

Lab Manual for Engrd 202, Virtual Torsion Experiment

Aluminum module

Introduction

In this module, you will perform data reduction and analysis for circular cross section aluminum samples. By plotting the torque vs. twist data for aluminum and performing analyses of the data you can infer relations between sample geometry, strength and stiffness. Seeing how the samples deform and fail will also help you to better understand material behavior under torsional loading. From the torque twist curve you can find quantities such as yield torque (for ductile materials), ultimate torque (for brittle materials), maximum torque, stiffness, and material properties such as shear strength and shear modulus. If you need, you can review the theory for data reduction and analysis for circular samples by going through the chalk-talks on basic theory and on testing of engineered materials.

Procedure

Select three data sets for aluminum. Each of the aluminum tests were performed using the same material, machined to different lengths, and inner and outer diameters. These geometries are labeled geometries 1-4 in the tables linked under “Test Data”. You will find the nominal dimensions for each geometry in the tables linked under “Test Data”. The actual, measured dimensions for each sample (which may differ from the nominal dimensions) are listed at the top of each individual data file. Data files are named according to the following convention: Material_Geometry_Repeat.***, where the stars are in place of the file type extension (For example AL_1_2.txt would be the text file containing data for the second test on an aluminum sample made using geometry 1).

Select one data set each from geometries 1, 2 and 3 of the aluminum tests (You may use any data set within a particular geometry since there are repeats of nominally identical samples). Plot the torque-twist curves for each data set; continue your analysis by completing tables 1 and 2, then proceed to answering the questions below and to writing your lab report. Step-by-step directions for completing the data and comparison sheets, (tables 1 and 2) are given at the end of the module

Lab Report

Your lab report should include the completed data sheets, graphs and a brief discussion of the lab procedure. The report should also provide answers to the questions below and any other discussion, observations or comments you wish to include.

Questions

1. For the aluminum tests, compare the elastic stiffness, k_{sample} , from geometries 2 and 3 to that for geometry 1. Do the relative values (i.e. ratios of k_{sample} from one geometry to the other) agree with theory?
2. Compare torque at first yield, T_y , for aluminum geometries 2 and 3. Repeat for geometries 1 and 2. When are the values different? Do the relative values of T_y agree with theory?
3. Calculate the shear modulus, G , and shear yield stress, τ_y , for the aluminum samples. Compare these to the reference values for these materials. Discuss any discrepancies between your measured values and the reference values. Do you notice any trend in the G values for aluminum as the sample dimensions change? Suggest a way to improve the measurement of G .
4. Review the virtual test for the aluminum and comment on the deformation of the sample during the test. If you were to replace this circular sample with a square sample of same length and polar moment of inertia, what difference would it make in the deformation?

Step by step instructions for completing Tables 1 and 2 for a given data set and Sample ID

- a) Select the data file and open it. You may choose to use a text file (.txt) or an Excel file (.xls). The Matlab GUI (VL_1_v10.m) uses the .txt files
- b) Enter the sample ID, material and the dimensions of the test sample on table 1. Use the information given in the header of the text file or Excel file. If you choose to use the Matlab program, this information will be displayed on the GUI.
- c) Calculate J (polar moment of inertia) and enter this value on row 3 of table 1.

- d) Plot the torque vs. twist for the sample. For this purpose, you may choose to use the Matlab GUI. In the Excel files the plots are provided to you. You may refer to ‘Hints for graphing’ in case of any difficulty in plotting the data.
- e) Now, plot the torque vs. twist curve in the linear region. Find the stiffness (slope of the torque-twist curve). Denote this value as k_{total} , the total stiffness (slide 5 of chalk talk on engineered materials). Enter this value in row 4 of table 1.
- f) Calculate the sample stiffness, k_{sample} (slide 6, 7 of the chalk talk on engineered materials). Using this value of stiffness, calculate shear modulus for the sample and enter this value in row 5 of table 1.
- g) Calculate the shear modulus, G , using the relation given in slide 7 of the chalk talk on engineered materials. Enter this value in row 6 of table 1.
- h) Calculate the yield torque (or ultimate torque for brittle materials) and the maximum torque (refer to slide 9 of the chalk talk on engineered materials) and enter these values into row 7 and 8 of table 1.
- i) Now, calculate yield strength or ultimate strength (refer to slide 10 of the chalk talk on engineered materials) and enter these values in row 9 of table 1.
- j) Look at the broken sample and comment on the type of fracture. Write your comments in row 10 of table 1.
- k) Follow this procedure for three of the four aluminum samples. Then transfer the data over to table 2 and complete the suggested comparisons.

Table 1. Circular sample dimensions

ID of the test sample used*			
Dimensions (mm)	GL: _____ OD: _____ ID: _____	GL: _____ OD: _____ ID: _____	GL: _____ OD: _____ ID: _____
J** (m⁴)			
<i>k_{total}</i> (N-m/rad)			
<i>k_{sample}</i> *** (N-m/rad)			
G (N/m²)			
T_y or T_u# (N-m)			
T_{max} (N-m)			
τ_y or τ_u # (N/m²)			
Fracture Description			

*Data file name

**To convert mm⁴ to m⁴, multiply by 10⁻¹².

***Corrected for machine compliance

T_y and τ_y for ductile materials, T_u and τ_u for brittle materials.

Table 2.Comparison sheet (Circular samples)

Specimen	1	2	3
ID of test sample used			
Material	AL 2024-T3	AL 2024-T3	AL 2024-T3
Reference material properties##	G= $\tau_y =$	G= $\tau_y =$	G= $\tau_y =$
Nominal dimensions	GL: <u>88.9 mm</u> OD: <u>12.7 mm</u> ID: <u>0.0 mm</u>	GL: <u>88.9 mm</u> OD: <u>12.7 mm</u> ID: <u>10.16 mm</u>	GL: <u>44.5 mm</u> OD: <u>12.7 mm</u> ID: <u>10.16 mm</u>
Measured size	GL: _____ OD: _____ ID: _____	GL: _____ OD: _____ ID: _____	GL: _____ OD: _____ ID: _____
J (m⁴)			
Torsional stiffness, k_{sample} (N-m/rad)			
T_y or T_u * (N-m)			
Length ratio	$\frac{L\#1}{L\#1} = 1$	$\frac{L\#2}{L\#1} =$	$\frac{L\#3}{L\#1} =$
Polar moment of inertia ratio	$\frac{J\#1}{J\#1} = 1$	$\frac{J\#2}{J\#1} =$	$\frac{J\#3}{J\#1} =$
Stiffness Ratio	$\frac{k\#1}{k\#1} = 1$	$\frac{k\#2}{k\#1} =$	$\frac{k\#3}{k\#1} =$
T_y ratio	$\frac{T_y\#1}{T_y\#1} = 1$	$\frac{T_y\#2}{T_y\#1} =$	$\frac{T_y\#3}{T_y\#1} =$

##You can find these values in many mechanics of materials textbook. A quick web reference is www.matweb.com

Turkey tibiotarsus module

Introduction

In this module, you will perform data reduction and analysis for turkey tibiotarsus bones. They are not circular in cross section and so the analysis for bones is different from the circular samples. In the analysis, you will approximate the bone as a hollow circular cross section. You will use the dimensions of the circular cross section to estimate the stiffness, shear modulus and strength of the bone.

You will plot the torque vs. twist curve and study it to examine the behavior of bone under torsional loading. From this plot you will determine whole bone ultimate torque and stiffness. Based on these values, you will deduce bone material properties such as shear strength and shear modulus. You may note that each individual bone behaves slightly different. Details of the sample geometry, as defined in slides 6 and 7 of the chalk talk on turkey bone, are provided along with each data file. For review refer to the chalk talk on turkey bone. To understand the calculations for cross sectional area and polar moment of inertia, refer to slide 7 of the chalk talk on turkey bone.

Procedure

Select one data set from the wet turkey bone test data and one from the dry turkey bone test data. The measured dimensions for each bone sample are listed at the top of the text and Excel data files. This information is displayed in the Matlab GUI as well. Data files are named according to the following convention: Material_Type_Repeat.***, where the stars are in place of the file type extension. For example turkeybone_Wet_3.xls would be the Excel file containing data for the test performed on wet turkey sample 3. Plot the torque-twist curves for the data set; continue your analysis by completing tables 3 and 4, then proceed to answering the questions below and to writing your lab report. Step-by-step directions for completing the data sheets, (tables 3 and 4) are given at the end of the module.

Lab Report

Your lab report should include the completed data sheets, graphs and a brief discussion of the lab procedure. The report should also provide answers to the questions below and any other discussion, observations or comments you wish to include.

Questions and data analysis for turkey tibiotarsus:

1. Find the shear modulus, G , and the shear strength, τ_u .
2. Using your textbooks and other resources, find a different material (or materials) with similar G values to the wet turkey bone. Do you think that this material can be used as an artificial bone?
3. Describe in words what the fracture surfaces look like. Do all the bones break exactly in the same way?
4. Suppose you want to breed super turkeys that were twice the mass of normal turkeys. Do you think the tibiotarsus bone would be thicker and or bigger in diameter ($2r_0$)? If so, by how much would these increase to double the torsional load carrying capacity of the wet bone?
5. Compare the results you got for the dry turkey bone to those for the wet turkey bone. How do the ultimate torque T_u , the bone stiffness, the shear modulus and shear strength differ?

Step by step instructions for completing Tables 3 and 4 for a given sample ID

a) Select the data file and open it. You may choose to use a text file (.txt) or an Excel file (.xls). The Matlab GUI (VL_1_v10.m) uses the .txt files.

b) Enter the sample ID, material and the dimensions of the test sample on table 3. Use the information given in the header of the text file or Excel file. If you choose to use the Matlab program, this information will be displayed on the GUI.

c) Calculate the area and polar moment of inertia of the equivalent circular cross section. Refer to slides 6 and 7 of the chalk talk on turkey bone for details. Enter these values in rows 2 and 3 of table 4.

d) Plot the torque vs. twist for the sample. For this purpose, you may choose to use the Matlab GUI. In the Excel files the plots are provided to you. You may refer to 'Hints for graphing' in case of any difficulty in plotting the data.

e) From the plot, find the ultimate torque T_u . Fill this value in row 4, table 4.

f) Now, plot the torque-twist curve in the linear region. Find the sample stiffness (equal to the slope of the line). Denote this value as k_{total} , the total stiffness (slide 8 of the chalk talk on turkey bone). Note that you may assume $k_{total} = k_{sample}$, since the test machine is almost infinitely stiffer than the bone sample. Enter this value in row 5, table 4.

g) Now using formulas given in slides 9 and 10 of the chalk talk on turkey bone, calculate the shear modulus and shear strength for the bone. Enter these values in rows 6 and 7 of table 4.

Table 3. Bone sample dimensions

Sample ID*		
Gauge length (mm)		
Sample dimension (mm)	$r_0 =$ _____ $r_i =$ _____	$r_0 =$ _____ $r_i =$ _____

*Data file name

Table 4. Measured and calculated data for turkey bone

Sample ID		
Area (m²)		
J (Polar moment of inertia) (m⁴)		
Ultimate Torque, T_u (N-m)		
Measured Stiffness, k_{sample} (N-m/rad)		
Shear modulus, G (N/ m²)		
Shear strength, τ_u (N/m²)		