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Torsion of Shafts

Mechanics and Dynamics (ACHA4026)

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Introduction

This assignment aims to show the results of a shaft modulus experiment to calculate the shear modulus using the 'Torsion of Circular Shafts' kit ES5. For this assignment, shear modulus describes the elasticity of a solid under the application of transverse internal forces. For this assignment, it refers to torsion, which is twisting a metal bar lengthwise. Shear modulus can be expressed in the equation of 'shear modulus = (shear stress) / (shear strain). Specifically, this equation is a version of Hooke's law of elasticity.

(Britannica (2024))

Experimental Procedure

To begin, the rotating chuck is attached to the work panel. Next, the grub screw is loosened and the current rod being measured is inserted into the rotating chuck. Before being inserted however, the diameter of the rod must be measured. Next, attach the fixed chuck to the work panel and insert the other end of the rod. The rotating chuck must then be zeroed. To zero the chuck it is required to use the transparent cursor. Hold the torque arm at the 0° mark and tighten the grub screws of the rotating chuck. Ensure the chuck has been zeroed by adding the maximum weight being used and removing it, ensuring that the rotating chuck has returned to the 0° mark. Once the chuck has been zeroed, add 100g of weight and measure. This will be repeated every 100g up to 500g, with each measurement being written down. These steps must be followed for all three rods of Brass, Aluminium and Steel. Lastly, disassemble the work piece and put them away properly.



Results

Load (m) (g)	Twist Angle (degrees)
100	6.5
200	13.5
300	19.5
400	25.5
500	31.5
Material: Brass	$L = 0.34\text{m}$ $D = 3.1\text{mm}$

Load (m) (g)	Twist Angle (degrees)
100	8.5
200	16.5
300	24
400	32
Material: Aluminium	$L = 0.34\text{m}$ $D = 3.1\text{mm}$

Load (m) (g)	Twist Angle (degrees)
100	3.5
200	6
300	8
400	10.5
500	13.5
Material: Steel	$L = 0.34\text{m}$ $D = 3.1\text{mm}$

Analysis

Using the data gathered from the experiment, we can calculate multiple things, such as, Load, Torque, Twist Angle in radians. It also allows us to create a graph of the twist angle against the load

Brass

		Shaft Modulus				
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (degrees)	Twist Angle (θ) (Radians)	TL	J θ
100	0.981	0.098	6.5	0.113	0.033	1.03E-12
200	1.962	0.196	13.5	0.236	0.067	2.14E-12
300	2.943	0.294	19.5	0.340	0.100	3.09E-12
400	3.924	0.392	25.5	0.445	0.133	4.04E-12
500	4.905	0.491	31.5	0.550	0.167	4.98E-12
Material: Brass	L= 0.34 m	D = 3.1 mm	J=	9.07E-12		

As seen from the results in the lab, as the load was increased the twist angle in degrees increased by roughly 6 to 7 degrees each time weight was added. The results show that as the load on the brass shaft increases, the torque and angle of twist increase proportionally. The J θ values increase linearly which follows the expected results of the experiment. The TL values also increase uniformly with load. This means that the brass shaft did not get too twisted and it followed the torsion equation.

Aluminium

		Shaft Modulus				
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (degrees)	Twist Angle (θ) (Radians)	TL	J θ
100	0.981	0.098	8.5	0.148	0.033	1.35E-12
200	1.962	0.196	16.5	0.288	0.067	2.61E-12
300	2.943	0.294	24	0.419	0.100	3.8E-12
400	3.924	0.392	32	0.559	0.133	5.06E-12
Material: Aluminium	L= 0.34 m	D = 3.1 mm	J=	9.07E-12		

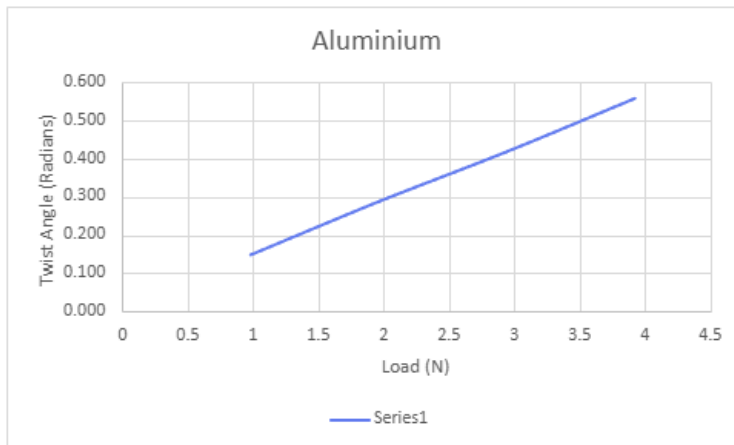
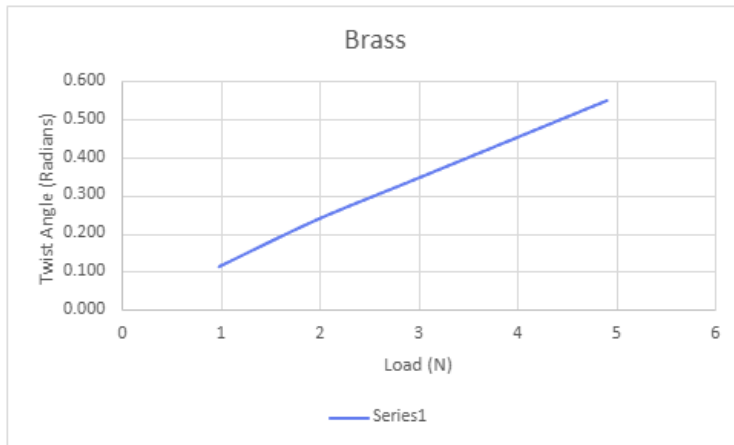
Due to being a more brittle metal, the load for aluminium was only able to be increased to a maximum of 400g. These results still show a constant increase in twist angle of about 8 degrees per 100g. As the load increases from 100 g to 400 g, the corresponding J θ values rise linearly from 1.35 E- 12 to 5.06 E- 12. The TL values also increase uniformly with load. This linear trend confirms elastic behaviour of the aluminium shaft

and shows that the torsion equation is satisfied, allowing the modulus of rigidity of aluminium to be determined from the data.

Steel

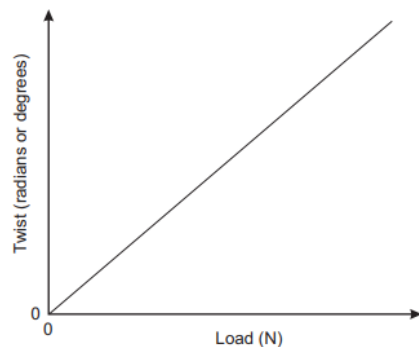
		Shaft Modulus				
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (degrees)	Twist Angle (θ) (Radians)	TL	J θ
100	0.981	0.098	3.5	0.061	0.033	5.54E-13
200	1.962	0.196	6	0.105	0.067	9.49E-13
300	2.943	0.294	8	0.140	0.100	1.27E-12
400	3.924	0.392	10.5	0.183	0.133	1.66E-12
500	4.905	0.491	13.5	0.236	0.167	2.14E-12
Material: Steel	L= 0.34 m	D = 3.1 mm	J=	9.07E-12		

The data shows that the twist angle for steel in degrees increases by roughly 2 to 3 degrees per additional 100g. The calculations show that as the load increases from 100 g to 500 g, the torque rises from 0.098 Nm to 0.491 Nm and the twist angle increases from about 3.5° to 13.5°. The TL values also stay consistent with the increase of load on the steel rod. This means that the results follow the expected trends that are likely to be seen.

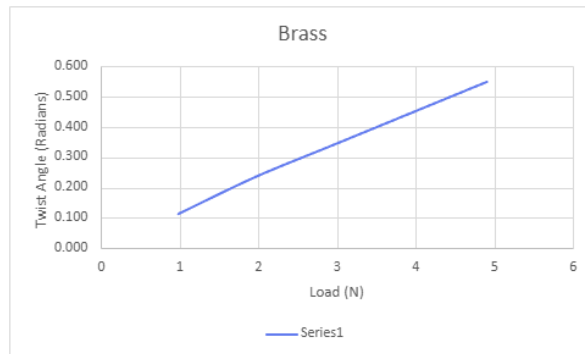


As seen in all three graphs, the twist angle against the load is almost linear. This follows the expected results as they should be constant and the graphs demonstrate this with slight deviations. This shows that the gathered results are quite accurate.

Conclusion



$$\theta \propto W$$



(TecQuipment (2012))

As no exact replica of our experiment could be found, using the perfect example graph provided in the guidance notes of the torsion kit. Using the graph, we can see that if our graph had been extended to the 0,0 point it would follow a very similar trendline to the perfect results. This proves that our results are what would be expected. The slight difference in our graph can be linked to either slight equipment deviation or slight human error. However, with how similar it is it proves that our results are accurate.

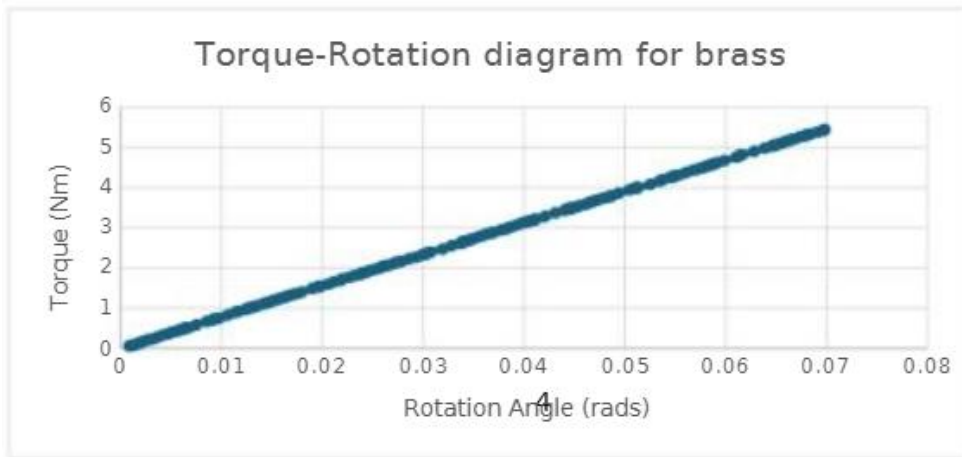
Table 3: Aluminum Torsion Test Data and Shear Modulus

Aluminum				
T(N.m)	θ (Deg)	θ (Rad)	G (GPa)	G_{av} (GPa)
0.100	0.80	0.0137	11.5	20.03
0.200	1.17	0.0204	15.8	
0.300	1.55	0.0271	17.9	
0.400	1.87	0.0326	19.8	
0.500	2.20	0.0384	21.0	
0.600	2.59	0.0452	21.4	

		Shaft Modulus				
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (degrees)	Twist Angle (θ) (Radians)	TL	J θ
100	0.981	0.098	8.5	0.148	0.033	1.35E-12
200	1.962	0.196	16.5	0.288	0.067	2.61E-12
300	2.943	0.294	24	0.419	0.100	3.8E-12
400	3.924	0.392	32	0.559	0.133	5.06E-12
Material: Aluminium		L= 0.34 m	D = 3.1 mm	J=	9.07E-12	

(Bessil Hedidor (2024))

A similar experiment which uses a different method shows a similarity between the twist angles. In both cases, the twist angle is shown to increase at a relatively constant rate. With both being similar it proves that the twist angle in our results are most likely correct with their measurements.



(Bessil Hedidor (2024))



We can also create a torque against twist angle graph to compare to the to this research papers torque against rotation angle graph. Comparing these it can be observed that they are quite similar with the almost perfectly straight line. This comparison shows that our results are similar to another person's results which implies they are somewhat correct.

Evaluation

Lots of methods were used to ensure there were a minimal number of errors while doing the experiment. To begin, we made sure that the rotating chuck was as accurately zeroed each time we changed the material rod. We also ensured that the weight added for each individual measurement was accurate. Whilst measuring the twist angle, we had at least two people watching the measurement apparatus to ensure we had the most accurate number recorded. We also made sure that the base and both the fixed and rotating chucks were in the same place for each material. In addition, we used a digital calliper for the diameter of each rod to ensure they are accurate to the amount of decimal places we needed.

Further Work

Given unlimited time and money, multiple things could've been improved. Firstly, I would higher tech and accurate equipment so that we could get a higher accuracy in our results. I would also repeat the experiment multiple times so that we could crossreference the results with each other to compare the resultsa and make the most accurate results possible and disregard any outliers in the results that may skew the final results. Next I would increase the number of materials tested to see if all materials followed the same theory or if any were outliers to the rules. Lastly, I would find as many available sources as possible online to compare my final results to have every base covered and get the definitive most accurate results possible.

References

Britannica "shear modulus" (<https://www.britannica.com/science/shear-modulus>)
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(file:///C:/Users/holga/Downloads/ES5%20Guidance_1012.pdf)
(Accessed: 02 January 2026)

Bessil Hedidor "Lab report 3 Torsion test on metals"
(<https://www.cliffsnotes.com/study-notes/20796016>) (Accessed 02 January 2026)