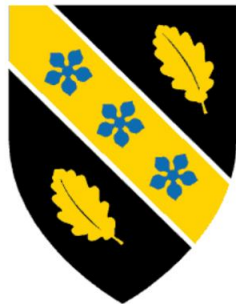


MODULE: MECHANICS AND DYNAMICS

MODULE CODE: ACHA4026

ASSIGNMENT 1

TORSION OF SHAFTS



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SUBMISSION DATE: SUN 4TH JANUARY 2026 - 10PM

1588 Words

(Tables not included as per Technical Report Guidelines)

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1 Introduction

This detailed report will cover a write up of an experiment that was carried out in the Lab. This experiment consists of exerting a twisting force on one end of a rod that has been fixed in place to gain a further understanding of "torsion of circular shafts". (TecQuiptment, 2012) This experiment includes testing three rods of different materials being brass, aluminium and steel. It will contain details of the experimental procedure that was followed as well as images taken during the experiment. This report will also include the results that were recorded and as well as calculated results that will be displayed in spreadsheets and graphs. Additionally, this report will also include a comparison between the results for shear modulus against the typical or expected results for shear modulus. Further to this, an evaluation will be conducted, detailing the ways in which errors during the experiment had been reduced or eliminated and control measures that were put in place. Further work will include control measures and different ways in which the experiment could be improved in terms of accuracy and repeatability, if unlimited time and resources were made available.

What is shear Modulus?

Shear modulus is a ratio that describes the torsional stiffness of a material by stating the shear stress and shear strain. This can be used to test different materials suitability for applications where a rod or beam will experience a twisting force. (TecQuiptment, 2012)

2 Experimental Procedure

Equipment required:

- Work panel
- Rotating chuck (With scale)
- Fixed chuck
- Weights
- Brass rod
- Aluminium rod
- Steel Rod
- Weights
- Vernier calliper (To measure diameter of rods)
- Allen Key (For tightening and loosening grub screws on fixed and rotating chuck)

Note: All was provided as part of the kit as well as the Assignment Brief, Guidelines and instructions/ Experimental Procedure.

Setup:

To prepare for this experiment, the work panel that featured holes across the surface to allow for the chucks and other components for different experiments to be attached at different heights and positions. With the help of the workbook provided, the setup was not difficult or very time consuming. Both chucks needed to be fixed to each side of the work panel. On the right side was the fixed chuck and on the left was the rotating chuck. These were fixed in place with plastic screws that were designed to be tightened by hand. After this, the first rod (Brass) was inserted through the left side of the fixed chuck and then threaded through to the rotating chuck. With the use of the provided Allen key, the grub screws on the fixed chuck were tightened to secure the rod and the scale was adjusted to be set to zero and the screw on the scale was tightened. While being held in place at zero, the grubscrews on the rotating chuck were tightened. At this point, the rod is secured at both ends, fixed at one end and allowed to be twisted from the other end when weights are added. Each rod (Brass, Aluminium and steel) is fitted in the same way. Before inserting each rod, the diameter of each was measured with the use of a vernier calliper.

The image below is showing the grubscrews being tightened, fixing the brass rod in place, before the scale was set to zero.

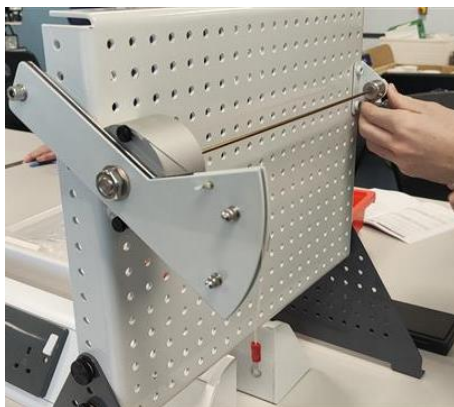


Figure 2.1

Below is an image showing the twist angle scale after being set to zero.

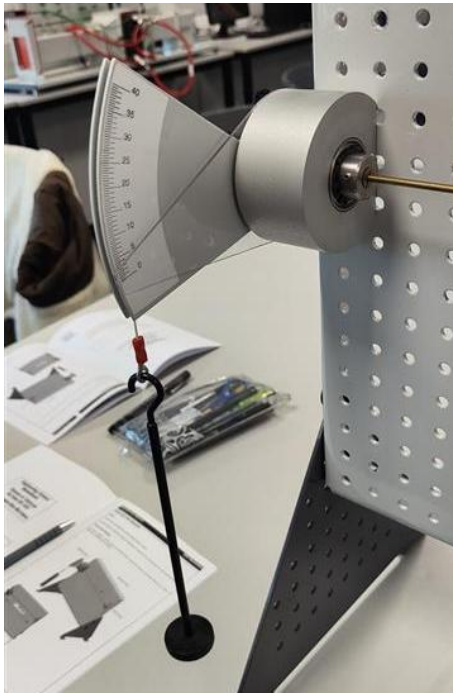


Figure 2.2

Experimental Procedure:

After initially setting up the experiment and ensuring the scale was zeroed and the rod was tightly secured, weights were added in increments of 100g. At each increment, the measurement from the scale was taken and recorded into the provided table in the “Twist angle” section. This was measured in degrees. This was repeated in increments of 100g until 500g was reached. It is important to note that for the Aluminium rod, 400g was the limit as 500g could twist the rod beyond its elastic limit, deeming it unusable for future experiments.

Additional images of experiment:

The image below is showing the brass rod supporting a load of 100g with the scale showing 6 degrees of twist angle.

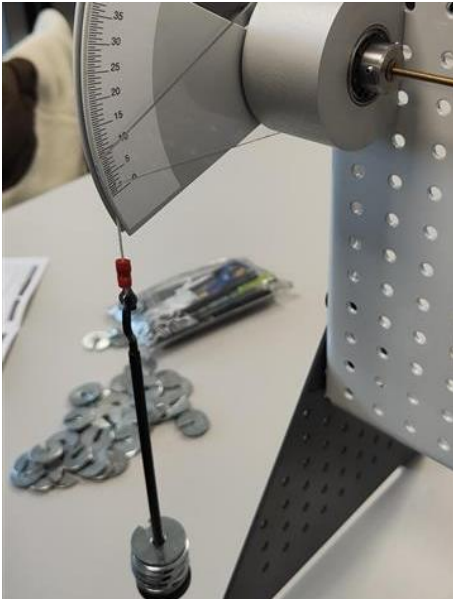


Figure 2.3

The image below is with the brass rod with a load of 500g and the scale showing 30.7 degrees.

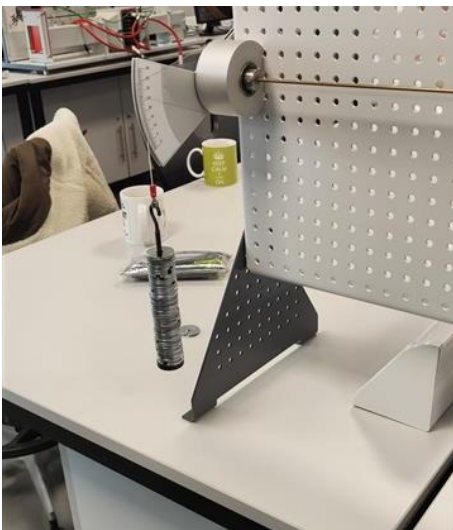


Figure 2.4

The image below is showing the steel rod supporting a load of 500g and reading 14 degrees of twist angle on the scale.

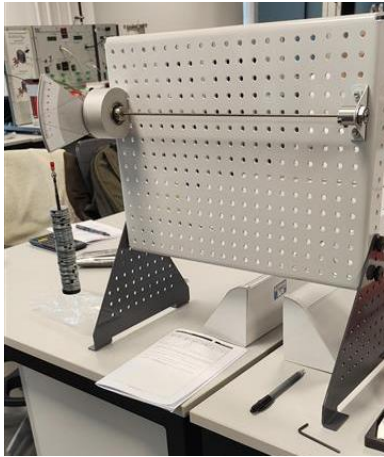


Figure 2.5

Note: Unfortunately images of the aluminium rod were not captured.

3 Results

Table 3.1

Load (m) (g)	Twist Angle (Degrees)		
100	6		
200	12.5		
300	18.5		
400	24.5		
500	30.7		
Material: Brass		$L = 0.34 \text{ m}$	$D = 3.1 \text{ mm}$

Table 3.2

Load (m) (g)	Twist Angle (Degrees)		
100	8.7		
200	16.5		
300	24		
400	32		
Material: Aluminium		$L = 0.34 \text{ m}$	$D = 3.05 \text{ mm}$

Table 3.3

Load (m) (g)	Twist Angle (Degrees)		
100	3.5		
200	6		
300	8.7		
400	11.5		
500	14		
Material: Steel		$L = 0.34 \text{ m}$	$D = 3.1$

4 Analysis

Table 4.1

Shaft Modulus						
Load (m) (g)	Load (w) (N)	Torque (T) (Nm)	Twist Angle (Degrees)	Twist Angle (θ) (Radians)	TL	$J\theta$
100	0.98	0.098	6	0.104	0.033	9.422×10^{-13}
200	1.96	0.196	12.5	0.218	0.066	1.975×10^{-12}
300	2.94	0.294	18.5	0.322	0.099	2.917×10^{-12}
400	3.92	0.392	24.5	0.425	0.133	3.850×10^{-12}
500	4.9	0.490	30.7	0.523	0.166	4.738×10^{-12}
Material: Brass		$L = 0.34 \text{ m}$		$D = 3.1 \text{ mm}$ $R = 1.55 \text{ mm}$	$J = 9.06 \times 10^{-12}$	

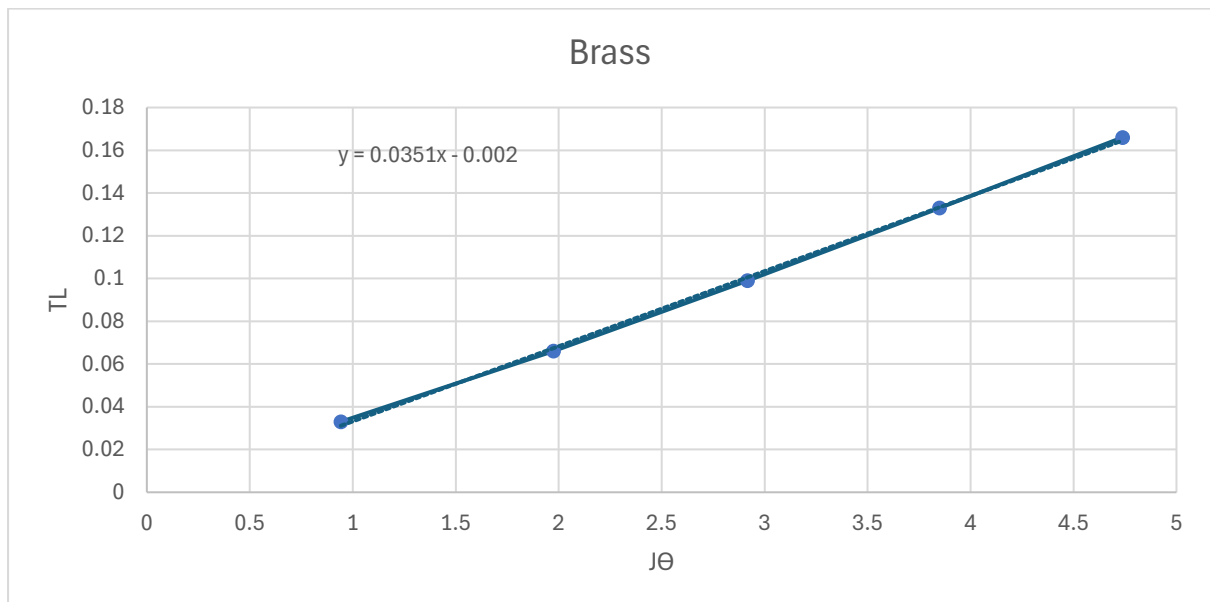


Figure 4.1

Table 4.2

Shaft Modulus						
Load (m) (g)	Load (w) (N)	Torque (T) (Nm)	Twist Angle (Degrees)	Twist Angle (θ) (Radians)	TL	$J\theta$
100	0.98	0.098	8.7	0.151	0.033	1.281×10^{-12}
200	1.96	0.196	16.5	0.287	0.066	2.436×10^{-12}
300	2.94	0.294	24	0.418	0.099	3.548×10^{-12}
400	3.92	0.392	32	0.558	0.133	4.737×10^{-12}

Material: Aluminium	$L = 0.34 \text{ m}$	$D = 3.05 \text{ mm}$	$J = 8.49 \times 10^{-12}$
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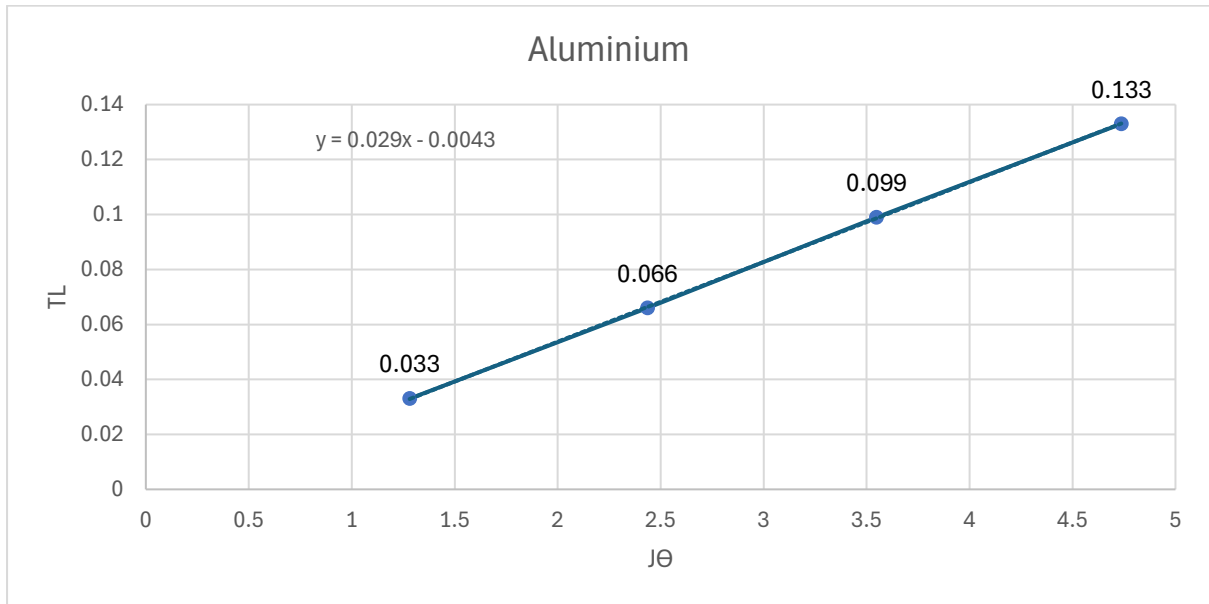


Figure 4.2

Table 4.3

Shaft Modulus						
Load (m) (g)	Load (w) (N)	Torque (T) (Nm)	Twist Angle (Degrees)	Twist Angle (θ) (Radians)	TL	$J\theta$
100	0.98	0.098	3.5	0.061	0.033	5.526×10^{-13}
200	1.96	0.196	6	0.104	0.066	9.422×10^{-13}
300	2.94	0.294	8.7	0.151	0.099	1.368×10^{-12}
400	3.92	0.392	11.5	0.200	0.133	1.812×10^{-12}
500	4.9	0.490	14	0.244	0.166	2.210×10^{-12}
Material: Steel		$L = 0.34 \text{ m}$		$D = 3.1$	$J = 9.06 \times 10^{-12}$	

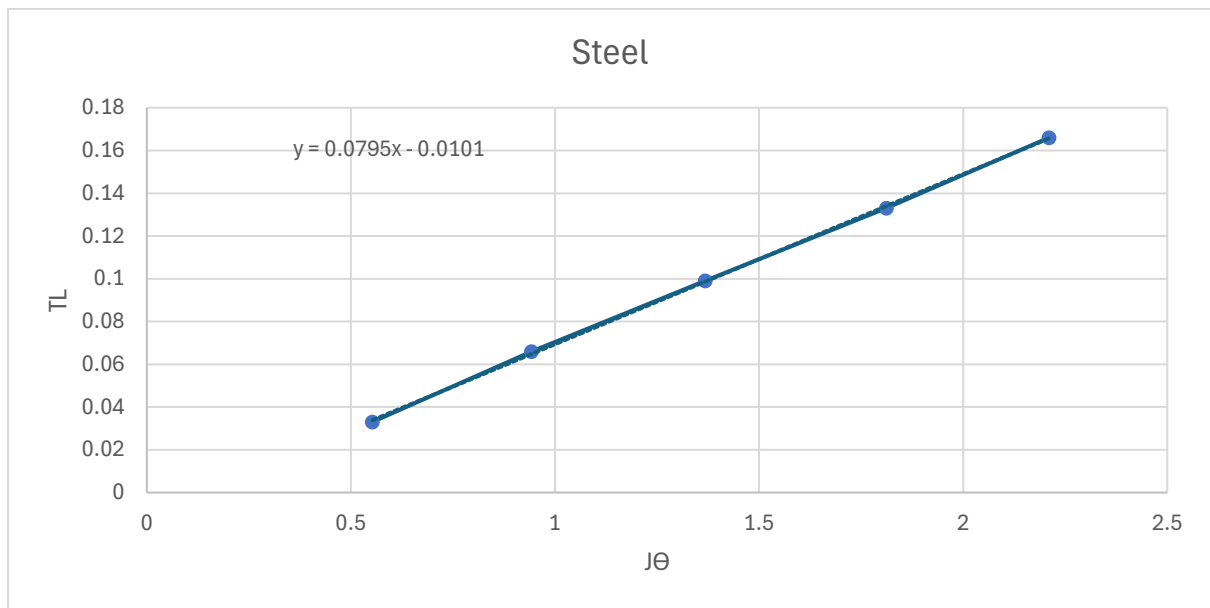


Figure 4.3

G Values (GPa):

Brass = 35.1

Aluminium = 29.0

Steel = 79.5

These values are representative of how rigid or susceptible to twisting a material is. The higher the value, the more force required to twist the material. The above results calculated from the experiment show steel as the most rigid material with the value 79.5GPa, and Aluminium being the most flexible material with a value of 29.0GPa, which is consistent with what is expected as Aluminium is a soft material.

5 Conclusion

Modulus of Rigidity

Measured

Table 5.1

Material	Value (gpa)
Brass	35.1
Aluminium	29.0
Steel	79.5

Textbook

Table 5.2

Material	Value (gpa)
Brass	38.0
Aluminium	25.5
Steel	79.6

(TecQuipment, 2012)

Researched

Table 5.3

Material	Value (gpa)
Brass	40.0
Aluminium	28.0
Steel	79.3

(Engineering ToolBox, 2005)

Are the values calculated from the experiment within 10% of the textbook values?

Brass: Yes, the value for modulus of rigidity is within 10% of the textbook value. The percentage difference between the calculated value from the experiment and textbook value is 7.6%.

Aluminium: No, the value for modulus of rigidity is not within 10% of the textbook value. The percentage difference between the calculated value from the experiment and textbook value is 13.7%. One possible cause of this may be due to human error while measuring diameter or due to aluminium being a weaker material causing it to slip inside the fixed chuck, leading to slight inaccuracies.

Steel: Yes, the value for modulus of rigidity is within 10% of the textbook value. The percentage difference between the calculated value from the experiment and textbook value is 0.12%.

Are the values calculated from the experiment within 10% of the researched values?

Brass: No, the value for modulus of rigidity is not within 10% of the researched value. The percentage difference between the calculated value from the experiment and researched

value is 12.3%. One possible cause of this could be due to human error when taking measurements. Another possible cause could be due to brass being a mix of copper and zinc. This could mean that the researched value used a different Brass alloy, which would affect the modulus of rigidity.

Aluminium: Yes, the value for modulus of rigidity is within 10% of the researched value. The percentage difference between the calculated value from the experiment and researched value is 3.6%.

Steel: Yes, the value for modulus of rigidity is within 10% of the researched value. The percentage difference between the calculated value from the experiment and researched value is 0.25%.

6 Evaluation

Overall, this experiment was successful and there were multiple control measures put in place to ensure that some errors were eliminated, minimised or avoided. One measure that was put in place was to ensure that the results were being read correctly and accurately. At each 100g increment, multiple students checked the scales. This way, every student who was reading the scales were required to agree. Another control measure that was put in place was ensuring the same student was tightening the grubscrews throughout the experiment and the same person was adding the weights throughout the experiment. This was to ensure that there was no confusion over how to add the weights or to tighten the grubscrews, allowing others to observe for mistakes. Not only did this avoid confusion, but it also saved time and allowed communication to be straight forward. A third control measure that was put in place was ensuring more than one student was to check that the scales were set to zero to ensure accuracy as far as the equipment will allow.

7 Further Work

Given unlimited time and resources, there are many ways that this experiment can be improved in terms of quality and accuracy. One way that this experiment can be improved is if it was to be carried out at least three times. As with all experiments, human error can occur and if the test is only being carried out once, it is made more difficult to identify human error, whereas carrying out the experiment at least three times allows for comparisons to be made to ensure accuracy and spot inaccuracies. Another way that this experiment can be improved is by following the experiment guidelines more thoroughly. While in the experiment that was carried out, the scale was zeroed each time a new rod was installed, it was missed that the full 500g was meant to be applied initially to ensure that when the load is removed, the scale returns to zero. This would have also eliminated the time that was lost when the scale had to be set to zero again as the rod slipped inside the fixed chuck and was required to be tightened. This then links to another way in which the experiment could be improved, which is the use of new or improved equipment. As the equipment is used for multiple groups of students each year, it is inevitable that the equipment will weaken or degrade, which could have been the reason for a rod coming loose inside the fixed chuck. One way the equipment could be improved is the fastening of the rod at both the fixed and rotating chucks. Additionally to these improvements, testing more materials including alloys can generate more data, allowing for more materials to be analysed. If the experiment was carried out using smaller increments, there would also be a higher level of accuracy as more data is extracted from the experiment. A major improvement to this experiment could be to use digital scales that can be calibrated to further ensure that the measurement is being read correctly and also to allow for a much higher level of accuracy.

8 Reference List

TecQuiptment LTD (2012) Engineering Science Worksheets – Torsion of Circular Sections Kit ES5

Engineering ToolBox (2005). *Modulus of Rigidity*. [online] Engineeringtoolbox.com. Available at: https://www.engineeringtoolbox.com/modulus-rigidity-d_946.html [Accessed 1 Jan. 2026].

TecQuiptment LTD (2012) Engineering Guidance Notes – Torsion Kit ES5