ASEN 3112 STRUCTURES

Lab 1 DESCRIPTION

Fall 2019

Version: September 12, 2019

I Summary

The first experimental lab involves testing two circular *thin wall* sections, one closed and one open, under applied torque, using an MTS Torsional Testing Machine. The purpose of the tests is to verify and correlate the theory with strain and twist-angle measurements.

II Timetable, groups, and logistics

II.1 Timetable

The experimental procedure will be described in demos that will be held in the Material Testing Module of PILOT, during the Recitation times. Attendance is mandatory and will be taken at the start of each demo; failure to attend will results in deduction of 50% of the grade. Each section will be divided in three groups, distributed as:

- Tuesday September 10th, 2019, at 12:30PM-1:05PM for students in Section 011 with last names starting with letters A to FEL.
- Tuesday September 10th, 2019, at 1:05PM-1:40PM for students in Section 011 with last names starting with letters FER to MARTIN.
- Tuesday September 10th, 2019, at 1:40PM-2:15PM for students in Section 011 with last names starting with letters MARTINSON to Z.
- Tuesday September 10th, 2019, at 2:30PM-3:05PM for students in Section 012 with last names starting with letters A to HA.
- Tuesday September 10th, 2019, at 3:05PM-3:40PM for students in Section 012 with last names starting with letters HU to RE.
- Tuesday September 10th, 2019, at 3:40PM-4:15PM for students in Section 012 with last names starting with letters RI to Z.

Students must attend the laboratory demonstration during their respective recitation times. Attendance to a different section need prior written approval from the instructors and will only be granted on account of a bona-fide reason, such as a medical emergency. In case of an emergency or unavoidable absence, students should contact the instructors as soon as possible.

II.2 Lab Groups

SignUpGenius slots are available at: https://www.signupgenius.com/go/8050b44a9aa23a5f58-lab1signup

Each slot has a limit of 7 students. As soon as this limit is reached, you are no longer permitted to sign up for that slot. The students signed up for a particular time slot will constitute the lab group. Each group selects a leader (the Group Leader, or GL) who will have the following responsibilities:

- Divide tasks to be accomplished in writing the report (e.g. writing specific sections, analyzing data and producing necessary plots/figures).
- Compile and edit the final report (ensure consistency between sections and make sure that other member's contributions are satisfactory).
- Provide internal deadlines to group members so that the lab report project stays on schedule.
- Keep a record of delegated tasks, internal deadlines, and confirmations from team members. This record can simply be a thread of emails between the group leader and group members. This will not be turned in but will be used by the TAs to resolve any disputes about participation scores.
- Provide a participation report for your group with a brief summary of each group member's tasks, contributions, and performance as a group member. It is the group leader's responsibility to organize the peer evaluation process to determine each group member's contribution grade (elaborated on Section IV.3). Note, the group leader should not assign a participation score without the input of the entire group.

Group members are responsible for timely communication with the group leader. If a student is assigned a task to complete with a deadline, the student should confirm that she/he will do so. If the student does not agree to the task or has difficulty with it and needs more time or help with the task, this should also be communicated to the group leader (well before the deadline).

II.3 Lab Reports

Each group prepares and submits one hard copy of the report, which is **due before class of September 30th, 2019**. Instructions for preparing this report are given in Section IV of this document. Grading weights are given in Addendum 1.

III Experiment Description

III.1 Operational Instructions

Please refer to the operational procedures for the MTS Torsion Module in setting up the apparatus. The document *Experimental Procedure* can be found on Canvas in the *Lab 1* folder. **Note: One TA or LA must be present during each group's time slot to supervise the process**.

III.2 The Closed Thin Wall Specimen (a.k.a. Closed Tube)

This specimen is identified as CTW, for Closed Thin Wall. It is the commercial circular tube depicted in Figures 3.1–3.2. It is also called the "closed tube" in the sequel for brevity. Nominal exterior dimensions are: exterior diameter $D_e = 3/4$ in, exterior radius $R_e = \frac{1}{2}D_e = 3/8$ in, and uniform wall thickness $t = 1/16$ in. For the test, L is taken as the extensometer gauge length in inches provided in the *Experimental Procedure* document. The material is stock aluminum tube.

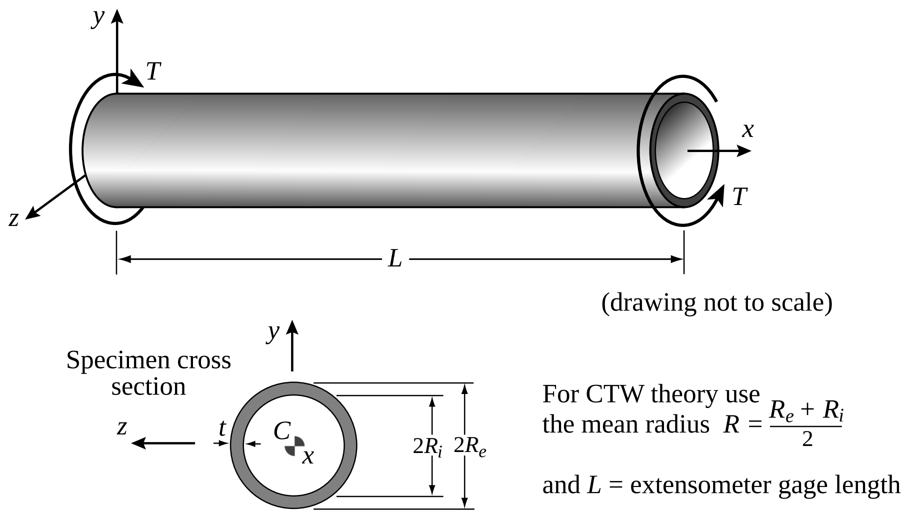

Figure 3. 1: CTW specimen: Torqued circular tube. Module grips are not shown.

The shear modulus of this material is $G \approx 3.75 \times 10^6$ psi. **Note: English units are used throughout this lab.**

The specimen is instrumented with a torsional extensometer, as described in the **Experimental Procedure** document.

This specimen is to be subjected to torque levels from $T_0 \approx 0$ lbs-in (calibration level) up to $T_{max} \approx 400$ lbs-in. At that level the maximum shear stress reaches roughly 8620 psi, which provides a safety factor of about 2.3–2.6 against yielding. Three sets of measurements are to be recorded at increasing torque levels:

1. The shear strain γ in degrees over the gauge length of the extensometer. This strain may be converted to microradians (μ). If the strain is small (which can be assumed if the specimen is not taken beyond yield), the twist angle ϕ over the length L is $\phi = \gamma\, L/R_e$, where R_e is the exterior tube radius.

Figure 3. 2: Photos of CTW specimen. Module grips are not shown.

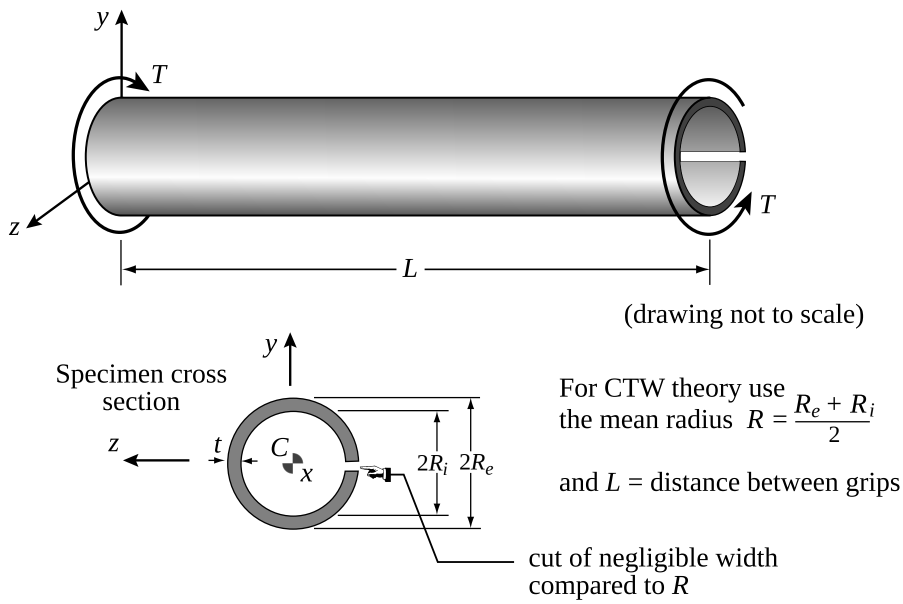

Figure 3. 3: OTW specimen: Torqued circular tube with longitudinal cut.

2. The total rotation applied to the specimen, as recoded by the testing machine.

3. The torque recorded by the testing machine.

III.3 The Open Thin Wall Specimen (a.k.a. Slitted Tube)

This specimen is identified as OTW, for Open Thin Wall. It is the same commercial tube used in the previous test with a longitudinal cut along its length. See Figures 3.3–3.4. It is also called the *slitted tube* in the sequel for brevity. Nominal cross section dimensions are the same as before. The cut width is to be assumed negligible compared to the cross section radial dimension. For the test L is taken as the extensometer gauge length in inches, which is provided in the *Experimental Procedure* document. The material properties are the same as those of the CTW specimen.

This specimen is to be subjected to torque levels in the range: $T_0 = 0$ lbs-in (calibration level) up to $T_{max} \approx 20$ lbs-in. **This range is much smaller than for the CTW specimen**. At that torque level the maximum shear stress is about 7800 psi, which provides a safety factor of approximately 2.8 against yielding. Note, however, that stress concentrations will occur at the slot ends, even after rounding the tips. The measurements of applied torque T and shear strain γ are like those described for the closed tube in Section III.2. The recovery of the twist angle, however, is different: $\phi = \gamma\, L/t$ instead of $\phi = \gamma\, L/R_e$.

IV Analysis and Report

IV.1 Report Organization

A hard copy of the Report is due Monday September 30th, 2019, before class time. **The report must be WORD or LATEX processed**. It must include:

- **Title Page**: Describes Lab, lists the name of the team members and identifies the group leader.
- **Results:** The results should address the questions in Section IV.2.
- **Appendix - Code:** A printout of all the code used to produce the results.
- **Appendix - Participation report.** More details on how the grade of individual group members is calculated can be found in Section IV.3.

IV.2 Report Content

The report will be graded on both technical content and presentation. Regarding the content, instead of an open-ended report, you should process the experimental data to address the specific questions posted below. Regarding presentation, make sure that you follow these guidelines:

- All plots should be readable. This includes using different color or line styles and a suitable font size for the axis labels and all other text in the plot. The range of both axes should be chosen to focus on the region of interest (i.e., the data).
- Show your work, including equations used and partial results.
- All results should be presented with appropriate units.
- Be quantitative when comparing results. Use percentage of error or deviation. Refer back to predicted error or variance when applicable.

IV.2.1 Analysis of the Closed Thin Wall Specimen

- Plot the torque vs. shear strain provided by the extensometer, as well as the torque vs. shear strain calculated using the total rotation angle imposed by the testing machine.

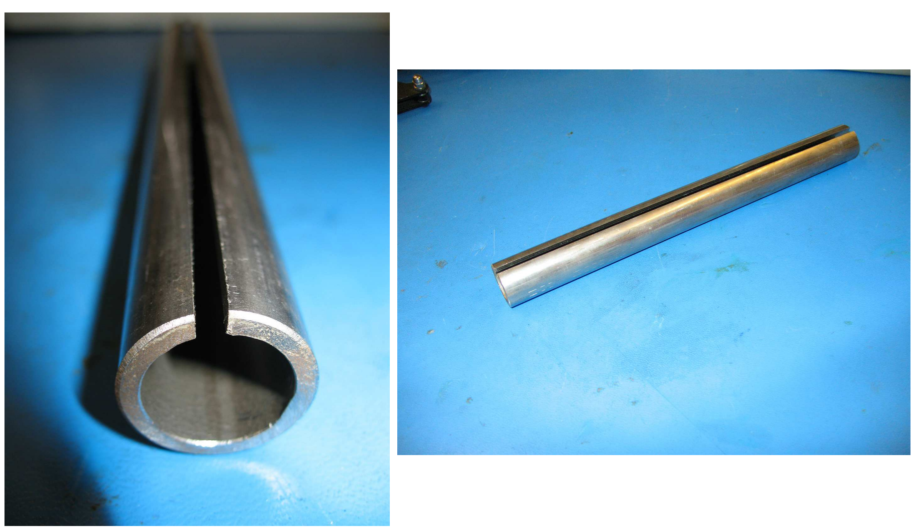

Figure 3. 4: Photos of slotted tube (OTW) specimen. Later replaced by one with 7-in-long slot to reduce grip end effects.

- Use least squares fitting to calculate the torsional rigidity, GJ, for the two ways to obtain the shear strain. Provide the value of the associate uncertainty.
- Compare the value of GJ obtained through the experiments with the theoretical predictions obtained using exact theory and thin wall theory. Discuss the differences.

IV.2.2 Analysis of the Open Thin Wall Specimen

- Plot the torque vs. shear strain provided by the extensometer, as well as the torque vs. shear strain calculated using the total rotation angle imposed by the testing machine.
- Use least squares fitting to calculate the torsional rigidity, GJ, for the two ways to obtain the shear strain. Provide the value of the associate uncertainty.
- Compare the value of GJ obtained through the experiments with the theoretical prediction obtained using thin wall theory. Discuss the differences. Which important assumption could you re-consider obtaining a more accurate prediction?

IV.2.3 Importance of the Extensometer

- For both specimens, compare the values of GJ obtained using the shear strain provided by the extensometer and by the testing machine. Discuss the relative differences.
- Discuss at least two reasons that justify the need of an extensometer to ensure accurate results, instead of using the readings from the testing machine.

IV.2.4 Plastic deformation

Consider now the case in which the samples are tested beyond the elastic regime. Assume that the material behavior is elastic - perfectly plastic, with yielding initiating at shear strain γ_y, see Figure 5. The test response will then consist of three regions: a region where the whole specimen is still in the elastic regime, a transition region in which part of the specimen has plasticized, and a region in which all the material of the specimen has yielded.

- Sketch the expected response of the specimen in the form of a T - γ plot, where T is total torque and γ is the maximum shear strain in the specimen. Clearly identify the three regions.
- Assuming a closed wall specimen with length L, external radius R_e, internal radius R_i, and thickness $t = R_e - R_i$, provide the shear strain γ corresponding to the transition between the regions. Express the shear strain as a function of γ_y and the geometry of the sample.

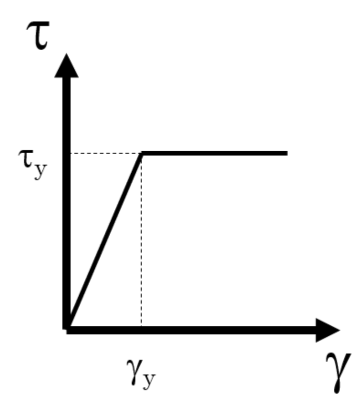

Figure 3. 5: Elastic-perfectly plastic material model. The shear and strain at yielding are τ_y and γ_y.

IV.3 Individual Contribution Evaluation and Deductions for No-Show

The group leader submits along with the report a separate participation report for your group with a brief summary of each group member's tasks, contributions, and performance as a group member. **Please make sure to include this as an Appendix in the report**.

The performance of each group member is rated with a "contribution factor" on a scale of 0 to 100%. A score of 100% indicates that the member contributed the expected share to the experiment and to the preparation of the report. The scores are normally assigned by *peer evaluation*, using the same procedures followed in the ASEN 200x sophomore courses. The group leader is responsible for administering the peer evaluation, tabulating and submitting the results of said peer evaluation.

The individual score will be equal to:

$$\text{Individual score} = \text{Group score} \times \frac{100 + \text{Contribution factor}}{200} \tag{1}$$

For example, if the group receives an overall score of 88.75 and the individual received a "contributing factor" of 90%, the individual score is $88.75 \times (100 + 90)/200 = 84.31$.

A no-show at the lab demos, without justification, will be penalized by a deduction of 50% from the final individual score. A no-show at group experiments, without justification, is deducted 50%. A no-show at both is deducted 100%. Students that miss one or both events on account of a bona-fide reason, such as a medical emergency or unavoidable absence, should contact instructors or TAs as soon as possible.

Addendum I. Report Grading

The score assigned to the lab report includes technical content (75%) and presentation (25%). This is a more detailed breakdown of the weights:

Category	Weight	Score	Contribution
Technical content			
Question 1	0.25		
Question 2	0.25		
Question 3	0.15		
Question 4	0.10		
Presentation			
Plots	0.10		
Grammar, style & spelling	0.10		
Formatting	0.05		
Total	1.00		(overall score)

The score within each category ranges from 0 to 100%. For example, if the score for 'Question 1' is 80%, it contributes $0.25 \times 80 = 20\%$ to the overall score. The final score of each team member is then calculated following the procedure detailed in Section IV.3.