AE351 - IITK

LAB 1 - Uniaxial Tensile Testing

Lab Objective: Perform uniaxial tension test on a dog-bone shaped tensile specimen. Plot stress vs. strain curve and analyze material behavior by identifying key material parameters.

Procedure:

1. Switch on the 10 kN Tinius Olsen universal testing machine (UTM). With the help of lab instructor understand the method of conducting tensile test and learn salient features of the software-in-use.

2. Hold the dog-bone shaped test specimen at the UTM grips and carefully mount 25 mm extensometer in between the gage length region of the specimen.

3. Load the specimen in displacement control mode at the speed suggested by the lab instructor.

4. Remove the extensometer at pre-decided (specified) load/strain value.

5. Continue loading the specimen until failure is observed.

6. Record the load vs. cross head displacement data and the load vs. strain gage data (**RAW DATA**).

7. Plot the stress vs. strain curve as discussed in the class.

8. Carefully observe the failed specimen and perform failure analysis. Analyze and discuss the material behavior from the stress-strain plot. Determine all material characteristics (including elastic modulus, yield stress, failure stress, elastic and plastic zones/limits and various strains).

9. Compare the experimental value of elastic modulus with the published data for the specimen-in-consideration. Calculate the percent differences between the measured and published values.

10. Identify sources of errors in your experiments/measurements.

Prepare a lab report using provided Lab Format guidelines.

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LAB 2 - Torsion Testing

Lab 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.

Procedure:

1. Go through the 'Notes on torsion experiments' detailed in next section.

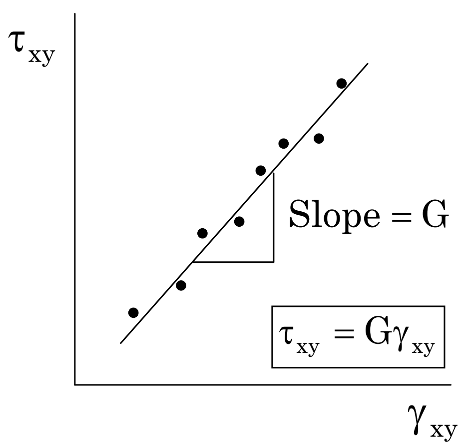
2. Torsion test experimental setup includes:
   a. Torsion test fixtures for holding the specimen and for applying the torque.
   b. Strain indicator equipment to measure strains.
   c. Carefully machined cylindrical shaft of aluminum mounted with a 0-45-90 strain gage rosette.

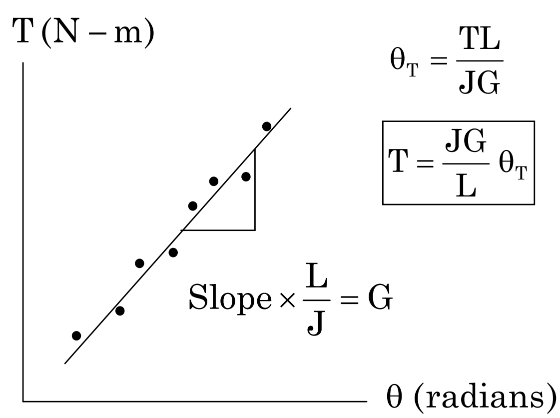
3. Apply loads to the torque arm. The load range and the load increment will be given by your lab instructor.

4. At each load, record the three strain gage readings, and the vertical deflection of the torque arm.

5. 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} vs. γ_{xy}), and Torque vs. Angle of Twist (T vs. θ_T).





7. Using linear regression fit the data (Draw a best possible straight line fit passing through all the data). Calculate shear modulus using the slope of the straight line fit (See, the plots).

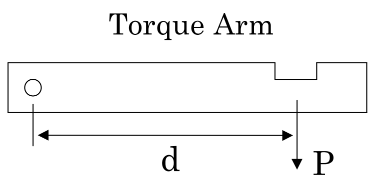
8. Compare experimentally measured G to the published value for your specimen material. Calculate the percent differences between the measured and published values.

9. Identify sources of errors in your measurements.

Prepare a complete lab report. Use the provided Lab Format as a guideline for preparing your report.

Notes on the Torsion Experiment

1. Calculation of Applied Torque

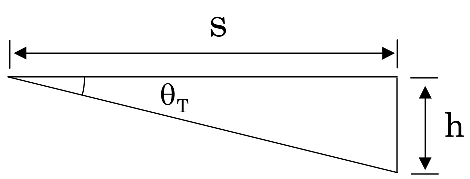


The torque is given by,

$$T = Pd,$$

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

2. Calculation of the Angle of Twist

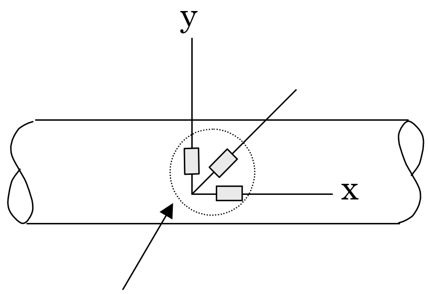


The angle of twist is measured by,

$$\tan\theta_T = \frac{h}{s},$$

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. <u>Calculation of Shear Strain from the 0-45-90 Strain Gage Rosette Data</u>



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

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

$$\varepsilon_n(\theta) = \varepsilon_x \cos^2\theta + \varepsilon_y \sin^2\theta + \gamma_{xy} \sin\theta\cos\theta$$

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

$$\varepsilon_0 = \varepsilon_x$$

$$\varepsilon_{45} = \frac{\varepsilon_x + \varepsilon_y + \gamma_{xy}}{2}$$

$$\varepsilon_{90} = \varepsilon_y$$

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.

$$\gamma_{xy} = 2\varepsilon_{45} - \varepsilon_0 - \varepsilon_{90}$$

<u>Measurements and Tabulation</u>

h = Vertical deflection of torque arm at gage location (mm)
r = Radius of the rod being twisted (mm)
s = Arm length till the location of the deflection gage (mm)
L = Length of the rod between two fixed ends (mm)

Units of calculated parameters:

Torque: T (N)
Angle of Twist θ (radians)
Shear strain γ_{xy} μ strains (10^{-6})
Shear stress τ_{xy} (MPa)

Other quantity to be calculated:
- Polar Moment of Inertia: $J = (\pi r^4/2)$ mm^4

#	load (N)	$\varepsilon_0(\mu)$	$\varepsilon_{45}(\mu)$	$\varepsilon_{90}(\mu)$	h (mm)	$\theta=\tan^{-1}(h/s)$	T=load*d(arm)	γ_{xy}	τ_{xy}
1									

2									
3									
4									
5									
6									

Calculate shear modulus from the T vs. θ and the τ_{xy} vs. γ_{xy} plots. Determine the error by comparing the published value of G for the material-in-consideration.

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LAB 3 - Beam Deflection and Strains

Lab Objectives: Experimentally measure the strain and deflection in a beam subjected to transverse loading. Determine the strain and the deflection variation along the beam using Euler-Bernoulli beam theory and compare the results with experimental measurements.

Procedure:

1. Go through the 'Notes on beam deflection and strains' detailed in the next section.

2. The experimental setup includes:
   d. A beam of rectangular cross section with carefully mounted (15) strain gages on its top surface
   e. Strain indicator (with Wheatstone bridge circuits) to record strain gage data
   f. Deflection dial gages to measure beam deflection

3. Mount the beam with simply supported boundary conditions. Measure beam dimensions and the location of strain gages with respect to the supports. Apply a concentrated load as specified by your lab instructor. Record all dial gage readings and the strain values using strain indicator equipment and tabulate your data.

4. Theoretically calculate strains at each of the strain gage locations using Euler-Bernoulli beam theory and compare your results with experimentally measured strain values. Generate graphs that show both your experimental measurements (as data points) and theoretical predictions (as solid lines/curves). Calculate the percent errors and discuss possible reasons for the discrepancies.

5. Perform the analysis steps mentioned above in 4 for the beam deflection.

6. Remove all dial gages. Simulate symmetric four point bend condition by applying two concentrated loads of the same magnitude symmetrically with respect to the supports. Tabulate strain data recorded using strain indicator equipment and repeat the analysis steps mentioned in 4.

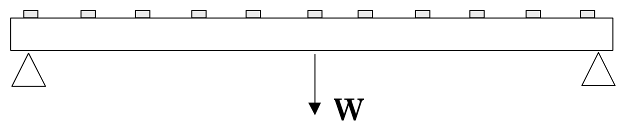
$$\sigma_x(x,y) = \frac{M(x)\,y}{I} \qquad \varepsilon_x(x,y) = \frac{M(x)\,y}{EI}$$

Prepare a complete lab report using the Lab Format guidelines provided.

Notes on the Beam Deflection and Strains

Experiment #1

The experiment consists of a simply supported Beam of rectangular cross section subjected to a concentrated load. The load is applied by hanging dead weight at the specified location of the beam. A total of 15 strain gages have been mounted on the top surface of the beam.



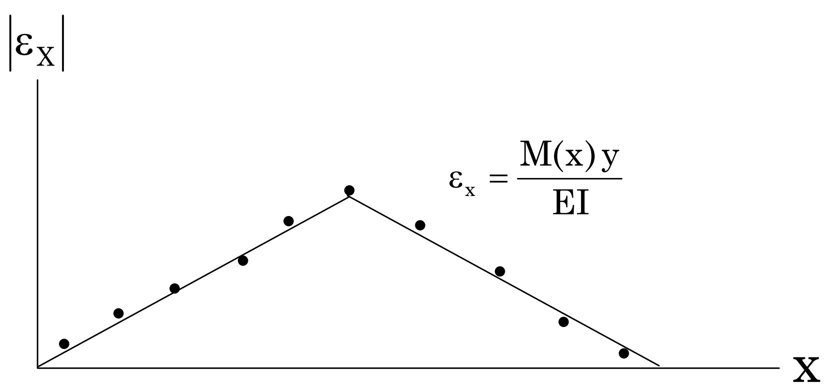
The strain gage locations from the neutral axis (y) are constant. Therefore, from Euler-Bernoulli beam theory the theoretical strain distribution on the top of the beam can be given by,

$$\varepsilon_x(x) = M(x)\left[\frac{y}{EI}\right] = C_2\ M(x)$$

where $C_2 = y/EI$ is a constant that can be calculated. As part of this experiment, you should generate a table such as shown below, which lists the measured and predicted strains at each gage location.

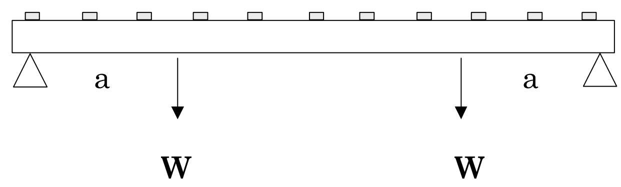
Strain Gage Number	x (inches)	M(x) (in-lb)	ε_x (μ) [Measured]	ε_x (μ) [Predicted]	Percent Difference
1					
2					
3					
4					
5					

Also, you should plot ε_x vs. x, to graphically compare the theoretical and experimental results. In your graph, use data points for your experimental measurements and a solid line for you theoretical prediction as shown below.



Experiment #2

This experiment consists of a beam with rectangular cross section subjected to a symmetric four point bend loading. As described in the Beam Experiment #1, measure strain values, tabulate your data, compare theoretical and experimental measurements by plotting graphs and perform error analysis as described in earlier experimental details.



Lab – 4

Principal axes of a given cross-section in a thin walled beam

Objective:

To determine the principal axes and the orientation of principal planes of an L section beam.

Procedure:

i) Measure the thickness of the web and flange of the L section. Also measure the length of the flange and the height of the web to determine the values of I_{zz}, I_{yy}, I_{yz}.
ii) Adjust the dial gauges to remove any zero error while supporting the pans with your hands to have the no load initial setup.
iii) Fix the y-direction load P_y, and for some random z-direction load P_z, note the beam deflections δ_y and δ_z
iv) Increase the loads in each of the pan and calculate the ratio of loads and the ratio of deflections produced. They should be almost equal i.e., the difference between these two ratios should be very small.
v) Repeat the steps above for different values of Py and Pz.

Equations:

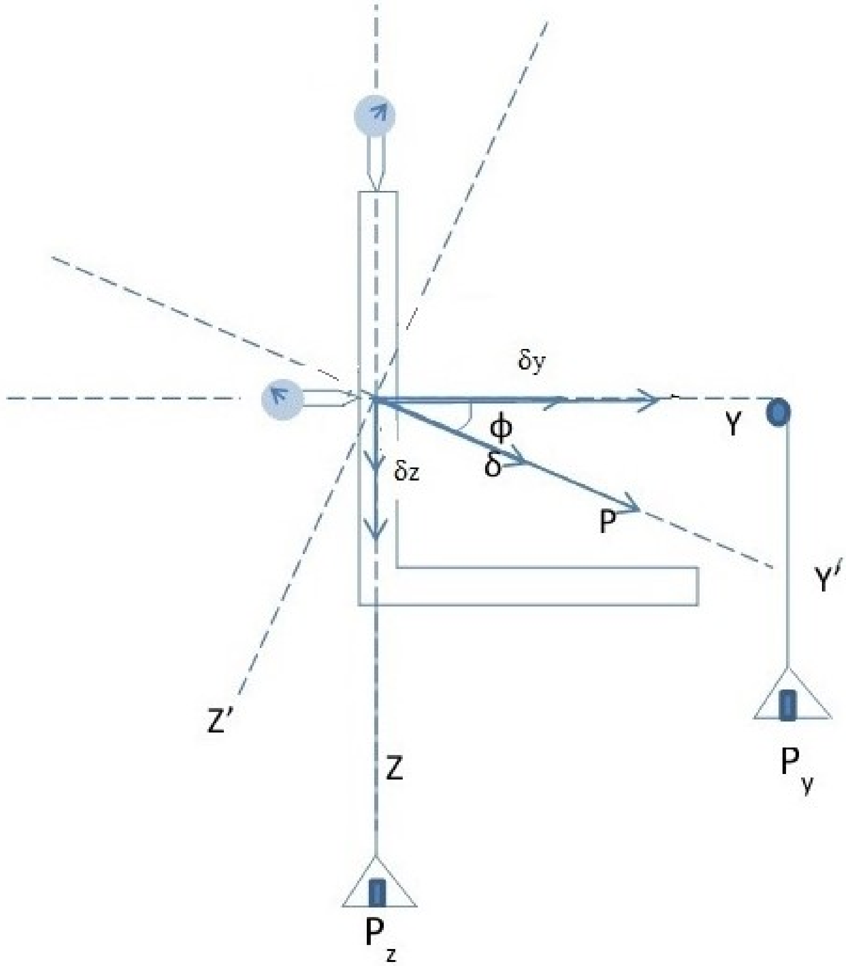
Theoretical

$$\tan 2\Phi = \frac{-2Iyz}{Iyy - Izz}$$

$$\tan \phi = \frac{P_y}{P_z} = \frac{\delta_y}{\delta_z}$$

Experimental

Experimental Setup



Tabulation:

Sl.No.	P_y (kg)	P_z (kg)	δ_y (mm)	δ_z (mm)	P_y/P_z	δ_y/δ_z