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ENGN0310 – Mechanics of Solids and Structures

Lab 2 – Soda Can Myth Busters

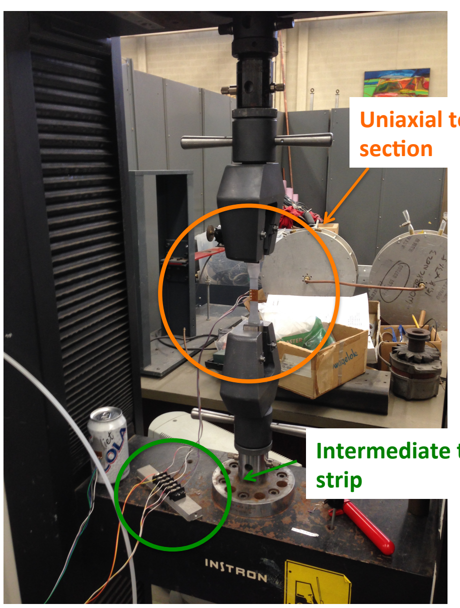
Myth #1: *Shaking a soda significantly increases the pressure inside the can.*

Myth #2: *Tapping the tab on a soda can with your finger a few times can reduce some of the pressure on the top of the can, causing less liquid to spray out upon opening.*

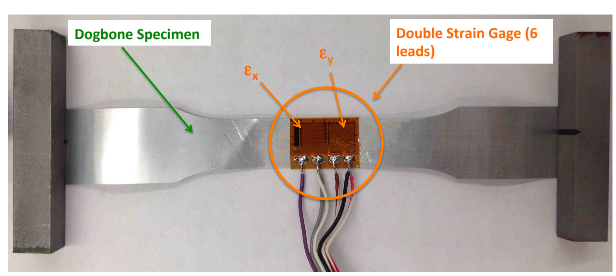
In class, we talked about hoop stress and strain for thin-walled pressure vessels. By using the thin-walled assumption, strain gages, and a dog-bone sample cut from the same type of can, we will determine how much (if any) the pressure increases inside the can when it is shaken. Secondly, we will determine whether we can decrease the pressure in a can after it has been shaken by tapping on the top, or any other technique that you may propose. However, in order to use the hoop stress and strain equations, we will need to know the material properties. Thus, we will specifically measure E and ν via an independent tensile test on a section of aluminum cut from the wall of the same brand of can.

2.1 Testing Equipment and Experimental Setup

Figures 1 and 2 contain the equipment and data acquisition that you will be using as part of the lab. Each of the components description and brief usage is listed below.

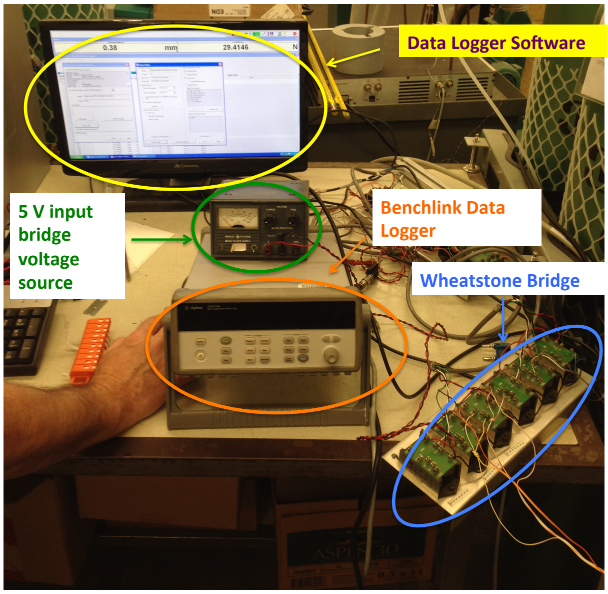


(a) Instron Tensile Testing machine with dog-bone sample loaded.

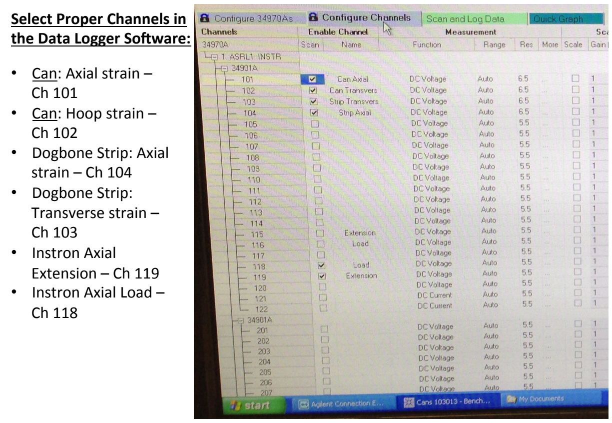


(b) Dog-Bone sample of the aluminum can with strain-gage attached.

Figure 1: Lab Equipment



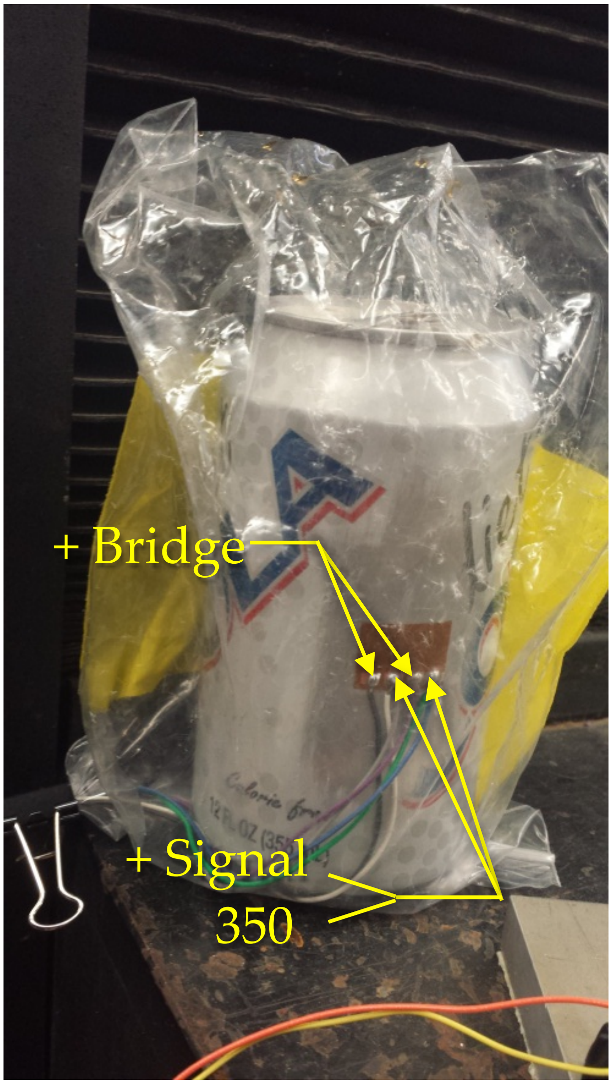
(a) Acquistion hardware and software interface to collect your voltage data.



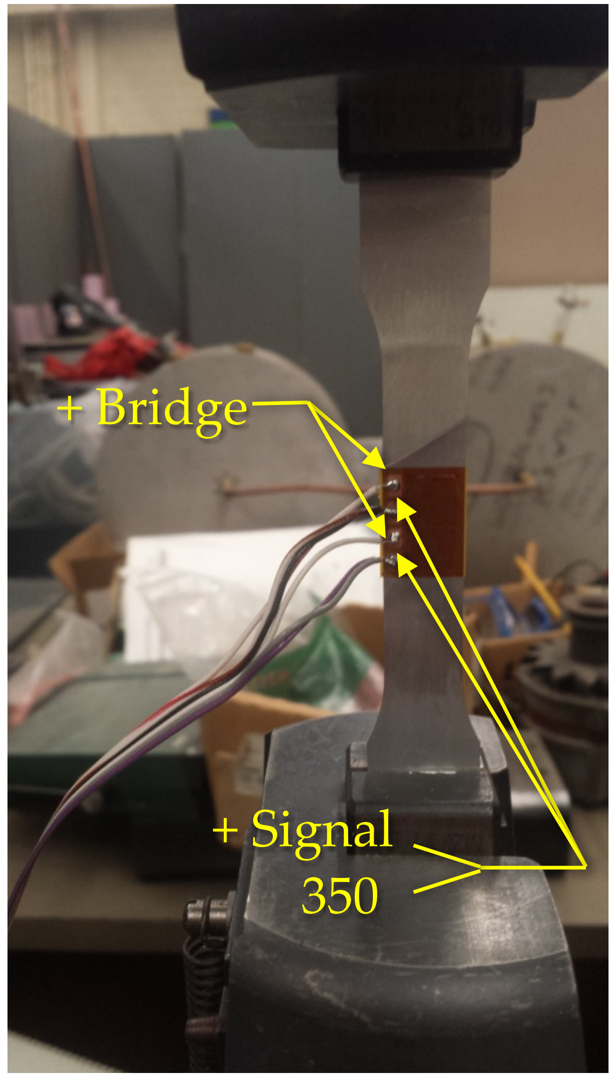
(b) Example Screen-Shot of the Data Acquisition Program.

Figure 2: Data Acquisition

- **Instron Machine**: Commercial material testing machine (Instron company) - commonly used to generate nominal uniaxial tension stress-strain curves to determine material properties.
- **Dog-bone sample**: name given for the common shape of materials used in the Instron. The dogbone shape ensures uniform strain across the samples gage section (center area).
- **Load Cell Transducer**: Analog device that measures how much force is being applied to it (just like a scale to measure weight). The typical output is a change in voltage, which needs to be converted to either Newtons or kilo Newtons.
- **Strain Gage**: A long, special resistor which directly relates changes in applied strain to changes in its resistance. The change in resistance of a strain gage is determined using a Wheatstone bridge and the strain gage factor (GF). Please review the concept behind strain gages (see last page). Here each can and dogbone sample has a pair of orthogonal strain gages attached with wire connections shown in Figs. 3 and 4.
- **Intermediate Terminal Strip**: Simple "extension cord" between the strain gages and the Wheatstone bridge.
- **Wheatstone Bridge**: It's a device consisting of four balanced internal resistors, one of which is a variable resistor and one of which is the unknown resistance of each strain gage. The variable resistor balances the unknown resistance allowing us to determine the strain gages resistance changes proportional to changes in strain. The final output from the Wheatstone bridge is a voltage proportional to the resistance changes of the strain gage (see more on the last page).

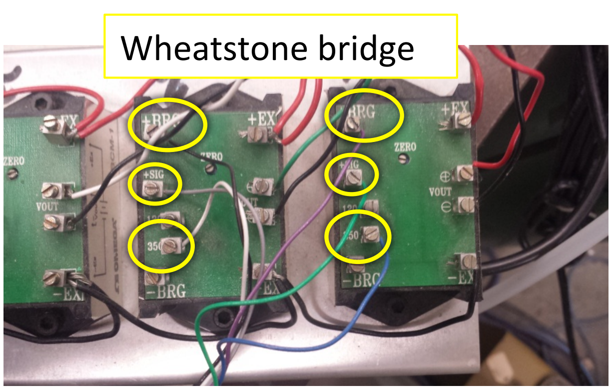


(a) Soda Can instrumented with strain-gage pair.

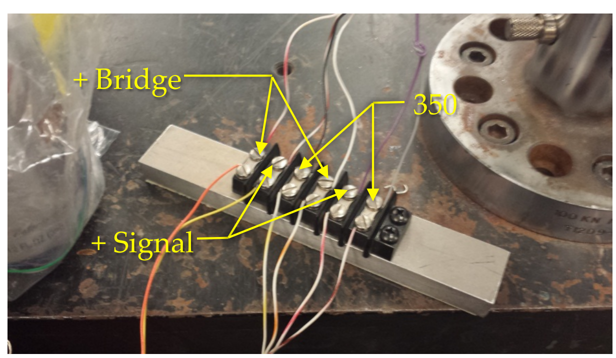


(b) Dog-Bone sample of the aluminum can with strain-gage attached.

Figure 3: Strain Gages on Soda Can and Dogbone



(a) Wheatstone bridge with matching wire connections for the soda can strain gages from Fig. 3(a).



(b) Intermediate terminal strip with matching wire connections to the strain gages in Fig.3(b)

Figure 4: Wheatstone bridge and wire connections

- **Data Logger**: Electronic device (Agilent 349070A) that collects all voltage channels from the strain gages and the Instron machine and converts them into a digital signal format (i.e., bits) that a computer can interpret.
- **Voltage Source**: Required voltage input source to the Wheatstone bridge (here: $V_{in} = 5Volts$).
- **Data Logger Software**: Data acquisition software to record and save your data coming from the Data Logger (Figure 2 (b) highlights all the data channels you will need to select to collect your strain and load data).

2.2 Important Experimental Details

(a) The raw data format that you will get from the Strain Gage Data Logger will be in units of Volts, i.e., you will get a V_{out}. To convert your voltage output signal, V_{out}, into actual strains, you will use the following conversion formula:

$$\epsilon_n = \frac{-4V_r}{2.067 \cdot (1 + 2V_r)}. \tag{1}$$

$$V_r = \frac{V_{out,strained} - V_{out,unstrained}}{V_{in}} = \frac{\Delta V_{measured}}{V_{in}}. \tag{2}$$

For your experiments, $V_{in} = 5Volts$.

(b) You will also need to convert the raw voltage signal from the Load Cell Transducer into an actual force. You will do this by using the following conversion:

$$Force = \Delta V_{measured} \cdot P_s = [V_{out,loaded} - V_{out,noload}] \cdot P_s, \tag{3}$$

where P_s is the load cell sensitivity, and is equal to $P_S = 1kN/Volt$.

2.3 Finding the Material Properties

To convert the hoop and longitudinal strains into stresses and ultimately the pressure inside your can, you will **need to know the Young's Modulus** E **and Poisson's Ratio** ν. To determine E and ν you will (with Mr. Corkum and the TAs' help) conduct a uniaxial tension test, generate a stress-strain curve (nominal), and calculate both ϵ_x and ϵ_y from your datalogger to compute ν.

(a)Using digital calipers measure the thickness and width of the dog bone sample, being careful not to squeeze the material. Zero the calipers with the jaws in the fully-closed position. **Take three thickness and three width measurements each**. Compute an average value for each dimension.

(b) Load the dog bone sample into the Instron, and attach the gage wires to the intermediate terminal strip and the Wheatstone bridge as shown in Fig. 3.

(c) Start the Data Logger Software making sure all appropriate channels are selected (see Fig. 2b). To record the **unstrained** and **unloaded** voltages, make sure you collect some data before you start actually extending the specimen in the Instron machine. Next, use the little scroll wheel on the Instron machine to slowly load your sample while carefully monitoring the extension and load increase on the computer monitor. **Have one of the TAs or Mr. Corkum supervise you during this process.** Once you have collected enough data to trace out the full stress-strain curve (elastic and plastic region), you may continue loading the sample until it breaks. The maximum load the strips can sustain $\sim$ 400N.

2.4 Measuring Pressure in the Can

Overview: The soda can is instrumented with an orthogonal strain gage pair. By measuring the hoop and longitudinal strains, you should be able to compute the pressure using our thin-walled vessel equations. This derivation should be completed BEFORE the beginning the lab! The process outlined below will have you shake the can, and measure the pressure rise (if any). It will allow you to attempt to lower the pressure through any tricks you wish (you may research methods before-hand if you wish) and take another measurement. Try any method you like, but document each one you try. At the very end of the lab you will finally crack open the can and measure the pressure drop and final pressure.

(a) **Determine the thickness and diameter of the can**. Before executing the experiment, you must measure the diameter of your can using digital calipers. Zero the calipers with the jaws in the fully-closed position and stand the can vertically. Measure the diameter by carefully laying the calipers over the top of the upright can. Slowly close the jaws around the can, being careful not to squeeze it. **Take three diameter measurements**.

(b) **Attach the six strain gage wires (there are six) to the Wheatstone bridge (Fig. 3)**. The wire soldered to the left pad of the first gage is connected to 'bridge', and the two wires soldered to the right pad of the first gage are connected to '+ signal' and '350', in any order. Repeat this for the second gage. If you're unsure on what to do, just ask one of the TAs.

(c) **Start and then run Data Logger, the data acquisition software**. Squeeze the can slightly to see if the strain gage is active. Begin shaking the can by turning it quickly back and forth, and be extremely careful not to dislodge any of the wires. Save a '.csv' file of the new strain values as acquired by Data Logger.

(d) Try and reduce the pressure of the can. Continue to take data, noting whether the strain decreases appreciably by tapping the can, turning it, or any other method you can think of. By looking at the live sampling on the data logger computer screen, you can see if the strains are changing at all.

(e) The last act is to open the can. Once you're ready alert the TA first. Let him make sure your can is in a plastic bag, and your data logger is set at the correct sampling rate and is collecting data. If it all check's out - go for it - crack it open!
(f) Make sure you save all your files and email them to yourself when you're done.

2.5 The Analysis

Using the conversion formulas provided above, your thickness and cross-sectional area measurements, convert all your raw voltage signal data into proper stress and strain data.

(a) Plot the nominal stress-strain curve from your uniaxial tension test. From the data calculate the Young's modulus, E. On the same label the Young's Modulus and the yield point (σ_0) as determined by using the 0.2% offset rule.

(b) Determine an empirical Poisson's ratio ν for the your dog-bone specimen using your measured strain gage values, ϵ_x and ϵ_y.

(c) On the same graph, plot your calculated ϵ_θ and ϵ_x can strain data versus time. Make sure your graph is properly labeled and looks professional!

(d) Using the thin-walled assumptions from class, convert the hoop and longitudinal strains to stresses and plot them versus time.
Compute the ratio between σ_θ and σ_x. How does the ratio compare to our analytical results from class. Discuss and quantify sources of error.

(f) Using the results from (d) plot pressure vs. time stating exactly, which stress component you used to compute pressure and why?

(g) Did you bust the myth? Comment and discuss your final results. Discuss possible sources of error and quantify them.