ASEN 3112 STRUCTURES

Lab 1 DESCRIPTION

Fall 2020

Version: September 7, 2020

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 from multiple repetitions of the torsion experiment already performed.

II Timetable, groups, and logistics

II.1 Lab Groups

Groups will be randomly assigned and the list of group members will be posted on Canvas. 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 TA/TFs 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). Guidelines for working in groups remotely can be found on the course page on CANVAS; see *Team Work Guidelines ASEN 3112 Fall 2020.pdf*.

II.2 Lab Reports

Each group prepares and submits one electronic copy of the report to be uploaded to **Gradescope before the class on September 28th, 2020**. 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 Procedure

The experiments are already performed and data are available to process. However, to gain insight into the procedure used to perform the experiments and collect data, please refer to the following resources all available on Canvas under **Lab 1** folder:

- MTS machine introduction video
- Torsion lab procedure & experiment video
- *Experimental Procedure* document
- Measurement data files (8 sets for each specimen). The details of the data files are described in the *Experimental Procedure* document.

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, $L = 10$ in is the gauge length in inches. The material is stock aluminum tube. 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. Eight sets of measurements are recorded at increasing torque levels:

1. The shear strain γ in degrees over the measuring length of the extensometer (1 in). 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. The axial strain is also reported in the data files, but is not used for any analysis.

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

3. The torque recorded by the testing machine.

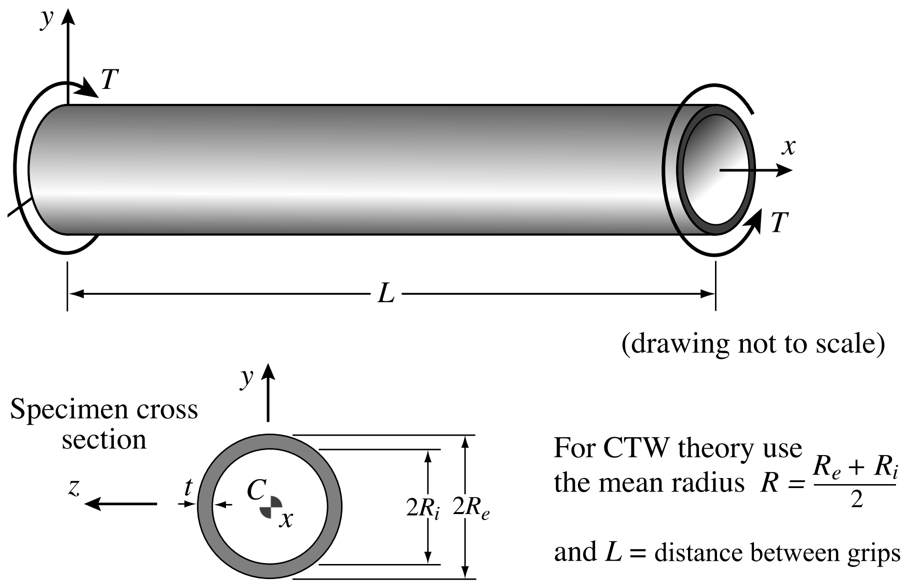

Figure 3. 1: CTW specimen: Torqued circular tube. Module grips are not shown.

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 $L = 10$ in is taken as the gauge length. 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

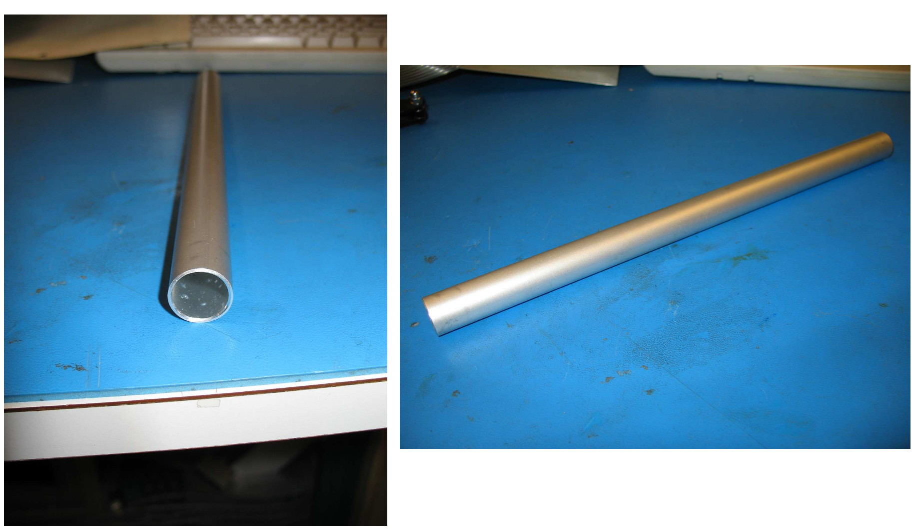

Figure 3. 2: Photos of CTW specimen. Module grips are not shown.

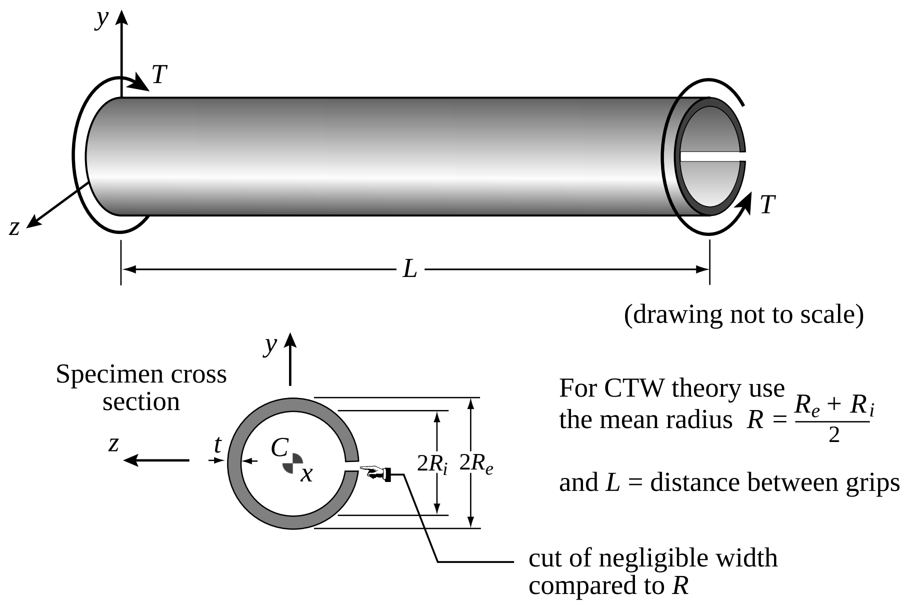

Figure 3. 3: OTW specimen: Torqued circular tube with longitudinal cut.

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 $\phi = \gamma\, L/R_e$.

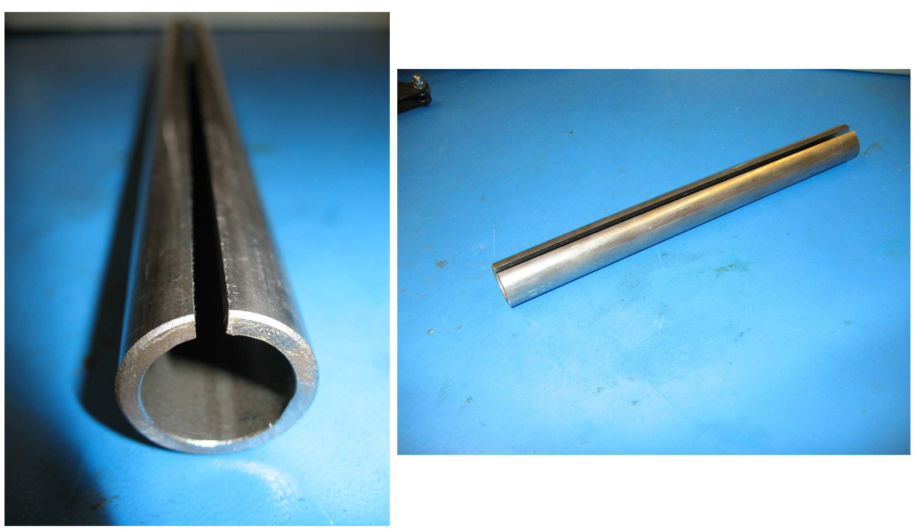

Figure 3. 4: Photos of slotted tube (OTW) specimen. Later replaced by one with 7-in-long slot to reduce grip end effects.

IV Analysis and Report

IV.1 Report Organization

An electronic copy of the report is due Monday September 28th, 2020, before class time and needs to be uploaded to Gradescope. **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. **The result section must not exceed 5 pages**.
- **Appendix - References.** List all literature and other external source used.
- **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.
- Provide all relevant information and discussion necessary to understand your work using a concise language and presentation style. Omit irrelevant information and wordy explanations.

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.
- Use least squares fitting to calculate the torsional rigidity, GJ, for the two ways to obtain the shear strain. Provide the value of the associated uncertainty. Repeat the GJ calculation for each data set after removing obvious outliers and take the average to report the final estimate of GJ. Provide the value of the associated 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. Repeat the GJ calculation for each data set after removing obvious outliers and take the average to report the final estimate of GJ. Provide the value of the associated 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 3.5. 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.

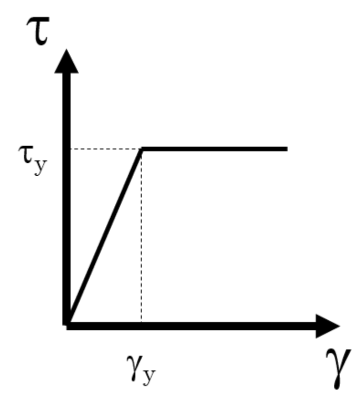

Figure 3. 5: Elastic-perfectly plastic material model. The shear and strain at yielding are τ_y and γ_y.

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 $88.75 \times (100 + 90)/200 = 84.31$. If a student does not participate in the group work, the group leader should inform the TA/TFs immediately.

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			
Questions in IV2.1	0.25		
Questions in IV2.2	0.25		
Questions in IV2.3	0.15		
Questions in IV2.4	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.