

STUDENT FEEDBACK FORM (ALED DAVIES)

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills		
Engagement with a suitable range of literature, including sources retrieved independently. Some of your work needed more depth and scope. Nevertheless, you did cover sufficient research to allow for the evaluation of results with many relevant points of interest identified.	20	13
2. Knowledge and Understanding Skills		
Very good knowledge of the underlying concepts and principles. Accurate and logical approach taken throughout demonstrating good understanding of the field of study. However, your research needed further depth and scope and at times the terminology. In particular I would have liked to see more on the practical application of the theory covered.	30	19
3. Cognitive and Intellectual Skills		
A very good attempt at the evaluation of the underlying concepts and principles. You did interpret the data correctly, and you demonstrated an ability to use evidence to support the argument. Some areas of the evaluation were underdeveloped (I would have liked to have seen more on flexural rigidity, for example).	20	12
4. Practical Application Skills		
A good and appropriate application of basic methods, materials, tools, and/or techniques. Clear appreciation of the context of the application. Good set of calculations, and reasonable values of E and G obtained. Minor issues with units and labelling identified. Beam stress included. I would have liked to have seen more on the practical application of the work covered.	15	11
5. Transferable Skills for Life and Professional Practice		
Coherent, organised and accurate work in a suitable structure. Work is generally well written but descriptive at times. Referencing was provided but needs to be improved. Summary also needed to be extended. You also need to ensure you use the correct tense and person is always used.	15	10

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)	%	65
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

Investigation into Elastic Constants

Course name- HNC Electrical Engineering

Module- Mechanical Engineering

Module Code: SGEE4017

Lecturer- Dr Chris Davies

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Summary

In this report I will be carrying out two tests exploring the investigation into elastic constants, I will be using three materials, focusing on Young's modulus of elasticity and the modulus of rigidity. These constants are essential for characterising a materials mechanical response under different types of stress, such as tension, compression and shear. By applying a controlled stress to our test materials this report calculates these constants to assess the materials under different loading conditions. Results with higher young modulus will exhibit greater stiffness whereas results with lower young modulus will display more flexibility. The findings highlight the importance of elastic constants in material selection for mechanical engineering applications, where mechanical properties like rigidity and elasticity directly affect how the material will perform.

A reasonable start to a summary but you also needed to include the results and main conclusions

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*Good structure but you
need a section numbering
system also*

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Always write in third person.

Introduction

The investigation into elastic constants is a fundamental aspect within mechanical engineering, it shows how different materials respond under different conditions. Elastic constants such as young's modulus and modules, describe the relationship between stress and strain. This will give us the information we need to measure how the material will perform mechanically, such as its elasticity. In this assignment I will carry out two tests to determine the properties of aluminium, 0.4% carbon steel and 70/30 Brass under different loading conditions. The first test I carried out was the tensile test on an aluminium beam, this tested the response of the material under a single point load in the centre of the beam. I could then measure the deflection from this single point load and compare this to theoretical results using young's modulus. The second test I carried out was the torsion test on 0.4% carbon steel rod and 70/30 Brass rod. This is where we applied a recorded torque to the material and measured the angle of twist, providing the results to measure the shears modulus of the material.

Aluminium, 0.4% carbon steel and 70/30 brass was selected as these materials are commonly used in the industrial world. Steel has high strength properties and is commonly used in structural applications, whereas brass is an alloy of copper and zinc and is valued for its corrosion resistance and flexibility. This assignment will show the methods and experimental results of the tensile and torsion test performed on the selected materials. The findings of the mechanical properties can then be applied to the mechanical engineering industry.

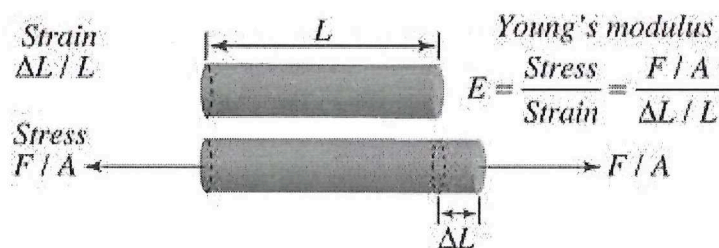
Objectives

- To measure the young's modulus of Aluminium using a tensile test, assessing the stiffness of the material under a single point load and comparing it to theoretical results
- To calculate the shear modulus of 0.4% carbon steel and 70/30 brass through a torsion test by analysing the relationship between applied torque and the resulting angle of twist.
- To compare the elastic constants of 0.4% steel and 70/30 brass, highlighting the differences in stiffness, ductility, and shear resistance between the material and our results.
- To analyse how 0.4% steel and 70/30 brass respond to torsional stresses, and look into how they would be used in real world engineering applications.
- To compare the relationship between elastic constants (young's modulus and shear modulus) and compare the experimental results with the theoretical results.

Young's Modulus

Young's modulus is the constant named after English physician and physicist Thomas Young, which defines how a solid material behaves when subjected to tension or compression in a single direction. For example, when a material is stretched or compressed along its length and then returns to the original shape, this demonstrates the materials elasticity. This module measures the materials resistance to change in length. (Encyclopedia Britannica (2019).)

Known also for the modulus of elasticity young modulus is calculated using the formula ($E = \frac{\text{stress}}{\text{strain}} = \frac{\sigma}{\epsilon}$)

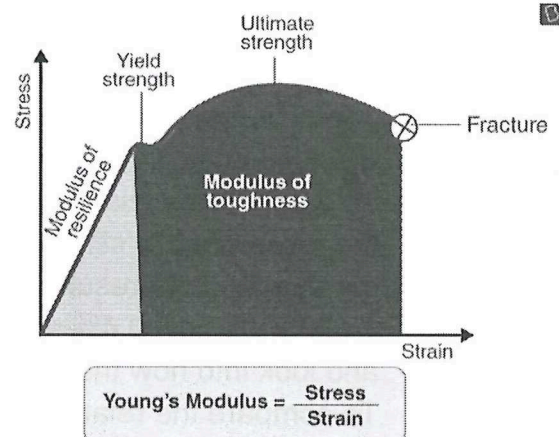


As shown in the figure a wire with length L and a cross section A experiences an increase in length Δ under force F applied to the length. Young's modulus of elasticity is defined as the force required to extend a wire of unit length and unit cross-sectional area by a certain amount effectively quantifying the material's stiffness. Testbook. (n.d.). *Modulus of Rigidity: Learn Definition, Formula, Unit, E = young's modulus (NM²)*

$\sigma = \text{stress applied to the material}$

$\epsilon = \text{strain applied to the material}$

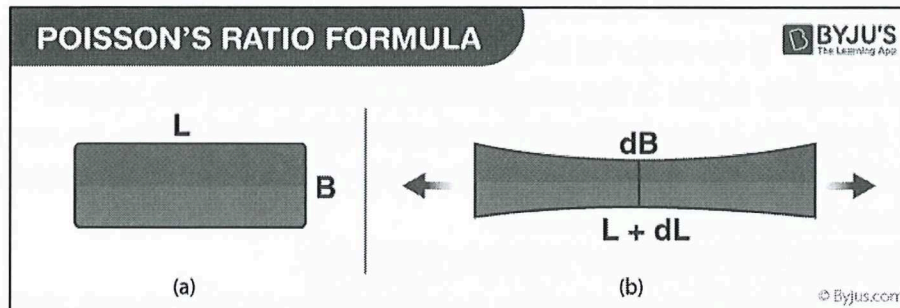
This graph illustrates the stress and strain relationship showing key points such as yield strength (where permanent deformation begins), the ultimate tensile strength (maximum stress the material can handle), and the fracture point (where the material breaks). The modulus of resilience represents the energy stored in the material up to the yield point while the modulus of toughness represents the total energy absorbed up to the fracture. This demonstrates the materials mechanical properties and resistance to deformation and failure



(BYJUS. (2023). *Modulus of Elasticity*)

Poisson's Ratio

Poisson's ratio is a material property that describes the ratio of lateral strain to axial strain, discovered by Simeon Denis Poisson. This theory measures how much a material will contract or expand in the directions perpendicular to the applied forces when stretched or compressed.



If you take a rod of any material and stretched it across the lateral axis, it will then begin to compress in the middle. If the original length of the material is taken as L and B , when the material is stretched the length will increase by an amount of dL and width will decrease by an amount of dB

$$\epsilon_t = -dB/B$$

$$\epsilon_l = dL/L$$

The formula for Poisson's ratio is,

$$\nu = -\frac{\text{lateral strain}}{\text{axial strain}}$$

$$\epsilon_t = \text{lateral or transverse strain}$$

$$\epsilon_l = \text{axial or Longitudinal strain}$$

$$\nu = \text{Poisson's Ratio}$$

BYJUS. (n.d.). *Poisson's Ratio - Longitudinal Strain and Lateral Strain*

Poisson's ratio is important as it contributes to the mechanical behaviour of a materials performance and structure. It affects the stiffness, strength, stability, vibration, buckling, fatigue, fracture, and failure of different materials. Using poisson's ratio can help mechanical engineers perfect their design and analysis of various materials and structures for applications of the real world.

www.linkedin.com. (n.d.). *What are the applications and implications of Poisson's ratio in engineering design and analysis?*

Modulus of rigidity

If a body has a specific shape and size, it is considered rigid. However, the objects that we encounter in everyday life are not perfectly rigid when subjected to an external force, the object can be compressed, stretched or bent. When an object is subjected to an external force the object will deform, some materials have the ability to return to its original shape after the force is removed this is all down to the elasticity of the material. If the material is to return to its original shape it will depend on its modulus of elasticity which is the ratio of the deformation to the original dimension of the body, this is the relationship between stress and strain, known as the modulus of elasticity which shows how the material will respond to an external force and if the force exceeds the elastic limit

Unacademy. (n.d.). *Knowing About the Modulus of Rigidity.*

There are three types of modulus of elasticity corresponding to three types of strain (axial, volumetric and shear)

Young's modulus

Modulus of rigidity (The Modulus of rigidity is also known as the shear modulus specifically relates to the materials resistance to shear deformation)

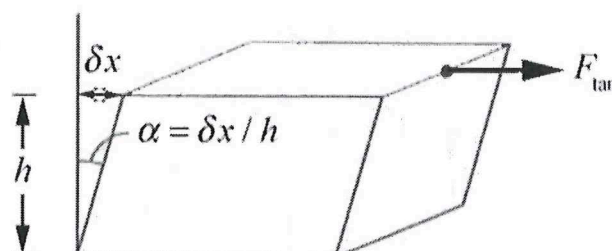
Bulk modulus

The formula for the modulus of rigidity is $G = \frac{\text{shearing stress}}{\text{shearing strain}}$

The modulus of rigidity decreases when the temperature increases, the thermal motion of the atoms increase violently, this leads to the weakening of intermolecular forces, meaning the material will be easier to strain and as the modulus of elasticity inversely related to strain, it will decrease as strain increases.

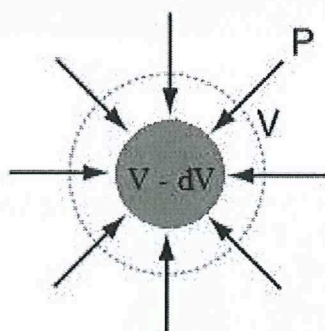
byjus.com. (n.d.). *How does the modulus of elasticity change with temperature?*

Shearing can be defined as the ratio of tangential stress to shear strain within a material's elastic limit. We can understand this by looking at the image below, the rectangular block has a fixed lower face and a force is applied to the upper face of the block A. the will create an equal and opposite force on the lower fixed face. The opposite focus will then create a torque, shearing the block into a parallelepiped by displacing its upper face while the lower face is fixed. Dourmashkin, P. (2020). 26.3: *Shear Stress and Strain*. [online] Physics LibreTexts. Available at:



Bulks modulus

Bulks modulus, a numerical constant that describes the properties of a solid or liquid material under uniform pressure applied to all surfaces. This pressure reduces the material volume, which typically returns to its original state once the pressure has been removed. Also known as incompressibility, the bulk modulus measures the materials resistance to volume changes under compression. Britannica (2019). Elasticity | Physics. In: *Encyclopædia Britannica*.



The calculation for bulks modulus is $k = \frac{-\Delta P}{\frac{\Delta V}{V_0}}$

k = bulks modulus (Pa)

ΔP = change in pressure

ΔV = change in volume

V_0 = initial volume

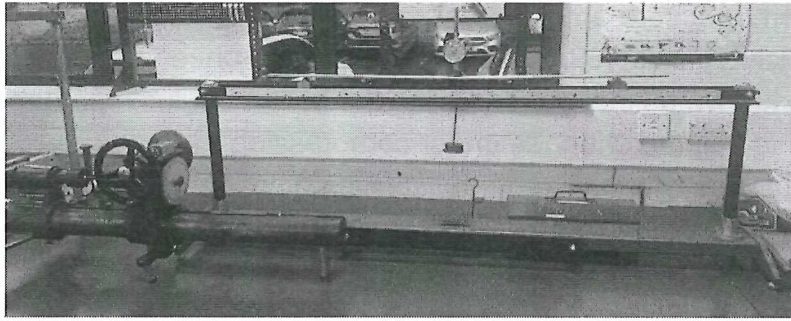
$\frac{\Delta V}{V_0}$ = volumetric strain

Testbook. (n.d.). *Modulus of Rigidity: Learn Definition, Formula, Unit, Examples*.

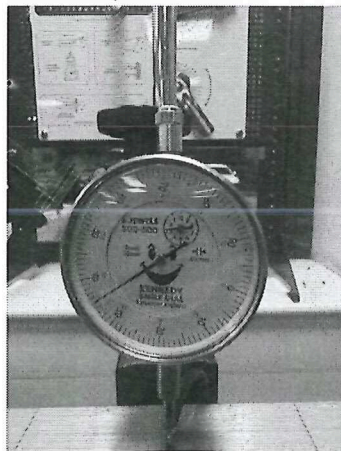
- ① You could have listed the expected values of each of the materials tested
- ② You could have investigated the relationships between the various elastic constants here.

Test 1 To investigate the effects of loading a beam

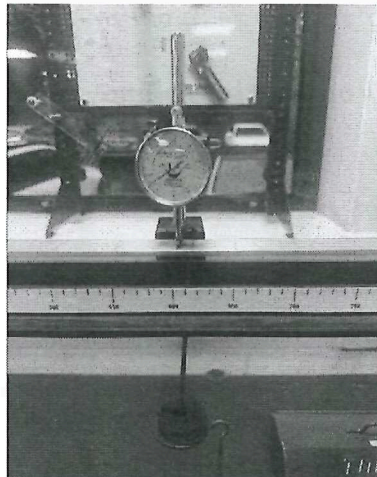
Equipment



- Aluminum beam ($L = 0.8\text{m}$) ($W = 0.030\text{m}$) ($H = 0.005\text{m}$)
- Point load applicator
- Calibrated weights
- Kennedy Dial Test Indicator (DTI to measure the deflection).



- measurement device (To measure the calibrated weight applied)



- grips/fixtures (to secure the beam in place during the test).
- Excel (to record and analyse data such as torque and angular displacement).

Method

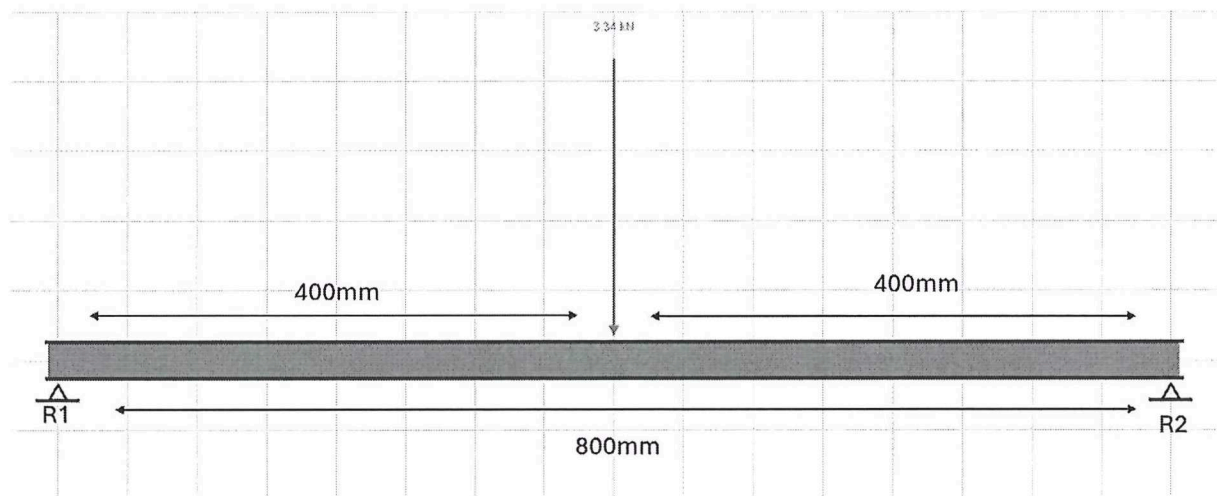
1. Get the aluminum beam
2. Place the beam on fixed supports

3. Position the loading device at the centre point along the beam's length.
4. Install the load cell to measure the applied force accurately.
5. Attach deflection measurement tools beneath the expected point of maximum deflection.
6. Gradually apply the load at the centre point on the beam.
7. Monitor and record the applied load and corresponding deflection at regular intervals.
8. Continue applying the load until the designated load has been reached
9. Record the maximum deflection and the corresponding load.
10. Plot load vs. deflection graphs.
11. assess data to determine material and structural properties such as deflection, stress, strain, and failure characteristics.
12. Compare the experimental deflection results with theoretical predictions



Calculations

The following diagram illustrates the equipment i used in test 1



Moment of equilibrium Reaction forces

Take the moments from R1

clockwise moments = anticlockwise moments

$$3.34 \times 0.4 = 0.8R2$$

$$1.336 = 0.8R2$$

$$R2 = \frac{1.336}{0.8}$$

$$R2 = 1.67N$$

$$R1 + R2 = 3.34$$

$$3.34 - 1.67 = R1$$

$$R1 = 1.67$$

Bending moments

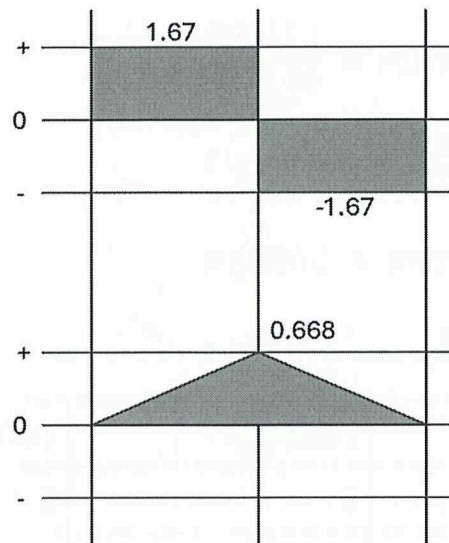
$$\underline{BM \text{ at } 1 = 0}$$

$$\underline{BM \text{ at } 2 = 0}$$

$$\underline{BM \text{ at } 3 = 1.67 \times 0.4 = 0.668}$$

$$Max \text{ BM} = 0.668Nm$$

Below is a illustration of the bending moment



Stress formula

$$\sigma = \frac{My}{I}$$

$$M = 0.668 \text{ NM}$$

$$y = 0.025 \text{ m}$$

$$I = \frac{bd^3}{12}$$

$$I = \frac{0.03 \times (0.005)^3}{12} = 3.125 \times 10^{-10} \text{ m}^4$$

Stress calculation

$$\sigma = \frac{0.668 \times 0.025}{3.125 \times 10^{-10}} = 5344000 \text{ N/m}^2$$

Youngs modulus calculations

$$EI = \frac{800 \times 2.1}{48} = 67.2 \text{ GN/m}^2$$

$$\text{Deflection} = \frac{WL^3}{48EI}$$

$$L^3 = 0.8^3 = 0.512 \text{ m}^3$$

$$E \times I = 67.2 \times 10^9 \times 3.125 \times 10^{-10} = 21 \text{ Nm}^2$$

$$WL^3 = 3.34 \times 0.512 = 1.71168$$

Deflection calculation

$$\text{Deflection} = \frac{1.71168}{48 \times 21}$$

$$\frac{1.71168}{1008} = 1.698 \times 10^{-3}$$

$$\text{Deflection} = 1.698\text{mm}$$

Deflection data table for aluminium

Load (lbs)	Load (kg)	Load (N)	Deflection (mm)
0	0	0	0
0.25	0.114	1.11	0.52
0.35	0.159	1.56	0.7
0.45	0.204	2	0.95
0.55	0.25	2.45	1.19
0.65	0.295	2.89	1.38
0.75	0.341	3.34	1.6

The calculations below show how to calculate load (kg)

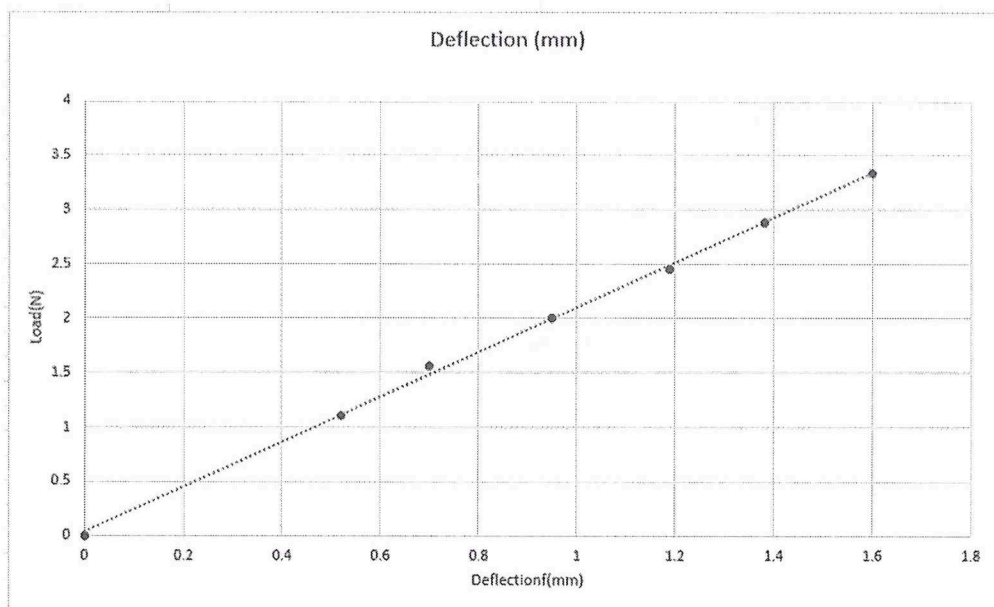
$$\text{Kilograms (kg)} = \text{Pounds (lbs)} \times 0.453592$$

The calculations below show how to calculate load (N)

$$g = 9.81\text{m/s}^2$$

$$\text{Force (N)} = \text{Mass (kg)} \times \text{Acceleration due to gravity (g)}$$

Load Vs Deflection graph



Better to have
placed this before
your calculations.

Analysis of results and observations

The difference between the experimental deflection (1.6mm) and the theoretical deflection (1.698mm) can be down to many factors, as theoretical calculations are based on an ideal situation that may not perfectly match real-world conditions. A comparison and possible reasons for the difference could be that actual materials have slight inconsistencies in density and their elastic composition which can change the way they react to forces. *Why do the experimental and theoretical values differ in the deflection of a beam?* The difference of 0.098mm (5.8%) is within a typical range between experimental and theoretical results as the theoretical value is assuming that it is in ideal conditions, while experimental setup induces real-world imperfections. This difference highlights the importance of validating theoretical results with experimental data to account for real world differences.

Reasonable value of E obtained.

From our calculations we can see that the maximum stress is seen directly in the centre at the top of the beam, the maximum stress calculated is 5344000N/m^2 (5.34MPa). This is also the max bending moment. To reduce the amount of stress there are many different factors that we can change such as, increasing the depth of the beam will increase the moment of inertia (I). We could also use a material with a higher yield strength such as steel instead of aluminium with a lower yield strength. If these can't be changed the last option would be to reduce the applied force that the beam sees or add in supports to negate the stress the beam sees.

Flexural rigidity and its significance

The definition of flexural rigidity is the material's product of elasticity (E) and the moment of inertia (I) of the cross section.

Flexural Rigidity = EI

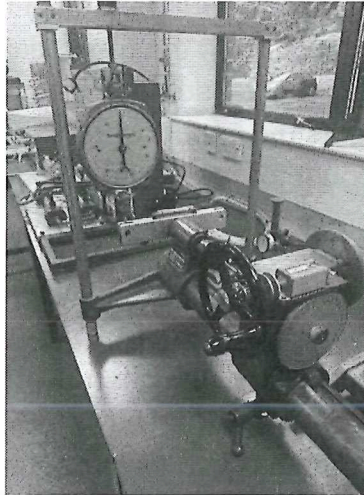
Yas could have explored this in more detail.

The significance of flexural rigidity determines the beam's resistance to bending. A higher value means the beam is stiffer and will experience less deflection under the same loading conditions. Testbook. (2024). *[Solved] The flexural rigidity is the product of.*

Test 2: Torsion test on 0.4% carbon steel and 70/30 brass

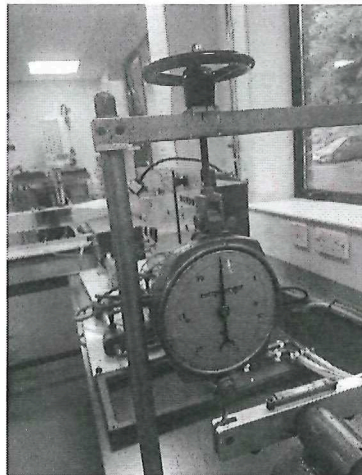
Equipment

1. Torsion testing machine (capable of applying controlled torque and measuring angular displacement).

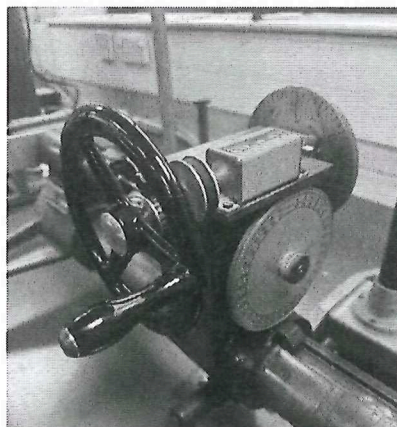


*Always label diagrams
and images.*

2. 70/30 brass cylindrical rod ($L = 0.09m$) ($D = 0.006m$)
3. 0.4% carbon steel rod ($L = 0.09m$) ($D = 0.006m$)
4. Torque sensor (to measure the applied torque).



5. Angular displacement measurement device (To measure the angular displacement)



6. grips/fixtures (to secure the rod in place during the test).
7. Excel (to record and analyse data such as torque and angular displacement).

Method

- Secure one end of the brass rod in the fixed grip of the torsion testing rig. Ensure the rod is positioned securely and aligned properly.
 - Attach the other end of the rod to the rotating grip of the machine. This will apply the torque to the 70/30 brass during testing.
 - Set the torsion testing machine to apply a controlled torque increasing the torque in controlled increments to measure the angular twist in increments of 0.5
 - Start the test. As torque is applied, measure and record the torque (T) and the corresponding angular displacement (θ) at regular intervals using the load cell and angular displacement device.
 - Ensure that you are recording both the torque and angular displacement in the excel data sheet.
 - Record the final torque and angular displacement at the point of failure or the maximum rotation you've set.
 - Analyse the torque vs. angular displacement data obtained during the test. Plot a torque-angle graph.
 - Calculate the shear modulus (G) of the 70/30 brass
 - Once the test is complete, carefully remove 70/30 brass from the machine
 - Then repeat this method for the 0.4% carbon steel rod
- 

Calculations and Results

Formulas

From the results i received from the both torsion tests that i carried out i am now able to work out the modulus of rigidity using the formulas below

T = applied torque (N·m),

L = length of material (m),

J = polar second moment of area

θ = angle of twist (rad).

G = Modulus of rigidity of the material

Firstly we had to convert the angle of twist from radians to degrees using the

formula $\text{Twist Angle (Radians)} = \text{Twist Angle (Degrees)} \times \frac{\pi}{180}$

The relationship between torque and angular displacement in a material can be expressed as:

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$$

Reference needed

The second moment of inertia can be calculated using the formula

$$J = \frac{\pi D^4}{32}$$

From this, the modulus of rigidity, G , can be determined as:

$$G = \frac{L}{J} \times \frac{T}{\theta} \rightarrow G = \frac{L}{J} \times \text{Slope of the graph}$$

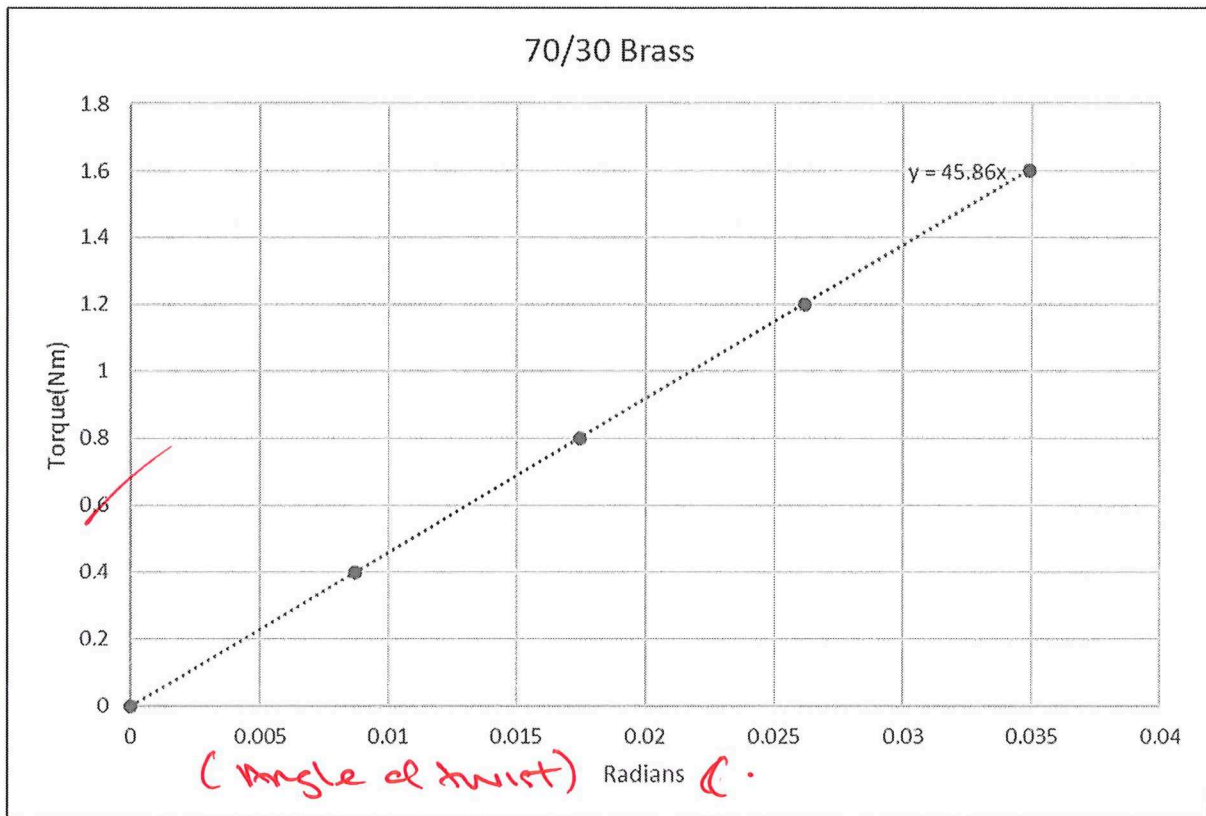
Torsion data table for 70/30 Brass

Torque (NM)	Twist (Degrees)	Radians
0	0	0
0.4	0.5	0.008722222222
0.8	1	0.017444444444
1.2	1.5	0.026166666667
1.6	2	0.034888888889

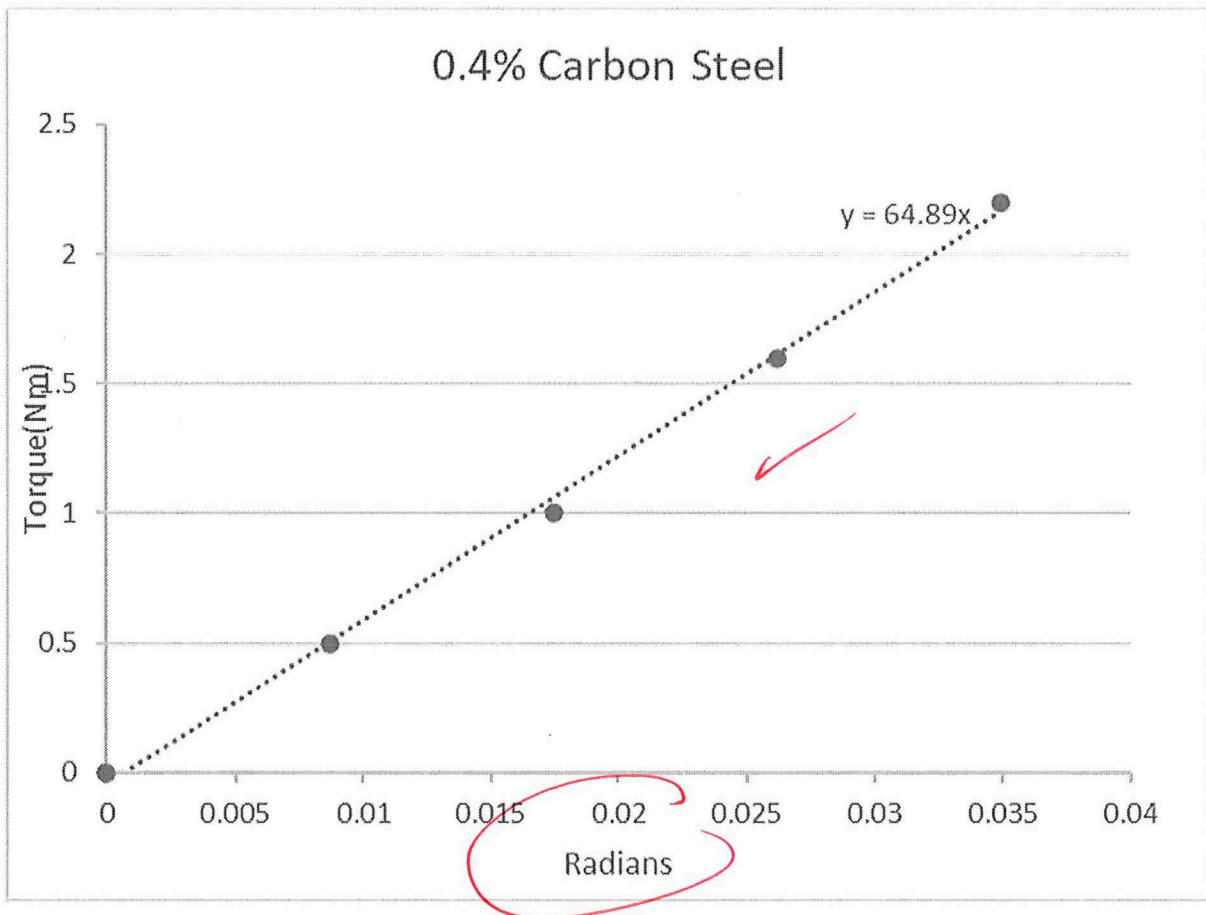
Torsion data table for 0.4% carbon steel

Torque (NM)	Twist (Degrees)	Radians
0	0	0
0.5	0.5	0.008722222222
1	1	0.017444444444
1.6	1.5	0.026166666667
2.2	2	0.034888888889

Torque (NM) Vs Twist Angle (Radians) for 70/30 Brass



Torque (NM) Vs Twist Angle (Radians) for 0.4% carbon steel



Modulus of rigidity for brass

$$x_1 = 0.0349$$

$$x_2 = 0.0087$$

$$y_1 = 1.6$$

$$y_2 = 0.4$$

$$m = \frac{1.6 - 0.4}{0.0349 - 0.0087} = 45.802$$

$$m = 45.802 \text{ NM/radian}$$

$$\theta = \tan^{-1}(45.802) = 88.749^\circ$$

$$J = \frac{\pi \times (0.005)^4}{32} = 6.1358 \times 10^{-11} \text{ m}^4$$

$$G = \frac{L}{J} \times \text{slope}$$

$$G = \frac{0.09}{6.1359 \times 10^{-11}} \times 45.802 = 67.181 \times 10^9$$

$$= 67.181 \text{ GPa}$$

Modulus of rigidity for 0.4 % steel

$$x_1 = 0.0349$$

$$x_2 = 0.0087$$

$$y_1 = 2.2$$

$$y_2 = 0.5$$

$$m = \frac{2.2 - 0.5}{0.0349 - 0.0087} = 64.886$$

$$m = 64.886 \text{ NM/radian}$$

$$\theta = \tan^{-1}(64.885) = 89.117^\circ$$

$$J = \frac{\pi \times (0.005)^4}{32} = 6.1358 \times 10^{-11} \text{ m}^4$$

$$G = \frac{L}{J} \times \text{slope}$$

$$G = \frac{0.09}{6.1359 \times 10^{-11}} \times 64.885 = 95.12 \times 10^9$$

$$= 95.120 \text{ GPa}$$

Analysis and observation

From the torsion test on 70/30 Brass and 0.4% steel rods shows a significant difference between their mechanical properties under a torsional load. From the results I calculated the modulus of rigidity (shear modulus). For 70/30 brass is 67.181 GPa where as 0.4% carbon steel is higher at 96.120 GPa . This shows that Carbon steel has a higher resistance to the shear deformation compared to brass. The torque Vs angular twist data shows that carbon steel can withstand a higher torque with smaller angular displacement compared to brass, highlighting its greater stiffness, whereas brass while less rigid could still be an option in applications where there is a need for flexibility or corrosion resistance.

Conclusion

These findings match with the material's typical industrial applications. Carbon steel is used within structures and load-bearing components, while brass is often chosen for its high resistance to environmental factors, this comparison shows the importance of selecting materials based on different requirements in engineering designs.

References

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