Metal Torsion Test

Introduction

In structural design, torsional moment may, on occasion, be a significant force for which provision must be made. The most efficient shape for carrying a torque is a hollow circular shaft; extensive treatment of torsion and torsion combined with bending and axial force is to be found in most texts on mechanics of materials.

When a simple circular solid shaft is twisted, the shearing stress at any point on a transverse cross-section varies directly as the distance from the center of the shaft. Thus, during twisting, the cross-section which is initially planar remains a plane and rotates only about the axis of the shaft.

Torsion members are frequently encountered in structures and machines. A structural member may need to resist torques induced by a load, such as wind or gravity. Machinery examples include motor vehicle drive shafts, torsion bar suspensions, ship propeller shafts, and centrifugal pump shafts. In the analysis of torsionally loaded members, we are primarily concerned with the torsion stress and the angle of twist on the shaft. In our laboratory experiment, the primary emphasis is on the recognition of torsion on the usual structural members, how the torsion stresses may be approximated and how such members may be selected to resist torsion effects.

Pure Torsion of Homogeneous Sections

A review of shear stress under torsion alone and of torsional stiffness seems a desirable beginning prior to considering structural shapes in locations where the warping of the cross-section is restrained. Refer to Figure 1. Consider a torsional moment ***T*** acting on a solid shaft of homogeneous material and uniform cross-section with radius ***r*** and segment length ***dx***. Assume no out-of-plane warping occurs, or at least that out-of-plane warping has negligible effect on the angle of twist ***dθ***. This assumption will be nearly correct so long as the cross-section is small compared to the length of the shaft and also that no significant reentrant corners exist. It is further assumed that no distortion of the cross-section occurs during twisting.

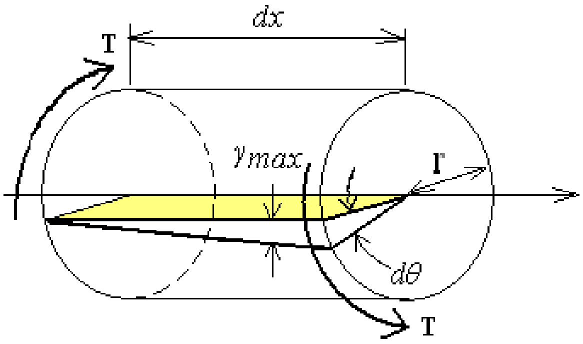


Figure 1 - Torsion in a homogenous section.

The maximum shear stress, $\boldsymbol{\tau_{max}}$, is computed by $\tau_{max} = \frac{Tr}{J}$; maximum shear stress, γmax, is $\gamma_{\max} = \frac{\theta r}{dx}$; shear modulus, $\boldsymbol{G}$, is $G = \frac{\tau_{max}}{\gamma_{\max}}$

In this torsion test, we considered the behavior of aluminum in the elastic range. It can be shown experimentally that there is a linear relationship between the shearing stress and shearing strain for any specific metallic material. This linear relationship can be used to calculate the constant of proportionality called the shearing modulus of elasticity (rigidity) and is a constant for a given material.

Equipment and Supplies

1. Tinius Olsen Torsion machine with electronic torque sensor (maximum torque is 1000 lb-in).
2. SIUE Rotational Encoder device.
3. Aluminum test sample, ½-inch diameter, about 18 inch long.
4. GENTEST data acquisition software.
5. Digital calipers or micrometers, linear scale.

Figure 2 - Tinius Olsen Torsion machine

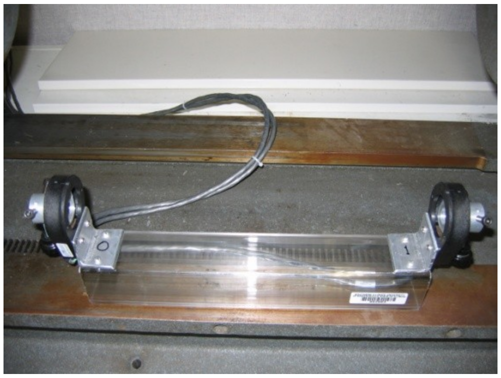


Figure 3 – SIUE Rotational Encoder device

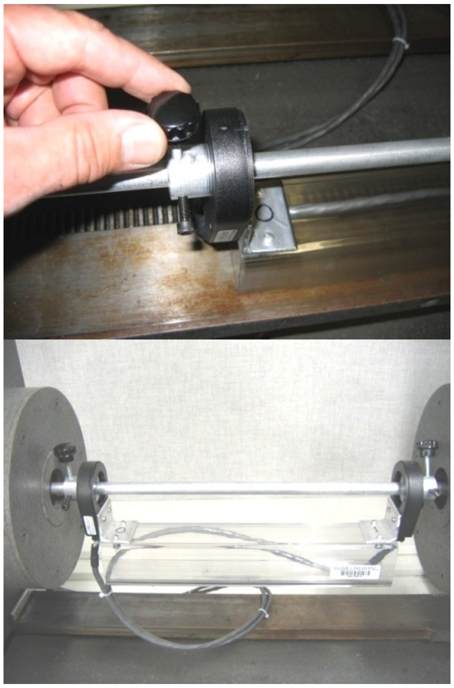
Procedure

This torsion test experiment is performed on an aluminum rod using a manual torsion application instrument. The rod is fixed at one end to the machine where the torques is measured, while the other end is connected to a chuck that is rotated by a hand-operated crank. A large dial gauge , and the torque sensor output to GENTEST, indicates the torque (in-lb) applied to the rod as the rod is twisted by the hand crank. The rotational encoder is attached to the rod by screws and its output to GENTEST gives the relative angle of twist developed in the rod as the torque is applied. The torque-twist data is used to compute the shear strain and the shear stress on the rod. From the shear stress-shear strain relational curve, the shearing modulus of elasticity (rigidity) cn be calculated, as well as the proportionality limit and the yield limit for each applied torque.

Initial Setup

1. Measure the diameter of the sample using vernier calipers or a micrometer.

2. Mark two dots on the specimen. Place them about 10 inches apart approximately centered between the two ends. Measure the distance between the two dots on the specimen which will be used to calculate the relative strain based on the total length.



3. Install the rod into the rotational encoder device. First tighten the two small screws at the left encoder end, then tighten the larger knob. Just make the connection firms, but do not overtighten. Then, while gently holding rod and pulling it to the left, gently push the right encoder end toward the right and tighten the screws at that end. The end result should be that there is no obvious longitudinal freeplay of the rod within the encoders and also no binding as the rod is rotated by hand.
4. Install the metal torsion sample and rotational encoder device assembly in the torsion machine loading grips. Leave roughly equal space between the encoder device and machine grips at each end of the specimen. Make sure the specimen is long enough for the machine to hold without any risk to slip during the test.
5. Start the GENTEST software. Select the Special test icon, then enter “torsion” when asked which experiment to run. Apply some torque to the sample and verify that GENTEST is receiving the torque information. Gently rock the rotational encoder device. You should see the encoder report an angle change. **IMPORTANT:** From this point forward, do NOT touch the rotational encoder device as this may introduce large errors in the reported angle.

Conducting and Completing the Experiment

1. There will be a test progression of three times loading and two times unloading. You will plot the data gleaned from all load-unload cycles on one graph.
2. Turn the torsion loading crank slowly counter-clockwise and continuously (1 cycle per second) to put a positive torque into the sample.
3. When loading, the torque reading will nearly stop in the plastic range -- do not reset the angle device to zero when strain hardening. This remaining angle is the real residual strain evidence. Actually you should not touch the rotational encoder angle readout again during the test.
4. After the first loading phase, the red index pointer on the torque dial will remain in its maximum position, keep it there. In the second loading we keep load going until the torque goes beyond the first torsion force, and so on for the third loading.
5. Remove the metal torsion sample and rotational encoder device assembly. Remove the sample from the rotational encoder assembly. Measure and record the distance between the two dots on the sample.