Mech 306

Lab #5 Part B
Thin-Wall Pressure Vessels

Group 35

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Abstract

In this lab, we conducted an experiment to determine air pressure in a carbonated beverage can by measuring the change in strain under different conditions. The two objectives were to determine the air pressure in the can at room temperature, and to determine the effect of temperature on the can pressure. To measure the effect of temperature, we attached strain gauges to the can and placed it in a ice bath. We periodically increased the temperature of the bath, and recorded the change in strain. By plotting the change in strain against the temperature of the bath, we could determine the change in air pressure in the can. To determine the air pressure of the can at room temperature, we first recorded the strain readings, depressurized the can, and then re-pressurized the can to its original state of strain. We determined the air pressure of the can to be 70 PSI, and we tentatively concluded that as temperature increases, the pressurized can exhibits a lessening effect in axial strain and an enlarging effect in circumferential strain.

Introduction

Pressure vessels are used a variety of different engineering fields. Some examples of pressure vessels are aerosol cans, diving tanks, and airlocks. These vessels have to be designed to withstand the load of external forces, as well strong internal internal forces. The results from this experiment describe the air pressure of a common carbonated beverage can, as well as the effect of temperature on the air pressure. An engineer could use this information to predict whether the can will able to withstand the change in pressure throughout its transportation from the factory to the consumer.

Methods

Part 1: Temperature Variance

The first part of our experiment, outlined below, was to measure the effect of temperature on the can pressure via strain.

1. Place two strain gauges on a pressurized can. Place one gauge circumferentially and the other axially.
2. Place another strain gauge (calling this gauge the "control gauge" from now on) on an empty can. The strain on the control gauge can then be subtracted from the ones on the pressurized can for each of the trials; this removes the effect of temperature on the strain gauges.
3. Create an ice bath of sufficient size to submerge the can and the control gauge in.
4. Attach all strain gauge wires to the switch and balance unit, and seal the can and control gauge inside a plastic bag so they can be submerged in the water without damaging the electronics.
5. Place the can and control gauge in the water and wait until the system reaches a steady state (strain readings stabilize). Record the temperature and the strain gauge readings.
6. Add some hot water to change the temperature of the system. Take measurements at temperature varying from 5-40℃. Repeat for around ~10 trials.

Part 2: Can Pressure

The second part of the experiment was to determine the air pressure in the can at room temperature.

1. With the can at room temperature, zero the strain gauge readings.
2. Depressurize the can and record the strain gauge readings (do not empty the can).
3. Install a valve in the cap with hot glue and re-pressurize the can until the strain gauge displays zero readings.
4. Record the pressure supplied which is the internal pressure of unopened can.

Results

Part 1:

Our results for the strain comparison at varying temperatures between the empty (control) can and the pressurized can are summarized in Table 1.1 below.

Table 1.1: Temperature vs Strain Measurements

Temperature (C)	Circumferential Pressurized Strain-1 (ul)	Axial Control Strain-2 (ul)	Axial Pressurized Strain-3 (ul)	Circumferential Control Strain-4 (ul)
25	0	0	0	0
6	-92	-226	-74	-473
9	-180	-250	-55	-313
12	-294	-96	-64	254
17	-254	-40	-58	29
22	-208	20	-36	-60
27	-175	87	-7	56
29	-50	127	-28	9
30	-131	150	-400	39
35	360	171	101	126
38	547	234	160	220

The figure below depicts the trends of the strain results recorded in Table 1.1. The general trend of the strain in both axial and circumferential respects shows an increase with increased temperature. Our results also have very low R^2 values, indicating high variation in our results

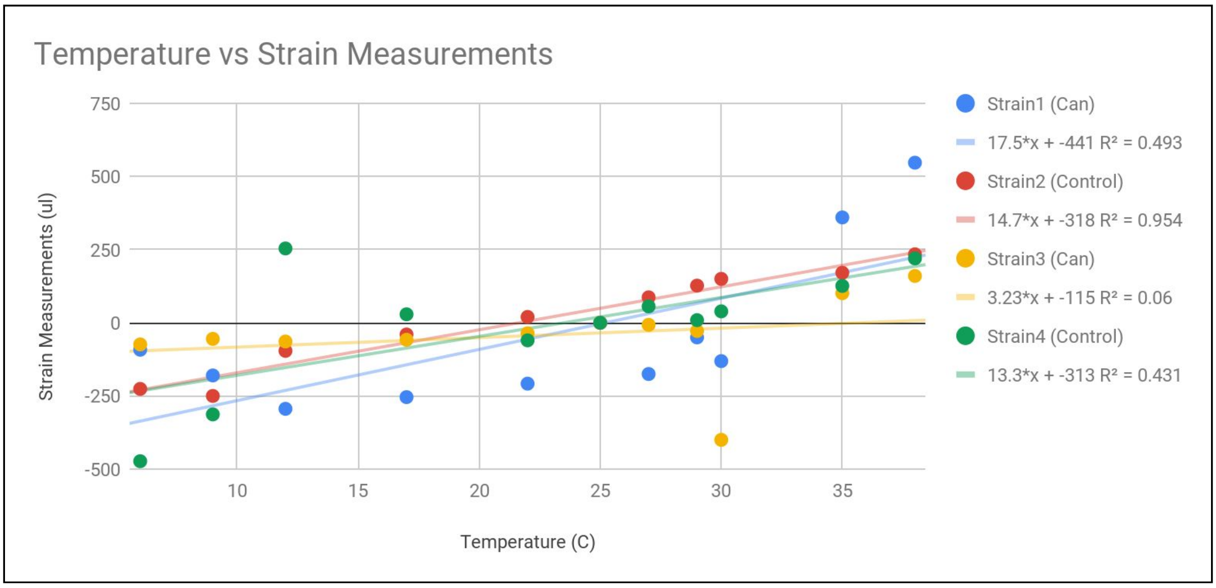

Figure 1.1: Temperature vs Strain Trends from Data in Table 1.1

Part 2:

Our readings did not reach the zero reading by applying 50 psi, which was the maximum allowed by the lab apparatus. As a result, we interpolated our data to estimate the original pressure in the can as found below in Table 2.1. We know that the axial and circumferential stress follow the equations below when apply the same gauge pressure:

$$\sigma_a = \frac{pr}{2t}$$

$$\sigma_\theta = \frac{pr}{t}$$

This is basically consistent with our results in Table 2.1 which shows that strain 1 axial strain is always smaller than strain 2 circumferential strain.

Table 2.1: Temperature vs Strain Measurements

Pressure (psi)	Axial Strain 1 (ul)	Circumferential Strain 2 (ul)
0	-356	-1762
49.8	-130	-378

The trend line of the following graph ε = 4.54*P - 356 and ε = 27.8*P - 1762. After interpolating them and calculating the intersections of pressure axis, we determined that the internal pressure of an unopened can is around **70 psi.**

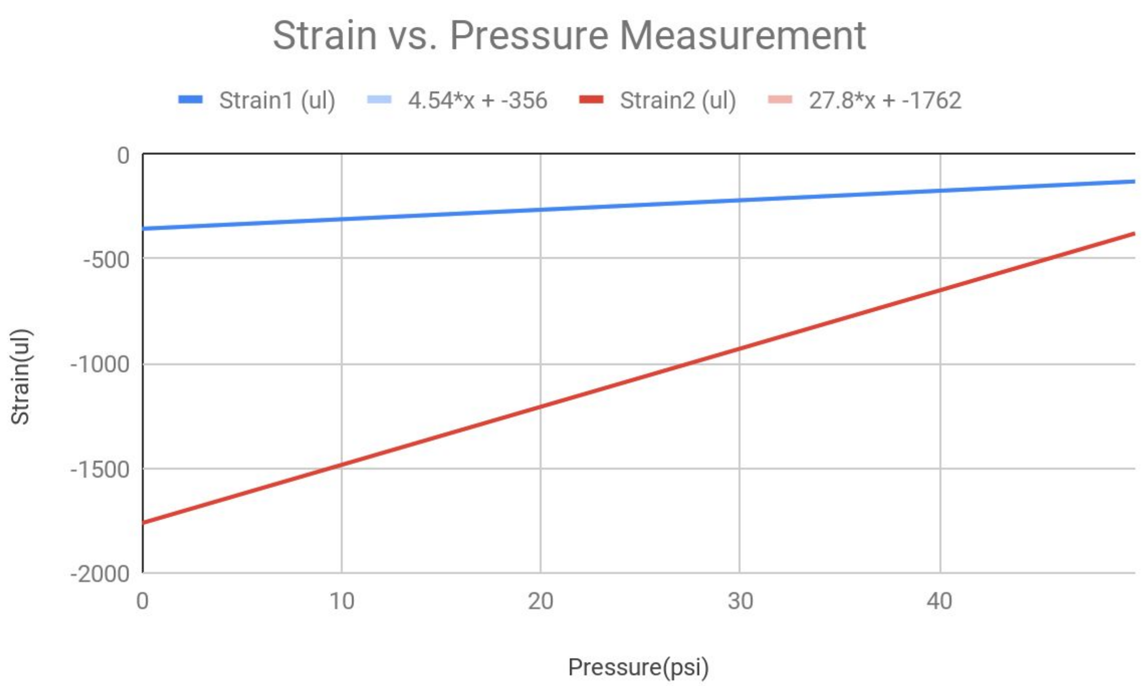

Figure 2.1: Strain vs Pressure Measurement from Data in Table 2.1

Analysis and Discussion

Part 1:

During the experiment, we took measures to reduce the error in recording our results such as crushing the ice to distribute the temperature more evenly, and drying the strain gauge contacts periodically to reduce electrical interference. While these measures reduced the recorded error in some aspects, our recorded data was affected by others as well.

The data that we recorded is noisy (average R^2 value of 0.64) and cannot provide an accurate numerical correlation between temperature and internal pressure; however, we can observe the general trends and form a conclusion. The trendlines of our strain data tend to increase and decrease from the room temperature measurement in proportion to temperature, which can be observed by the positive linear slopes in Figure 1.1. The pressurized can exhibits a lessening effect in axial strain and an enlarging effect in circumferential strain; therefore, the effect on internal pressure by temperature increase is unclear from the gathered data in this lab.

The error in the observed data can be attributed to several sources including:

- the can's buoyancy and the force applied to keep it submerged,
- the presence of prior plastic deformation in the can,
- the water pressure from the heating/cooling method,
- the temperature distribution of the water,
- the control can's reduced mass, and
- the water leaking into the bag and affecting the strain gauges.

The majority of these causes could affect the results significantly and should be addressed in future experiments to attain more accurate results.

Part 2:

Theoretically strain 1 should be half of strain 2 but in our experiment the axial strain is smaller than we expected. We think the hot glue mass on top of the contributed to this discrepancy since it adds negative axial stress on the can. Also, the two lines in Figure 2.1 should intersect the pressure axis at the same point at 0 psi, but based on our data trend line they show 78.41 and 63.48 psi respectively, so we took the average and concluded that original internal pressure of the can is around 70 psi.

Comparing to given data that the pop can pressure at room temperature is 50-60 psi, our results are close to this value. Below are some source of error that may have caused our experimental internal pressure to be higher than expected:

- Can not completely cooled down to room temperature after part 1 experiment,
- Pouring out too much liquid after opening the can,
- Inadequate sealing on can,
- Carbon dioxide dissolved in the pop come out due to high temperature, and
- Other changes in carbon dioxide concentration due to many changes in pressure

Conclusion

The initial objective of the experiment was to determine the internal pressure within the can, and our result gives 70 psi which is close to the expected value of 50-60 psi. We took actions to minimize sources of error, such waiting a long period of time to let the can cool down to room temperature, creating a strong seal on the can, and keeping most of the liquid when re-pressurizing. However, it was difficult confirm that the can had cooled down completely because we had no method to directly measure the can temperature. Also the carbon dioxide concentration may have increased (dissolved out from the liquid) due to the motion of the can in the experiment. These errors contribute to the higher internal pressure but our experiment was still fairly successful.

We also investigated the effect of temperature on the can pressure. Heating the can in the water causes a lot of issues because water pressure and buoyancy affected the stress on the can, and water leakages may have caused inaccurate readings. Our data is very noisy and thus cannot give us a numerical relationship between temperature and can pressure. From the trend line in Figure 1.1 we can tentatively conclude that as temperature increases, the pressurized can exhibits a lessening effect in axial strain and an enlarging effect in circumferential strain. The internal pressure cannot be determined since we need to consider poisson's ratio and relative magnitude of each strain and our data is unclear here.