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Torsion of Shafts

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1. Introduction

The students within 1st year of the Motorsports Engineering course at the University of Wales Trinity St. David were split into small groups to complete laboratory sessions so they could gather empirical data to aid in their investigations into torsion behaviour within different materials. They were looking to use their theoretical knowledge alongside this session to find the modulus of rigidity for three specimen materials.

Materials selected for use within different areas of engineering often come down to their suitability for the task. For example, an engineer may use a material for its strength against different loads. However, depending on the project, the material may also need to have a minimum or maximum elasticity or modulus of rigidity to ensure it can survive daily loads. Sometimes the material may need to withstand vertical stretching or compression, where other times it may need to allow a level of torsion to be applied. One such example of this is where an engineer may be designing an anti-roll bar system for implementation on a road going vehicle.

An anti-roll bar (ARB), like that in figure 1 (Suspension Secrets, 2017) acts like a torsional spring between two sides of an axle, transferring loads during the cornering of a vehicle. A track focused car would have a stiffer ARB than that present on a road vehicle. There are 3 ways to change the stiffness of an anti-roll bar.

- Change the diameter of the material used.
- Change the length of the cantilevers on the ARB/connect the drop links in a hole that is a shorter length from the bar to make it stiffer.
- Selecting an ARB made from a material with a higher modulus of rigidity for a stiffer bar.

A material's modulus of rigidity is its resistance to shear stress and strain when undergoing loads applied torsional loading. (G) the definition of Modulus of Rigidity is the ratio of shear stress to the displacement per measurement of the length of a given sample. (Engineering ToolBox, 2005)



Figure 1 - Suspension ARB Image (Suspension secrets, 2017)

Important Notations in this document:

Table 1 - Notations within the document

Symbol	Meaning	Units
θ	Angle of twist	Radians
Diameter	Determines the size of circular objects	d or $\varnothing$
G	Modulus of rigidity	Pa or $N.m^{-2}$
J	Polar second moment of area	M^4
L	Length	M
m	Mass	g
W	Load	N
T	Torque	Nm
R or r	Radius	m

2. Experimental Procedure

The experiment was completed using the Torsion of Circular Sections Kit ES5 from TecQuipment Ltd 2012.

The first step of the procedure is to set up the apparatus onto a work panel such as in figure 2.

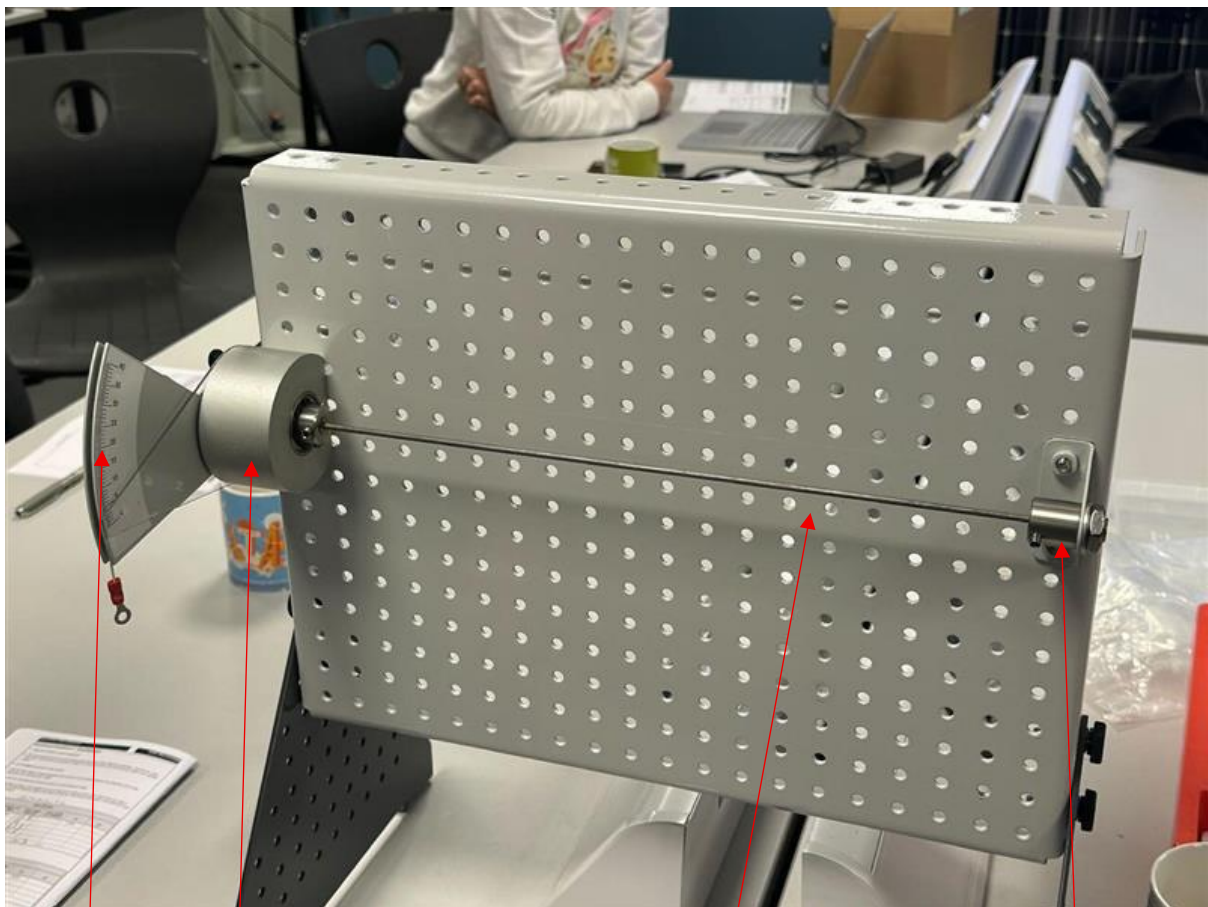


Figure 2 - TecQuipment Apparatus Secured to Work Panel

Rotating chuck

Material specimen

Twist angle gauge

Fixed chuck

When fitting a specimen, you must

- Use the Allen key provided with the set to loosen the grubscrews on both chucks
- Slide the specimen into the fixed chuck from the outside of the assembly
- Push the specimen through as far as it will go into the rotating chuck
- Tighten the grub screws on both the chucks
- Then zero the rotating chuck

To zero the rotating chuck you must loosen the grubscrews to allow the torque arm to move without twisting the specimen, align the arm at 0° and retighten the screws. If any adjustment is needed, there are small thumbscrews that hold the transparent plastic in place that can be loosened to move the plastics up or down for a more accurate zero.

Before carrying out the experiment the zero should be tested to ensure that everything is appropriately tight. To do this, you should load the hooked weight carrier with the maximum weights needed for the experiment and load it onto the cord for a few seconds. Once removed, the testers should check to ensure the scale has returned to its zero position (figure 3). Failure to do so indicates the specimen may have slipped in one of the chucks. (TechQuipment, 2012).



Figure 3- Zeroed Scale

- First, identify the three materials within the kit. One is aluminium, one is steel and one is brass.
- Fit the brass specimen into the chucks.
- Measure the diameter using a calliper and calculate its J value.
- Set and zero the chucks.
- In increments of 100 g, add weights up to a maximum of 500g to the cord.
- Each time you add a weight, record the twist angle at the moment arm.
- To reduce friction effect, you can gently tap the work panel when each weight is added or take the hooked carrier off the apparatus each time a weight is changed.

- Unload the weights and repeat the same procedures for each material, however, when using aluminium, you should not exceed 400g of load as it may twist the rod beyond its elastic limit (TecQuipment, 2012).



Figure 4 - The First Increment of Weights

As seen in figure 4, there are only 9 weights on this carrier as the carrier itself weighs 10g, so this adds up to the first 100g of weight added to take the first recording.

3. Results

Table 2 – Brass Results Data

Load (m) (g)	Load (W) (N)	Torque	Twist Angle (deg)	Twist angle (θ) (radians)	TL	$J\theta$
100	0.98	0.098	7	0.12	0.031	0.146
200	1.96	0.196	16	0.28	0.063	0.333
300	2.94	0.294	18.5	0.32	0.094	0.385
400	3.92	0.392	24.5	0.43	0.126	0.510
500	4.91	0.491	30	0.52	0.157	0.625

Material: Brass

L: 0.34 M

D: 3.32mm

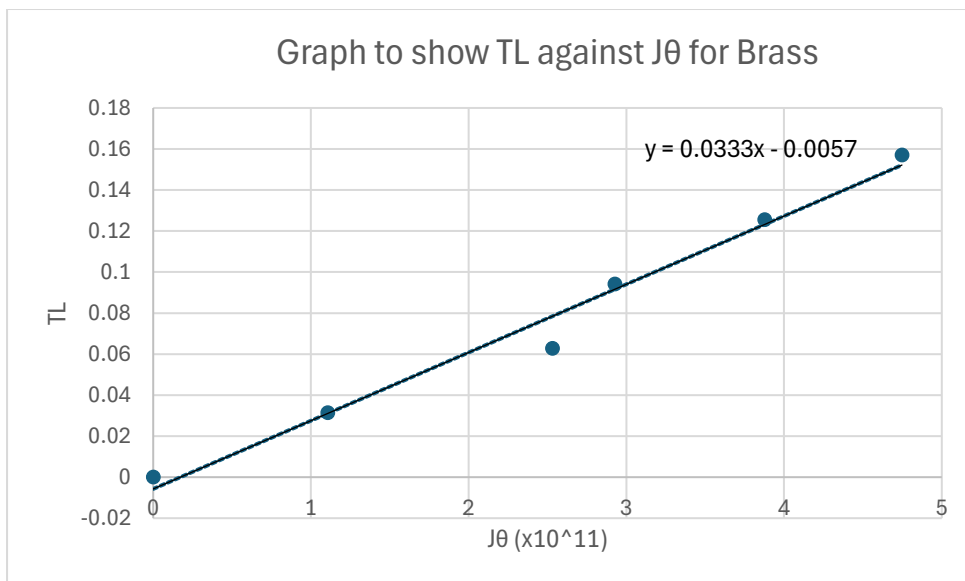


Figure 5 - Brass Results Graph

When looking at figure 5, it can be seen that the value for 'G' (shear Modulus) is 0.2528, which also translates to 25.28 GNm^{-2} . The graph shows a linear relationship between Polar second moment of area and TL. The second datum point on the graph does fall out of line within this pattern, however the group conducting this test were having issues securing the indication arm with the thumbscrews due to wear and tear on the TechQuipment kit. The anomalous result being so early in the graph could show some slip between the chucks and the material.

Table 3 - Aluminium Results Data

Load (m) (g)	Load (W) (N)	Torque	Twist Angle (deg)	Twist angle (θ) (radians)	TL	J θ
100	0.98	0.098	7.5	0.13	0.03332	1.22
200	1.96	0.196	15	0.26	0.066708	2.44
300	2.94	0.294	23	0.40	0.100062	3.73
400	3.92	0.392	32	0.56	0.133416	5.20

Material: Aluminium

L: 0.34 M

D: 3.12mm

J: 1.19×10^{12}

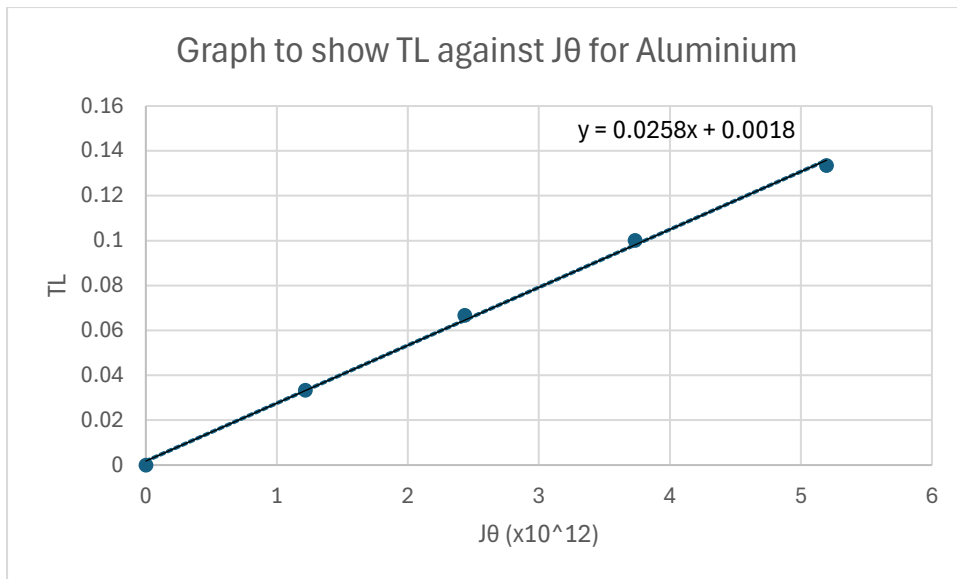


Figure 6 - Aluminium Results Graph

Figure 6 once again highlights a linear relationship between Polar second moment of area and TL with a gradient showing a 'G' value of 0.0258 or 25.8GNm^{-2} .

It is worth noting that this table only has 4 datum points due to the weight only being increased to 400g (see experimental procedure). Having more datums to record would perhaps have been beneficial as the group could have noted any changes to the gradient, and therefore differences in the shear modulus values.

The recommended Shear modulus shows that the aluminium could be either grade 1100, or grade 2014. (Engineering Toolbox, 2014).

Table 4 - Steel Results Data

Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (deg)	Twist angle (θ) (radians)	TL	J θ
100	0.98	0.098	2.5	0.04	0.033	0.40
200	1.96	0.196	5	0.09	0.067	0.80
300	2.94	0.294	7.5	0.13	0.100	1.20
400	3.92	0.392	10	0.17	0.133	1.60
500	4.91	0.491	12.5	0.22	0.167	2.00

Material: Steel

L: 0.34 M

D: 3.11mm

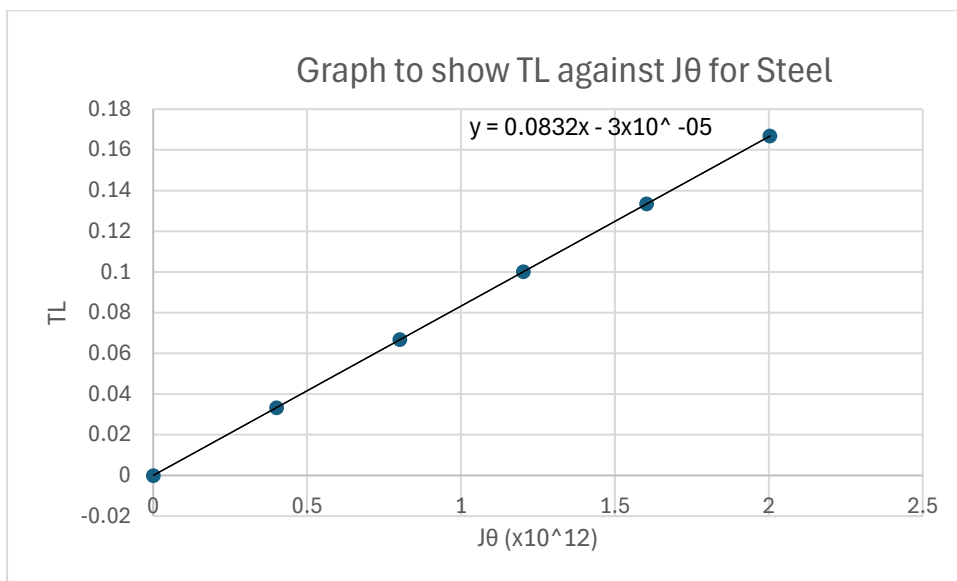


Figure 7 - Steel Results Graph

Figure 7 shows a shear modulus value of 0.0832, or 83.2 GNm^{-2} . Once again, a linear relationship within the graph. The datums being so tightly plotted along the trendline shows that a good level of consistency during the test. For example, this could mean that the team consistently waited for the indication arm to stop moving before recording any results throughout the testing of this metal. The closest nominal value to that of the textbook found

during research was structural steel, with a shear modulus of 79.3 Gnm^{-2} . (Engineering ToolBox, 2005)

4. Validation and Conclusion

The values for each metal's shear modulus compared to expected results:

Table 5 - Empirical Results Compared to Nominal Data

Material	Empirical value	Nominal textbook value
Aluminium	25.8	25.5
Brass	25.28	38.0
Mild Steel	83.2	79.6

Both the aluminium and mild steel values are within 10% of the nominal textbook values (ES5 Guidance, TechQuipment Ltd 2012). The differences between the empirical values and the nominal values are likely due to user error when recording the diameter of the rods used in the experiment.

The brass value, however, is not within 10 percent of the textbook values. When investigating this, it can be seen that aluminium and steel both had a diameter of ~3.1mm whereas the brass was recorded as ~3.3mm.

This may seem like a small error, however when finding the value for 'J', the equation used is:

$$\frac{3.142 * 0.00332^4}{32}$$

The diameter is being multiplied by the power of 4 within the equation, which would increase the effect of the measurement error on the final values.

After changing the diameter to 3.1mm in an excel sheet, the 'G' value was 33.3GNm^{-2} .

This is still outside of a 10% margin, however, is only 0.9 units outside of that 10%, showing that perhaps if the team took more time when taking measurements, or didn't have issues with the chucks slipping during experimentation, then perhaps this value, as well as the others would be closer to the nominated values.

Upon doing some further research, the composition of the brass alloy can change its shear modulus which makes sense as the structural composition is affected by the concentration of each material used (Harbinger Engineering, 2024).

Brass 360, or free machining brass has a shear modulus of 5370 ksi (Harbinger Engineering, 2024) which equates to $\sim 37 \text{ Gnm}^{-2}$. Interestingly this would put the value from the empirical testing back within a 10% margin with this metal similar to what was discussed previously. This could be an indication that this is the type of brass the specimen is made from.

5. Evaluation

When carrying out the testing, the team took a number of precautions to ensure the test was carried out fairly:

- Using a level workbench.
- Doing the test on the same area of the workbench.
- When measuring with callipers, at least 3 members viewed the scale to ensure that they all agreed on the diameter.
- The same person tightened the grub screws and thumbscrews each time.
- Following the experimental procedure (TechQuipment Ltd, 2012).

The equipment booklet states that storage temperatures should be -25°C to $+55^{\circ}\text{C}$, and that the operating temperature should be within a range of $+5^{\circ}\text{C}$ to $+40^{\circ}\text{C}$, but being that the experiment was completed in Wales, it would have been within this range when the test was completed.

6. Further Work

Given unlimited time/resources the experiment could be made better in a few ways:

- Indents on the specimens where they sit in the chucks to provide a way to lock the samples in place, this reduces the likelihood of slipping during testing.
- The indication arm could be digitally replaced, reducing the possibility of user error when taking measurements of angle change.
- Increase the range of specimen materials to give students a better comparison between materials.
- Provide students with different lengths of the same materials so the students can see the effect the length has on the results.

7. References/Bibliography

Arzaghi, M., Fundenberger, J.J., Toth, L.S., Arruffat, R., Faure, L., Beausir, B. and Sauvage, X. (2012). Microstructure, texture and mechanical properties of aluminum processed by high-pressure tube twisting. *Acta Materialia*, [online] 60(11), pp.4393–4408.
doi:<https://doi.org/10.1016/j.actamat.2012.04.035>.

Engineering ToolBox (2005). *Modulus of Rigidity*. [online] Engineeringtoolbox.com. Available at: https://www.engineeringtoolbox.com/modulus-rigidity-d_946.html [Accessed 4 Jan. 2026].

Engineering Toolbox (2014). *Aluminum Alloys - Mechanical Properties*. [online] Engineeringtoolbox.com. Available at: https://www.engineeringtoolbox.com/properties-aluminum-pipe-d_1340.html [Accessed 4 Jan. 2026].

Engineering, H. (2024). *Common Brass Alloys Used in CNC Machining*. [online] Harbinger Engineering. Available at: <https://harbinger.engineering/blog/commonly-machined-brass-alloys> [Accessed 2 Jan. 2026].

Joyce, P., 2004, June. Two Experiments to Teach Modulus of Elasticity and Modulus of Rigidity. In *2004 Annual Conference* (pp. 9-1326).

King, J. (2023). *Anti-Roll Bars Guide: How They Can Improve Handling*. [online] Fast Car Entertainment. Available at: <https://www.fastcar.co.uk/tuning-tech-guides/anti-roll-bars-explained-how-they-can-improve-handling/> [Accessed 1 Jan. 2026].

Suspension Secrets. (2017). *Anti-Roll Bars*. [online] Available at: <https://suspensionsecrets.co.uk/anti-roll-bars/> [Accessed 1 Jan. 2026].

TechQuipment, 2012 (n.d.). *Key Features Engineering Science*.

TecQuipment. (2025). *TORSION OF CIRCULAR SECTIONS KIT*. [online] Available at: <https://www.tecquipment.com/torsion-of-circular-sections-kit> [Accessed 1 Jan. 2026].

Trento, C. (2025). *Shear Modulus (Modulus of Rigidity)*. [online] Samaterials.com. Available at: [https://www.samaterials.com/content/shear-modulus-\(modulus-of-rigidity\).html](https://www.samaterials.com/content/shear-modulus-(modulus-of-rigidity).html) [Accessed 4 Jan. 2026].