Torsion Testing of Structural Metals

Standards
- *ASTM E143: Shear Modulus at Room Temperature*

Purpose
- To determine the shear modulus of structural metals

Equipment
- *Tinius-Olsen Lo-Torq* Torsion Machine (figure 1.2.1)
- Computer with *LabVIEW*®
- Twist gauge
- Caliper to measure dimensions of specimen
- Permanent marker
- Specimens: 1018 steel (tube) and 6061-T6 aluminum (rod)
- Safety glasses

Figure 1.2.1. *T-O Lo-Torq* torsion machine

Experimental Procedure
1. Obtain one steel and one aluminum specimen and label them for your group and draw a straight line along the specimen using the maker.

2. Using the caliper, find the mean diameter using at least five measurements. From the diameter, calculate the mean radius, *r*. Calculate the corresponding polar moment of inertian, *J*.

$$J_{solid} = \frac{\pi}{2} r^4 \qquad (1.2.1)$$

$$J_{tube} = \frac{\pi}{2}\left(r_o^4 - r_i^4\right) \qquad (1.2.2)$$

3. Ensure that the twist gage is set to 0°.

4. Place the specimen in one of the grips so that you can see the line and "lightly" tighten the wedges using the provided hex wrench. Slide the torque meter/grip toward the motor until the free end of the specimen is fully inserted into the other grip and tighten the wedges (figure 1.2.2). Tighten the grip slide mount. Calculate the gage length of the specimen by measuring the distance between the faces of the grips and adding 14 mm.

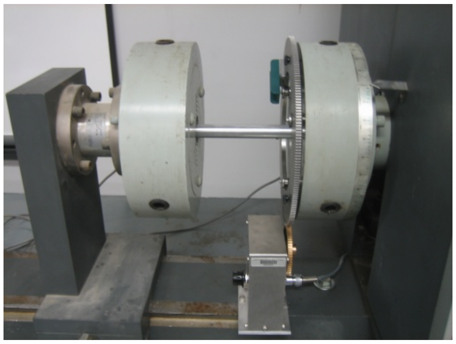

Figure 1.2.2. Specimen mounted in grips.

5. Type initial data into the torsion test program (figure 1.2.3). Click Run.

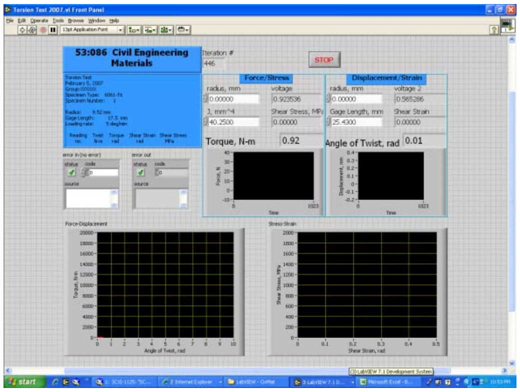

Figure 1.2.3. Screenshot of program.

6. Set speed to ~ 5°/min, zero the torque and start test (figure 1.2.4).

Figure 1.2.4. Torsion controls.

7. When the specimen reaches the plastic range (permanent deformation), stop the machine. Notice the line is now twisted. Remove the specimen.

8. Obtain the data/results file from the computer and copy it to your own disk.

Analysis and Results

- For each measurement of torque and angle of twist, the shear stress and shear strain are calculated.

$$\tau = \frac{Tr}{J} \tag{1.2.3}$$

$$\gamma = \frac{\theta r}{L_0} \tag{1.2.4}$$

where:

$\tau \equiv$ shear stress, MPa (psi)
$\gamma \equiv$ shear strain, radians
$T \equiv$ applied torque, N·m (in·lb)
$\theta \equiv$ angle of twist, radians
$J \equiv$ polar moment of inertia, mm^4 (in^4)
$r \equiv$ mean radius, mm (in)
$L_0 \equiv$ gage length, mm (in)

- Plot the shear stress versus shear strain curve.

- If possible, determine yield shear strength, $\boldsymbol{\tau_{yd}}$, using the 0.2% offset method.

- Calculate the shear modulus.

$$G = \frac{\tau}{\gamma} \tag{1.2.5}$$

where:

G $\equiv$ shear modulus, MPa (psi)
$\tau \equiv$ shear stress, MPa (psi)
$\gamma \equiv$ corresponding shear strain, radians

- Calculate the Poisson's ratio. Recall:

$$G = \frac{E}{2(1+\nu)} \tag{1.2.6}$$

where:

E $\equiv$ modulus of elasticity (found in lab 1.1), MPa (psi)

Theory Discussion

If you are really observant and compare this experiment to the tensile test, you might question why these specimens appear to yield at a different stress than they did during the tensile test. To understand this, you must understand the failure criteria of materials. There are several failure theories available and they basically boil down to fracture (brittle materials) and yielding (ductile materials). The specimens that we are testing are considered ductile materials; therefore we will use a yield criterion. Common yield criteria are the *Tresca* yield criterion and the *von Mises* yield criterion.

- The *Tresca* criterion states that yielding will occur when the maximum shear stress reaches a critical value, which was found using the simple uniaxial tension test. The Tresca criterion is given as:

$$\max\left(\left|\frac{\sigma_1-\sigma_2}{2}\right|,\left|\frac{\sigma_2-\sigma_3}{2}\right|,\left|\frac{\sigma_1-\sigma_3}{2}\right|\right)=\frac{\sigma_y}{2} \tag{1.2.7}$$

- The *von Mises* criterion states that yielding will occur when the octahedral shear stress reaches a critical value, also found using the uniaxial tension test. The von Mises criterion is given as:

$$\frac{1}{3}\left[\left(\sigma_1-\sigma_2\right)^2+\left(\sigma_2-\sigma_3\right)^2+\left(\sigma_1-\sigma_3\right)^2\right]=\frac{\sqrt{2}}{3}\sigma_y \tag{1.2.8}$$

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Torsion Worksheet

Group:____ Date:____________________

6061-T6 Aluminum

Average Diameter: __________________

Average Radius (r): _________________

Polar Moment of Inertia (J): __________

Gage Length (L_0): __________________

Yield Shear Stress (τ_{yd}): ______________

Shear Modulus (G): _________________

Poisson's Ratio (v): _________________

1018 CR Steel

Average Diameter (out): _____________

Average Radius (r_o): ________________

Average Diameter (in): _____________

Average Radius (r_i): ________________

Polar Moment of Inertia (J): __________

Gage Length (L_0): __________________

Yield Shear Stress (τ_{yd}): ______________

Shear Modulus (G): _________________

Poisson's Ratio (v): _________________