# DETERMINE THE MODULUS OF RIGIDITY 0F THE MATERIAL OF A ROD BY STATIC METHOD

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## INTRODUCTION

Modulus of rigidity or shear modulus (ŋ) is a measure of shearing stress which produce the shear strain. Its simply the ratio of shear stress to shear strain. It tells us about the shear deformation undertaken by a body on exposure to shearing forces of different magnitude. As the name suggests it tells us how 'rigid' the body is i.e. resistant to shear forces.

## PURPOSE OF THE EXPERIMENT

Modulus of rigidity, or the shearing modulus, is used to determine how elastic or bendable materials will be if they are sheared, which is being pushed parallel from opposite sides. This property becomes the useful part of many calculations, and it is called the co-efficient of elasticity during sharing.

## DEFINATION OF MODULUS OF RIGIDITY

Modulus of rigidity is The co-efficient of elasticity for a shearing force it is define as: “The ratio of shear stress to the displacement per unit original length”.

## AIM, APARATUS & WORKING FORMULA

### Aim :

To determine the modulus of rigidity of the material of a given rod by static method using the horizontal pattern of Barton's apparatus.

### Apparatus Required:

Horizontal pattern of the BARTON's apparatus, half kilogram slotted weights with hanger, Thread, Meter scale and screw gauge.

### Working Formula:

The modulus of rigidity,

$$\boxed{\eta = \frac{180MgDl}{\pi^2 r^4 \theta}}$$

Where $M$ = Load suspended

$g$ = acceleration due to gravity

(g =980 cm/$(sec)$^2)

$D$ = Diameter of the pulley.

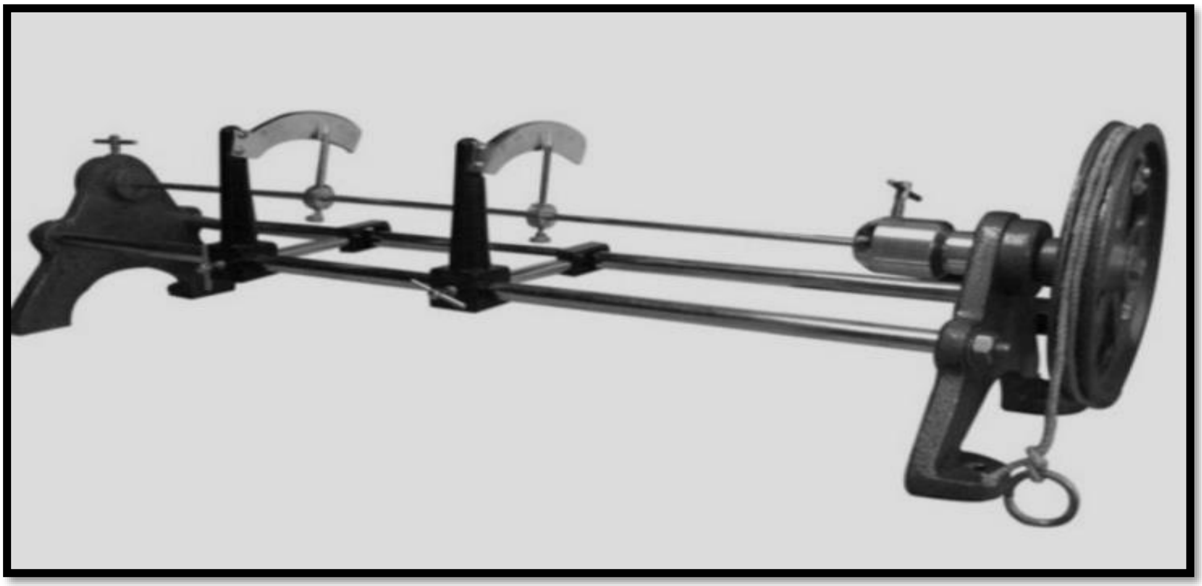
$r$ = Radius of the experimental rod.

$\theta_1$ = the angle of twist produced at pointer No.1

$\theta_2$ = The angle of twist produced at pointer No.2

$\theta = \theta_1 - \theta_2$

$l = l_2 - l_1$ = The length of the rod between the two pointers



## DESCRIPTION OF APARATUS

The horizontal pattern of Barton's apparatus is shown in fig. 1. The experimental rod AB is rigidly clamped at the end A. The other end is attached to the Centre of a pulley B (of large diameter). Pulley can rotate about the axis of the rod. The pulley is provided with a hook to whom a thread is tied. This thread is wound over the pulley and its free end is attached with a hanger or pan. There are two pointers which can be clamped anywhere on the experimental rod and they move over the circular scales as shown in fig. 1 when a load is applied.

Fig. 1: The horizontal pattern of Barton's apparatus

**Theory:**

When mass M is suspended in the hanger, then Mg will be the weight in the hanger. So, moment of this force about the axis of rotation (axis of experimental wire)

$= Mg\ x\ \frac{D}{2}$

Where D is diameter of the pulley.

If $\boldsymbol{\theta}$ is the twist produced in the rod of radius r at a distance l from the fixed end then restoring couple set up in the wire = $\frac{\pi\theta\eta r^4}{2l \times 180^\circ}$

In equilibrium, external couple = Restoring couple

$$\text{or} \quad Mg\ x\ \frac{D}{2} = \frac{\pi\theta\eta r^4}{2l \times 180^\circ}$$

$$\text{or} \quad \eta = \frac{180MgDl}{\pi^2 r^4 \theta}$$

To remove the error due to uncertainty in the position of the clamped end of the rod, note down the twist $\theta_1$ and $\theta_2$ for two lengths $l_1$ and $l_2$, then we have

$$\eta\,\theta_1 = \frac{180MgDl_1}{\pi^2 r^4}$$

and $$\eta\,\theta_2 = \frac{180MgDl_2}{\pi^2 r^4}$$

Therefore $$\eta = \frac{180MgD\,(l_2-l_1)}{\pi^2 r^4(\theta_2-\theta_1)}$$

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## Procedure:

1. Find the least count of screw gauge. Measure the diameter of the experimental rod at different points using the screw gauge. Find the mean diameter and then radius of the rod.

2. Find out the circumference (2πr) of the Pulley by wrapping the rope once around the pulley and measure the length of the rope by a centimeter scale. Then calculate the diameter of pulley.

3. Clamp the pointers at different places and measure the distance ($l_2$-$l_1$) between them using meter scale.

4. Put the hanger on the pulley and fix the pointer attached to the circular scale at the zero position.

5. Put a load of 0.5 kg on the hanger and observe the readings of the two circular scales ($\theta_1$ and $\theta_2$) accordingly and measure the corresponding angle of twist ($\theta_2$-$\theta_1$) of the rod.

6. Increase the load in steps of 0.5 kg on the hanger up to 3.0 kg and observe the differences of readings ($\theta_2$-$\theta_1$) between two circular scales.

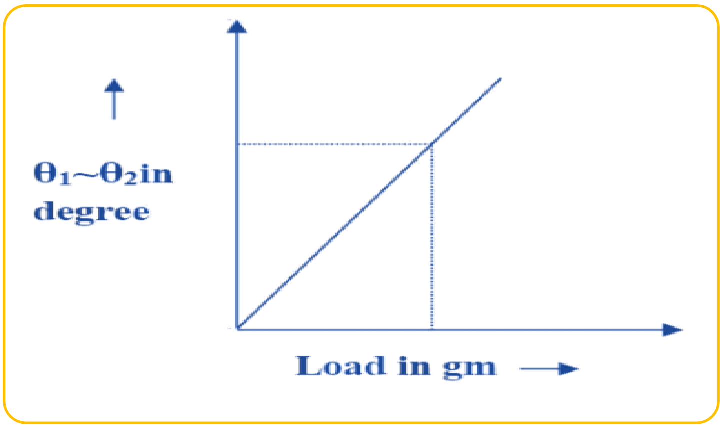
7. Now repeat steps 5 and 6 by decreasing the load in steps of 0.5 kg from 3.0 kg to zero loads.

8. Take mean of two and find out mean ($\theta_2$-$\theta_1$) for each load.

9. Plot the graph between load M vs angular twist of rod mean (θ_2−θ_1), by taking load M on X-axis and twist on Y-axis. The graph will be straight line passing through the origin. Find the slope of the graph and calculate M/ (θ_2−θ_1) by using slope of the graph.

10. Calculate modulus of rigidity of the material of the rod using the formula

$$\eta=\frac{180MgD(l_2-l_1)}{\pi^2 r^4(\theta_2-\theta_1)} = \frac{180gD(l_2-l_1)}{\pi^2 r^4)} \frac{M}{(\theta_2-\theta_1)}$$



## EXPERIMENTAL OBSERVATION(S)

Circumference of the pulley C = ----------- cm

Length of the between two pointers ($l\_2 - l\_1$)= -----cm

Determination of least count of screw gauge

Smallest division in the main scale (x): ----------- cm

No. of division in the circular scale (n):-------------

Least count(L.C) =$X/n$ = ------------ cm

## TABLE FOR DETERMINATION OF RADIUS OF THE ROD USING SCREW GUAGE

| NO OF OBS | M.S.R (cm) | C.S.R (cm) | TOTAL (cm) | MEAN (cm) | AMOUNT OF ERROR (cm) | ACTUAL DIAMERER (cm) | ACTUAL RADIUS (cm) |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

## DETERMINATION OF ANGLE OF TWIST

### Table 2- For twist of the rod due to application of the load

| Sl. No | Load(M) gm | Twist for load increasing | | | Twist for load decreasing | | | Angle of twist Mean $\boldsymbol{\theta}_1 \sim \boldsymbol{\theta}_2$ |
|---|---|---|---|---|---|---|---|---|
| | | Reading of first pointer $\phi_1$ | Reading of second pointer $\phi_2$ | Twist $\boldsymbol{\theta}_1(\phi_1-\phi_2)$ | Reading of first pointer $\phi_1'$ | Reading of second pointer $\phi_2'$ | Twist $\boldsymbol{\theta}_2$ $(\phi_1'-\phi_2')$ | |
| 1 | 500 | | | | | | | |
| 2 | 1000 | | | | | | | |
| 3 | 1500 | | | | | | | |
| 4 | 2000 | | | | | | | |
| 5 | 2500 | | | | | | | |
| 6 | 3000 | | | | | | | |

**Calculations:**

The modulus of rigidity of Rod $\eta = \frac{180gD\,(l_2-l_1)}{\pi^2 r^4}\ \frac{M}{(\theta_2-\theta_1)}$

Circumference of pulley = 2πR= πD =------------------- cm.

*Diameter of pulley, D=* $\frac{Circumference}{\pi}$ *= ------- = -------- cm*

Acceleration due to gravity, g= ---------------- cm/sec$^2$

**From table 1,**

Diameter of the Rod, d= ------------ cm,

Radius of the Rod, r= d/2 = --------cm

**From table2,**

By plotting the graph between angle of twist Mean $(\theta_2 - \theta_1)$ vs load M (gm.), taking angle of twist on y-axis and load on x-axis we get a straight line passing through the origin.

From graph find, $\frac{M}{(\theta_2-\theta_1)} = \frac{1}{slope}$ = -------- gm. /degree

DETERMINE THE MODULUS OF RIGIDITY OF THE MATERIAL OF A ROD BY STATIC METHOD

The modulus of rigidity of Rod $\eta$ = --------------dyne/cm$^2$

Standard value of modulus of rigidity for material (..........................) of rod = ---------------- dyne/cm$^2$

Calculate % error by using the formula

$$= \frac{standard\ value - calculated\ value}{standard\ value} \times 100\%$$

= ----------------------- %

Result : The modulus of rigidity of the material (................) of the supplied Rod is found to be ---------------------- dyne/$cm^2$. With error of -------------- %

<u>CONCLUSION :</u>

1. From the value of modulus of rigidity we know about the strength of the material.

2. Modulus of rigidity doesn't depend on the length, breadth, depth, and radius of the material. It is depend only the property of the material.

3. The modulus of rigidity varies from one material to another.