Indian Institute Of Technology Kanpur

AE 351A
Experiments in Aerospace Engineering 2020-21
Semester II

Torsion Testing

Submitted By:

Ankit Lakhiwal

(ankitl@iitk.ac.in)

Department of Aerospace Engineering

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1 Objective

Perform a torsion (shear) test on a shaft with a circular cross section and measure the shear modulus of a material using two different methods.

2 Introduction And Theory

Torsion is a moment that twists/deforms a member about its longitudinal axis. In sections perpendicular to the torque axis, the resultant shear stress in this section is perpendicular to the radius. Assumptions :

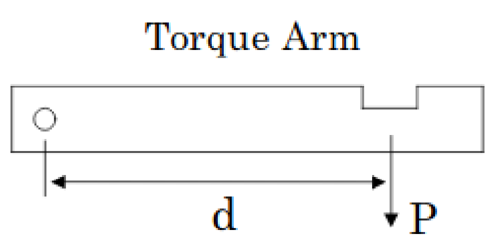
- Plane sections remain plane and perpendicular to the Torsional axis
- Material of the shaft is uniform
- Twist along the shaft is uniform
- Axis remains straight and in-extensible
- Angle of rotation is small, hence length of shaft and its radius remain unchanged

For shafts of uniform cross-section the torsion is:

$$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$$

Where T= torque applied for twisting
J = Polar Inertia
R= Radius of the shaft
τ = Shear stress
G= Modulus of Rigidity
L = Length of the shaft
θ = Angle twisted

1. Calculation of Applied Torque

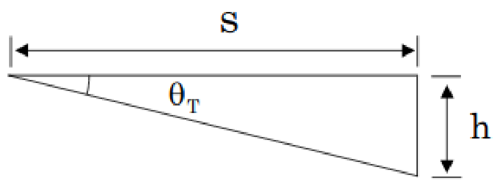


The torque is given by,

$$T = Pd \tag{1}$$

where P is the applied load, and d is the length of the torque arm

2. Calculation of the Angle of Twist

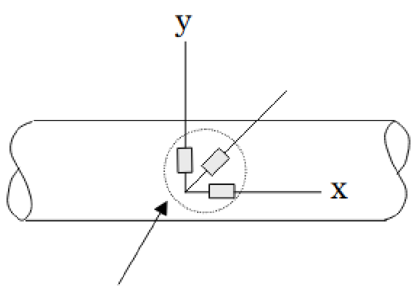


The angle of twist is measured by,

$$\tan \theta_T = \frac{h}{s} \tag{2}$$

where h is the vertical deflection of the torque arm measured using a deflection dial gage, and s is the distance between the center of the shaft and the dial gage.

3. Calculation of Shear Strain from the 0-45-90 Strain Gage Rosette Data



$0^\circ - 45^\circ - 90^\circ$ Strain Gage Rosette

From strain transformation equation the normal strain for a given orientation can be calculated by using mechanics of solids equation,

$$\epsilon_n(\theta) = \epsilon_x \cos^2\theta + \epsilon_y \sin^2\theta + \gamma_{xy} \sin\theta\cos\theta$$

Applying this relation at each of the gage angles leads to:

$$\epsilon_0 = \epsilon_x$$
$$\epsilon_{45} = \frac{\epsilon_x + \epsilon_y + \gamma_{xy}}{2}$$
$$\epsilon_{90} = \epsilon_y$$

The shear strain can be obtained by rearranging the above expressions, where ϵ_0, ϵ_{45} and ϵ_{90} are the strain values recorded using 0-45-90 strain gage rosette.

$$\gamma_{xy} = 2\epsilon_{45} - \epsilon_0 - \epsilon_{90} \tag{3}$$

3 Equipment's

1. Aluminium alloy 6063 T-6 specimen
2. Strain gage
3. Strain indicator
4. Dial gage
5. Weights
6. Torsion test fixtures

4 Procedure and Measurements

- Took measurement of specimen

Material	AA6063
Radius of Beam(**R**)	10mm
Total length of Beam(**L**)	687mm
Distance between shaft centre and dial gage(**s**)	135mm
Torque Arm Length(**d**)	170mm

Table 1: Initial measurement of specimen

- Applied loads to the torque arm and increased load by 10N
- Recorded all the three strain gage readings, and the vertical deflection of the torque arm at each load.
- Determined the torque, shear strain, and the angle of twist for each applied load. Tabulated all measurements and calculations.

5 Results And Discussion

5.1 Sample Calculations

- **Polar moment of inertia**

$$J = \pi R^4/2$$

$$J = \frac{\pi * (0.01)^4}{2}$$

$$J = 1.5707 * 10^{-8} m^4$$

- **For 14.715N load**
  - h =1.29 mm
  - **Angle of twist** $\theta = \tan^{-1}(\frac{1.29}{135}) = 0.0096$ rad
  - **Torque**

$$T = 2 * load * (torquearmlength)$$
$$= 2 * 14.715 * 0.170$$
$$= 5.0031 N.m$$

  - **Shear Strain**

$$\gamma = 2\epsilon_{45} - \epsilon_0 - \epsilon_{90}$$
$$= 2 * 61 - (-1) - 0.019$$
$$= 122.981 \mu m/m$$

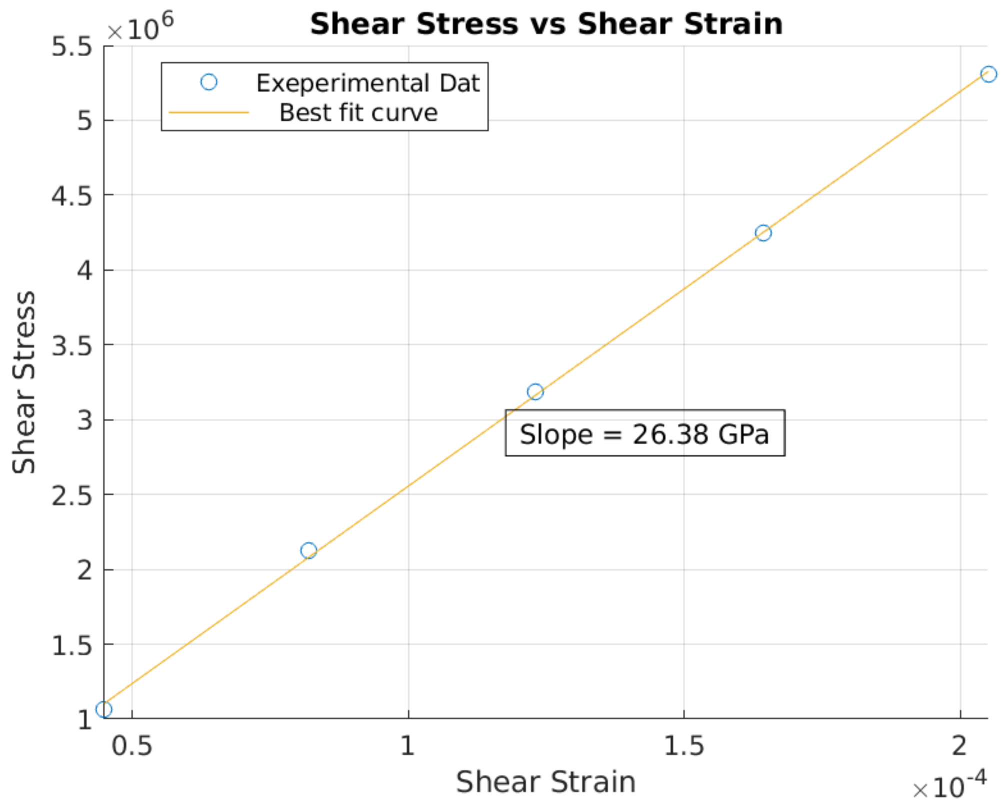
  - **Shear Stress**

$$\tau = \frac{T * R}{J}$$
$$= \frac{5.0031 * 0.01}{1.5707 * 10^{-8}}$$
$$= 3.18 MPa$$

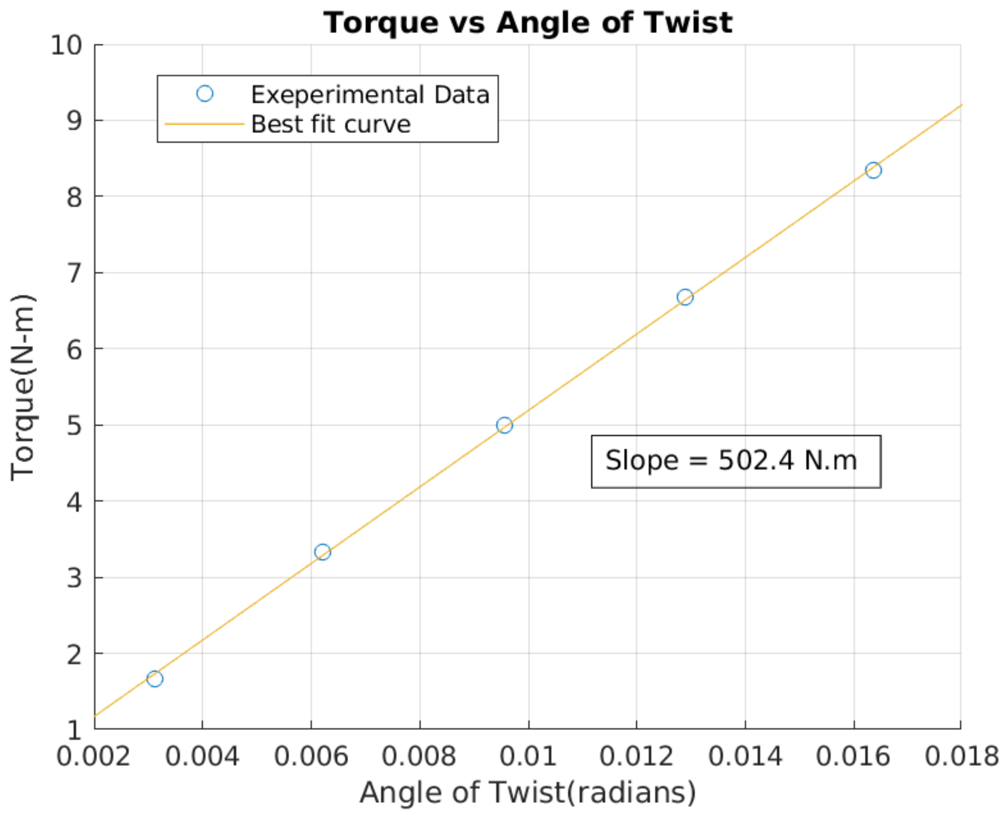
5.2 Data Presentation

Load (N)	ϵ_0 ($\mu m/m$)	ϵ_{45} ($\mu m/m$)	ϵ_{90} ($\mu m/m$)	h (mm)	$\theta = \tan^{-1}(h/s)$ (radian)	Torque (N.m)	γ_{xy} ($\mu m/m$)	τ_{xy} (MPa)
4.905	0	22.5	0.02	0.42	0.0031	1.6677	44.98	1.061
9.81	-1	40.5	0.015	0.84	0.0062	3.3354	81.985	2.1234
14.715	-1	61	0.019	1.29	0.0096	5.0031	122.981	3.1851
19.62	-1.5	81.4	0.016	1.74	0.0129	6.6708	164.284	4.2468
24.525	-2	101.5	0.012	2.21	0.0164	8.3385	204.989	5.3085

Table 2: Experimental Data



slope of the curve : **G (Rigidity modulus)** = 26.38 GPa



$$slope of the curve = \mathbf{JG/L} = 502.4 N.m$$
$$\mathbf{G} = slope * (L/J)$$
$$\mathbf{G} = \frac{502.4 * 0.687}{1.5707 * 10^{-8}}$$

$$\mathbf{G} = 21.97 GPa$$

5.3 Discussion and Error analysis

1. Stress-Strain curve (Method-I)
   - Published Shear modulus = 25.8 GPa
   - Experimental Shear modulus = 26.38 GPa
   - Error =
   $$\frac{26.38 - 25.8}{26.38} * 100\% = \mathbf{2.19\%}$$

2. Torque-Twist angle curve (Method-II)

    - Published Shear modulus = 25.8 GPa
    - Experimental Shear modulus = 21.97 GPa
    - Error =

$$\frac{25.8 - 21.97}{25.8} * 100\% = \mathbf{14.84\%}$$

6 Conclusion

- The shear modulus value obtained from stress strain curve is more accurate because the values are recorded from the pure torsion region.
- In method II, whole specimen is considered for calculation, however whole specimen is not only under the action of pure torsion but bending also.
- The difference in value obtained from Method II is also due to the human error that might have occurred during the experiment.

7 Appendix

Experimental Table

Load	h	strain_0	strain_45	strain_90
4.905	0.42	0	22.5	0.02
9.81	0.84	-1	40.5	0.015
14.715	1.29	-1	61	0.019
19.62	1.74	-1.5	81.4	0.016
24.525	2.21	-2	101.5	0.012