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Title of Report: Engineering Skills Technical Report

Module name (Mechanics and Dynamics)

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Date:4/1/2026

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1. Introduction

The aim and objective of this assignment is to determine the shear modulus of shafts by utilizing a torsion testing apparatus and to be able to recognize how its characteristics alter by using different types of materials.

In mechanical engineering applications, there are many components that endure torsional loads such as axles, driveshafts and transmission shafts. Therefore, modulus of rigidity is essential characterizing its material property, calculating how resistant a material is to deformation. Within engineering, comprehending the concept of torsional behavior is important to ensure when manufacturing shafts that endure twisting motion can safely withstand applied loads without it failing or deforming where it can no longer return to its original state.

2. Experimental Procedure

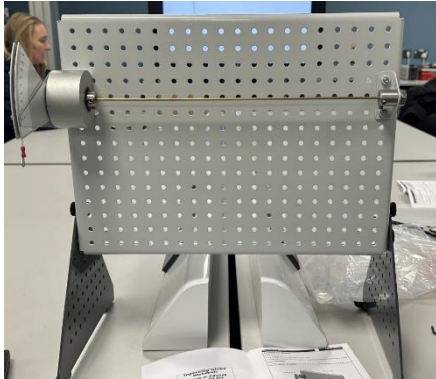


Figure 2.1 Apparatus setup

Initially, an experimental setup must be constructed portrayed in Figure 2.1. The setup consists of a rotating chuck with a torque arm scale and a transparent cursor attached onto it and a fixed chuck to hold the test specimen in place. To ensure that the experimental setup is constructed correctly, an image within the booklet includes a reference of how the setup must look like. To begin constructing the apparatus ensure that both chucks, the fixed and the rotating chuck are secured and fastened opposite of one another onto the back panel by using the provided screws. To ensure proper alignment, count the holes in the image, replicating how it must be constructed shown in the booklet.

Furthermore, to finish preparing the setup slide the test specimen inside the fixed chuck where the test specimen is then mounted horizontally between the two chucks. After the test specimen is horizontally mounted, to prevent it from slipping tighten the grubscrews on the fixed chuck with a hexagon tool that is provided making sure that the test specimen is pushed all the way

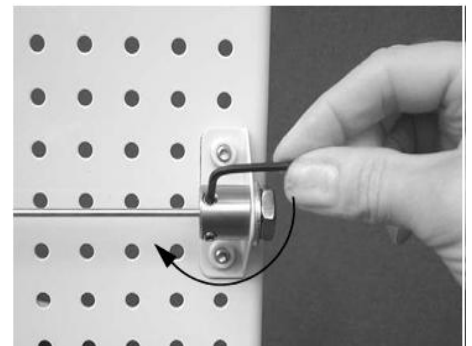


Figure 2.2 tightening mechanism

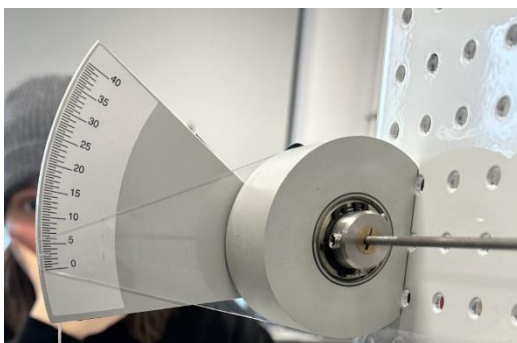


Figure 2.3 Rotating chuck along with transparent angle cursor

through.

Next, before starting the experiment ensure that the rotating chuck angular scale is set to zero so accurate readings are acquired within the experiment, to avoid preloading the specimen, loosen the grubscrews on the rotating chuck so the torque arm scale can freely move so that it can be zeroed correctly. After setting the arm to zero use the hexagon tool to tighten it in place, conveniently there is a transparent cursor and it can

be easily adjusted by rotating a little thumbscrew on the back just in case the arm slightly moves during the process of tightening the grub screws.

To begin the experiment, add 100g in increments onto the weight hanger reaching a maximum weight of 500g, apart from the aluminum shaft to avoid permanent deformation then along the way of each increments ensure to record the values of twist angle portrayed on the scale arm. Three different materials are utilized; that being brass, aluminum and steel, another measurement that is required to be recorded is the diameter of each shaft this is essential as it is utilized for later computations, measure it by utilizing a dial caliper gauge that is provided within the kit.

3. Results

Load (g)	Twist Angle (degrees)
100	6.5
200	12.5
300	18
400	24
500	31
Material: Brass Length(m) = 0.34	

Load (g)	Twist Angle (degrees)
100	8.5
200	16
300	23.5
400	31
Material: Aluminium Length (m) = 0.34	

Load (g)	Twist Angle (degrees)
100	3
200	5.5
300	8
400	11
500	14
Material: Steel Length(m) = 0.34	

4. Analysis

Load(m) g	Load (W) N	Torque (T) Nm	Twist Angle (degrees)	Twist Angle (radians)	TL	Jθ	
100	0.98	0.098	6.5	0.113	0.033	1.03E-12	
200	1.96	0.196	12.5	0.218	0.067	1.98E-12	
300	2.94	0.294	18	0.314	0.100	2.85E-12	
400	3.92	0.392	24	0.419	0.133	3.80E-12	
500	4.91	0.49	31	0.541	0.167	4.91E-12	
Materia: Brass	Length(m) =	0.34	Diameter(mm) = 3.1	(m) = 0.0031		Polar moment (j) =	9.06665E-12

Figure 4.1 Experimental table showing torsion of shafts

The experimental data portrayed above Figure 4.1 shows the relationship between the applied load, torque, twist angles, TL representing a product of the applied torque acting across the shaft length and Jθ a term used accounting for both twist and shaft geometry. These information on the table corresponds to the shaft when torsional load is being applied, firstly, as the applied load incrementally increases by 100g from 100-500 the torque proportionally increases along with the applied load, resulting in a gradual increase within the twist angle. The linear increase implies that the shaft has not surpassed its deformation region during the experiment.

Furthermore, the twist angle is accumulated during the experiment measured by the use of an angle scale attached onto the rotating chuck, as it is measured in degrees which is not in scientific unit, it must then be converted to radians an SI unit used by engineers and scientists which can be calculated by the use of a given formula: twist angle $\times (2 \times \pi)$ divided by 360 (TecQuipment, 2012) After the twist angle in degrees have been converted to radians, the following column can be calculated by: Torque $\times$ Length of shaft (TL).

The next values to be calculated are Jθ; to calculate Jθ the polar moment of area must first be calculated, by implementing the use of the formula: $J = \pi \times \text{Diameter}^4$ divided by 32 ensure to convert the diameter into its SI base unit (TecQuipment, 2012) after calculating the polar moment of area, the following column can be filled by: polar moment of area $\times$ twist angle in radians

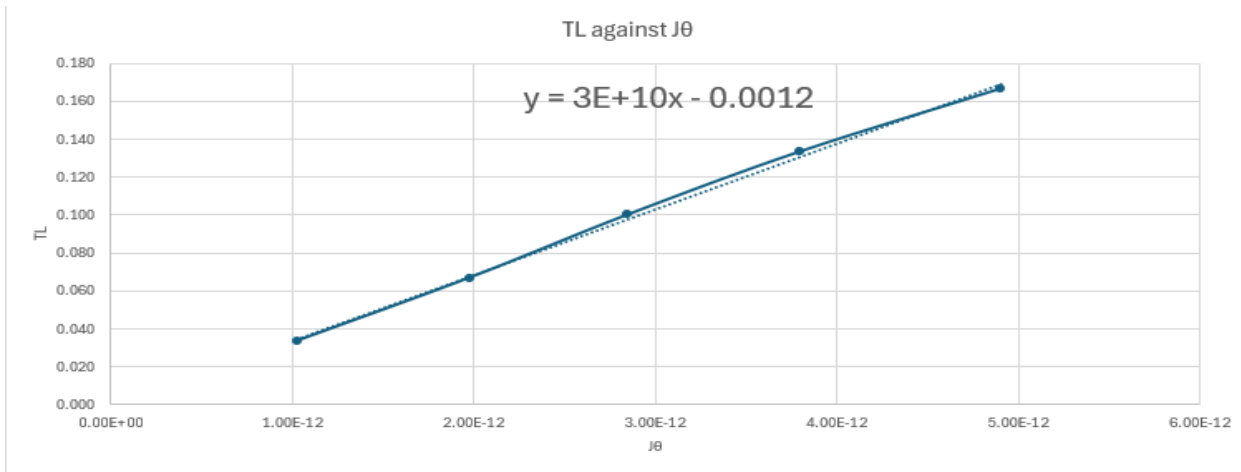


Figure 4.2 Graph for Brass

To determine the shear modulus of the test specimen; brass shaft, a graph has been plotted of TL against $J\theta$ portrayed in Figure 4.2, The graph above portrays a strong positive linear relationship between TL and $J\theta$ with a slight anomaly from the trendline, the torsion theory is still valid as it does not deviate at a large rate implying this material is still within its deformation region. Modulus of rigidity is determined within the gradient, unfortunately it's not within 10% of nominal value for the brass shaft of 38 GPa provided within the booklet (TecQuipment, 2012) . There are several reasons why this can occur, this could be due to slippage within the chucks, the scale not being zeroed properly during the experiment or twist angle values not properly recorded.

Load(m) g	Load(W) N	Torque(T) Nm	Twist Angle (degrees)	Twist Angle (radians)	TL	$J\theta$	
100	0.98	0.098	8.5	0.148	0.033	1.35E-12	
200	1.96	0.196	16	0.279	0.067	2.53E-12	
300	2.94	0.294	23.5	0.410	0.100	3.72E-12	
400	3.92	0.392	31	0.541	0.133	4.91E-12	
Material: Aluminium		Length(m) = 0.34	Diameter(mm) = 3.1		(m) = 0.0031	Polar moment (j) =	9.06665E-12

Then, repeat the process for the following materials: aluminum and steel.

Load(m) g	Load(W) N	Torque(T) Nm	Twist Angle (degrees)	Twist Angle (radians)	TL	Jθ	
100	0.98	0.098	3	0.052	0.033	4.75E-13	
200	1.96	0.196	5.5	0.096	0.067	8.70E-13	
300	2.94	0.294	8	0.140	0.100	1.27E-12	
400	3.92	0.392	11	0.192	0.133	1.74E-12	
500	4.91	0.49	14	0.244	0.167	2.22E-12	
Material: Steel		Length(m) =	0.34	Diameter(mm) = 3.1	(m) = 0.0031	Polar moment (j) =	9.06665E-12

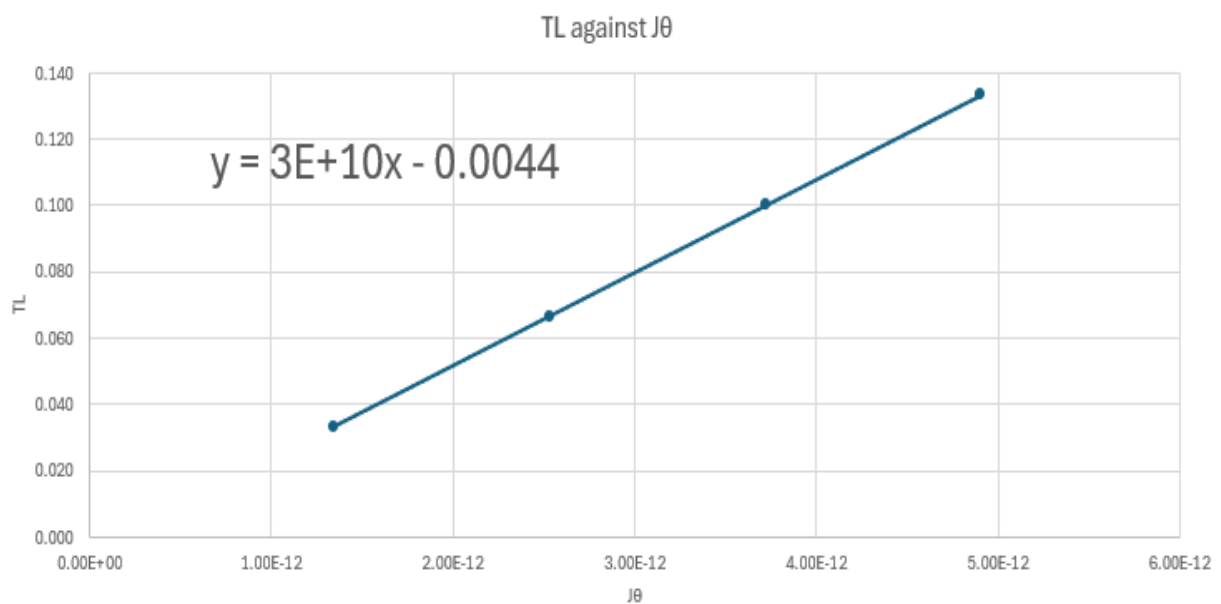


Figure 4.2.1 Graph for Aluminum

The graph above shows a perfect linear relationship between TL and Jθ following a perfect path. The direct proportional straight line implies that it obeys Hooke's law in shear, the characteristic of this material can be described as deforming elastically where it hasn't reached the stage of permanently deforming and can return to its original state (TecQuipment, 2012). Shear modulus is acquired within the gradient, in comparison to the nominal value provided within the booklet, the modulus of rigidity within the conducted experiment came close.

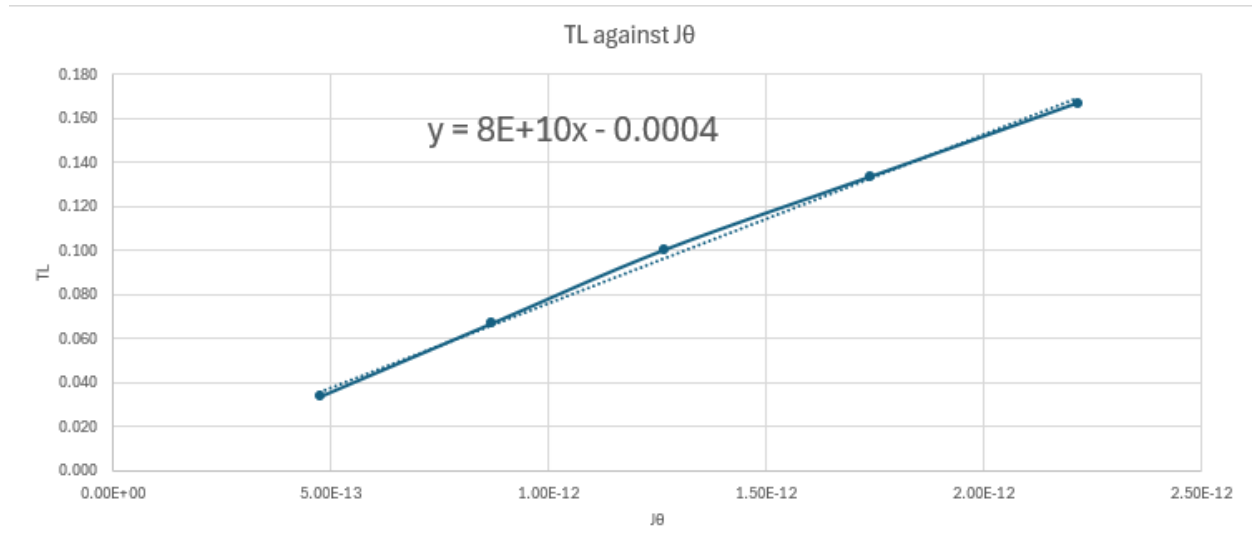


Figure 4.2.2 Graph for Steel

Lastly, within the graph above portrays the relationship between TL and $J\theta$ for the steel shaft. The graph above shows a reasonably consistent pattern where it starts to slightly deviate along its midst travel. The modulus of rigidity within this graph corresponds near perfect in comparison to the nominal value that was given in the book, which had the value of 79.6 GPa for mild steel.

5. Conclusions

In comparison of all the materials, aluminum is expected to have the lowest modulus of rigidity as it is a softer metal compared to brass and steel. For brass the experimental modulus of rigidity was acquired to be 30 GPa where the value is way lower in comparison to the nominal value of 38 GPa (TecQuipment, 2012), the disagreement between these figures may lie within individuals ability to record measurements accurately.

Overall, this experiment demonstrated how the characteristics of the shafts can alter when different materials are used.

6. Evaluation

When carrying out experiments, consider various errors that could occur impacting data collection. For example, on this occasion there could be minor human errors such as the ability to record information due to eyesight hinderances, different individuals have varying eyesight therefore to minimize a negative impact on the data collecting, referring to the torque arm scale, only one person must take charge that has a very healthy eyesight or an enlarged arm scale. In addition to this, to further minimize other errors that could potentially have an impact within the experiment, thus referring to the ability to zero the torque scale arm correctly, this could have an impact as the test specimen could have a preload tension acting on it if the rotating chuck was not loosened properly when zeroing the arm.

7. Further work

To make this experiment the best version that it could be and provide a much more accurate outcome is to eliminate any form of apparatus errors. A significant error encountered is that the torque arm within the rotating chuck kept slipping. This can be eliminated by implementing the use of a much sturdy apparatus, for instance the brass material had issues with excessive slippage within the torque arm where the load became far too great.

8. References

TecQuipment. (2012).

TecQuipment. (2012). Engineering Science. In *Torsion Kit ES5* (pp. 15-24).

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