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Date: 10/06/2022
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EMCH 316
Lab #3

Stress Analysis via
Strain Gauge Rosettes

OBJECTIVE: To analyze the stress in a thin-walled, closed-ended pressure vessel which is internally pressurized with a gas with the use of strain gauge rosettes.

PROCEDURE

For this lab, the data was given, as the experiment could not be performed. If you wish to view the official procedure, please refer to the Lab 3 manual.

DATA AND RESULTS

Table 1. Pressure vessel specifications.

	Vessel #1	Vessel #2
Material	Aluminum	Aluminum
Young's Modulus	70 GPa	70 GPa
Poisson's Ratio	0.33	0.33
Outside Diameter	14.6 cm	14.6 cm
Wall Thickness	3.35 mm	3.66 mm

Table 2. Internal Pressure of Vessel # 4.

Internal Pressure	**230 (psi)**	1.58579 (MPa)

Table 3. Strain Readings.

Channel	Strain Reading (Actual)
a	**82**
b	**186**
c	**329**
d	**85**
e	**272**
f	**323**

ANALYSIS OF DATA

- Determination of r and the applied stresses using the Strength of Materials solution:

Vessel 1	Vessel 2
r = 71.325mm	r=71.17mm
I = 33.763MPa	I=30.836MPa
II = 16.882MPa	II=15.418MPa

Vessel 1

$$r = \frac{((outer\ r) + (inner\ r))}{2} = \frac{\left(\frac{146}{2}\right) + \left(\left(\frac{146}{2}\right) - 3.35\right)}{2} = 71.325mm$$

$$\sigma 1 = \frac{P * r}{t} = \frac{1.58579 * 71.325}{3.35} = 33.763MPa$$

$$\sigma 2 = \frac{P * r}{2 * t} = \frac{1.58579 * 71.325}{2 * 3.35} = 16.88MPa$$

Vessel 2

$$r = \frac{\left((outer\ r) + (inner\ r)\right)}{2} = \frac{\left(\frac{146}{2}\right) + \left(\left(\frac{146}{2}\right) - 3.66\right)}{2} = 71.17mm$$

$$\sigma 1 = \frac{P * r}{t} = \frac{1.58579 * 71.17}{3.66} = 30.836MPa$$

$$\sigma 2 = \frac{P * r}{2 * t} = \frac{1.58579 * 71.17}{2 * 3.66} = 15.418MPa$$

- Determine the applied and Principal Stresses from aligned rosette data using Hooke's Law

Aligned (a,b and c)

$$\sigma_{xx} = \frac{E}{1 - v^2}(\varepsilon_a - v\varepsilon_c) = \frac{70 * 10^9}{1 - 0.33^2}\left(82 * 10^{-6} + 0.33(329 * 10^{-6})\right) = 14.97MPa$$

$$\sigma_{yy} = \frac{E}{1 - v^2}(\varepsilon_c - v\varepsilon_a) = \frac{70 * 10^9}{1 - 0.33^2}\left(329 * 10^{-6} + 0.33(82 * 10^{-6})\right) = 27.97MPa$$

$$\boldsymbol{G = \frac{E}{2(1 + v)} = 26.3\ GPa}$$

$$\boldsymbol{\tau xy = \gamma xy * G = G * (a + c - (2 * b))} = \mathbf{1.0257\ MPa}$$

Unaligned (d,e and f)

$$\sigma_{xx} = \frac{E}{1 - v^2}(\varepsilon_D - v\varepsilon_F) = \frac{70 * 10^9}{1 - 0.33^2}\left(85 * 10^{-6} + 0.33(323 * 10^{-6})\right) = 15.05MPa$$

$$\sigma_{yy} = \frac{E}{1 - v^2}(\varepsilon_F - v\varepsilon_D) = \frac{70 * 10^9}{1 - 0.33^2}\left(323 * 10^{-6} + 0.33(85 * 10^{-6})\right) = 27.58MPa$$

$$\boldsymbol{G = \frac{E}{2(1 + v)} = 26.3\ GPa}$$

$$\boldsymbol{\tau xy = \gamma xy * G = G * (d + f - (2 * e))} = \mathbf{-3.58\ MPa}$$

- Determination of Principal Stresses using Mohr's circle for (d,e and f)

$$C = \frac{\sigma_{xx} + \sigma_{yy}}{2} = \frac{15.05 + 27.58}{2} = 21.32MPa$$

$$R = \sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{15.05 - 27.58}{2}\right)^2 + (-3.58^2)} = 7.22MPa$$

$$\sigma_1 = C + R = 21.32MPa + 7.22MPa = 28.54MPa$$
$$\sigma_2 = C + R = 21.32MPa - 7.22MPa = 14.1MPa$$

$$\alpha = arctan\left|\frac{\tau_{xy}}{\sigma_{xx} - \sigma_{yy}}\right| = \text{arctan}\left|\frac{-3.58MPa}{\frac{15.05MPa - 27.58MPa}{2}}\right| = 29.74\ degree$$

$$\theta = \frac{\alpha}{2} = 14.87\ degree$$

Figure 1. Mohr's circle.

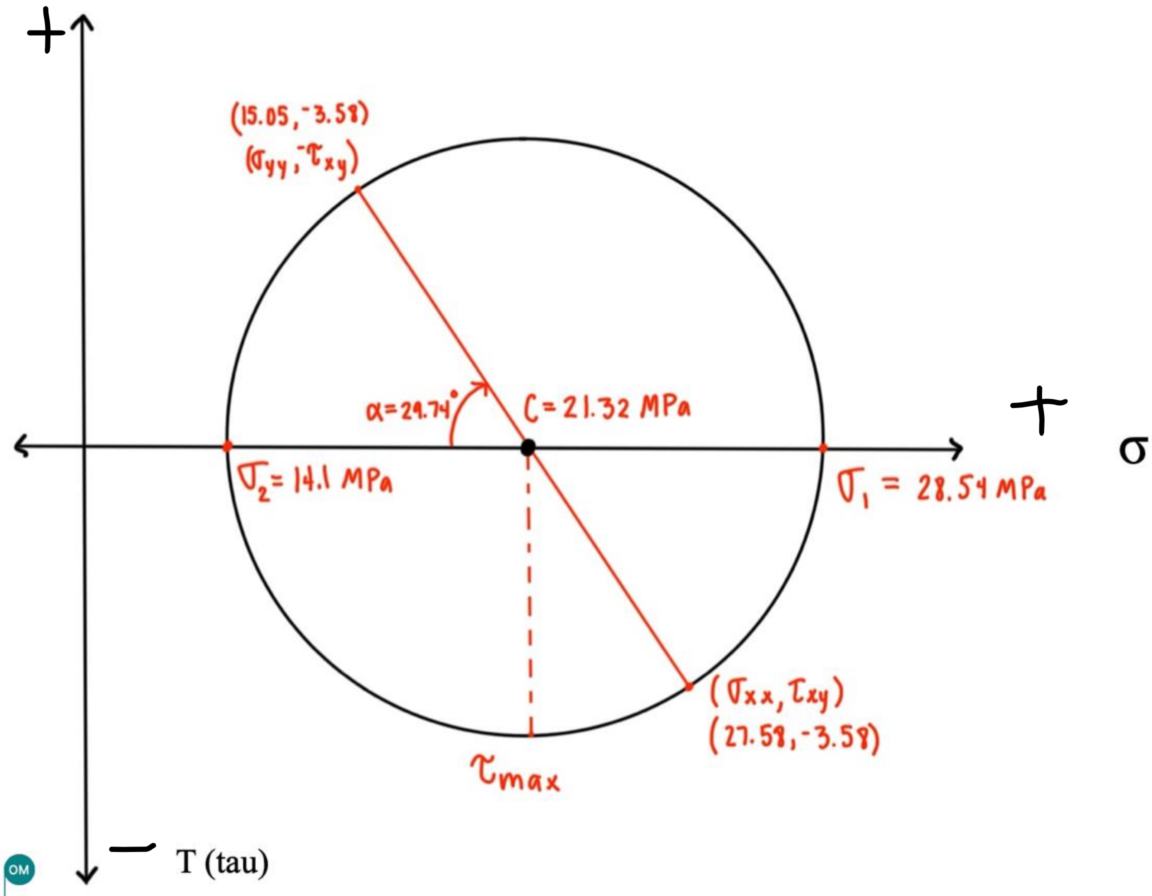


Figure 2. Aligned readings for a, b, c.

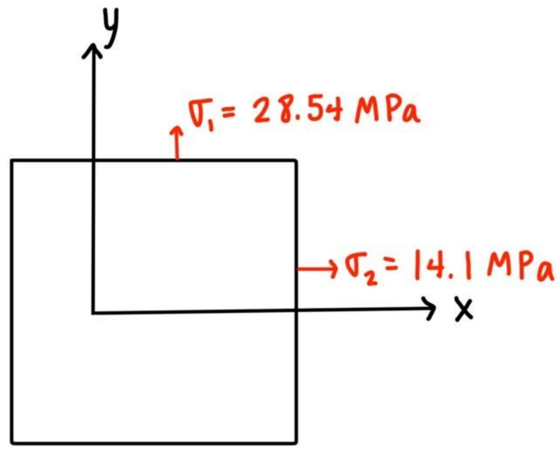


Figure 3. Unaligned readings for d, e, f.

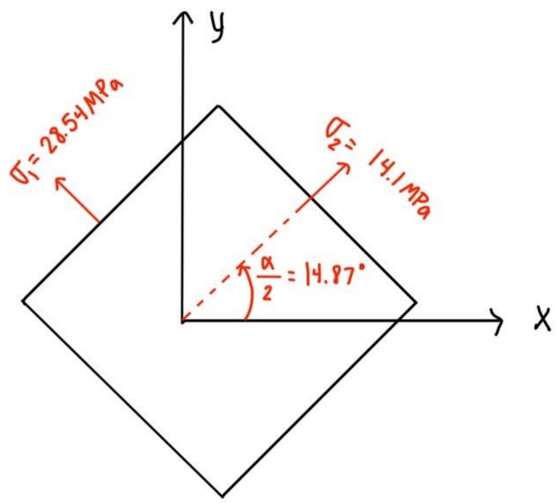
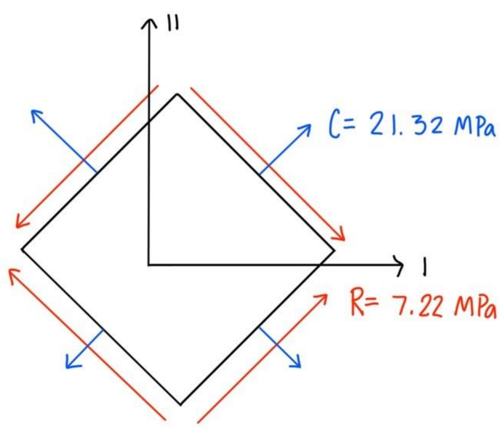


Figure 4. Unaligned Max Shear stress orientation readings d, e, f.



DISCUSSION OF RESULTS

1. What was the approximate radius-to-thickness ratio for the pressure vessels? Were the thin wall approximations valid?
    a. The ratio comes out to be r/t = 21.8, and the thin wall approximations were valid because this number calculated was greater than 10.
2. The ends of the vessels are relatively massive to keep the vessel from expanding radially in the vicinity of the ends. Does this have any bearing on the analysis?
    a. To make vessels like this, geometry is very important. Since Hooke's law was being used for this calculation, the geometry is not important in the analysis of the pressure vessel.
3. Compare and contrast the 3 different methods of determining the Principal Stresses.
    a. 1 Strength of Materials, 1. Hooke's Law, 3 Mohr's circle were the three methods used. These methods are used to calculate the principal stresses, but they all require different inputs to calculate them. For Strength of Materials, we need the geometry and pressure, for Hooke's law we need values from the rosette and Mohr's circle requires more calculations for radius, center and so on.
4. Explain why the applied and Principal Stresses are similar.
    a. These values were similar because they are found by similar values but with different approaches. The pressure vessel aligns the hoop stress and the axial stresses from the Strength of Materials formulas.

CONCLUSIONS

This experiment successfully displayed the various strategies for solving stress-strain data. Although the experiment could not be carried out during the lab period, having the data allowed us to fully comprehend the conceptual differences between using the analytical strength of materials solution, the experimental solution obtained from a gauge aligned with the principal axes, and the solution obtained from a randomly oriented rosette. It is crucial to note that some of these computations vary from the other approaches, however these various numbers may be used to separate the principal stresses using conceptual analysis.