Experiment #3

Torsion Test on Metals

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Section PI-X

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1. Objective

The objective of this lab is to determine the shear modulus of different structural materials like brass, aluminum, and steel. These materials have negligible creep compared to the strain produced immediately upon loading.

2. Introduction

The shear modulus of elasticity is a very important property of a material that engineers must consider when designing the components of a system like the transmission shaft of a car. The shear modulus of elasticity is a measurement of the rigidity of the body given by a ratio of shear stress to shear strain below the proportional limit. In other words, the stiffness to shear forces. The torsion of a material (usually considered in cylindrical form) produces shear stresses in the body. The shear stress varies linearly from the center of the sample (cylinder) where the shear stress is zero to the maximum radius from the center where the shear stresses is at the greatest. The simple theory of torsion assumes that when the sample is in pure torsion that the planar sections remain planar after the torsion was applied but only in circular sections. This does not apply to other shapes of sections.

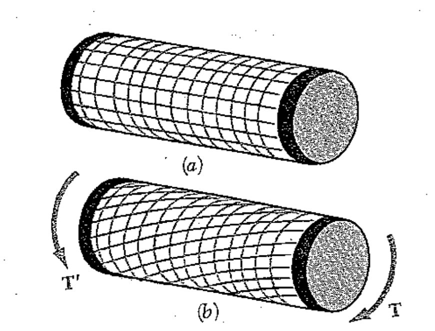


Figure 1: The Application of a Torsion Load on solid bars
[from Beer F. and Johnston, R. (1992)]

3. Procedure

Start by measuring the diameter of the specimen at three different sections to determine the average diameter of the sample using the micrometer. Note The gauge length of the specimen at the different stations. Proceed to press the green start button on the torsion testing machine display. Wait until the test is completed and the test data shows up on the computer desktop as a csv file to your specific group. This csv file can easily be opened with Excel or other spreadsheet software.

4. Analysis of the results

$$(1)\, J = \frac{(\pi D^4)}{32}$$
$$(2)\, G = \frac{Tl}{\theta J}$$
$$(3) D = \frac{(D1 + D2 + D3}{3}$$

where
T= torque, N(mm)
L= gauge length
θ = angel of twist, radians
J= polar moment of inertia, mm^4

Measurements of materials

sample	Diameter, D	Gauge length, L	Polar moment inertia, J
steel	6.062 mm	76 mm	$132.58\, mm^4$
aluminum	4.998 mm	100 mm	$61.26\, mm^4$
brass	6.007 mm	76 mm	$127.83\, mm^4$

Polar moment inertia, J

Steel

$$J = \frac{(\pi D^4)}{32}$$
$$J = \frac{(\pi (6.062mm)^4)}{32}$$

$$J = 132.58\, mm^4$$
$$J = 1.3258 \times 10^{-10} m^4$$

Aluminum

$$J = \frac{(\pi D^4)}{32}$$
$$J = \frac{(\pi (4.998mm)^4)}{32}$$
$$J = 61.26\, mm^4$$
$$J = 6.126 \times 10^{-10}\, m^4$$

Brass

$$J = \frac{(\pi D^4)}{32}$$
$$J = \frac{(\pi(6.007mm)^4)}{32}$$
$$J = 127.83\ mm^4$$
$$J = 1.2783 \times 10^{-10}\ m^4$$

Shear modulus, G

Steel

$$G = \frac{Tl}{\theta J}$$
$$G = \frac{(0.98NM)(0.076m)}{(0.0091)(1.3258 \times 10^{-10}m^4)}$$

G =61.733 GPa

Data for steel

Time (sec)	Torque (Nm)	Angle (deg)	angle(rad)	Shear Modulus
0	0.01	0.05	0.00087266	6568832770
0.1	0.07	0.09	0.0015708	25545460771
0.2	0.14	0.12	0.0020944	38318191156
0.3	0.19	0.15	0.00261799	41602607541
0.4	0.25	0.18	0.00314159	45616894234
0.5	0.33	0.22	0.00383972	49266245772
0.6	0.4	0.24	0.00418879	54740273080
0.7	0.46	0.27	0.00471239	55956723593
0.8	0.54	0.31	0.00541052	57212414445
0.9	0.6	0.34	0.00593412	57960289144
1	0.67	0.37	0.00645772	59474566968
1.1	0.77	0.42	0.00733038	60214300388
1.2	0.85	0.46	0.00802851	60690302763
1.3	0.92	0.49	0.00855211	61666593348
1.4	0.99	0.52	0.00907571	62530235019
1.5	1.06	0.56	0.00977384	62169310141
1.6	1.12	0.58	0.01012291	63423212948
1.7	1.18	0.61	0.01064651	63534612034
1.8	1.25	0.64	0.01117011	64148757516
1.9	1.33	0.68	0.01186824	64239320468

Data for Aluminum

Time (sec)	Torque (Nm)	Angle (deg)	Angle(rad)	G
0	0.03	0.61	0.01064651	459977999
0.1	0.05	0.67	0.01169371	697976566
0.2	0.06	0.74	0.01291544	758342106
0.3	0.08	0.79	0.0137881	947127694
0.4	0.08	0.81	0.01413717	923741825
0.5	0.08	0.83	0.01448623	901482986
0.6	0.09	0.85	0.0148353	990305574
0.7	0.1	0.89	0.01553343	1050886065
0.8	0.1	0.92	0.01605703	1016618041
0.9	0.12	0.95	0.01658063	1181417176
1	0.13	0.99	0.01727876	1228156745
1.1	0.15	1.02	0.01780236	1375424409
1.2	0.15	1.05	0.01832596	1336126569
1.3	0.15	1.08	0.01884956	1299011942
1.4	0.17	1.11	0.01937315	1432423979
1.5	0.18	1.15	0.02007129	1463929979
1.6	0.19	1.17	0.02042035	1518844732
1.7	0.2	1.19	0.02076942	1571913610
1.8	0.2	1.21	0.02111848	1545931567
1.9	0.22	1.27	0.02216568	1620184973

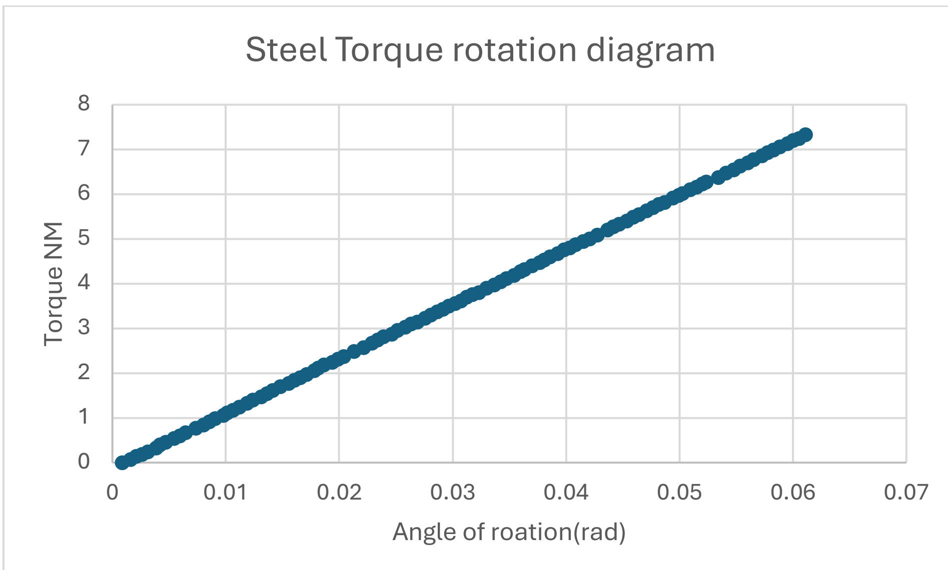
Data for brass

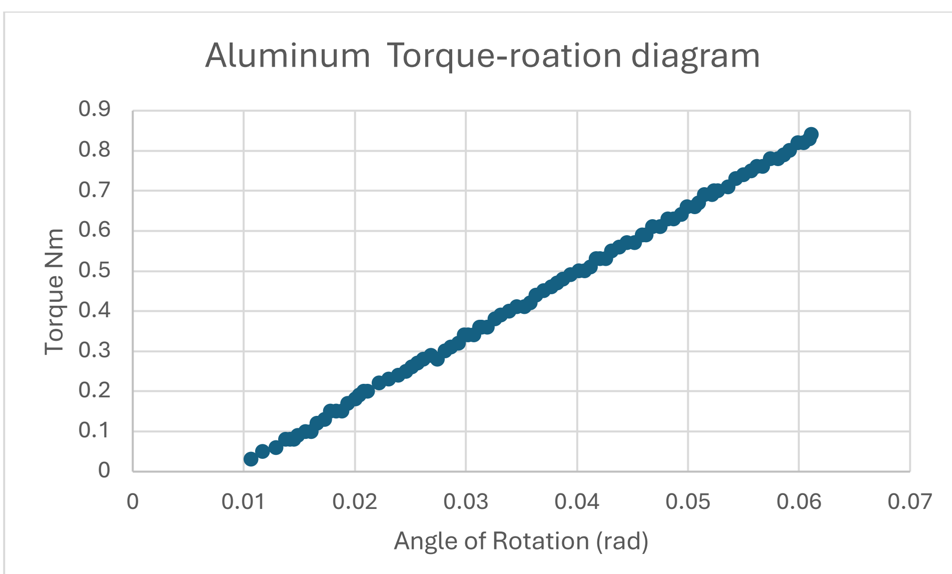
Torque (Nm)	Angle (deg)	Angle (rad)	G
0.08	0.07	0.00122173	38930984169
0.09	0.07	0.00122173	43797357190
0.12	0.1	0.00174533	40877533377
0.16	0.12	0.0020944	45419481530
0.17	0.14	0.00244346	41364170679
0.2	0.15	0.00261799	45419481530
0.23	0.17	0.00296706	46087415082
0.27	0.2	0.00349066	45987225049
0.31	0.23	0.00401426	45913171547
0.34	0.25	0.00436332	46327871161
0.37	0.28	0.00488692	45013950445
0.4	0.29	0.00506145	46985670548
0.43	0.32	0.00558505	45774321230
0.47	0.35	0.00610865	45743906398
0.51	0.37	0.00645772	46953923474
0.54	0.4	0.00698132	45987225049
0.58	0.43	0.00750492	45947615036
0.63	0.46	0.00802851	46653706572
0.67	0.49	0.00855211	46578141773
0.7	0.51	0.00890118	46755348634

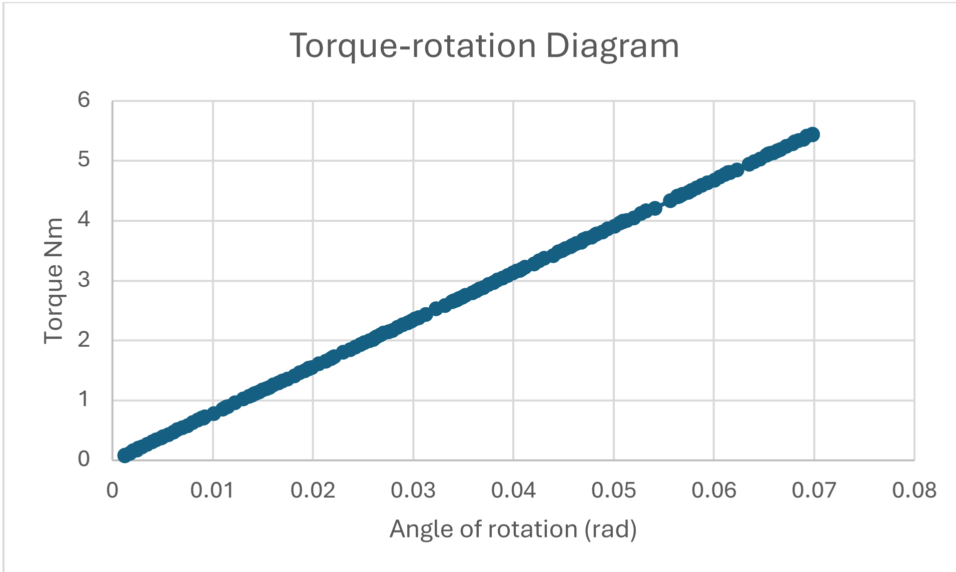
Experimental Shear modulus

Sample	**Average shear modulus**
Steel	64.883 GPa
Aluminum	18.17 GPa
brass	46.24 GPa

Torque-Rotation Diagram







The experimental value obtained for steel is 64.883 GPA and the literature value is 77 GPa. The obtained value resembles the literature value but does seem to hold some inaccuracy. The maximum torque applied was only 7.33 N.m and the max literature value for torque is 10.5 N.m. The experimental value obtained for aluminum was 18.17 GPa and the literature value is 26 GPa. Again this does resemble the literature value but does hold a significant amount of inaccuracy. For brass the experimental value obtained was 46.24 GPa and the literature value is 39 GPa. This sample is the only one where the experimental value is greater than the literature value but still odes resemble it.

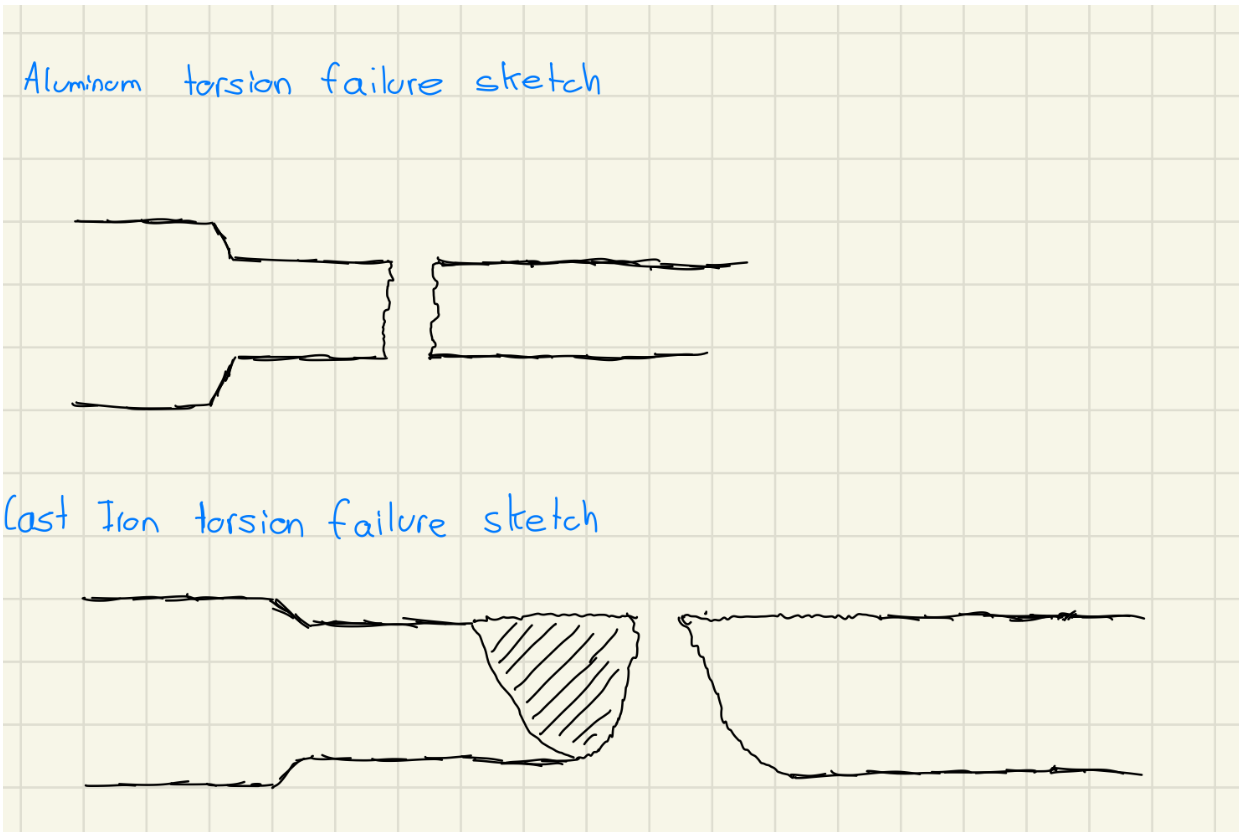
A possible factor that could have affected the results is that the samples have underwent creep and fatigue. Since many trials have been tested on the same samples, and the machines have been zeroed many times with the sample, the sample suffers many tiny torsions which are not taken into account. These torsions probably lead to tiny cracks or creep in the sample. Some materials are affected more by this like aluminum.

5. Discussion

1. An advantage of tubular specimens is that they have a great strength ratio than cylindrical. It has a low polar moment of inertia compared to solid cylinders which makes its modulus of shear stress higher according to (2).The average shear stress in a tubular sample is way higher than in a solid cylinder and it's value is closer to the maximum shear stress. Some disadvantages is that they are very easy to bend compared to solid cylinders and they have less torsional rigidity

   For solid cylindrical samples, some advantages are that their torsional rigidity is high compared to tubular specimens and are much more resistant to bending. Some disadvantages is that the average shear stress is minimum since the smallest shear is 0, and it has a high polar moment of inertia lower it's resistance to shear stress.

2.



Aluminum torsion failure sketch
Cast Iron torsion failure sketch

References

Beer F. and Johnston, R. (1992) Mechanics of Materials, McGraw-Hill.

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“Torsion Test.” *STEP Lab*, 8 Feb. 2024, step-lab.com/torsion-test/.