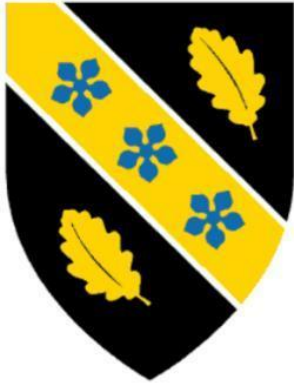


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Torsion of Shafts

Mechanics and Dynamics (ACHA4026)

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Contents

1.	Introduction	1
2.	Experimental Procedure	2
3.	Results	4
4.	Analysis	5
5.	Conclusion	8
6.	Evaluation.....	9
7.	Further Work	10
8.	References.....	11

1. Introduction

This report details an experiment on three different metals, where the metal rods have a torsional load applied and the results are used to calculate different figures, including the Modulus of Rigidity, known as 'G'.

Understanding torsional loads is critical in engineering. Any kind of vehicle uses rotational motion of some kind to drive the vehicle forwards. Chassis systems are also subject to all sorts of forces, including torsional forces. To create and optimise a chassis or any other kind of system that deals with rotational forces the engineer must have an understanding of different materials and their properties under these loads.

2. Experimental Procedure

Before experimentation began, the diameter of each length of material had to be taken. Each specimen was measured and recorded to be used later in analysis.

The experiment materials were then set up.

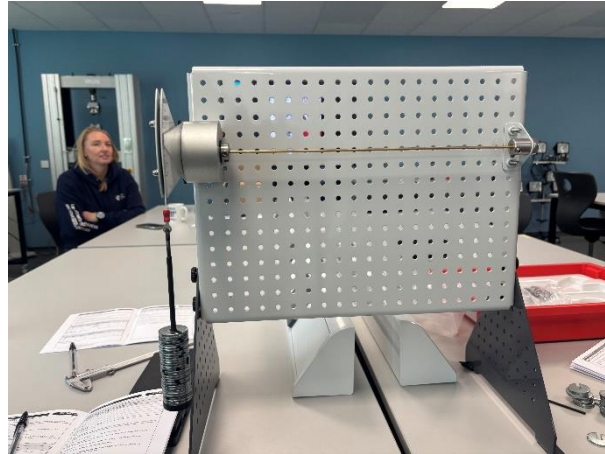


Figure 1 - Experiment Setup

Figure 1 shows the setup for the experiment, with the brass material fitted into the chucks on either end. The retaining screws are sufficiently tightened down to prevent the material slipping in them while under load. The length of material between the chucks is measured, and made sure to be 340mm, or 0.34m.

With no weight attached to the string on the end of the torque arm, the device is then zeroed, wherein the dial is adjusted to read zero while under no load.

A weight of 100g is attached to the end of the string, ensuring that the 10g weight of the carrier is included to ensure accuracy.

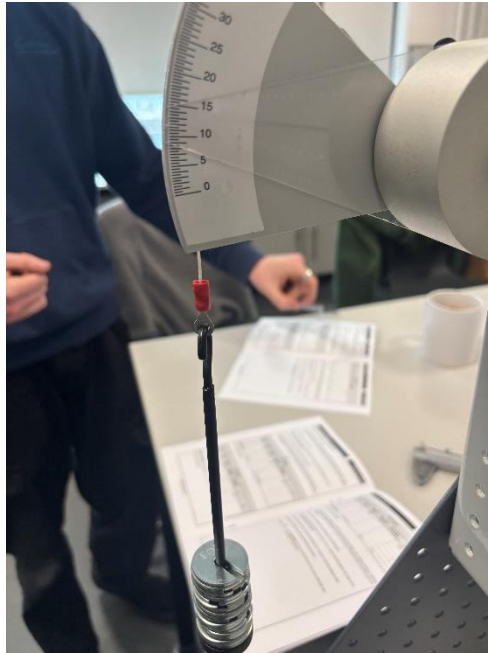


Figure 2 - Measuring Dial in use

Figure 2 shows the dial showing a reading with a weight attached. This dial shows the twist in degrees that the material undergoes from its fixed end when under load.

The twist is measured at 100g and the weight is removed. Once the weight is removed it is confirmed that the dial returns to zero degrees. If it does not the dial is re-zeroed and everything is checked to ensure the experiment is working correctly.

Extra weight is added to total 200g, and the procedure is repeated.

The procedure is repeated until a 500g load is measured (400g for aluminium), and the remaining materials have the process repeated until all three materials have measurements taken.

3. Results

Below are the raw data for the three materials, Brass, Aluminium and Steel.

Brass	
Load (g)	Twist Angle (degrees)
100	6
200	11.75
300	17.8
400	23.6
500	29.5

Aluminium	
Load (g)	Twist Angle (degrees)
100	7.5
200	15.25
300	22.75
400	30.5

Steel	
Load (g)	Twist Angle (degrees)
100	2.5
200	5
300	7.5
400	10
500	12.5

4. Analysis

Using the raw data collected and some known values:

Torsion Arm Length (m)	0.1
Sample Length (m)	0.34
Sample Diameter (m)	0.0031
Sample Radius (m)	0.00155

The following can be calculated for each material:

Brass	J (m^4)	9.06665E-12				
Load (kg)	Load (N)	Torque (Nm)	Twist Angle (Degrees)	Twist Angle (radians)	TL	JΘ
0.1	0.981	0.0981	6	0.104719755	0.033354	9.49E-13
0.2	1.962	0.1962	11.75	0.205076187	0.066708	1.86E-12
0.3	2.943	0.2943	17.8	0.310668607	0.100062	2.82E-12
0.4	3.924	0.3924	23.6	0.411897703	0.133416	3.73E-12
0.5	4.905	0.4905	29.5	0.514872129	0.16677	4.67E-12

Aluminium	J (m^4)	9.06665E-12					
	Load	Torque					
Load (kg)	(N)	(Nm)	Twist Angle (Degrees)	Twist Angle (radians)	TL	JΘ	
0.1	0.981	0.0981	7.5	0.130899694	0.033354	1.19E-12	
0.2	1.962	0.1962	15.25	0.266162711	0.066708	2.41E-12	
0.3	2.943	0.2943	22.75	0.397062405	0.100062	3.6E-12	
0.4	3.924	0.3924	30.5	0.532325422	0.133416	4.83E-12	

Steel	J (m^4)	9.06665E-12				
Load (kg)	Load (N)	Torque (Nm)	Twist Angle (Degrees)	Twist Angle (radians)	TL	JΘ
0.1	0.981	0.0981	2.5	0.043633231	0.033354	3.96E-13
0.2	1.962	0.1962	5	0.087266463	0.066708	7.91E-13

0.3	2.943	0.2943	7.5	0.130899694	0.100062	1.19E-12
0.4	3.924	0.3924	10	0.174532925	0.133416	1.58E-12
0.5	4.905	0.4905	12.5	0.218166156	0.16677	1.98E-12

The load is converted from g to kg, as is base units.

The load value in newtons is established by multiplying the load weight in kg by gravity, at 9.81m/s².

The Torque value is obtained by multiplying the load in Newtons by the length of the Torque Arm, which in this experiment was 100mm or 0.1m.

The twist angle in radians is obtained in this case by using the Excel function RADIANS(), but mathematically this would be done by multiplying the measured angle in degrees by 2π.

The value TL is the Torque figure multiplied by the length of the material.

The value for the Polar Second Moment of Area in M⁴, otherwise known as J, is calculated from the diameter of the material with the following equation:

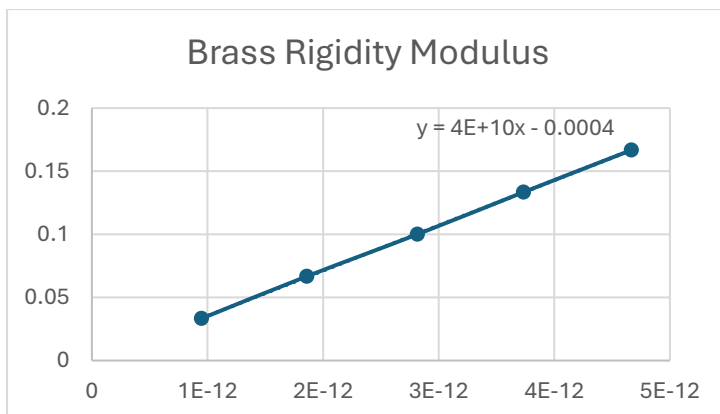
$$J = \frac{\pi \times Diameter^4}{32}$$

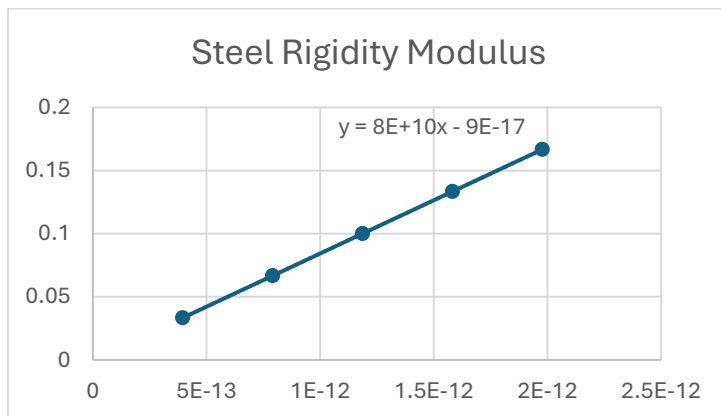
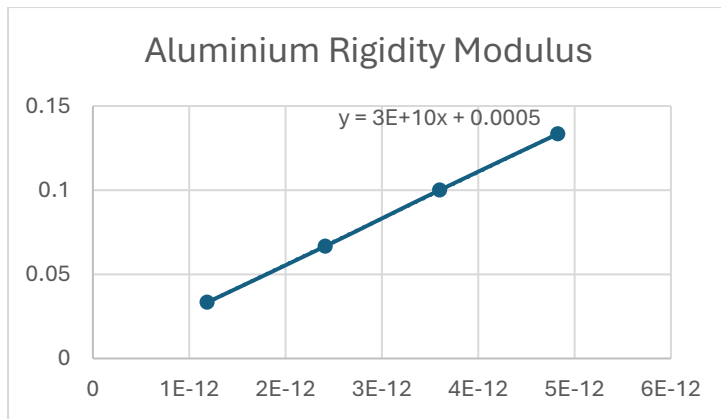
Which for all three materials gives the value 9.06665E-12, or 9.06665×10^{-12} .

The value JΘ is calculated by the Twist Angle in Radians multiplied by the value of J for each material.

Using these values, we can plot 'TL' against 'JΘ' in a graph, and use the gradient of this graph to determine the value G – the Modulus of Rigidity in Pascals or N/m².

The graphs are plotted as follows:





This gives a value for G of 35.81GPa for Brass, 27.55GPa for Aluminium, and 84.31GPa for Steel.

5. Conclusion

The values obtained track well with other researched examples when compared to each other.

For Brass a value of 35.81 GPa was obtained, with an average value of 38.9 GPa quoted by (MatWeb). The value quoted here was 8.63% higher than the measured value.

For Aluminium a value of 27.55 GPa was obtained, and according to (Fnides, Bensana et al. 2023) the modulus for aluminium alloys was between 33.249 GPa and 32.729 GPa, an average of 32.989 GPa. The value quoted here was 19.92% higher than the measured value. This is a significant disparity.

For Steel a value of 84.31 GPa was obtained. According to (Matlakhova, Pessanha et al. 2023) their researched values were between 79.2 GPa and 76.5 GPa, an average of 77.85 GPa. Here the quoted value is 7.66% less than the measured value.

The figures for brass and steel tracked reasonably well between other researched figures and the figures calculated here. There are several factors that could affect the result, so being within 10% is not bad. The figure for aluminium is further out than this, coming in significantly lower than figures researched. This could be because of several factors such as the specific material alloy, as well as the method of measurement.

6. Evaluation

During the experiment there were several methods used to try to eliminate error with the results.

One of these was as mentioned in the method, where after taking a measurement, it was confirmed that the dial reset to zero. If the dial read anything other than zero with no weight attached, the material must have slipped in the chuck due to insufficient tightening of the jaws. This would lead to an erroneous result, and by checking this did not happen this eliminated the error.

Undertaking the experiment were multiple people to a group. When taking measurements and counting weights each result and input was checked by multiple people. This ensured that the readings were fair on the analogue dial, and that the weight applied was not miscounted.

7. Further Work

Despite the effort to eliminate error, there is further precaution that could be taken to ensure more accurate results.

One thing that could be done is taking each measurement multiple times and using an average figure for each of these. This way if a single result was erroneous, it would be at least offset by the rest of the results hopefully being correct. If noticed, it could also be struck off and not used if a cause for the erroneous reading was identified.

Another measure for accurate readings could be in the materials used. The materials supplied here were not known exactly what they were – the contents of each alloy, especially the brass and steel, would make a large difference on the results expected.

As well as this, the materials used were quite thin. If a thicker material was used for the test a higher load could be applied and more weight increments used. This would increase the accuracy of the results gained.

Finally, the method of taking results could be improved. As previously stated the dial was analogue with small increments. Even when using multiple people the human factor can come in to play and results misread. A better solution would be to have a digital display to measure the twist, as well as weigh exactly the load applied to the material.

8. References

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