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Engineering Discipline



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1. Introduction

The aim of this report is to determine the modulus of rigidity/shear modulus of a cylindrical shaft specimen by using an apparatus designed to measure the twisting moment of said shaft. Due to the shaft experiencing a twisting moment, angular deformation takes place and is directly proportional to the applied torque whilst staying within the elastic limit for each individual specimen based on the properties of each material. This report will also present shear modulus results that have been researched. This is done to compare results from the analysis section respectively. The purpose of this comparison is to assess the validity of the results taken during the experimental procedure and subsequent data analysis.

2. Experimental Procedure

The procedure for the experiment is quite straightforward as it consists of only three different materials: Aluminium, Brass and Steel. It can be assumed that the Aluminium weighs less than the Brass and especially Steel due to its real-world applications compared to that of brass and steel. The experiment begins with the preparation of the first specimen, Brass. The diameter of the shaft has been measured at 0.0031 millimetres with the use of a digital vernier callipers, using the average figure from different places on the shaft will give the most accurate reading for the experiment (assuming the diameter of the specimen has no deformities or abnormalities).

A fixed and rotating chuck must first be fixed onto the apparatus parallel from each other at either end of the width of the apparatus using grubscrews to secure them, which are tightened with an Allen key (hex tool). It is also essential that the alignment of the cylindrical shaft with a length of 0.340 millimetres is levelled consistently between the fixed and rotating chucks at 0 degrees, any deviation from this step will give inaccurate readings. It is also recommended that the rotating chuck is zeroed to ensure that this error in procedure is mitigated.

Torque is then applied gradually to the cylindrical shaft by operating the loading system attached to the torsion testing apparatus. This load is subsequently increased in increments of 100 grams up to 500 grams, with exception to aluminium as the elastic limit of the material coupled with the small diameter of 0.0031 will cause the specimen to twist beyond its elastic limit. Whilst this occurs it is recommended that this procedure to measure the twisted angle, per 100 grams, is repeated at least three times per increment to ensure accuracy of the measured twisted angle under each weight to find the average figure or most consistent figure. It is important that the load being tested must be handled correctly. Any unnecessary movements like too much force being applied when releasing the load will also lead to inaccuracies in measurements seen on the twisted angle scale.

Once all readings are confirmed to be consistent, they are converted from degrees into radians and substituted into the torsion equation.



Figure 1 Weights in 10g

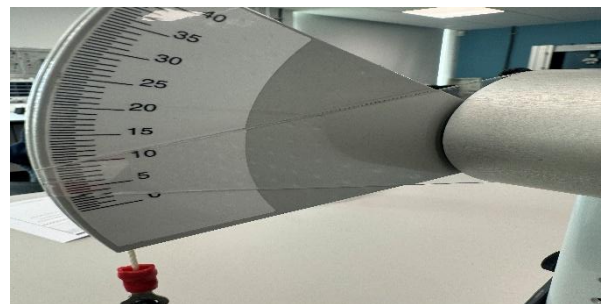


Figure 2 Scale

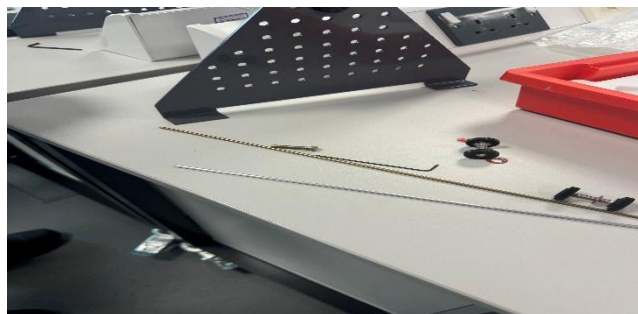


Figure 3 Brass, Aluminium and Steel rod

3. Results

This is the raw data collected from the experimental procedure. Aluminium is shown to have a significantly greater twist angle compared to that of steel when measured in the increment range of a 400-gram load. The difference is approximately 13.5 degrees.

Load (m) (g)	Load (w) (N)	Load (T) (Nm)	Twisted Angle (Degrees)	Twisted Angle (Radians)	TL	J θ
100			6.5			
200			12.5			
300			18			
400			24			
500			30			
Material: Brass	L=	0.34	D=		J=	

Figure 4 Raw data for Brass

Load (m) (g)	Load (w) (N)	Load (T) (Nm)	Twisted Angle (Degrees)	Twisted Angle (Radians)	TL	J θ
100			8.5			
200			17			
300			25.5			
400			32			
Material: Aluminium	L=	0.34	D =	0.0031	J =	

Figure 5 Raw data for Aluminium

3. Results

Load (m) (g)	Load (w) (N)	Load (T) (Nm)	Twisted Angle (Degrees)	Twisted Angle (Radians)	TL	J θ
100			3			
200			5.5			
300			8			
400			10.5			
500			13			
Material: Steel	L =	0.34	D=	0.00313	J =	

Figure 6 Raw data for Steel

4. Analysis

The data sets in these excel tables presents the raw data taken from the laboratory experiment and uses it to determine the shear modulus of the different materials. (Aluminium, Brass and Steel). The primary focus of this analysis is to ensure consistency with the predetermined band of tolerance for the GPa or GN.m⁻² value of each material specimen.

The excel formulae used:

To determine "Load (w) (Newtons)" =B3*9.81/1000

To determine "Load (T) (Newton Meters)" =C3/10

To determine "Twisted Angle in (Radians)" = E3*PI()/180

To determine "TL" =D3*\$D\$8

To determine "J" =PI()*F8^4/32

To determine "J0" =\$H\$8*F3

Load (m) (g)	Load (w) (N)	Load (T) (Nm)	Twisted Angle (Degrees)	Twisted Angle (Radians)	TL	J0
100	0.981	0.0981	6.5	0.113446401	0.033354	1.02858E-12
200	1.962	0.1962	12.5	0.218166156	0.066708	1.97804E-12
300	2.943	0.2943	18	0.314159265	0.100062	2.84837E-12
400	3.924	0.3924	24	0.41887902	0.133416	3.79783E-12
500	4.905	0.4905	30	0.523598776	0.16677	4.74728E-12
Material Brass:	L=	0.34	D=	0.0031	J=	9.06665E-12

Figure 7 Shear Modulus Data for Brass

Load (m) (g)	Load (w) (N)	Load (T) (Nm)	Twisted Angle (Degrees)	Twisted Angle (Radians)	TL	J0
100	0.981	0.0981	8.5	0.148352986	0.033354	1.34506E-12
200	1.962	0.1962	17	0.296705973	0.066708	2.69013E-12
300	2.943	0.2943	25.5	0.445058959	0.100062	4.03519E-12
400	3.924	0.3924	32	0.558505361	0.133416	5.06377E-12
Material Aluminium:	L=	0.34	D =	0.0031	J =	9.06665E-12

Figure 8 Shear Modulus Data for Aluminium

4. Analysis

Load (m) (g)	Load (w) (N)	Load (T) (Nm)	Twisted Angle (Degrees)	Twisted Angle (Radians)	TL	J θ
100	0.981	0.0981	3	0.05235988	0.033354	4.93374E-13
200	1.962	0.1962	5.5	0.09599311	0.066708	9.04518E-13
300	2.943	0.2943	8	0.13962634	0.100062	1.31566E-12
400	3.924	0.3924	10.5	0.18325957	0.133416	1.72681E-12
500	4.905	0.4905	13	0.2268928	0.16677	2.13795E-12
Material Steel:	L =	0.34	D=	0.00313	J =	9.42274E-12

Figure 9 Shear Modulus Data for Aluminium

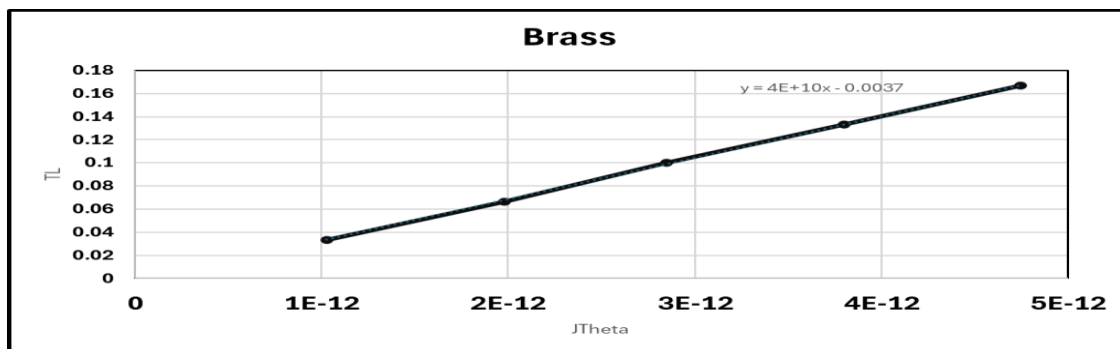


Figure 10 Shear Modulus Graph Data for Brass

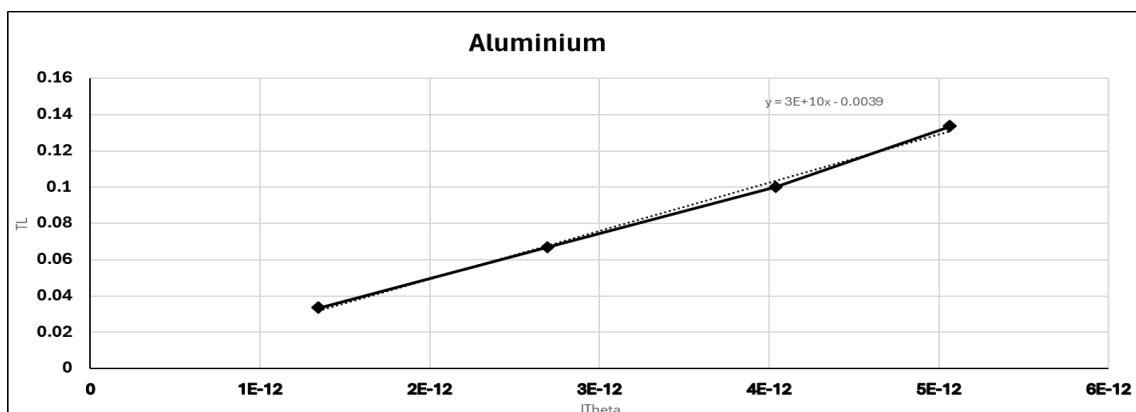


Figure 11 Shear Modulus Graph Data for Aluminium

4. Analysis

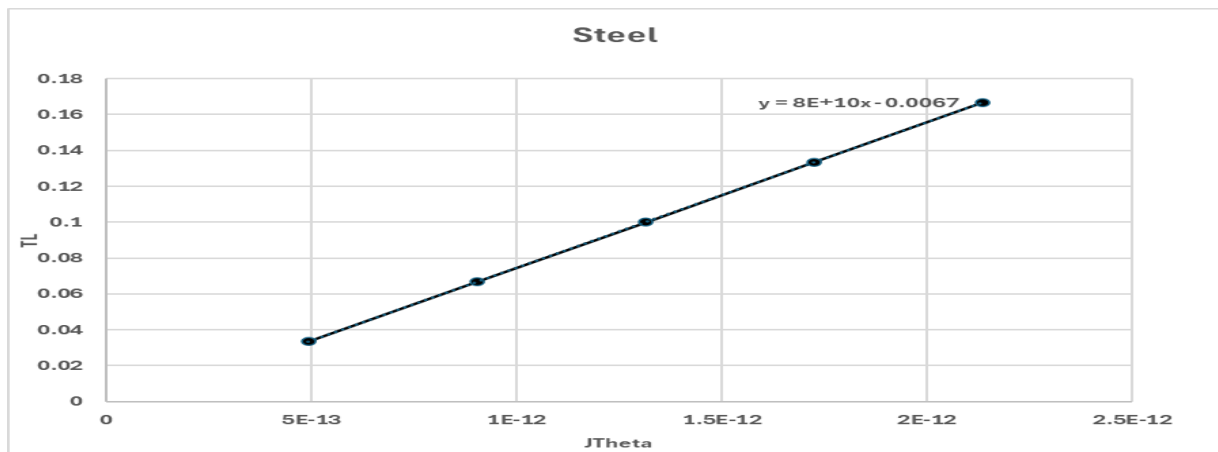


Figure 12 Shear Modulus Graph Data for Steel

5. Conclusion

This section presents a comparison between the shear modulus values obtained from research carried out by ([Raj, Aetukuri and Nanda, 2022](#)) and ([Rajesh, 2026](#)).

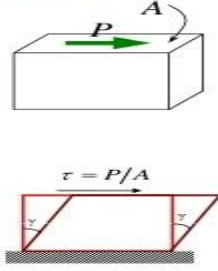
Metal	Yield strength (MPa)	Shear modulus (GPa)
Stainless steel (SS304 L)	515	77
Copper	210	45
Tungsten	750	161
Molybdenum	360	120
Nickel	317	72
Aluminium	90	25
Polycrystalline Lithium	0.89	2.83

Figure 13 Research Data for Steel & Aluminium

Shear modulus (modulus of rigidity)

Shear modulus, $G = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{\tau}{\gamma}$

Sl. No.	Material	Modulus of rigidity
1	Aluminium (pure)	26
2	Aluminium alloys	26-30
3	Brass	36-41
4	Bronze	36-44
5	Cast iron	32-69
6	Copper (pure)	40-47
7	Rubber	0.0002-0.001
8	Steel	75-80
9	Wrought iron	75



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Figure 14 Research Data Brass

The experimental results from the Excel graphs reiterate that aluminium has the highest twist of elastic angular deformation for applied torque, confirming that aluminium has the lowest shear modulus compared to that of brass and especially steel. This detail is consistent with the researched sheer modulus value of 25 GPa or 26-30 GPa. Thus, indicating the lowest resistance to torsional deformation.

Steel has the smallest angle of twist for a given torque, indicating the highest resistance to torsional deformation. This data also matches with the referenced data table above which states that steel has a relatively high shear modulus of 77 – 80 GPa. Thus, steel has the most minute elastic deformation compared to that of aluminium and brass.

Brass subsequently is the more balanced material of the two. Whereas aluminium has more elasticity and steel has more rigidity. Brass fall in between the two, indicating a more moderate resistance to elastic deformation. This is correlated in the referenced tables for the sheer modulus rating.

6. Evaluation

One of the primary sources of error arises from torque measurements. Inaccuracies can occur when using the 10-gram weights by applying too much downforce when releasing the weights. To reduce this, it is advisable to only release the weights from the top of the scale and let gravity perform the work. Friction inside the pulleys system itself could also skew results, the best way to eliminate these discrepancies would be to either take an average result from the twisted. Additionally, if weights are used it is advisable to ensure each weight is 10 grams.

If the material rods are not aligned correctly this will also skew the results for the twisted angle in degrees by a significant margin. Keeping a detailed list of checks to perform throughout the experiment is vital to ensure accurate data. Any discrepancy to the data will affect the result for the shear modulus. This error will lead to the experiment's effectiveness being nullified, subsequently forcing participants to have to repeat the experiment.

7. Further Work

Under the assumption that the shear modulus experiment has unlimited resources and time, it can be assumed naturally that better equipment/ instruments will garner more precise and accurate results.

A digital system that has been recently calibrated would be a good replacement for the current analogue apparatus. Another improvement would be to implement a computer-controlled motorized torsion system to perform the experiment without the chance of human error. Theoretically, the system could also apply torque in even smaller increments as well as measuring the torque being applied to the shaft simultaneously. By eliminating inconsistencies in loading, the experiments accuracy is significantly improved.

The twist angle could also be improved by implementing a scale that also measures how long it takes for the twist angle to occur and compare that time difference with the other materials. It would also be advisable to scan the shafts themselves to ensure no abnormalities or warping of the material.

Environmental effects could also be a contributing factor to inaccuracies within the experiment/lab area. By removing any chance for an increase in humidity, pressure and/or temperature ensure a more cohesive environment to perform the experiment within. An increase in temperature could lead the experiment to fail as the material could expand.

It would also be interesting to analyse the materials under significant stress whilst performing the experiment. This could be done by using a device that pulls the shaft in two directions to simulate stress.

If possible, it would also be productive to consider the effect the system itself has on the experiment especially if it's an analogue system as elements may cause friction within parts, such as the cord-pulley system for the weights. A separate graph could take these losses due to friction into account and mitigate them from the final excel results. See Figure(s) 7-9.

By allowing for unlimited resources, it is advisable to fully automate the system to eliminate human error and allow for continued experimentation throughout the analysis phase of the experiment. This will allow for a far more accurate overall result to compare referenced sheer modulus results. See figures 13-14.

8. References

(Raj, Aetukuri and Nanda, 2022)	Reference list Raj, V., Aetukuri, N.P.B. and Nanda, J. (2022). Solid state lithium metal batteries – Issues and challenges at the lithium-solid electrolyte interface. <i>Current Opinion in Solid State and Materials Science</i>, 26(4), p.100999. doi:https://doi.org/10.1016/j.cossms.2022.100999.
(Rajesh, 2026).	SHAMJITH KM (2026). <i>Mechanics of structures - module I</i>. [online] Slideshare. Available at: https://www.slideshare.net/slideshow/mechanics-of-structures-module1/37713602 [Accessed 4 Jan. 2026].