

## **Torsion Testing of Metals**

### **Purpose**

In this laboratory we will conduct torsion tests on steel and bronze specimens cut according to geometry shown in the appendix..

These materials have unique characteristics, including ultimate strength, yield strengths, modulus of shear and modulus of elasticity. These properties will be measured/calculated by conducting torsion tests with precision data acquisition equipment using the loading frame described in the appendix. The data acquisition equipment will collect data on torque and angle of twist and store them for later use in a text file.

### **Experimental Procedure**

- 1) Measure the diameter and the ridge-to-ridge length of each specimen. The diameter will be used to calculate stress given load and the length will be used to measure strain.
- 2) Observe each sample's failure surface. Indicate if the failure was ductile or brittle.
- 3) After the lab is complete, download the data for each of the materials from the Web for later use in Excel.

### **Analysis**

- 1) Plot curves of torque vs. angle of twist for all the specimens on a single graph
- 2) Using Excel, convert Torque to stress and angle of twist to shear strain for all the specimens on a single graph. The data from the tests is arranged in 3 columns: angle of twist (degrees) and Torque (Nm).
- 3) Determine the Shear modulus as well as the Young's modulus for each specimen
- 4) Calculate the proportional limit shear stress for each specimen
- 5) Calculate the 0.2% offset strength for each specimen. Compare this value to the ultimate strength.

### **Report Requirements**

Your report should provide an introduction, an explanation of the experimental procedures, the results of these experiments including a tabulation of the central results (such as strength), and conclusions and observations, including answers to the various questions asked in the analysis section above.

Please include in the appendix any sample computations needed to provide backup for your spreadsheet calculations. Make sure to clearly mention all appendix contents in the body of the report and to label all appendix items clearly. It is never appropriate to include items in the appendix which are not mentioned in the report.

**Torsion Test Overview**

Testing of round circular samples is another method of determining a basic engineering relationship in structural materials. Unlike tensile testing, torsional tests are not complicated by the phenomenon of necking and reduction in areas.

A simple torsion test is relatively easy to perform, the angle of twist is increased at a constant rate and the corresponding torque is measured at predetermined increments. These values can be graphed to find a number of engineering values. As in a tensile test, there will be an elastic or linear portion of the curve where a proportional relationship can be used to determine engineering values. In a Torque vs. Angle of twist relationship, the value that will be determined is the modulus of rigidity, also known as the shear modulus. By using the polar moment of inertia and a specific length of shaft, the torque and angle of twist can be used to determine the shear modulus using the following relationship

$$\phi = TL/JG$$

where: T is the applied torque  
L is the length of the sample being tested  
J is the polar moment of inertia  
G is the shear modulus  
 $\phi$  is the angle of rotation within the tested length.

Note the relationship between the modulus of elasticity, E, and G the modulus of shear within the linear elastic range of the material is described by Hooke's law, which relates E, G, and Poisson's ration,  $\nu$ . The knowledge of any two can be used to find the third using the relationship

$$E = 2G / (1 + \nu)$$

It is easy to recognize that the torsional test measures shear stress vs. shear strain to find the shear modulus where as in a tensile test, axial stress and axial strain are used to determine Young's modulus. Engineering values or material properties that can be found from torsional testing include the shear modulus, proportional limit shear stress, and the proportional modulus of rupture. The shear stress is at a maximum at the outside surface of the material and can be calculated using the relationship

$$\tau = T*c/J$$

the highest shear stress that the material can withstand and still return to its original geometry is at the limit of the proportional portion of the graph and is known as the proportional limit shear stress. The torsional modulus of rupture is the stress calculated at rupture.

Finding the Shear modulus is a simple matter of graphing the Shear stress vs. Shear strain and finding the slope within the linear elastic range.

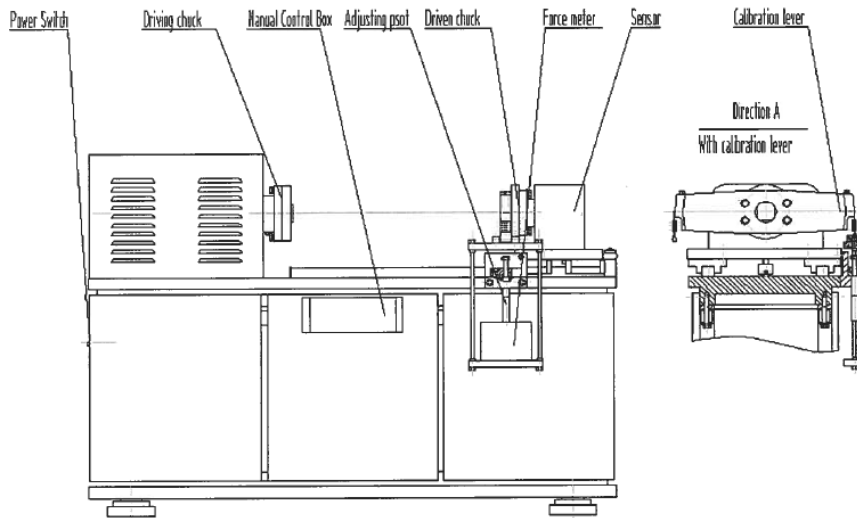
The shear strain is given as

$$\gamma_{xy} = \phi c/L$$

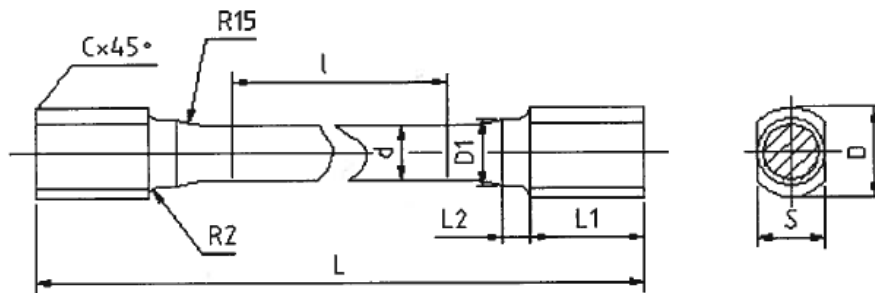
where: c is the radius of the solid circular sample  
L is the length over which the angle of twist is measured  
 $\phi$  is the angle of twist.

The corresponding shear stress is  $\tau = Tc/J$ .

Schematic view of the testing rig



Typical specimen geometry for metallic materials



d	D	D1	S	l	L1	L	r	c	L2
8-11	16	12	12	10d	20	l+60	2	1	5
12-17	24	18	18	10d	20	l+70	2	2	10
18-25	32	27	24	10d	30	l+90	3	3	10