# Memo

To: TA's

From: Christian Arriaga-Franco

CC:

Date: 11/20/25

Re: Lab 5 – Material Testing

The values that were obtained by conducting material tests on several different materials through various methods, refer to the materials hardness, surface roughness, and Youngs Modulus. This was done with the following instruments: Phase II Rockwell Hardness tester, Mitutoyo roughness tester, and a Mark-10 ESM750 Tensile tester along with the extensometer. The values for all tests are in the figures and tables below.

Table 1: Young's Modulus obtained from testing the acrylic specimen

Material	Acrylic
Young's Modulus (GPa)	$2.573112228 \pm 0.192086441$
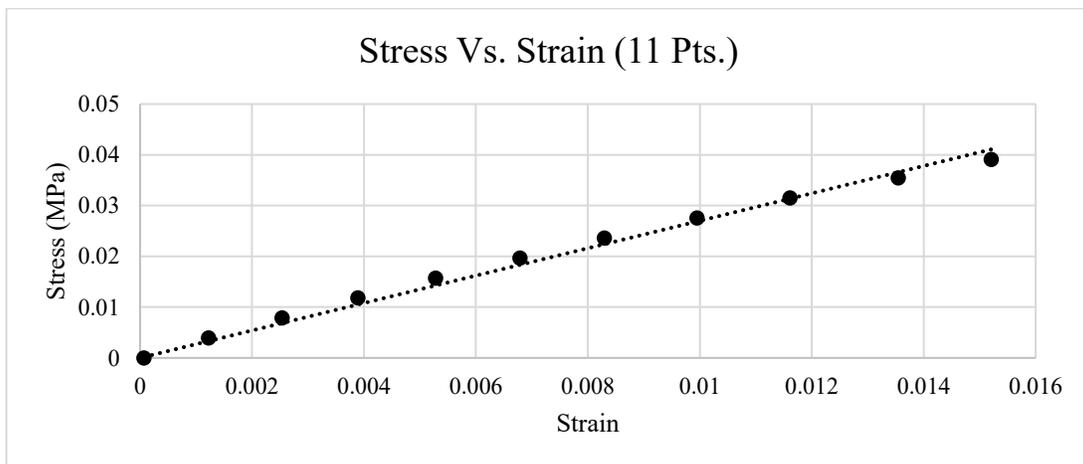
Figure 1: Stress Vs. Strain Plot of 11 randomly selected points from tensile test

The Young's Modulus value found in table 1 was obtained through 11 randomly selected points throughout the experiment which will be shown in the appendix.

Table 2: Hardness (HRC/HRB) values obtained from hardness testing various materials

Material	Test	Hardness Value
AR500	C	57.6 ± 5.765715047
Aluminum	C	5.8 ± 3.646084201
Brass	B	73.6 ± 10.71298429

Table 3: Roughness (Ra) values obtained from roughness testing various patterns

Roughness Pattern	Ra Value
125P	1.9668
16BL	0.3968
500P	3.4694

The values obtained from the roughness test not only included Ra values but Rq, Rp, and Rv values. The difference between them is what they measure. Ra is a general descriptor of the surface roughness, called the arithmetic average. Rq ,measures the root-mean-square of the roughness otherwise known as RMS roughness and magnifies, or is sensitive to, large peaks and valleys. Rp measures the tallest single peak with respect to the mean line which is sensitive to the most single extreme point and Rv measures the deepest valley with respect to the mean line which is sensitive to scratches or pits. Ra was reported as it is the best overall measure of roughness on the surface.

Appendices (Next pages)

Raw Data

Sample Calculations

Raw Data – Tensile Test

Load (N)	Time (s)	Voltage (V)	Stress (Pa)	Stress (GPa)	Strain
0	0	0.13412	0	0	6.6396E-05
150	141	0.143915	3939076.044	0.003939076	0.001225145
300	188.1	0.155015	7878152.088	0.007878152	0.002538275
450	232.8	0.166442	11817228.13	0.011817228	0.003890089
600	274.95	0.178195	15756304.18	0.015756304	0.005280469
750	315.05	0.190928	19695380.22	0.01969538	0.006786782
900	355.95	0.203661	23634456.26	0.023634456	0.008293096
1050	397.85	0.2177	27573532.31	0.027573532	0.00995391
1200	439.35	0.231738	31512608.35	0.031512608	0.011614605
1350	483	0.248062	35451684.4	0.035451684	0.013545735
1490	525.2	0.262101	39128155.37	0.039128155	0.015206548

Width (m)	Thickness (m)
0.01272	0.00299
0.0129	0.00296
0.01336	0.0029
0.01275	0.00288
0.0129	0.00300

Sample Calculations – Tensile Test – MAX LOAD

Strain calibration

$$\varepsilon_{max} = 0.1183(V_{@max}) - 0.0158 = 0.1183(0.262101) - 0.0158 = 0.015206548$$

Stress calculation

$$\sigma_{max} = \frac{F_{max}}{A} = \frac{F_{max}}{T_{avg} * W_{avg}} = \frac{1490}{\sum\frac{T_i}{N} * \sum\frac{W_i}{N}} = \frac{1490}{\sum\frac{T_i}{N} * \sum\frac{W_i}{N}} = \frac{1490}{(0.002946)(0.012926)} = 39128155.37\ Pa$$

Youngs Modulus calculation

$$E = \frac{\sigma_{max}}{\varepsilon_{max}} = \frac{\frac{F_{max}}{A}}{\varepsilon_{max}} = \frac{39128155.37\ Pa}{0.015206548} \approx 2573112228\ Pa \approx 2.57 Gpa$$

Youngs Modulus Uncertainty calculation - Formulas

$$U_E = \sqrt{U_{E,Area}{}^2 + U_{E,Force}{}^2}$$

$$U_{E,Area} = \frac{\partial E}{\partial A} * U_A = -\frac{F}{A^2 \varepsilon} * U_{Area}$$

$$U_{E,Force} = \frac{\partial E}{\partial F} * U_{Force} = \frac{1}{A\varepsilon} * U_{Force}$$

$$U_{Force} = 2.5$$

$$U_{Area} = \sqrt{U_{Area,width}{}^2 + U_{Area,thickness}{}^2}$$

$$U_{Area,width} = \frac{\partial A}{\partial W} * U_{Width} = T * U_{Width}$$

$$U_{Area,thickness} = \frac{\partial A}{\partial T} * U_{Thickness} = W * U_{Thickness}$$

$$U_{Width} = \sqrt{U_{res,w}{}^2 + U_{rand,w}{}^2}$$

$$U_{Thickness} = \sqrt{U_{res,t}{}^2 + U_{rand,t}{}^2}$$

Youngs Modulus Uncertainty calculation - Data

$$U_{rand,w} = s_w * t_{n=5,95\%} = 0.000256476 * 2.77 = 0.000710439 \, m$$

$$U_{res,w} = \frac{0.00001}{2} = 0.000005 \, m$$

$$U_{Width} = \sqrt{0.000710439^2 + 0.000005^2} = 0.000710456 \, m$$

$$U_{rand,t} = s_t * t_{n=5,95\%} = 5.36656 * 10^{-5} * 2.77 = 0.000148654 \, m$$

$$U_{res,t} = \frac{0.00001}{2} = 0.000005 \, m$$

$$U_{thickness} = \sqrt{0.000148654^2 + 0.000005^2} = 0.000148738 \, m$$

$$U_{Area,width} = 0.002946 * 0.000710456 = 2.093 * 10^{-6} \ m^2$$

$$U_{Area,thickness} = 0.012926 * 0.000148738 = 1.92259 * 10^{-6} \ m^2$$

$$U_{Area} = \sqrt{2.093 * 10^{-6^2} + 1.92259 * 10^{-6^2}} = 2.84201 * 10^{-6} \ m^2$$

$$U_{E,Area} = -\frac{1490}{(3.808 * 10^{-5})^2 (0.015206548)} * (2.84201 * 10^{-6}) = -192037916.9 \ Pa$$

$$U_{E,Force} = \frac{1}{(3.808 * 10^{-5})(0.015206548)} * 2.5 = 4317302.395 \ Pa$$

$$U_E = \sqrt{(-192037916.9 \ )^2 + (4317302.395)^2} = 192086440.5 \ Pa \ \approx 0.192 \ GPa$$

$$E \approx 2.57 \pm 0.192 \ GPa$$

Raw Data – Hardness Test

	Material Type		
Test #	AR500 Steel HRC	Aluminum HRC	Brass (Gold) HRB
1	56	6	73
2	61	7	77
3	57	5	77.5
4	58	4	68
5	56	7	72.5

Sample Calculations – Hardness Test

Hardness value mean calculation

$$\bar{x}_{AR500} = \frac{\sum y_i}{N} = \frac{288}{5} = 57.6$$

$$\bar{x}_{Aluminum} = \frac{\sum y_i}{N} = \frac{29}{5} = 5.8$$

$$\bar{x}_{Brass} = \frac{\sum y_i}{N} = \frac{368}{5} = 73.6$$

Hardness uncertainty value calculation

$$U_{AR500} = \sqrt{U_{AR500,res}{}^2 + U_{AR500,rand}{}^2}$$

$$U_{Aluminum} = \sqrt{U_{Aluminum,res}{}^2 + U_{Aluminum,rand}{}^2}$$

$$U_{Brass} = \sqrt{U_{Brass,res}{}^2 + U_{Brass,rand}{}^2}$$

$$U_{AR500,res} = \frac{1}{2} = 0.5$$

$$U_{AR500,rand} = s_{AR500} * t_{n=5,95\%} = 2.073644135 * 2.77 = 5.743994255$$

$$U_{AR500} = \sqrt{0.5^2 + 5.743994255^2} = 5.765715047$$

$$U_{Aluminum,res} = \frac{1}{2} = 0.5$$

$$U_{Aluminum,rand} = s_{Aluminum} * t_{n=5,95\%} = 1.303840481 * 2.77 = 3.611638132$$

$$U_{Aluminum} = \sqrt{0.5^2 + 3.611638132^2} = 3.646084201$$

$$U_{Brass,res} = \frac{1}{2} = 0.5$$

$$U_{Brass,rand} = s_{Brass} * t_{n=5,95\%} = 3.863288754 * 2.77 = 10.70130985$$

$$U_{Brass} = \sqrt{0.5^2 + 10.70130985^2} = 10.71298429$$

$$HRC_{AR500} = 57.6 \pm 5.765715047$$

$$HRC_{Aluminum} = 5.8 \pm 3.646084201$$

$$HRB_{Brass} = 73.6 \pm 10.71298429$$

Raw Data – Roughness Test

	125P Pattern			
Test #	Ra	Rq	Rp	Rv
1	2.022	2.613	7.261	3.315
2	1.989	2.557	7.009	3.409
3	1.923	2.492	6.848	3.175
4	1.94	2.484	6.806	3.133
5	1.96	2.498	6.794	3.362

	16BL Pattern			
Test #	Ra	Rq	Rp	Rv
1	0.392	0.502	0.672	1.681
2	0.392	0.507	0.729	1.821
3	0.396	0.517	0.663	1.87
4	0.403	0.526	0.688	1.794
5	0.401	0.521	0.674	1.734

	500P Pattern			
Test #	Ra	Rq	Rp	Rv
1	3.539	4.651	8.963	11.614
2	3.517	4.701	9.029	11.951
3	3.529	4.691	8.924	11.832
4	3.333	4.259	8.514	9.537
5	3.429	4.24	8.258	8.887

Sample Calculations – Roughness Test

Hardness value mean calculation

$$\overline{Ra}_{125P} = \frac{\sum Ra_i}{N} = \frac{9.834}{5} = 1.9668$$

$$\overline{Ra}_{16BL} = \frac{\sum Ra_i}{N} = \frac{1.984}{5} = 0.3968$$

$$\overline{Ra}_{500P} = \frac{\sum Ra_i}{N} = \frac{17.347}{5} = 3.4694$$