MECHANICS LAB
AM 317

EXP 4
TORSION OF CIRCULAR RODS

I. OBJECTIVES

I.1 To become familiar with torsion tests of rods with solid circular cross sections.

I.2 To observe the relation between shear stress (τ) and shear strain (γ).

I.3 To experimentally determine the shear modulus (G) of three different circular metal rods.

II. INTRODUCTION AND BACKGROUND

The stress distribution in a torsion member such as a transmission shaft is non-uniform; it varies from zero at the centroidal longitudinal axis to a maximum at the outer fibers.

In many engineering applications, such as torque transmission and in springs, the torsional behavior critically governs the design. In many cases the maximum torsional stress is the limiting factor in design while in others, it may be the maximum permissible angle of twist.

III. EQUIPMENT

III.1 TERCO Twist and Bend Machine, MT3005.

III.2 3 circular rods of various materials.

III.3 Tools: dial gauge, micrometer, dead-weights, weight pans, and hex keys.

IV. PROCEDURE

IV.1 Measure the diameters of the three rods, calculate the polar moment of inertia of each rod and record the results on the data sheet. Measure and record the actual lengths of the rods.

IV.2 For a torque of 1.75 N-m (17.5 N at a radial distance of 100 mm), calculate the maximum shear stress. Check your results with the Instructor before continuing.

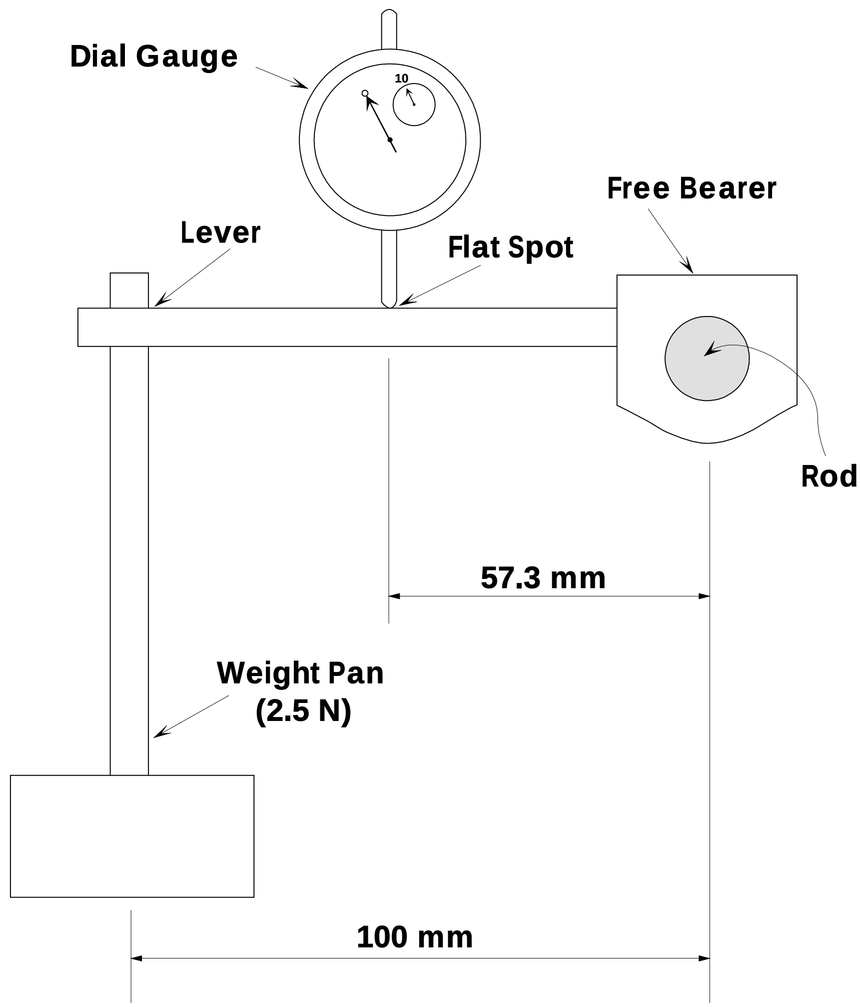

Figure 1 Set Up for Torsion Test

IV.3 Insert the first rod through the torsional fastening components of the bearers and lock rod into the left bearer first. The rod should then be fastened into the free bearer on the right with the lever close to the upper limit pin. Obtain the rod gage length to be used in the tests.

NOTE: 5 to 10 lb-in. of torque on each Allen screw is sufficient to lock each bearer. *DO NOT OVER TORQUE THESE SCREWS*.

IV.4 Make sure the dial gauge shaft is aligned with the small groove at the center of the flat spot on the lever. Carefully lower the gauge until the small hand reads 10. The large hand may be set to zero by carefully rotating the outer ring of the dial face.

NOTE: The dimension between the groove on the lever and the axis of the rod is 57.3 mm., thus, one revolution of the gauge corresponds to one degree of twist in the rod.

IV.5 Torque is applied to the rod by placing the knife edges of the weight pan in the groove near the tip of the lever. The weight of the pan is 2.5N. Adding three 5-N weights produces the maximum allowable torque. Before recording the lever deflections as a function of the applied load, exercise the setup three or four times by applying and removing the full 17.5-N weight. This will allow minute slippages to occur at the contact surfaces. You will be ready to record data when the large hand of the dial gauge returns to the exact location (+ or - 1.0 unit) it was at prior to applying the load.

Apply torque to the rod in the increments indicated on the data sheet and record the corresponding angle of twist. Record data during both the loading and unloading cycle and note the amount of hysterisis for each material.

IV.6 Repeat steps IV.3 through IV.5 for the second and third rods.

IV.7 Release and remove the rod from the fastening components of the machine.

V. REPORT

V.1 Make a plot of shear stress vs. shear strain for each rod. Each curve should be approximately linear. Calculate the slope of the best straight line fit through each set of data points. The slope of the shear stress vs. shear strain curve is the shear modules (G), using a constant for each rod, derived from the following expressions:

$$\tau = \frac{Tr}{J} \qquad \text{shear stress}$$

$$\gamma = \frac{r\theta}{L} \qquad \text{shear strain}$$

$$G = \frac{\tau}{\gamma} \qquad \text{shear modulus}$$

where:

T **= torque applied to rod**

r **= radius of rod**

J **= Polar moment of inertia of rod (**$J = \frac{1}{2}\pi r^4$**)**

L **= gauge length of rod**

θ **= maximum rotation of rod (radians)**

Use a linear regression analysis to draw a best fit curve through the data points for each rod. The regression analysis will use a least squares fit to find the slope and y-intercept of a line through each set of data points. The slope is the shear modules G.

V.2 Determine the Factor of Safety with respect to yield for shear stress. The Factor of Safety is the yield strength divided by the calculated stress. Assume the following properties:

Material	Shear Yield Strength (MPa)
Aluminum Alloy (2024-T3)	207
Brass	165
Magnesium Alloy (AZ31 Extrusion)	94
Structural Steel (A36)	145
Titanium Alloy (Ti-6Al-4V)	550

V.3 Also discuss the following:

a. The linearity of the data for each material.

b. The amount of hysteresis observed.

c. Compare the shear moduli obtained by this experiment with values given in one Strength of Materials textbook and one online resource.

VI. REFERENCES

Beer, F., Johnston, E.R., DeWolf, J. & Mazurek, D., Mechanics of Materials, 7th edition, McGraw Hill, 2014.

Hibbeler, R.C., Mechanics of Materials, 9th edition, Prentice Hall, 2013.

Popov, E.P., Engineering Mechanics of Solids, 2nd edition, Prentice Hall, 1998.

Khan, A.S., Pandey, A, Gnäupel-Herold, T. & Mishra, R.K., Mechanical response and texture evolution of AZ31 alloy at large strains for different strain rates and temperatures, International Journal of Plasticity, 27 (2011), 688 – 706.

Table I Rod Dimensions and Maximum Stress

Specimen	Rod #1	Rod #2	Rod #3
Color			
Diameter (mm)			
Actual Length (mm)			
Gauge Length (mm)			
Polar Moment of Inertia J (mm^4)			
Max. Shear Stress for T = 1.75 N-m			

Table II Angle of Twist vs. Applied Load

Specimen / Load (N)	Rod #1	Rod #2	Rod #3
0			
2.5			
7.5			
12.5			
17.5			
12.5			
7.5			
2.5			
0			

Table III
Comparison of Results with Values from One Textbook and One Online Resource

Specimen	Rod #1	Rod #2	Rod #3
Material			
G from experiment (GPa)			
G from a textbook (GPa)			
G from an online resource (GPa)			
Maximum % Deviation			

Table IV Factor of Safety

Specimen	Rod #1	Rod #2	Rod #3
Material			
Calculated Max. Shear Stress			
Shear Yield Strength			
F.S. of Shear Yield			