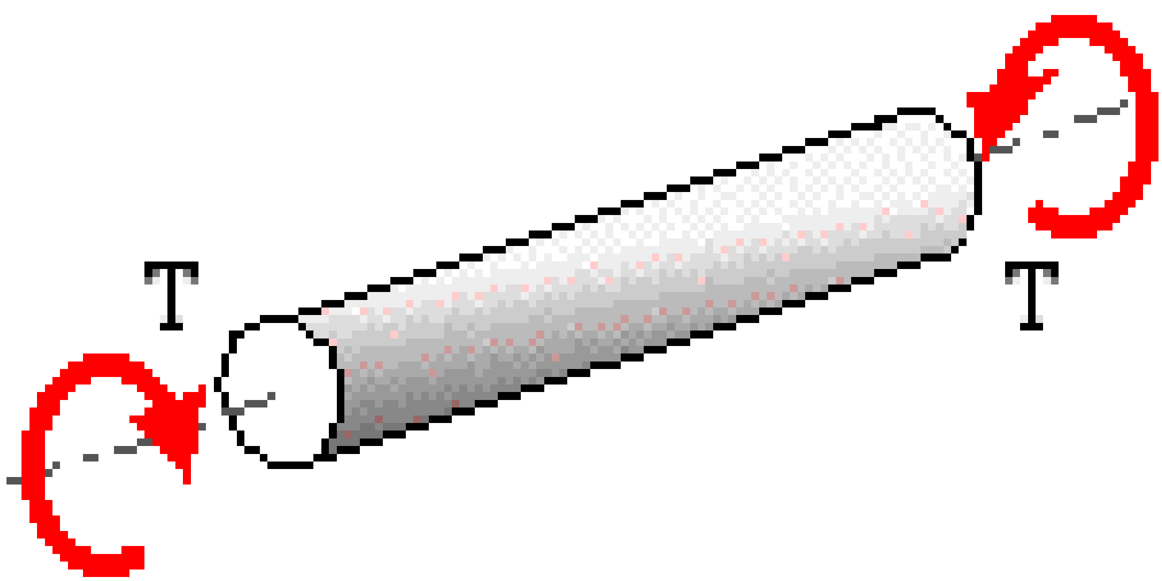
# ME 313 L

# TORSION TESTING OF MATERIALS



## OBJECTIVE

The objective of this experiment is to determine the mechanical properties of materials under torsion tests using angular speed control.

The properties to be measured are the shear modulus, shear stress, shear strain, max. shear stress, and modulus of resilience.

## BACKGROUND

Torsion tests allow direct measurement of the shear modulus (***G***) of a material. This ability makes torsion testing, although not as common, a useful partner for tensile testing in determining the mechanical properties of a material.

There are two kinds of torsion experiments: torque control and angular speed control. Torque control experiments apply a uniformly increasing torque to the specimen and the amount of strain is measured as an angle through which the specimen has turned. Angular speed control turns the specimen at a specific angular speed while the torque is measured.

Angular speed control is the type of experiment we will be doing, thus the directly measured quantity in this experiment will be torque.

## THEORY

### Notation

| Symbol | Description | Units |
|---|---|---|
| *A* | Area | $m^2$ |
| *M* | Applied Moment | Nm |
| *F* | Force | N |
| *L* | Total Length of a specimen | m |
| *L* | Test Length | m |
| *T* | Torque | Nm |
| *J* | Polar Moment of Inertia | $m^4$ |
| *G* | Shear Modulus | $Nm^{-2}$ |
| *D* | Diameter of specimen | m |
| *R* | Radius of specimen | M |
| *T* | Shear Stress | $Nm^{-2}$ |
| *Γ* | Shear Strain | |
| *Θ* | Angle of twist | Radians |

## Modulus of Rigidity or Shear Modulus (G)

The Shear Modulus or Modulus of Rigidity is a measure of the rigidity of the material when in 'shear' when it is twisting. It is a ratio of the **shear stress** and the **shear strain** of the material:

$$G = \frac{ShearStress}{ShearStrain} = \frac{\tau}{\gamma} \qquad (1)$$

## Torsional Stress and Strain

### Polar Moment of Inertia (J)

This is an equation that shows the ability of a circular cross-section beam or specimen to resist torsion (twisting). A higher polar moment of inertia shows that the beam or specimen can resist a higher torsion or twisting force. The diameter of the beam determines polar moment of inertia. A larger diameter gives a larger polar moment of inertia.

$$J = \frac{\pi D^4}{32} \qquad (2)$$

The general equation for the torque in a circular cross-section beam or specimen is:

$$\frac{T}{J} = \frac{G\theta}{l} \qquad (3)$$

### Torque (T)

The twisting force (torque) at the end of a specimen is the moment of force on the torque arm:

$$T = F \times TorqueArmLength(m) \qquad (4)$$

### Shear Stress (τ)

The theoretical shear stress for a solid circular bar is

$$\tau = \frac{TD}{2J} \qquad (5)$$

### Shear Strain (γ)

The theoretical shear strain for the solid circular bar is

$$\gamma = \frac{\tau}{G} = \frac{r\theta}{l} \qquad (6)$$

A rearrangement of the Shear Modulus (divide eq. 5 by 6) gives:

$$G = \frac{(TD)/(2J)}{(r\theta)/l} \qquad (7)$$

### Modulus of Resilience (Ur)
This describes the capacity of the material to absorb energy elastically. It is given by the strain energy per unit volume at the proportional limit given in the following equation:

$$Ur = \frac{\tau_{pl}^2}{2G} \quad (8)$$

Ur = Modulus of Resilience or shear loading energy at the proportional limit

$\tau_{pl}$ = Shear stress at proportional limit (MPa)

### Modulus of Rupture (Tm)
This describes the value of the maximum shear stress in the extreme fiber of a member of circular cross section loaded to failure in torsion, is computed from the equation:

$$\tau_m = \frac{TmR}{J} \quad (9)$$

where, Tm = maximum twisting moment

### Fracture Types

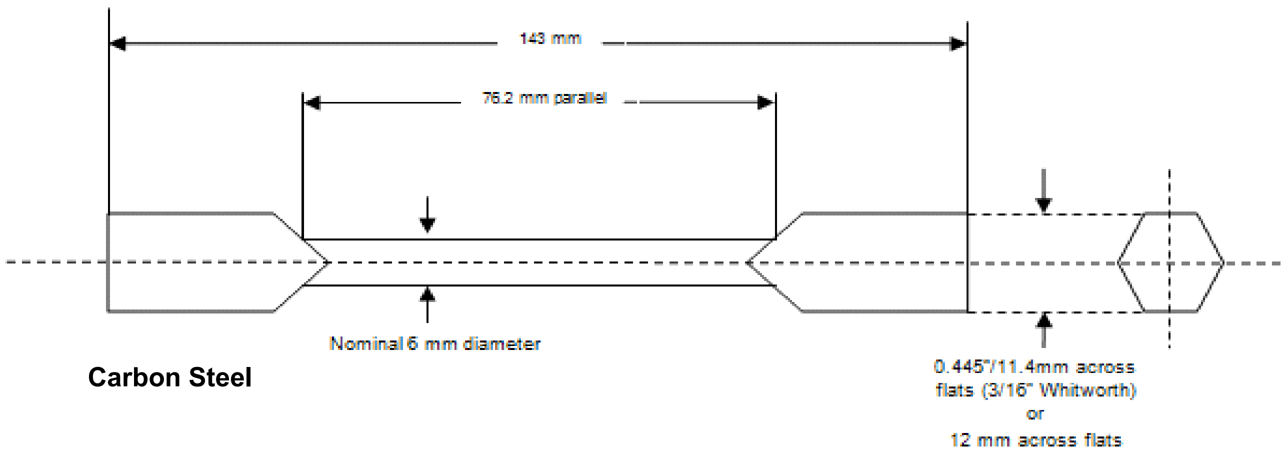
Different types of fractures may be caused by different types of stresses. For a ductile material, the fracture would be in shear (longitudinal, splitting) and for a brittle material, the fracture (also called helical fracture) would be tensile (45° splitting).

## Equipment

This experiment is performed using The SM1001 30Nm Torsion Testing Machine shown in the figure below.

Figure 2: SM1001 30Nm Torsion Testing Machine

## Specimen




**Carbon Steel**

## Setup

1. Accurately measure and record the dimensions of your specimen.
2. Choose the correct sockets to fit your specimen
3. Fit the sockets to the torque head and the gearbox output.
4. Fit the specimen to the sockets. Slide the gearbox output shaft along so that the specimens ends fit fully into each socket.
5. Switch on both Digital Meters, and press their 'Press to zero' buttons.
6. To remove any mechanical error (or 'backlash'), slowly turn the Gearbox Hand Wheel until the load display starts to show a small value of torque, then use the 'Press to zero' buttonns to set all displays to zero.

## Procedure

1. Create a table of results similar to the table below.

| **Specimen Material:**<br>**Specimen Dimensions:** | |
|---|---|
| **Angle (degrees)** | **Torque (Nm)** |
| 1. | |
| 2. | |
| 3. | |
| 4. | |
| 5. | |
| 6. | |
| 7. | |
| 8. | |
| 9. | |
| 10. | |
| | |
| | |
| | |
| | |

2. Press the ‘Peak Hold’ button of the Load Meter so that it records the maximum torque in the test.
3. For the first part of the test the specimen will be stressed in its elastic region, so you must increase the angle of twist in small steps of 1 degree.
4. At each angle, record the angle and torque value.
5. After approximately 10 degrees, the specimen has passed its upper yield point. You can now increase the angle size between measurements to larger increments.
6. Continue to increase the angle until the specimen breaks or ruptures.

## Requirements

1. Plot a chart of torque (vertical axis) against angle of twist in degrees (horizontal axis).
2. Compute shear stress, $\tau$, and shear strain, $\gamma$. Plot also $\tau$-$\gamma$ curve.
3. From the data obtained, determine the following properties for the specimen.
    a. Torsional Stress and strain (eqns 5 and 6)
    b. Shear Modulus (eqn. 7)
    c. Shear stress at proportional limit (from the shear stress- shear strain plot)
    d. Modulus of Resilience (eqn. 8)
    e. Modulus of Rupture (eqn. 9)

4. Discuss the type of fracture due to the applied torque.