LAB 2 - Torsion Test
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AE351
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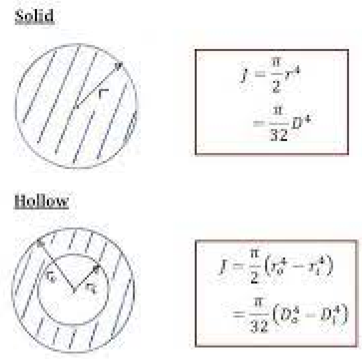
- **OBJECTIVE:**

Perform a torsion (shear) test on a shaft with a circular cross-section and measure *the shear modulus, G* of material using two different methods [Shear Stress vs. Shear Strain Plot and Torque vs. Angle of Twist plot].

- **INTRODUCTION AND THEORY:**



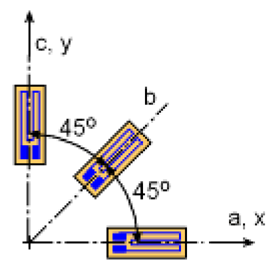
G -- Shear Modulus or Rigidity Modulus
Polar Moment of Inertia, J = (π*r^4/2), for solid circle.
Length of the Sample, L

1. Torque Calculation : Torque T = load * arm length

2. Relation between Shear Stress, $\tau_{XY,}$ and Shear Strain, γ_{XY}:
τ_{XY} = G* γ_{XY} and τ_{XY} = (T*r)/J

3. Relation between Torque, T and Deflection Angle, θ: T= (GJ/L)*θ

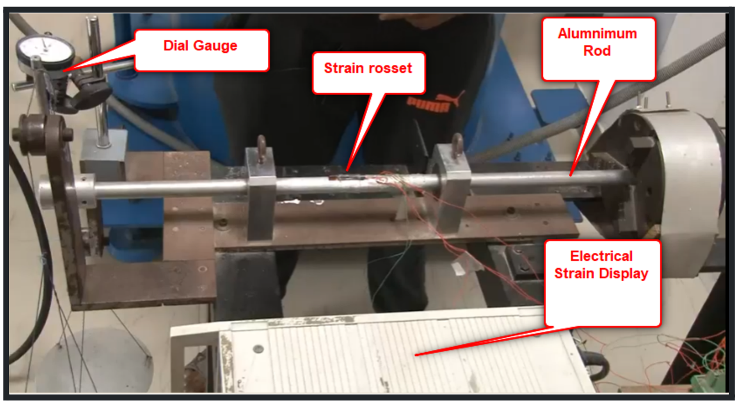
4. Calculation of Shear Strain from the Strain Rosset (0˚, 45˚ , and 90˚ strain gauge)



$\varepsilon_n(\theta) = \varepsilon_X\cos\theta + \varepsilon_Y\sin(\theta) + \gamma_{XY}\sin(\theta)\cos(\theta)$;
By Applying this formula(or equivalently applying the Mohr's Circle transformation) to θ =0˚, θ =45˚ and θ =90˚ and further reducing it we can obtain the following relation:
Shear strain $\gamma_{XY} = 2\varepsilon_{45} - \varepsilon_0 - \varepsilon_{90}$

- **EQUIPMENT AND OPERATING CONDITIONS:**

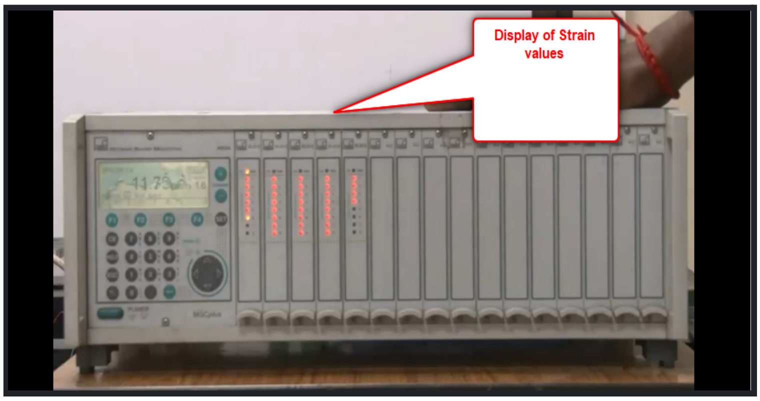
1. Torsion test fixtures for holding the specimen and for applying the torque.
2. Carefully machined cylindrical shaft of aluminum mounted with a 0-45-90 strain gage rosette.
   - Aluminium 6063-T6
   - The Rod is fixed at one end and at the free end torque can be applied.
   - The Strain Rosset is used to measure the strain rate at the point.
3. A mechanical Dial gauge (to measure the vertical deflection)

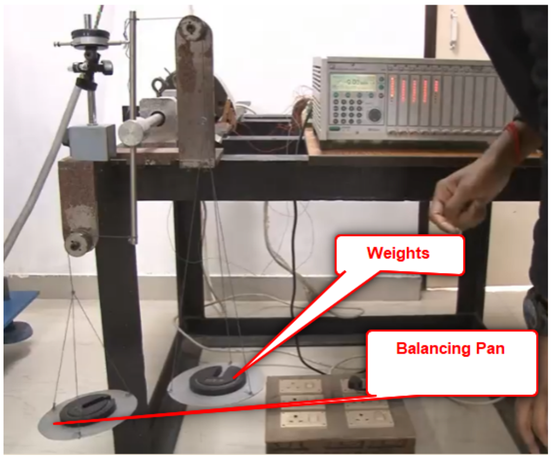


4. Electrical Strain indicator equipment to display the measured strains.

- The 0° strain gauge is connected to Channel 6.
- The 45° strain gauge is connected to Channel 7.
- The 90° strain gauge is connected to Channel 8.
- The indicator shows strain value in micrometre/m ≡ 10^{-6}.

5. Weights of 5N each (this will be used to generate torque)





- Some Important Dimensions:

h = Vertical deflection of torque arm at gage location = dial gauge reading
r = Radius of the rod being twisted = 10mm
s = Arm length till the location of the deflection gage
= Distance b/w shaft centre and dial gauge = 135mm

L = Length of the rod between two fixed ends (mm) = 687mm
d = Torque arm = 340 mm (170mm)*2

- **PROCEDURE :**

1. Setup the experimental devices properly as shown and described in the above figures.
2. Apply loads to the torque arm. The load range and the load increment will be increased by 5N each time
3. At each load, record (and Note down) the three strain gauge readings, and the vertical deflection of the torque arm.

4. Determine the torque, shear strain, and the angle of twist for each applied load. Tabulate all measurements and calculations.

6. Use the measured data to generate plots of Shear Stress vs. Shear Strain (τ_{XY} and γ_{XY}), and Torque vs. Angle of Twist (T vs. θ).

7. Using linear regression to fit the data. Calculate shear modulus, G using the slope of the Linear Regression line for each of the two plots separately.

- **Collected Data : [DATASET 1]**

S. No.	Load (N)	ε_0 (x 10^6)	ε_{45} (x 10^6)	ε_{90} (x 10^6)	h (mm)
1	5	0	19.6	0.017	0.41
2	10	-1	38.2	0.013	0.82
3	15	0	59.5	0.018	1.24
4	20	-2	77.8	0.015	1.68
5	25	-3	98.1	0.011	2.11

- **RESULTS AND DISCUSSION :**

(a) Calculations and Plots

Data Used: DATASET 1
Total DataPoints -- 5
- ***I am using MatLab Script to analyze and plot the Data***

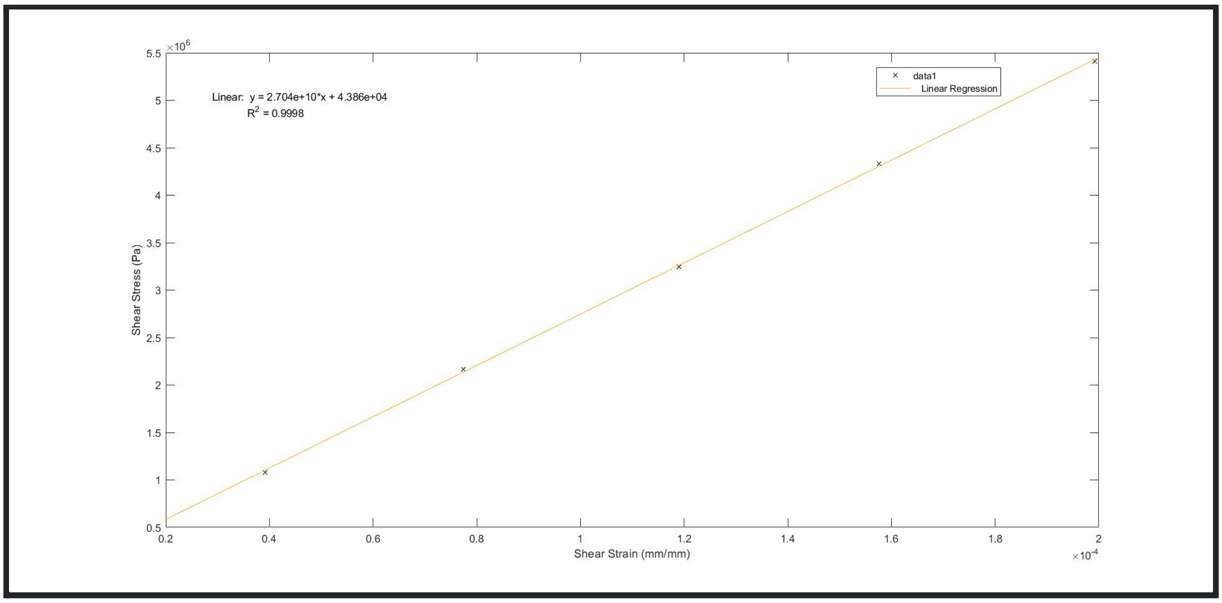
Polar Moment of Inertia, J = (π*r^4/2) =15707.96 mm^4

Torque T = load * d
angle of Twist θ = arctan(h/s)
Shear strain $\gamma_{XY} = 2\varepsilon_{45} - \varepsilon_0 - \varepsilon_{90}$
Shear stress τ_{XY} = (T*r)/J

S. No.	Load (N)	ε_0 (x 10^{-6})	ε_{45} (x 10^{-6})	ε_{90} (x 10^{-6})	h (mm)	$\theta=\tan^{-1}(h/s)$ (radian)	T=load*d (Nm)	τ_{XY} (MPa)	γ_{XY}(x 10^{-6})
1	5	0	19.6	0.017	0.41	0.00304	1.7	1.082254	39.183
2	10	-1	38.2	0.013	0.82	0.00607	3.4	2.164508	77.387
3	15	0	59.5	0.018	1.24	0.00918	5.1	3.246762	119
4	20	-2	77.8	0.015	1.68	0.01244	6.8	4.329015	157.6
5	25	-3	98.1	0.011	2.11	0.01563	8.5	5.411269	199.2

1. Plot of the Shear Stress vs Shear Strain data [for all 5 datapoints]

Shear Stress, τ_{XY} (MPa)	Shear Strain, γ_{XY}(x 10^{-6})
1.082254	39.183
2.164508	77.387
3.246762	119
4.329015	157.6
5.411269	199.2



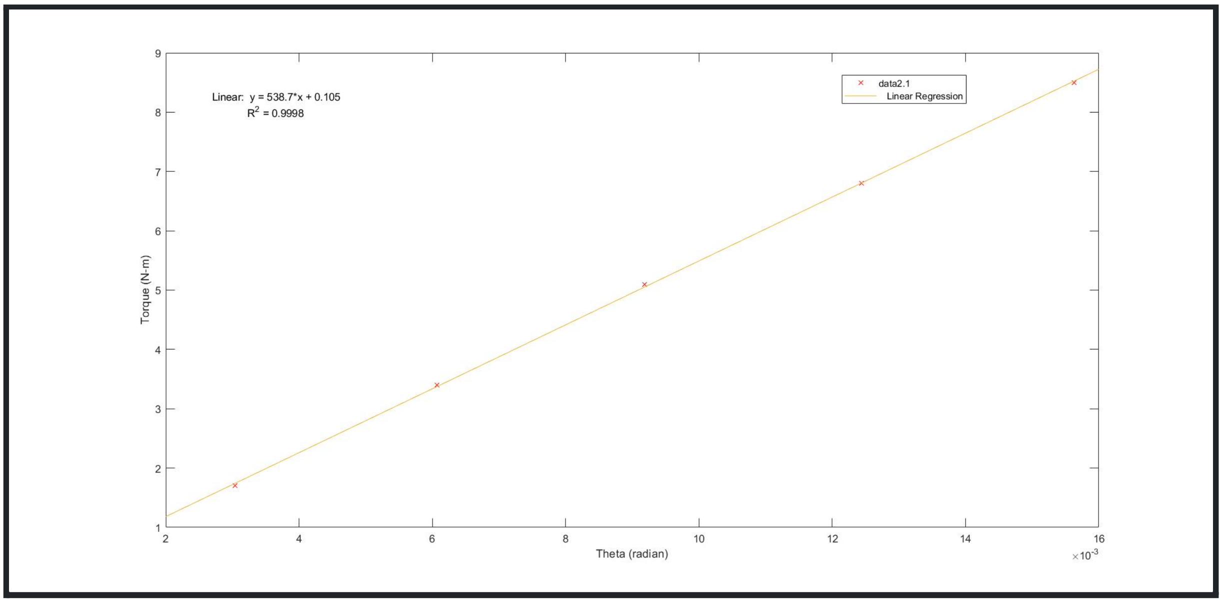
- ***PLOT1***

Equation of the Linear Regression line: $y = 2.704*10^{10}x + 4.386*10^4$

Shear Modulus (from this plot) G_1 = Slope of the Linear Regression line
= $2.704*10^{10}$ Pa = 27.04 GPa

2. Plot of the Torque vs Theta data [for all 5 datapoints]

$\theta=\tan^{-1}(h/s)$ (radian)	T=load*d (Nm)
0.00304	1.7
0.00607	3.4
0.00918	5.1
0.01244	6.8
0.01563	8.5



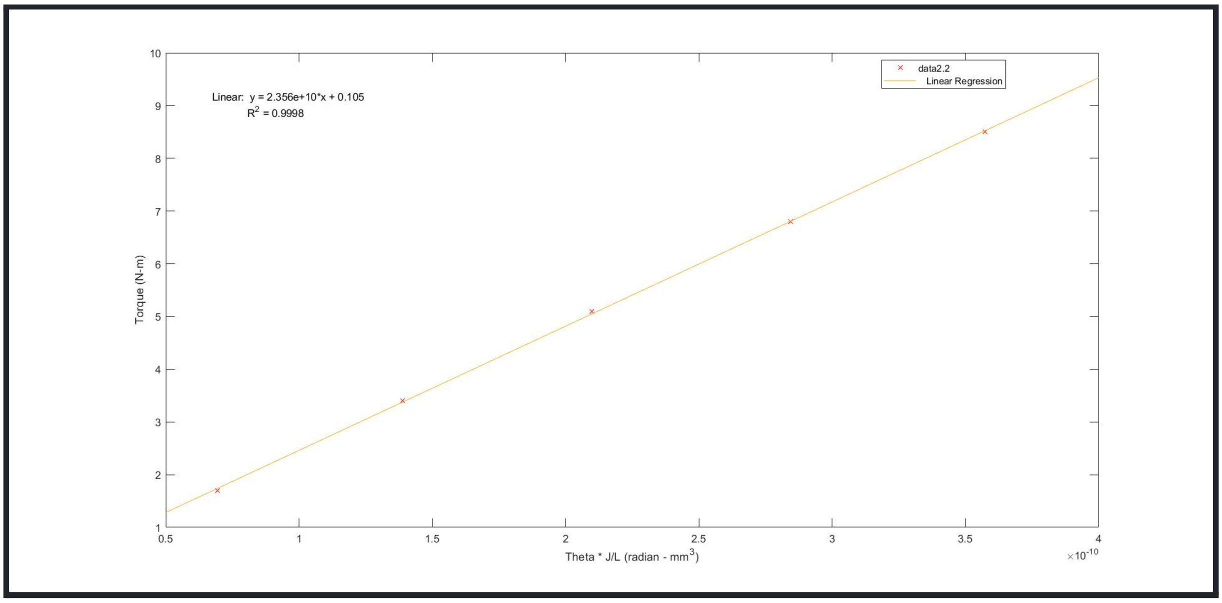
- ***PLOT2***

Equation of the Linear Regression line: $y = 538.7*x + 0.105$

Shear Modulus (from this plot) G_2 = Slope of (above) Linear Regression line*(J/L)

$= 538.7 \text{ N-m} * (687*10^{-3}/15707.96*10^{-12}) m^{-3}$

$= 23.56$ GPa



- PLOT3

Observe that we can directly obtain G_2 from Plot3.

b. Discussion and error analysis :

Published Value of Shear Modulus, G of Aluminium 6063 -T6 is 25.8 GPa.

% Error formula = |Approximate value – Exact Value|/Exact value * 100.

%error in G_1 (wrt Published value of G) = |(25.80-27.04)|/25.80 * 100 = 4.81%
%error in G_2 (wrt Published value of G) = (25.80-23.56)/25.80 * 100 = 8.68%

c. Sources of Error :

1. The dial gauge and strain gauge reading should be set to 0 prior to placing the weight on the pan
2. Before taking the strain reading you should make sure that there is no oscillation in the pan after the loading.
3. Insert the connections of the strain gauge into the electrical strain measuring device properly.

- **Conclusion :**

--Summary of the Calculations done for the Given Sample-- *(Reporting data up to 2 significant digits)

Shear Modulus Calculated from Shear Stress Vs Shear Strain data, G_1	27.04 GPa
Shear Modulus Calculated from Angle of Twist vs Torque data, G_2	23.56 GPa
%error in G_1 (wrt Published value of G)	4.81%
%error in G_2 (wrt Published value of G)	8.68%

Also from the error we can comment that the method I (calculating G from Shear Stress Vs Shear Strain plot) employed is more correct.

- **Reference:**
    - http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6063T6 (for Al6063-T6 data)
    - Pictures from Google and Lectures
- **Appendix :**

The Matlab code used:

```
%% Stress Vs Strain
%strain data: E_0 -- 0deg Strain Gauge || E_45 -- 45deg Strain Gauge ||
% E_90 -- 90deg Strain Gauge || Shear_Strain

E_0 = [0;-1;0;-2;-3].*10^-6;
E_45 = [19.6;38.2;59.5;77.8;98.1].*10^-6;
E_90 = [0.017;0.013;0.018;0.015;0.011].*10^-6;

Shear_Strain = 2*E_45 - E_90 - E_0;

%Shear_Stress

Shear_Stress = [1.082254;2.164508;3.246762;4.329015;5.411269].*10^6;

plot(Shear_Strain,Shear_Stress,'xk');
xlabel("Shear Strain (mm/mm)");
ylabel("Shear Stress (Pa)");

%% Torque Vs Theta
% torque -- T || Deflection Angle -- Theta

T = [1.7;3.4;5.1;6.8;8.5]
Theta = [0.00304;0.00607;0.00918;0.01244;0.01563] .* (15707.96 * 10^-9 / 687);

plot(Theta,T,'xR');
xlabel("Theta * J/L (radian - mm^3");
ylabel("Torque (N-m)");

T = [1.7;3.4;5.1;6.8;8.5]
Theta = [0.00304;0.00607;0.00918;0.01244;0.01563] ;

plot(Theta,T,'xR');
xlabel("Theta (radian)");
ylabel("Torque (N-m)");
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