California State University, Long Beach

Department of Mechanical and Aerospace Engineering

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Lab Report
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Title: TORSION TEST OF METALS AND POLYMERS

Course Number: MAE 361
Section Number: Sec 03
Class Number: Eng 4 125

Instructor: Dr. Shamim Mirza

OBJECTIVE

The purpose of the experiment is to observe the modulus of elasticity of different engineering materials and to be able to develop a shear stress and shear strain diagram in the elastic range. In this experiment, the materials being used are a steel bar and an aluminum bar.

PROCEDURE and LIST OF APPARATUS

Apparatus

Figure 1:Tinius Olsen Lo-Torq Torsion Testing Machine

Figure 2: Pittsburgh Digital Caliper

A torsion test is conducted in order to determine the amount of force required to twist a material. The test is done by inserting a specimen into a machine that applies force up to a certain angle. The effects of the applied forces can be observed through a graph or data values which can help identify a material's properties.

The first step is to turn on the torsion testing machine. No warm-up period is required for this machine. The drum angle is then set to zero using the START, FORWARD/ REVERSE, and SPEED controls on the torsion testing machine. When triggering the START, the movement direction must be specified which is shown on the drum. The diameter of the sample is then measured in three different locations, at the two ends and in the center of the bar, using a digital caliper. The diameter measurements are recorded onto the data sheet.

After taking the measurements, the specimens are mounted in the self-tightening chucks of the machine. In order to do so, the weighing chuck is slid along the bed of the machine and the jaws of the chuck are opened to permit insertion of the specimen. The specimen is then inserted into the loading chuck and the weighing chuck assembly is slid to the right until it is stopped by the specimen ends bearing against the inside of the chuck. The weighing chucks are adjusted about ½ inch and the specimen is repositioned midway between the chucks. The jaws are tightened alternately so that the reference lines on the pins of each grip are concentric with the reference rings on the face plates of the chucks. The length of the specimen is measured from grip to grip and recorded on the data sheet.

On the Control panel, the test parameters are set by the instructor. In this case, a twist angle of 3° was used at a range of 0-1000 lb-in of torque where the range used depends on the material being tested. This is done carefully to get a good graph. After exiting the user interface, a graph will appear on the screen.

Before starting the test, the display screen is checked by the instructor to make sure all the proper indicators are set in place. The test is started using the START/STOP and FORWARD switch and the speed is adjusted by using the SPEED knob to make sure the speed isn't too high. The machine is stopped once the graph starts to deviate from linearity at an angle of 3°. The test is then repeated in the opposite direction by using START and REVERSE switches. This process is continued until the graph is back to zero.

Once finished, the STEP is pressed so that the bottom right corner shows DONE. The graph is then printed using the PRINT button. The graph is used to take the values of torque and twist angle for use in the calculations.

The final step is to unload the specimen from the machine. The same process is repeated from start to finish if another specimen is being tested.

Samples

Figure 3: Steel Bar

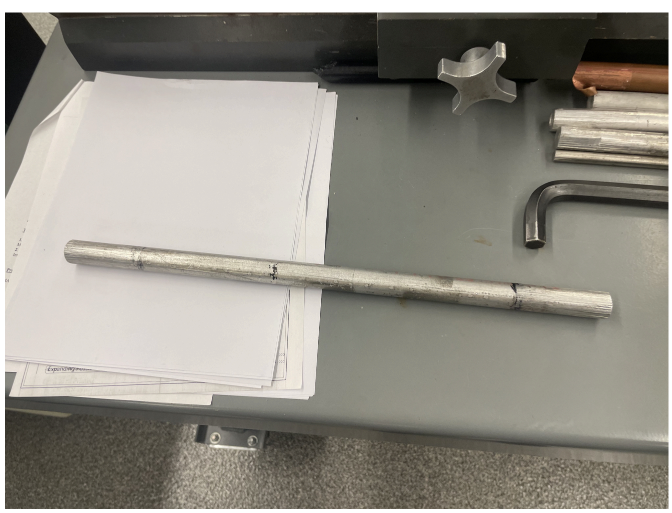

Figure 4: Aluminum Bar

DATA & RESULTS

Table 1: Diameter and Length of Steel and Aluminum Rods

Material	**Diameter at 3 different points (Inches)**	**Length (Inches)**
Steel	**D1 = .75** **D2 = .75** **D3 = .75**	**L = 13.75**
Aluminum	**D1 = .746** **D2 = .748** **D3 = .75**	**L = 11.15**

Table 1: Steel Data Loading

Torque T In.-lbs	Angle θ Degrees	Angle θ radians	Shear Stress τ psi	Shear Strain γ radians	Shear Modulus G ksi	Gstan	%Error Gexp	γ theor rad	% Error γ exp
0	0	0	0	0	0	10878	N/A	N/A	N/A
56	.20	0.003491	676.043	9.52E-05	7101	10878	34.72	6.21E-05	34.72
112	.34	0.005934	1352.086	1.62E-04	8355	10878	23.20	1.24E-04	23.20
168	.50	0.008727	2028.129	2.38E-04	8521	10878	21.66	1.86E-04	21.66
224	.73	0.012741	2704.172	3.47E-04	7782	10878	28.46	2.49E-04	28.46
280	.96	0.016755	3380.215	4.57E-04	7397	10878	32.00	3.11E-04	32.00
336	1.30	0.022689	4056.258	6.19E-04	6555	10878	39.74	3.73E-04	39.74
392	1.63	0.028449	4732.301	7.76E-04	6099	10878	43.93	4.35E-04	43.93
448	1.92	0.033510	5408.344	9.14E-04	5918	10878	45.60	4.97E-04	45.60
504	2.40	0.041888	6084.387	1.14E-03	5326	10878	51.04	5.59E-04	51.04
560	2.82	0.049218	6760.430	1.34E-03	5037	10878	53.70	6.21E-04	53.70

Table 2: Steel Data Unloading

Torque T In.-lbs	Angle θ Degrees	Angle θ radians	Shear Stress τ psi	Shear Strain γ radians	Shear Modulus G ksi	Gstan	%Error Gexp	γ theor rad	% Error γ exp
0	0	0	0	0	0	10878	N/A	N/A	N/A
56	1.2	0.020944	676.043	5.71E-04	1184	10878	39.12	6.21E-05	39.12
112	1.44	0.025133	1352.086	6.85E-04	1973	10878	21.87	1.24E-04	21.87
168	1.69	0.029496	2028.129	8.04E-04	2521	10878	26.82	1.86E-04	26.82
224	1.93	0.033685	2704.172	9.19E-04	2944	10878	22.94	2.49E-04	22.94
280	2.15	0.037525	3380.215	1.02E-03	3303	10878	29.64	3.11E-04	29.64
336	2.3	0.040143	4056.258	1.09E-03	3705	10878	35.94	3.73E-04	35.94
392	2.52	0.043982	4732.301	1.20E-03	3945	10878	33.73	4.35E-04	33.73
448	2.68	0.046775	5408.344	1.28E-03	4240	10878	31.03	4.97E-04	31.03
504	2.84	0.049567	6084.387	1.35E-03	4501	10878	48.62	5.59E-04	48.62
560	2.84	0.049567	6760.430	1.35E-03	5001	10878	54.03	6.21E-04	54.03

Table 3: Aluminum Data Loading (error in data due to slippage)

Torque T In.-lbs	Angle θ Degrees	Angle θ radians	Shear Stress τ psi	Shear Strain γ radians	Shear Modulus G ksi	Gstan ksi	%Error Gexp	γ theor rad	% Error γ exp
0	0	0	0	0	0	3916	N/A	N/A	N/A
18	0.1	0.001745	219.047	5.85E-05	3742	3916	4.43	5.59E-05	4.43
36	0.22	0.00384	438.095	1.29E-04	3401	3916	13.14	1.12E-04	13.14
54	0.36	0.006283	657.142	2.11E-04	3118	3916	20.37	1.68E-04	20.37
72	0.48	0.008378	876.189	2.81E-04	3118	3916	20.38	2.24E-04	20.38
90	0.7	0.012217	1095.236	4.10E-04	2673	3916	21.75	2.80E-04	21.75
108	0.95	0.016581	1314.284	5.56E-04	2363	3916	19.66	3.36E-04	19.66
126	1.22	0.021293	1533.331	7.14E-04	2147	3916	15.18	3.92E-04	15.18

144	1.46	0.025482	1752.378	8.55E-04	2050	3916	17.65	4.47E-04	17.65
162	1.93	0.033685	1971.425	1.13E-03	1745	3916	15.44	5.03E-04	15.44
180	2.4	0.041888	2190.473	1.41E-03	1559	3916	20.19	5.59E-04	20.19

Table 3: Aluminum Data Unloading (error in data due to slippage)

Torque T In.-lbs	Angle θ Degrees	Angle θ radians	Shear Stress τ psi	Shear Strain γ radians	Shear Modulus G ksi	Gstan ksi	%Error Gexp	γ theor rad	% Error γ exp
0	0	0	0	0	0	3916	N/A	N/A	N/A
18	1.68	0.029322	219.047	9.84E-04	223	3916	14.31	5.59E-05	14.31
36	1.85	0.032289	438.095	1.08E-03	404	3916	19.67	1.12E-04	19.67
54	2.12	0.037001	657.142	1.24E-03	529	3916	16.48	1.68E-04	16.48
72	2.28	0.039794	876.189	1.33E-03	656	3916	13.24	2.24E-04	13.24
90	2.46	0.042935	1095.236	1.44E-03	761	3916	20.58	2.80E-04	20.58
108	2.67	0.0466	1314.284	1.56E-03	841	3916	18.53	3.36E-04	18.53
126	2.8	0.048869	1533.331	1.64E-03	935	3916	16.11	3.92E-04	16.11
144	2.91	0.050789	1752.378	1.70E-03	1029	3916	13.73	4.47E-04	13.73
162	2.98	0.052011	1971.425	1.74E-03	1130	3916	21.14	5.03E-04	21.14
180	3	0.05236	2190.473	1.76E-03	1247	3916	18.15	5.59E-04	18.15

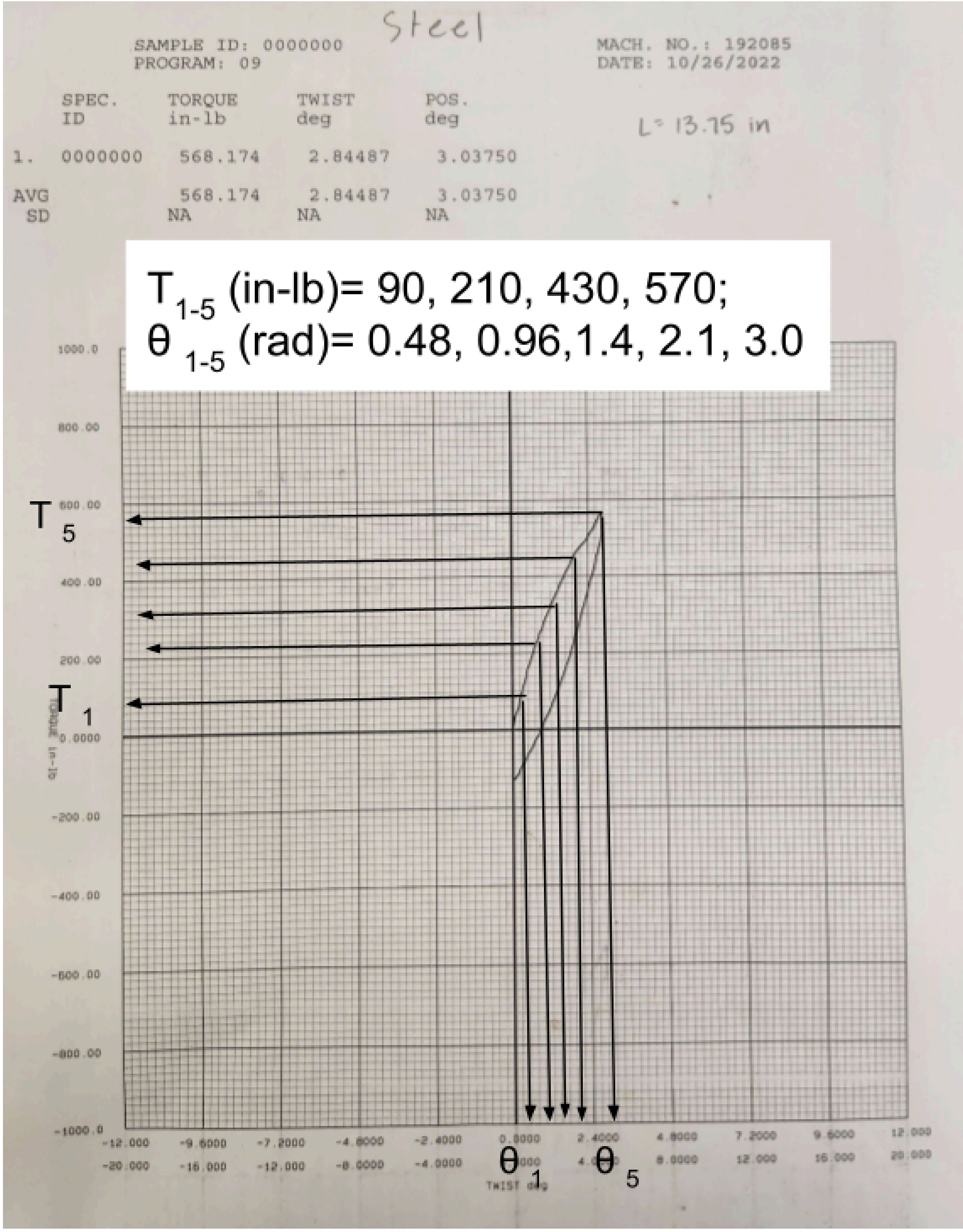

Figure 5: Steel Torque vs Twist Angle Graph

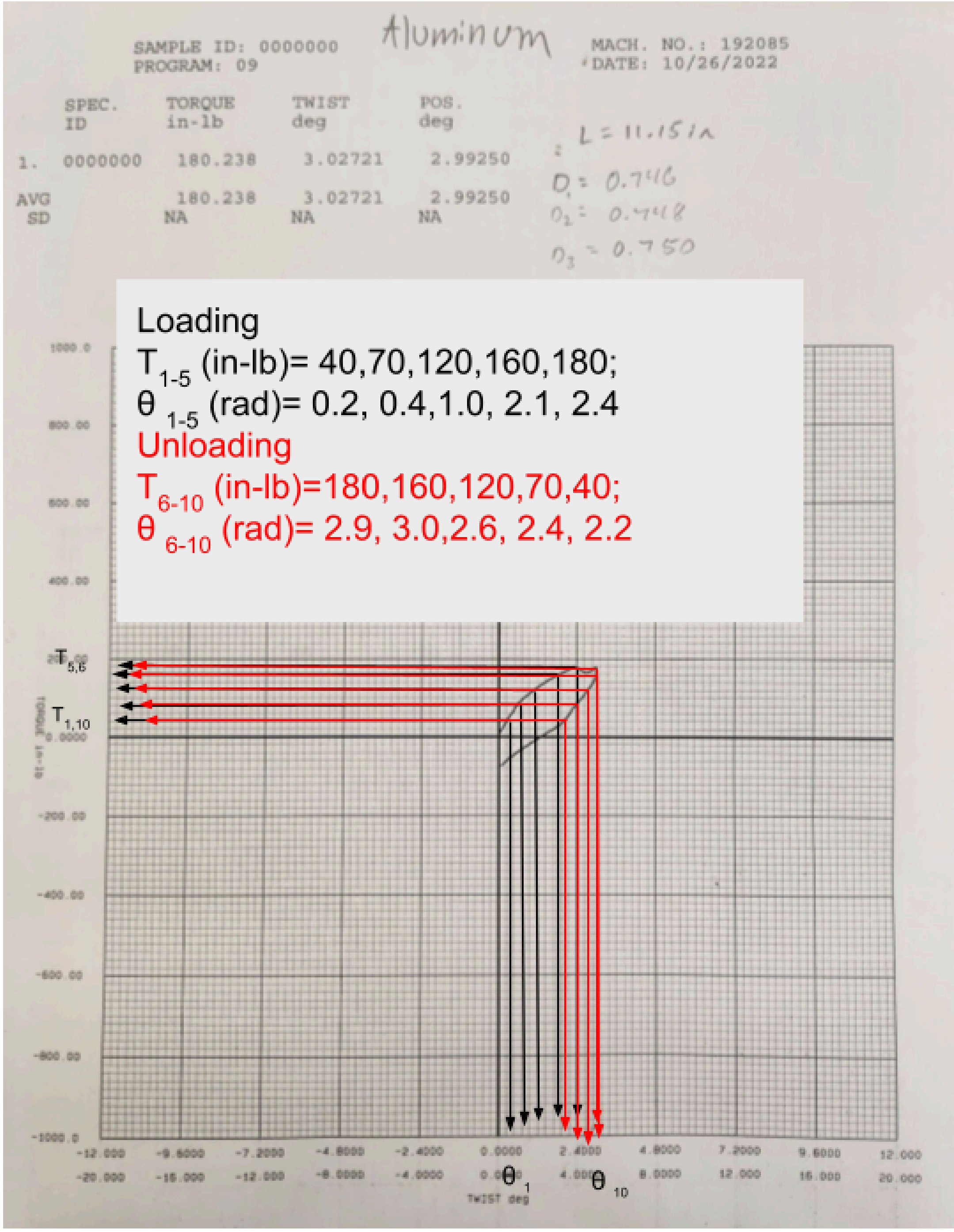

Figure 6: Aluminum Torque vs Twist Angle Graph

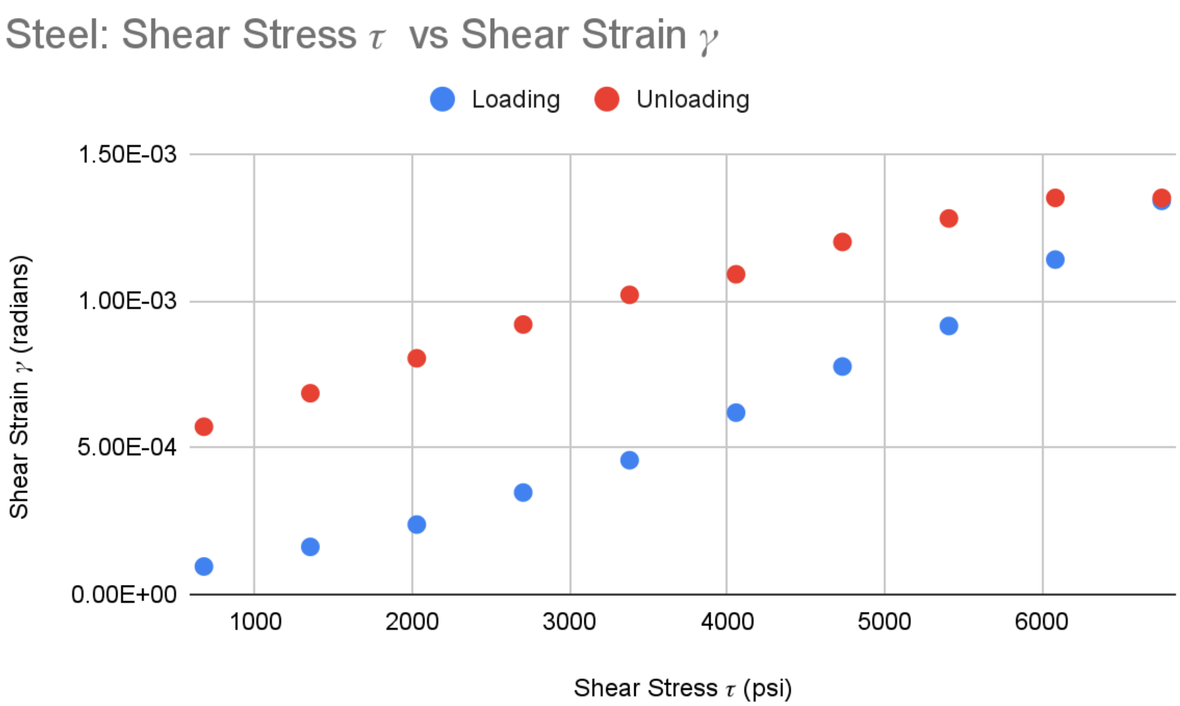

Figure 7: Steel Shear Stress vs Shear Strain

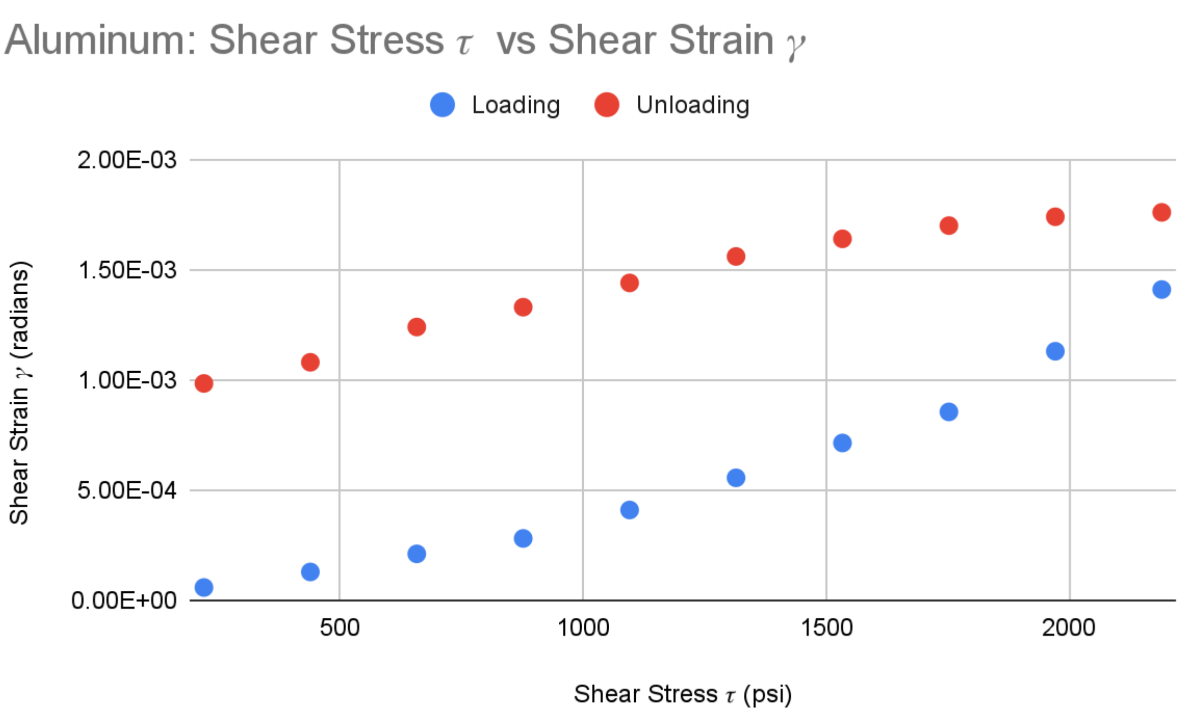

Figure 8: Aluminum Shear Stress vs Shear Strain

SAMPLE CALCULATIONS for STEEL

1. Shear Stress τ =Tc/J =Tc/($\pi c^4/2$)= T/($\pi c^3/2$)= 56/($\pi(.75/2)^3/2$) = 676.04 psi
2. Shear Strain γ_{exp}= cxθ/L= .75/2x .003491/13.75= 9.52x10^{-5} rad
3. G_{exp}=$\boldsymbol{\tau}_{exp}/\gamma_{exp}$= 126.76 psi/9.52x$10^{-5}$= 7.100x$10^3$ksi
   a. G_{st}= 10.9x10^3ksi, % Error = (G_{st}-G_{ex})/G_{st} x 100% = (10.9-7.1)/10.9 x100%= 35%
4. γ_{theor}= τ_{exp}/G_{st}= 676/(10.9x10^6)= 6.21E-05 rad
   a. % Error = (γ_{theor}-γ_{exp})/γ_{exp} x 100%= |(6.21x10^{-5}-9.52x10^{-5})|/9.52x10^{-5} x100%=35%

DISCUSSION

Referenced Aluminum shear modulus: 3.9x10^3 ksi, Steel shear modulus: 10.9x10^3ksi

For our actual values, we ended up with much smaller values of the shear modulus than the published values. This was most likely due to the improper securing rod during tests. Since the rod was loose, it ended up slipping during the actual test. The slip most likely decreased the actual shear modulus, explaining the large error. This is especially present in the aluminum’s torsion graphs as there was a slippage evident.

ANSWERS TO INSTRUCTOR’S QUESTIONS

1. Specify three assumptions that have been made in deriving the equations used in this experiment. (3 points)

The first assumption is that the material is homogeneous and isotropic in its entire length. The second assumption is that the applied torque is uniform across the length of the material and that it obeys Hooke’s law. The third assumption is that the cross section remains circular throughout the whole process of the torsion test.

2. Name three limitations of torsion formulae. (3 points)

The torsion equations can be only used with a circular shaft, materials that are homogeneous in nature, and material must obey Hooke's law.

3. Can the same equations be used with a square shaft? Explain. (4 points)
The same equations cannot be used with a square shaft because a square shaft has a different cross-section. Since there is no constant radius, we cannot use c.

4. Can the same formulae be used for a hollow shaft? Explain. (4 points)
Yes, the same formulae can be used for a hollow shaft, as long as it is a circular cross section. Shear strength is dependent on a constant circular radius in the formulae so the same method would work.

5. How does shearing strain vary with the distance from the axis of the shaft? (2 points)
Shear strain increases as the distance from the axis increases since they are proportional to each other. Shear strain reaches its maximum value once it reaches the outer surface of the shaft.

6. Large shafts of ocean liners are often made hollow. Explain the reason for this. Use a diagram if necessary. (4 points)
Ocean liners often use hollow shafts because they are as strong as solid ones but they are less heavy. Since a hollow shaft has less mass than a solid shaft, it creates less drag and consumes less fuel. Typically the center of the shaft experiences less stress and combined with less material cost, hollow shafts are ideal for more efficient performance and production.

RECOMMENDATIONS AND CONCLUSIONS

In this lab, we have seen the effects of torsion as they reach their modulus of elasticity through loading and unloading. Depending on how the metal is fitted, the metal will either twist normally, or experience an interruption. Additionally, we have been able to gain a greater understanding of the relationship between shear stress and shear strain as the metal twists. In both metals, the shear strain and shear strain increase as more load is added. In order to fix the shear modulus, groups should ensure that the rod is firmly tightened in order to avoid slipping.

Additionally, making sure the rod is not too much on one side would also assist in preventing slip.

8. REFERENCES AND ACKNOWLEDGEMENT

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