LABORATORY MANUAL FOR SEARLE'S APPARATUS: DETERMINATION OF YOUNG MODULUS OF A WIRE

EXPERIMENT

Searle's apparatus

AIM

To determine Young's modulus of the material of a given wire by using Searle's apparatus.

APPARATUS AND MATERIAL REQUIRED

Searle's apparatus, slotted weights, experimental wire, screw gauge and spirit level.

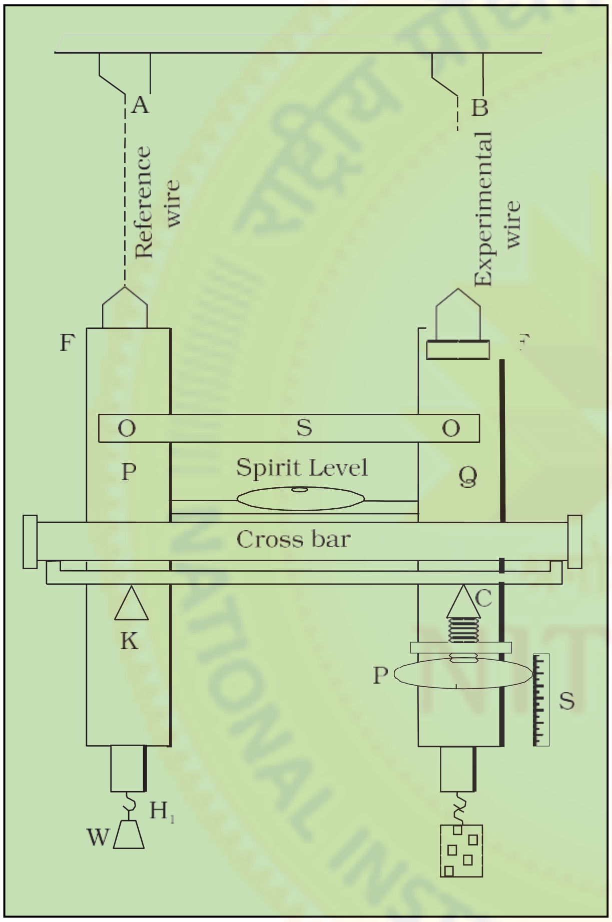

Fig. E 9.1:
Searle’s apparatus for determination of Y of a wire

SEARLE'S APPARATUS

It consists of two metal frames P and Q hinged together such that they can move relative to each other in vertical direction (Fig. E9.1).

A spirit level is supported on a rigid crossbar frame which rests on the tip of a micrometer screw C at one end and a fixed knife edge K at the other. Screw C can be moved vertically. The micrometer screw has a disc having 100 equal divisions along its circumference. On the side of it is a linear scale S, attached vertically. If there is any relative displacement between the two frames, P and Q, the spirit level no longer remains horizontal and the bubble of the spirit level is displaced from its centre. The crossbar can again be set horizontal with the help of micrometer screw and the spirit level. The distance through which the screw has to be moved gives the relative displacement between the two frames.

The frames are suspended by two identical long wires of the same material, from the same rigid horizontal support. Wire B is called the experimental wire and wire A acts as a reference wire. The frames, P and Q, are provided with hooks H_1 and H_2 at their lower ends from which weights are suspended. The hook H_1 attached to the reference wire carries a constant weight W to keep the wire straight.

the hook H_2 is attached a hanger on which slotted weights can be placed to apply force on the experimental wire.

PRINCIPLE

The apparatus works on the principle of Hookes' Law. If l is the extension in a wire of length L and radius r due to force F $(=Mg)$, the Young's modulus of the material of the given wire, Y, is

$$Y = \frac{mgL}{\pi r^2 l}$$

PROCEDURE

1. Suspend weights from both the hooks so that the two wires are stretched and become free from any kinks. Attach only the constant weight W on the reference wire to keep it tight.

2. Measure the length of the experimental wire from the point of its support to the point where it is attached to the frame.

3. Find the least count of the screw gauge. Determine the diameter of the experimental wire at about 5 places and at each place in two mutually perpendicular directions. Find the mean diameter and hence the radius of the wire.

4. Find the pitch and the least count of the micrometer screw attached to the frame. Adjust it such that the bubble in the spirit level is exactly in the centre. Take the reading of the micrometer.

5. Place a load on the hanger attached to the experimental wire and increase it in steps of 0.5 kg. For each load, bring the bubble of the spirit level to the centre by adjusting the micrometer screw and then note its reading. Take precautions to avoid backlash error.

6. Take about 8 observations for increasing load.

7. Decrease the load in steps of 0.5 kg and each time take reading on micrometer screw as in step 5.

OBSERVATIONS

- Length of the wire (L) = ...
- Pitch of the screw gauge = ...
- No. of divisions on the circular scale of the screw gauge = ...
- Least count (L.C.) of screw gauge = ...
- Zero error of screw gauge (if any) = ...

Table 1: Measurement of diameter of wire (d)

Pitch of the screw gauge = ...
Least count of the screw gauge = $\frac{pitch}{Total\ no\ of div.\ in\ circular\ scale}$ = ...

No. of obs.	Main Scale Reading (MSR) (mm)	Circular Scale Reading (CSR)	d Total Reading (MSR+CSR×L.C) (mm)	Mean breadth (d) (mm)
1.				
2.				
3.				

Mean diameter (corrected for zero error if any) = ...
Mean radius **(r)** = ...

MEASUREMENT OF EXTENSION l

Pitch of the micrometer screw = ...

No. of divisions on the circular scale = ...

Least count (L.C.) of the micrometer screw = ...

Acceleration due to gravity, g = ...

Table for measurement of extension with load (l)

Table [C-1] FOR LOAD INCREASING

No. of obs.	Load (kg)	No. of rotation x pitch = (A)	Initial Disc Reading (I)	Final Disc Reading (F)	Diff. (F-I)	Diff. X L.C. (B) (mm)	Extension (A+B) (mm)	Cumulative Extension (l) (mm)
1.	0.5						.... (l_1)	(l_1)
2.	1.0						.... (l_2)	($l_1 + l_2$)
3.	1.5						.... (l_3)	($l_1 + l_2 + l_3$)
4.	2.0						.... (l_4)	(l_1+.....+l_4)
5.	2.5						.... (l_5)	(l_1+.....+l_5)

Table [C-2] FOR LOAD DECREASING

No. of obs.	Load (kg)	No. of rotation x pitch = (A)	Initial Disc Reading (I)	Final Disc Reading (F)	Diff. (I-F)	Diff. X L.C. (B) (mm)	Extension (A+B) (mm)	Cumulative Extension (l) (mm)
1.	2.5						.... (l_5)	$(l_1 + \cdots + l_5)$
2.	2.0						.... (l_4)	$(l_1 + \ldots + l_4)$
3.	1.5						.... (l_3)	$(l_1 + l_2 + l_3)$
4.	1.0						.... (l_2)	$(l_1 + l_2)$
5.	0.5						.... (l_1)	(l_1)

Table [C-3] for mean extension for each load and calculation of Young's Modulus

Length of the wire (L) = ...

Mean radius (r) =....

$$Y = \frac{MgL}{\pi r^2 l}$$

Load (Kg)	Cumulative Extension for load increasing	Cumulative Extension for load decreasing	Mean Depression (l_{mean})	Y ($\times 10^{11}$) N/m^2
0.5				
1.0				
1.5				
2.0				
2.5				

CALCULATIONS

Show calculation of Y for each load.

Calculate the average value of Young's modulus.

CALCULATIONS OF YOUNG'S MODULUS FROM GRAPH

Plot a graph between load along X-axis and corresponding mean extension along Y-axis. It should be a straight line. Find the slope line. Using this value, find the value of *Y*.

Slope $= \frac{l}{M}$; $\quad Y = \frac{MgL}{\pi r^2 l}$

$$\therefore Y = \frac{gL}{\pi r^2} \times \frac{1}{slope}$$

ERROR CALCULATIONS

$$Y = \frac{MgL}{\pi r^2 l}$$

- **For maximum Error in Y:**

$$\therefore \frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta g}{g} + \frac{\Delta L}{L} + 2\frac{\Delta r}{r} + \frac{\Delta l}{l}$$

$\Delta m \text{ and } \Delta g = zero, as\ these\ are\ not\ measured$

ΔL – the least count of the scale used for measuring L.

Δr – the least count of the micrometer screw gauge used for measuring r.

Δl – least count of the device used for measuring extension.

$$\therefore \frac{\Delta Y}{Y} = \frac{\Delta L}{L} + 2\frac{\Delta r}{r} + \frac{\Delta l}{l}$$

Find ΔY.

RESULT

∴The Young's modulus ***Y*** of the material of the wire

(using table) = $Y \pm \Delta Y$ **(N/m²)**

(using graph) = $Y \pm \Delta Y$ **(N/m²)**

PRECAUTION

1. Measure the diameter of the wire at different positions, check for its uniformity.

2. Adjust the spirit level only after sufficient time gap following each loading/unloading.

SOURCES OF ERROR

1. The diameter of the wire may alter while loading.
2. Backlash error of the device used for measuring extension.
3. The nonuniformity in thickness of the wire.

DISCUSSION

Which of the quantities measured in the experiment is likely to have maximum affect on the accuracy in measurement of Y (Young's modulus).

SELF ASSESSMENT

1. If the length of the wire used is reduced what will be its effect on extension and on the stress on thewire.

2. Use wire of different radii (r_1, r_2, r_3) but of same material in the above experimental set up. Is there any change in the value of Young's modulus of elasticity of the material? Discuss your result.