

## E5: Torsion of a circular rod

### 1. Objective:

- (a) To obtain the torque vs angle of twist graph for the specimen in order to obtain its shear modulus and compare the results with theoretical values.

### 2. Theory/Background (related to the experiments):

The stress-strain relationship of metals usually starts off as a linear correlation between stress and strain, meaning the material behaves elastically. However, once the stress exceeds a certain point known as the yield stress, the relationship becomes non-linear and the material's response is referred to as plastic. This behaviour is called strain-hardening, where the slope of the curve increases with increasing strain beyond the yield point.

In our experiment, we will simplify this strain-hardening behaviour and consider the material as having an elastic-perfectly plastic response, which can be approximated as a horizontal line. When a metal shaft is subjected to high torque, the plastic deformation begins at the outer fibers and spreads inward as the torque increases.

For a perfectly plastic shaft, beyond a certain point, the shaft can no longer resist further torque applied, and this is referred to as the limiting torque ( $T_L$ ). The relationship between torque and twist for a perfectly plastic material is described by the equation

$$T = (4/3)T_Y (1 - 0.25(\theta_Y/\theta)^3),$$

where  $T_Y$  and  $\theta_Y$  represent the torque and angle of twist at the onset of yield.

Our goal is to evaluate the difference between the experimental results and the predictions made for a perfectly plastic material. We expect that real materials will strain-harden and cause deviations from these predictions.

### 3. Equipment Required:

- (a) Torsion tester setup
- (b) Vernier callipers
- (c) Marker
- (d) Ruler.

### 4. Experimental Method:

- (a) Attach the rod securely to the torsion apparatus which comprises a sturdy base and a torque gauge.
- (b) Apply torque to the rod by rotating it with a motorized torque device. - Determine the rod's angle of rotation through an angle measuring encoder.
- (c) Determine the rod's torsional rigidity by dividing the applied torque by the angle of rotation.
- (d) Conduct the experiment with varying torque levels and calculate the torsional rigidity for each instance.
- (e) Present the results in a graph and compare them to the theoretical values derived from the rod's material characteristics.

### 5. Expected outcomes:

- (a) the amount of twist the rod undergoes when torque is applied to it.
- (b) Plotting the "applied torque vs angle of twist" curve we can get the shear modulus for the rod and we expect that the graph of the data should be linear until the the material is in elastic regime then it should be non linear as per the theory.