T_3)$
= $D / d [(T_1 / T_2) (T_3 / T_4)]$
Mechanical Advantage (M.A.) = W / P
Efficiency, $\eta$ = M.A. / V.R.

**Layout diagram:**




**Single Purchase Winch Crab**




**Double Purchase Winch Crab**

**Procedure:**

1. Count the number of teeth of the pinion A and spur gear B.
2. Measure the circumference of pulley and of load drum with a string and meter rod or measure the diameter with an outside caliper.
3. Wrap the string round the effort pulley and the other free end of the string will carry the effort.
4. Wrap another string round the load drum to carry load W in such a manner so that as the effort is applied, the load is lifted up.
5. Suspend a load W on the string of the load drum and put the weights in the effort pan so that load starts moving up gradually.
6. Note down the values of W and P and calculate the M.A., V.R. and efficiency.
7. Increase the load W and again find the value of P.
8. In this way take at least six reading at different values of load.
9. Plot the graph between W & P and W & Efficiency.
10. Take W along horizontal axis.
11. Repeat the same procedure for double winch crab.

**Observation:**

1) No of teeth on pinion-$P_1 = T_2$
2) No of teeth on pinion-$P_2 = T_4$
3) No of teeth on spur gear $S_1 = T_1$
4) No of teeth on spur gear$S_2 = T_3$
5) Diameter of the effort pulley =2R
6) Diameter of the load axle = 2r

**Observation table:**

For single winch crab:

| S.No. | Load (W) | Effort (P) in Nt. | Distance moved by effort | Distance moved by load | V.R. | M.A. | Efficiency |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

For double winch crab:

| S.No. | Load (W) in Nt. | Effort (P) in Nt. | Distance moved by effort | Distance moved by load | V.R. | M.A. | Efficiency |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

**Calculations:**

M.A. = W/P
V.R. =
Efficiency = M.A. /V.R

**Conclusion:** Hence the Single and Double Purchase Winch Crab is studied.

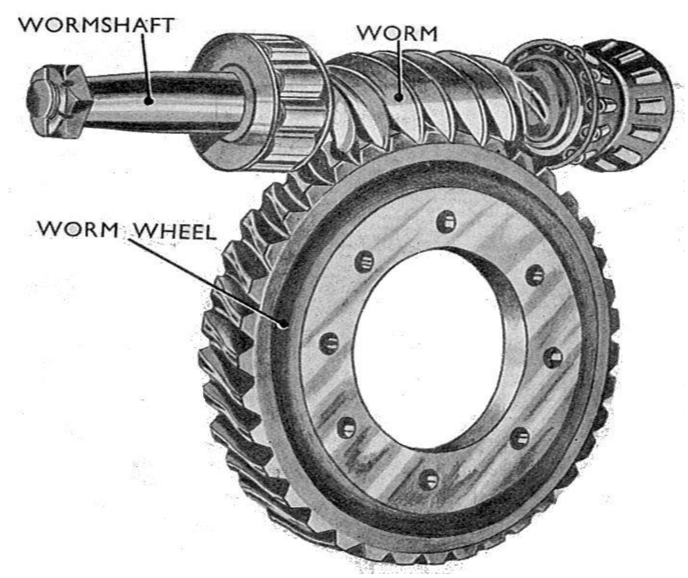
**OBJECTIVE:** To determine Mechanical Advantage, V.R. and Efficiency of worm and worm gear of single, double and triple start.

**Apparatus:** Worm and worm gear of single, double and triple start and weights.

**Theory:** As the pulley of the worm moves through n revolutions, n teeth of the wheel pass completely through the worm. If there are N teeth in the worm wheel, then N revolutions will have to be given to the pulley of the worm to rotate completely the worm wheel. So that if the effort applied at the pulley of the worm moves through N revolution the load is raised up by the a distance equal to the length of the circumference of the pulley of the worm wheel.
So that velocity ratio is

$$\frac{\text{N x circumference of pulley of worm}}{\text{Circumference of pulley of worm wheel}}$$

**Layout Diagram:**




**Worm and worm gear**

**Procedure:**

1. Wrap the string round the pulley of the worm the free end of which is to be tied to the effort.
2. Wrap another string to carry the load round the pulley the worm wheel in such a manner that as the effort is applied the load is lifted up.
3. Suspend a small weight (w) through the free end of the second string and suspend another weight (p) through the free end of the first string which should just move the load upward.
4. Note w and P, so that mechanical advantage is given by W/ P
5. Increase the load (w) gradually and increase the effort (p) correspondingly and take in this way about seven readings.
6. Measure the circumference of the pulley of the worm and also that of the worm wheel.
7. The percentage efficiency is given by W x 100 /PV
8. Plot a graph between w and p.
9. The same procedure can be followed for single, double and triple start worm and worm wheel.

**Observations:**

1. Circumference of pulley of the worm ($2\pi R_1$) = _________ cm.
2. Circumference of pulley of the worm wheel ($2\pi R_2$) =_________ cm.
3. No of teeth in the worm wheel (N) =
4. Velocity ratio for single start= $(N \times 2\pi R_1)/((2\pi R_2)*1)$
5. Velocity ratio for double start= $(N \times 2\pi R_1)/((2\pi R_2)*2)$
6. Velocity ratio for triple start= $(N \times 2\pi R_1)/((2\pi R_2)*3)$

**Observations Table for single start:**

| S. No. | Weight Lifted (W) | Effort Applied (P) | Mech. Adv. = W/P | Velocity Ratio | % Efficiency =W/PV x 100 |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |

**Observations Table for double start:**

| S. No. | Weight Lifted (W) | Effort Applied (P) | Mech. Adv. = W/P | Velocity Ratio | % Efficiency =W/PV x 100 |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |

**Observations Table for triple start:**

| S. No. | Weight Lifted (W) | Effort Applied (P) | Mech. Adv. = W/P | Velocity Ratio | % Efficiency =W/PV x 100 |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |

**Conclusion:** Hence the efficiency of single, double and triple worm and worm wheel is completed.

**Objective: To determine the M.A., V .R. and efficiency of a square thread screw jack and plot a graph between W and P and W and efficiency.**

**Apparatus used:**

1. Screw Jack Apparatus
2. Slotted & Conical Weights
3. Nylon String
4. Meter Rod & Pan

**Theory:**

This machine is used for lifting heavy load with the application of a smaller effort. It may have different shapes but the principle is same I, e, it works on the principle of a screw. The screw head carries the load w. the nut is fixed and the screw is rotated by means of a lever. The effort p is applied at the screw is rotated by means of a lever. The effort p is applied at the end of the lever. Please see fig.

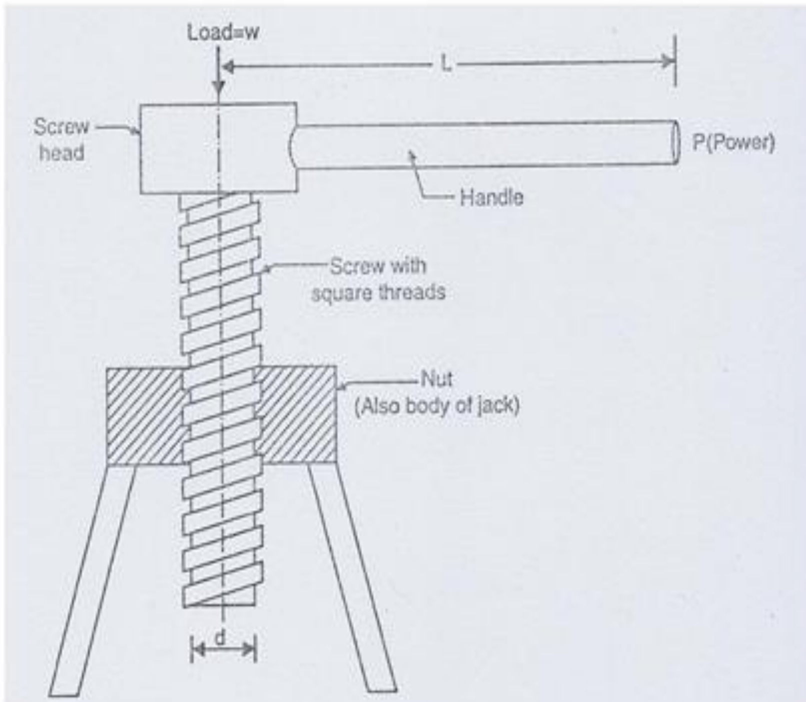
Now if the screw head revolves through n number of revolutions, the load w placed on the screw head will move by a distance p x n, where p is the pitch of the screw thread. The effort p will move a distance n x 2 R, where 2r is the circumference of the screw head over which P is coming.

Therefore

$$V = \frac{\text{Distance moved by the effort P}}{\text{Distance moved by the load W}}$$

$$= \frac{n \times 2\pi R}{n \times p} = \frac{2\pi R}{p}$$

**Layout Diagram:**




**Square thread screw jack**

**Procedure:**

1. Wrap on string round the circumference of the screw head and take it over a small pulley. Effort p1 is tied to the free end of this string.
2. Wrap another string around the circumference of the screw head in the same direction in which the above string is wounded and take it over the other small pulley.
3. Place a load w on the screw head.
4. Suspend p1 and p2 to the free ends of both the strings coming over the two small pulleys. This load p1 and p2 should be increased gradually suitable to give a just upward motion to the load w placed on the screw head.
5. Note down w and p to determine the M.A. i.e. W/p. in this case p1+p2 will be the value of p.
6. p1 and p2 should be noted down carefully.
7. Take in this way about 10 reading by increasing w and finding out the corresponding value of P(p1+p2).
8. Measure the circumference of the screw head.
9. Measure the pitch i.e. the distance between the two consecutive threads.

**Observations**

1. Circumference of the screw Head =
2. Pitch =

**Observation Table:**

| S. No. | Load Lifted Upward W | Effort P1 | Effort P2 | Total Effort P1+P2 | M.A. = W/P | Velocity Ratio V | Percentage Efficiency |
|---|---|---|---|---|---|---|---|
| 1.<br>2.<br>3.<br>4.<br>5. | | | | | | | |

**Result:** Hence efficiency of the screw jack is determined as ___________.

**Conclusion:** Mechanical advantage, Velocity ratio and efficiency of a square thread screw jack have been successfully determined.