Mechanical Laboratory 2

Lab 5: Soda Can Experiment

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MMAE-419-L01

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EXPERIMENTAL SETUP AND PROCEDURE:

Eight measurements of soda cans diameter **(D)** and wall thickness **(t)** are being measured in order to get most accurate dimensions of soda can for this experiment and results are recorded in **Table 1.** Aluminum soda can had rectangular strain gage rosette fixed on its wall **(Figure 1)** and positioned like it is shown in **Figure 4.** Rectangular strain gage rosette was connected to strain indicator that was obtaining three strain measures, one for each channel. One channel was recording strain in longitudinal direction, while other two channels measured strain when angle was +45° and when it was -45 off longitudinal direction. Air tank under pressure was connected at only opening of soda can so air can be forced into can. Pressure indicator was set to measure pressure in the soda can **(Figure 2)**. Soda can was placed in the safety cage **(Figure 3)** to avoid any injuries in case soda can explodes. Strain and pressure indicator values were set to zero and those values were first set of measurements. Pressure was increased in increments of 5psi to maximum 80psi and measurements of pressure and three strains were recorded at each pressure point **(Table 2)**.

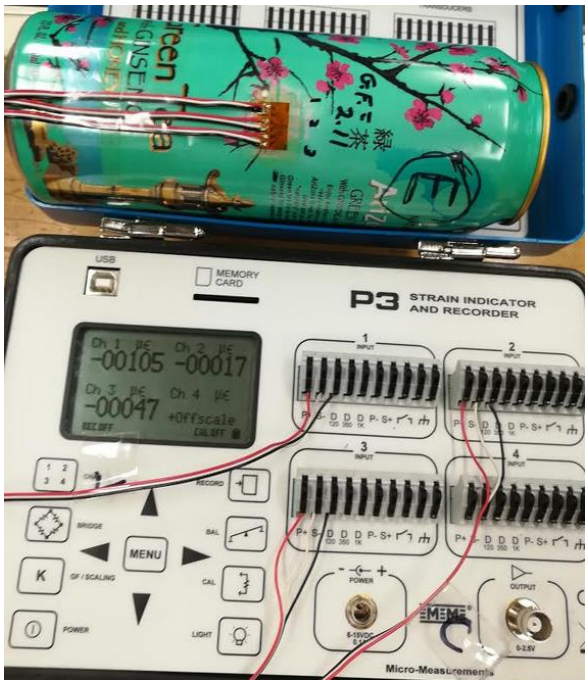

Figure 1. Soda can with glued strain gauges connected to strain indicator

Figure 2. Measured pressure indicator

Figure 3. Soda can in the safety cage

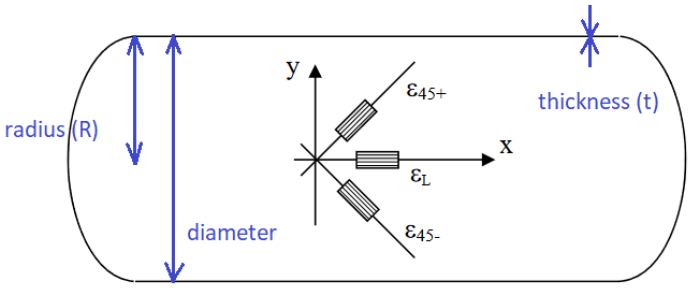

Figure 4. Sketch of gage orientations with dimensions of pressure vessel

ANALYSIS OF DATA:

Average can diameter **(D)** and wall thickness **(t)** is calculated **(Table 1)** and was used for further calculations. Raw data, acquired from rectangular strain gage rosette **(Table 2)**, is being used to calculate hoop strain ($\boldsymbol{\varepsilon_\theta}$)**,** longitudinal stress ($\boldsymbol{\sigma_L}$), hoop stress ($\boldsymbol{\sigma_\theta}$)**,** pressure calculated from longitudinal stress ($\boldsymbol{P_L}$)**,** pressure calculated from hoop stress ($\boldsymbol{P_\theta}$)**.**

The longitudinal strain ($\boldsymbol{\varepsilon_L}$) is already measured while hoop strain is calculated by manipulating **(1)** when ϕ=+45° and when and ϕ =-45°,

$$\varepsilon_\phi = \frac{\varepsilon_L+\varepsilon_\theta}{2} + \frac{\varepsilon_L-\varepsilon_\theta}{2}\cos(2\cdot\phi) + \frac{\gamma_{L\theta}}{2}\sin(2\cdot\phi) \qquad \textbf{(1)}$$

By combining those two equations (when ϕ=+45° and when ϕ =-45°), equation for hoop strain **(2)** is set up, which can be applied only in setup that we had (shown in **Figure 4**), meaning when angles are +45° and -45° and rectangular strain gage rosette is used. For each pressure point separately hoop strain is calculated and results are shown in **Table 2**.

$$\varepsilon_\theta = \varepsilon_{+45} + \varepsilon_{-45} - \varepsilon_L \qquad \textbf{(2)}$$

Equations for longitudinal strain **(3)** and hoop strain **(4)** have two unknowns where $\boldsymbol{\sigma_L}$ is longitudinal stress, $\boldsymbol{\sigma_\theta}$ is hoop stress, $\boldsymbol{\nu}$ is Poisson's ratio and **E** is Young's Modulus,

$$\varepsilon_L = \frac{1}{E}(\sigma_L - \nu\sigma_\theta) \qquad \textbf{(3)}$$

$$\varepsilon_\theta = \frac{1}{E}(\sigma_\theta - \nu\sigma_L) \qquad \textbf{(4)}$$

By combining **(3)** and **(4),** two unknowns, longitudinal stress (**5**), hoop stress (**6**) can be found. Using those two equations longitudinal stress, hoop stress is calculated, and results are shown in **Table 2**.

$$\sigma_L = \frac{E(\varepsilon_L + \varepsilon_\theta \nu)}{1-\nu^2} \qquad \textbf{(5)}$$

$$\sigma_\theta = \frac{E(\varepsilon_\theta + \varepsilon_L \nu)}{1-\nu^2} \qquad \textbf{(6)}$$

The longitudinal stress can also be expressed with **(7)**, where **R** is radius of can $\boldsymbol{P_L}$ is internal pressure and **t** is thickness of the wall. Longitudinal stress ($\boldsymbol{\sigma_L}$) is result of pressure acting on ends of cylinder and it courses stretching the length of the soda can.

$$\sigma_L = \frac{RP_L}{2t} \qquad \textbf{(7)}$$

By manipulating **(7)** pressure $\boldsymbol{P_L}$ can be found **(8)**:

$$P_L = \frac{\sigma_L\, 2\, t}{R} \qquad \textbf{(8)}$$

The hoop stress is calculated using **(9)**, where **R** is radius of can $\boldsymbol{P_\theta}$ is internal pressure and **t** is thickness of the wall. Hoop stress ($\boldsymbol{\sigma_\theta}$) is result of radial pressure that causes stretching of diameter/radius of soda can.

$$\sigma_\theta = \frac{RP_\theta}{t} \qquad \textbf{(9)}$$

By manipulating **(9)** $\boldsymbol{P_\theta}$ pressure can be found **(10)**:

$$P_\theta = \frac{\sigma_L\, t}{R} \qquad \textbf{(10)}$$

Longitudinal and hoop pressure %error is calculated for each pressure point separately by using **(11)** and **(12)** and average of each is shown in **Table 2**.

$$\left|\frac{P_L - P_m}{P_m}\right| x100 \qquad \textbf{(11)}$$

$$\left|\frac{P_\Theta - P_m}{P_m}\right| x100 \qquad \textbf{(12)}$$

%error for soda can diameter **(D)** and thickness**(t)** are respectfully:

$$\left|\frac{D_i - D_{ave}}{D_{ave}}\right| x100 \qquad \textbf{(13)}$$

$$\left|\frac{\boldsymbol{t_i - t_{ave}}}{\boldsymbol{t_{ave}}}\right| x100 \qquad \textbf{(14)}$$

Table 1. Soda can dimension measurements with % error and elastic properties

Measurement of Soda Can Dimensions

	D [in]	t [in]	%error D	%error t
	2.863	0.0043	0.087245	2.050114
	2.871	0.0044	0.191939	0.22779
	2.874	0.0042	0.296632	4.328018
	2.872	0.0045	0.226837	2.505695
	2.871	0.0046	0.191939	4.783599
	2.861	0.0044	0.157041	0.22779
	2.856	0.0045	0.33153	2.505695
	2.856	0.0042	0.33153	4.328018
Average	2.8655	0.00439	0.22684	2.61959
St. Dev.	0.0074	0.00015	0.08749	1.78534

Elastic Properties of Soda Can (Al)

E [Gpa]	ν
72	0.33

Table 2. Experiment raw data and calculated values

Experimental Measurents				Calculated Values					stress ratio	pressure ratio	pressure ratio
P_m [psi]	ε_{45+}	ε_L	ε_{45-}	ε_θ	σ_L [MPa]	σ_θ [MPa]	P_L [psi]	P_θ [psi]	σ_θ/σ_L	P_L/P_m	P_θ/P_m
0	0.000000	0.000000	0.000000	0.000000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000075	0.000022	0.000076	0.000129	5.217	11.010	4.637	4.893	2.110	0.927	0.979
10	0.000152	0.000046	0.000153	0.000259	10.623	22.153	9.441	9.845	2.085	0.944	0.985
15	0.000234	0.000071	0.000232	0.000395	16.269	33.809	14.460	15.025	2.078	0.964	1.002
20	0.000313	0.000097	0.000310	0.000526	21.863	45.087	19.432	20.037	2.062	0.972	1.002
25	0.000393	0.000125	0.000390	0.000658	27.645	56.499	24.571	25.108	2.044	0.983	1.004
30	0.000471	0.000149	0.000465	0.000787	33.023	67.562	29.351	30.025	2.046	0.978	1.001
35	0.000553	0.000179	0.000546	0.000920	38.994	79.108	34.658	35.156	2.029	0.990	1.004
40	0.000636	0.000208	0.000628	0.001056	44.963	90.870	39.963	40.383	2.021	0.999	1.010
45	0.000718	0.000250	0.000708	0.001176	51.556	101.686	45.823	45.189	1.972	1.018	1.004
50	0.000807	0.000278	0.000794	0.001323	57.738	114.310	51.318	50.799	1.980	1.026	1.016
55	0.000888	0.000312	0.000873	0.001449	63.845	125.397	56.746	55.727	1.964	1.032	1.013
60	0.000969	0.000343	0.000957	0.001583	69.923	137.050	62.148	60.905	1.960	1.036	1.015
65	0.001047	0.000367	0.001036	0.001716	75.408	148.437	67.023	65.966	1.968	1.031	1.015
70	0.001126	0.000394	0.001118	0.001850	81.163	159.984	72.138	71.097	1.971	1.031	1.016
75	0.001207	0.000424	0.001203	0.001986	87.213	171.772	77.515	76.336	1.970	1.034	1.018
80	0.001293	0.000460	0.001292	0.002125	93.828	183.963	83.395	81.754	1.961	1.042	1.022

Table 3. Average longitudinal and hoop pressure %error

Average longitudinal pressure % error	2.895
Average hoop pressure % error	1.049

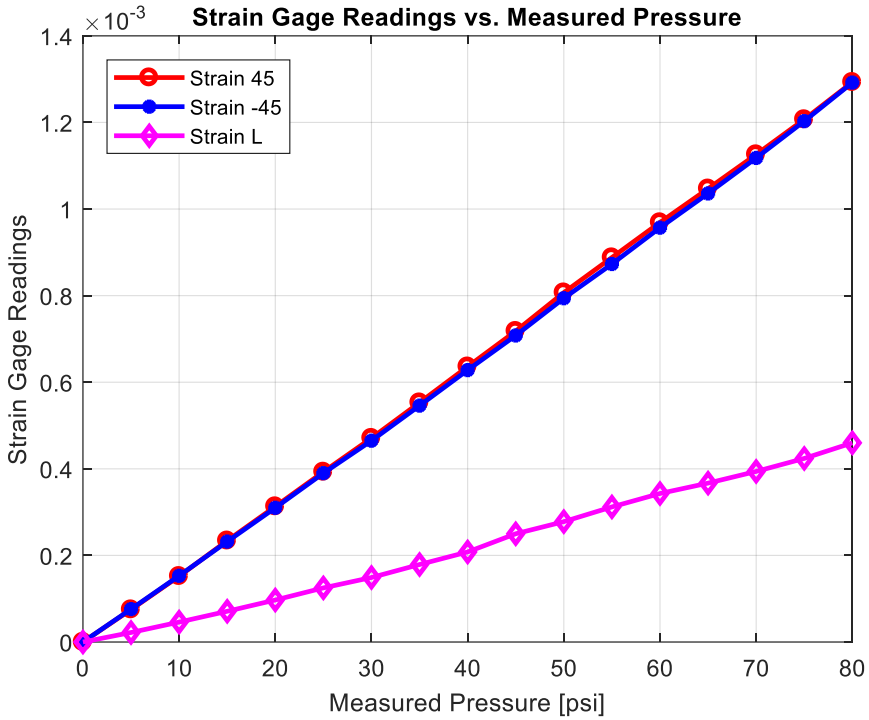

Figure 5. Strain gage readings vs. measured pressure plotted

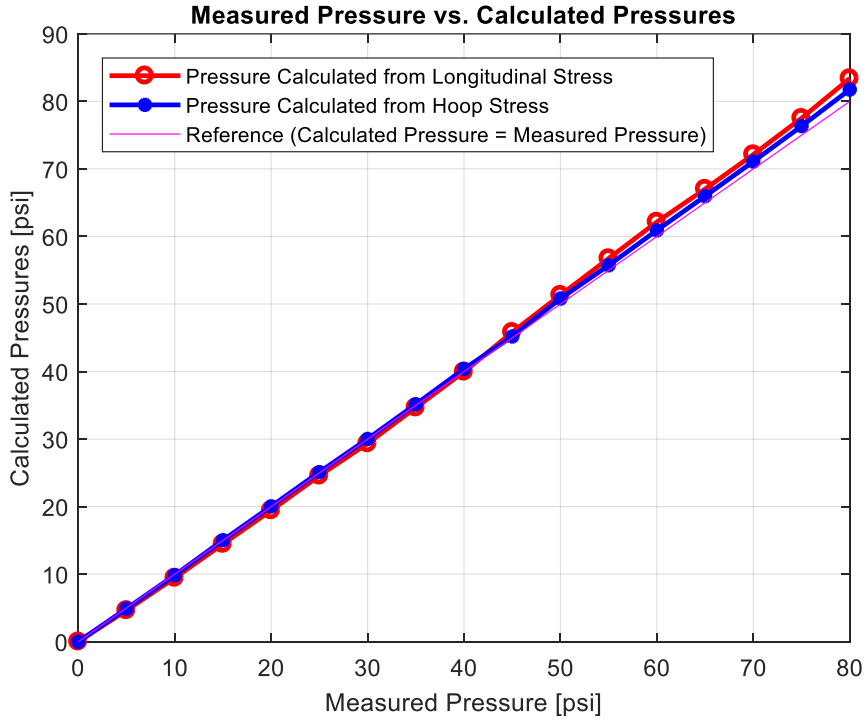

Figure 6. Measured pressure vs. pressure calculated from strain gage readings plotted

Ideally measured pressure vs. calculated pressure should be equal and pressure calculated from longitudinal stress and pressure calculated from hoop stress should be along reference line shown in **Figure 6.** Average error for pressure calculated from longitudinal stress is 2.895% while average error for pressure calculated from hoop stress is 1.049% **(Table 3)**. That difference is also visible in **Figure 6**, where data points for pressure calculated from longitudinal stress are more distant from reference line than it is the case for data points for pressure calculated from hoop stress.

Possible source of error might be if rectangular strain gage rosette is not fixed perfectly +45° and -45° off longitudinal axis. Strain gage being perfectly aligned is crucial information while calculating hoop strain since term $(2 \cdot \phi)$ term in **(1)** must be exactly ±90° for +45° and -45°. If it is not the case **(2)** is not totally correct. Other source of error is that thickness of soda can wall oscillates around 2.6% as it is shown in **Figure 1**. Which mean that thickness of soda can is not uniform along all soda can wall. Error due to measurements of diameter of a can is less than 0.1%, as it is shown in **Figure 1,** and can be neglected.

REFERENCES:

Mechanical Behavior of Materials 4th Ed. by Norman E. Dowling (Pearson, 2013 ISBN 0-13-139506-8)

Dr. Murat Vural, MMAE 419 Soda Can Experiment Handout, IIT, Chicago