Determination of Torsional Rigidity of Various Materials

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Abstract: Torsional rigidity is the torque required for producing a twist of one radian per unit length of the shaft. Mathematically, it is the product of the modulus of rigidity and polar moment of inertia. In this present work we have taken 4 different materials and torsion testing was carried out on those materials to find the torsional rigidity values for all the four materials. Here the values calculated are done practically on the torsion test machine and modulus of rigidity was calculated, further the polar moment of inertia was found out and then finally the product of polar moment of inertia (J) and modulus of rigidity (G) was found out which is the torsional rigidity (C). Similarly, for all the four materials the torsional rigidity was calculated and graphs were also drawn.

Keywords: Torsional rigidity, Modulus of rigidity, Polar moment of inertia, Torque, Diameter, Length.

Introduction

Torsion is the twisting action of a body where one end tends to bend about longitudinal axis and the other end turns in the opposite direction. It is the product of modulus of rigidity and polar moment of inertia.

\[ \text{Torsional rigidity} = G \times J \]

Modulus of rigidity is defined as the ratio of shear stress to the shear strain. Experimentally it can be determined by the stress-strain curve.

\[ \text{Modulus of rigidity} (G) = \frac{\tau}{\gamma} \]

Polar moment of inertia is the measure of a beam’s ability to withstand torsion.

\[ \text{Polar moment of inertia} (J) = \pi d^4/32 \]

From the theory of Torsion:

\[ \frac{T}{J} = \frac{T}{r} = \frac{(C.\theta)}{l} \]

Where, \( T = \) Torque, \( J = \) Polar moment of inertia, \( T = \) Shear stress, \( r = \) Radius of the specimen, \( C = \) Modulus of rigidity, \( \theta = \) Relative angle of twist (in radians), \( l = \) Length of the specimen.

Experimental Procedure

There are certain steps that need to be followed for carrying out the experiment.

1. Firstly measure the diameter of the specimen at three different places and take the average diameter.
2. Then measure the length of the sample taken.
3. Adjust the twist scale and torque scale to zero initially.
4. Apply the torque gradually by hand and note the corresponding relative twist values. The torque is increased in steps of 200 kg-cm up to a maximum of 1600 kg-cm.
5. The readings on twist scale are noted for each increment of 200 kg-cm torque and tabulated.
6. The applied torque is gradually released in steps of 200 kg-cm and the twist values on twist scale are noted and tabulated.

The same procedure is applied for all the four selected materials.

Tabulated Columns

The diameter of the specimen is, \( d = 6\text{mm} \).
The length of the sample is, \( L = 250\text{mm} \).
The polar moment of inertia, \( J = (\pi d^4)/32 \).
Where \( d = 6\text{mm} \), \( J = 127.2\text{mm}^4 \).

After carrying out the experiment the values are noted down in the tables. The values of the Stainless steel specimen are shown in table-1.
Table-1: Stainless steel.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Twist (kg-cm)</th>
<th>Torque (in degrees)</th>
<th>Average Torque</th>
<th>G N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Applying</td>
<td>Releasing</td>
<td>Mean</td>
<td>In degrees</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>15</td>
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</tr>
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<td>8</td>
<td>52</td>
<td>46</td>
<td>49</td>
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<td>10</td>
<td>60</td>
<td>60</td>
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</table>

The values of the Aluminium specimen are shown in table-2.

Table-2: Aluminium

<table>
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<tr>
<th>S.No</th>
<th>Twist (kg-cm)</th>
<th>Torque (in degrees)</th>
<th>Average Torque</th>
<th>G N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Applying</td>
<td>Releasing</td>
<td>Mean</td>
<td>In degrees</td>
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<td>13</td>
<td>12.5</td>
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<td>6</td>
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<td>18</td>
<td>18</td>
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<td>8</td>
<td>25</td>
<td>24</td>
<td>24.5</td>
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</table>

The values of the Copper specimen are shown in table-3.

Table-3: Copper

<table>
<thead>
<tr>
<th>S.No</th>
<th>Twist (kg-cm)</th>
<th>Torque (in degrees)</th>
<th>Average Torque</th>
<th>G N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Applying</td>
<td>Releasing</td>
<td>Mean</td>
<td>In degrees</td>
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<tr>
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<td>10</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

The values for Modulus of rigidity (G) and Torsional rigidity (C) for the materials are as follows:

Calculations

From experimental investigation:

\[
G = \frac{(T.\theta)}{(J.\theta)}, \quad C = GJ
\]

For stainless steel, \(G = 75865.126 \text{ N/mm}^2\)
Torsional rigidity, \(GJ = 9.65 \times 10^6 \text{ N-mm}^2\)

For aluminium, \(G = 34131.536 \text{ N/mm}^2\)
Torsional rigidity, \(GJ = 4.34 \times 10^6 \text{ N-mm}^2\)

For Copper, \(G = 52304.328 \text{ N/mm}^2\)
Torsional rigidity, \(GJ = 6.65 \times 10^6 \text{ N-mm}^2\)

For Iron, \(G = 66742.232 \text{ N/mm}^2\)
Torsional rigidity, \(GJ = 8.48 \times 10^6 \text{ N-mm}^2\)

From graph:

\[
G = \frac{(I}{J)}(dT/d\theta), \quad C = GJ
\]

For stainless steel, \(G = 78420.86 \text{ N/mm}^2\)
Torsional rigidity, \(GJ = 9.97 \times 10^6 \text{ N-mm}^2\)

For aluminium, \(G = 33139.5 \text{ N/mm}^2\)
Torsional rigidity, $G_J = 4.21 \times 10^6 \, \text{N-mm}^2$

For Copper:
$G = 51537.20 \, \text{N/mm}^2$
Torsional rigidity, $G_J = 6.55 \times 10^6 \, \text{N-mm}^2$

For Iron:
$G = 63124.88 \, \text{N/mm}^2$
Torsional rigidity, $G_J = 8 \times 10^6 \, \text{N-mm}^2$

The graphs drawn for the taken specimens are shown in graphs: 1, 2, 3, 4.

Graph-1: Stainless steel.

Graph-2: Aluminium

Graph-3: Copper.

Graph-4: Iron.
Conclusion

From the above conducted experiment on four specimens it was observed that stainless steel has more torsional rigidity among the other three specimens. The sequence of the four specimens is as follows: Stainless steel > Iron > Copper > Aluminium. This sequence can be concluded from the above tabulated values which were obtained both from the experimental investigation and as well as from the graph.

References

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