**NOTRE DAME UNIVERSITY**

**FACULTY OF ENGINEERING**

**CEN 204**

**SECTION "D"**

**EXPERIMENT#8**

**TORSION TEST**

**Abstract**

In this experiment the test under question is the torsion test where different types of materials having different length and radius. This experiment will be divided into 4 parts once the same type of material will be used but with different radii second same material with different length third with different materials but same radius and a part when one material with specified length but the applied load will change. In all the above cases the theoretical and experimental arc of twist of the rod will be calculated compared and graphed.

**Introduction**

The test under question in this experiment is the torsion test. This experiment will be divided into four parts. In this experiment torsion will be affected by several factors which are: length, radius, diameter and the type of material tested. In each case one of these factors will be varying while the other factors will remain constants. In the first case the material used is copper while the radius of the rod will be varying, in the second case the material used is aluminum but the length of the rod will be varying, in the third case four different materials will be used which are: steel, copper, brass and aluminum having same length but different modulus of rigidity. While in part 2 an aluminum rod will be under tasting having a specified length and radius but now the applied moment is varying by varying the applied load. In all these parts the theoretical and experimental values for the arc of twist will be calculated discussed and graphed in addition to the percentage error.

**Apparatus and list of equipments**

* Steel, aluminum, brass and copper rods
* Dial gage
* 2 drill shucks that can be separated by various distances
* Weights of 0.1, 0.2,0.5,1,1.5 and 2 KG
* Caliper
* Measuring tape

**Theoretical analysis**

For the first part option "A" material used is copper with radius respectively 5, 6, 8 and 10mm:

Radius=10mm

L= 400mm, Lf=345mm, G=48000N/mm^2

Y=80.5\*0.01=0.805mm

Y'=Y-Di=0.805-0.09=0.715mm

Mt=100\*1\*9.807=980.7 N/mm

ג(exp)=R\*ᶲ=d/2\*Y'/S

ᶲ=y'/S=0.715/57.3=0.012478184

)גexp)=10/2\*(0.715/57.3)=0.062390924mm

ג(theo)=Lf\*ˠ=Lf\*(Fn/G)\*(16\*100/∏\*d^3)

ג=345\*(9.807/48000)\*(16\*100/∏\*10^3)

ג=0.035899148mm

For part 1 option "B"

The material used is aluminum having respective length 636, 536, 435, and 402mm

G=26950N/mm^2 Diameter=10mm F=1 kg

L=636mm Y=1.46mm Lf=580mm

Y'=1.46-0.09=1.37mm

Mt=100\*9.807=980.7N/mm

ג exp=R\*ᶲ=d/2\*(y'/S)

ג=5\*(1.37/57.3)=0.119546247mm

ג theo=Lf\*(Fn/G)\*(16\*100/∏\*d^3)

ג=580\*(9.807/26950)\*(1600/∏\*10^3)

ג=0.107491843mm

For part 1 option "C"

In this parts the 4 materials are used having the same length and diameter

Steel L=33.6 Lf=28.2 diameter=12mm G=80850N/mm^2

Y=19.5\*0.01=0.195

Y'=0.195-0.09=0.105

Mt=100\*1\*9.807=980.7

גexp=R\*ᶲ=d/2\*(Y'/S)

ג=6\*(0.105/57.3)=0.010994764mm

גtheo=Lf\*(Fn/G)\*(16\*100/∏\*d^3)

ג=282\*(9.807/80850)\*(1600/∏\*12^3)

ג=0.01008165mm

For part 2

In this part the material used is aluminum

L=400mm Diameter=10mm G=26950N/mm^2 F=0.5kg

Y=14\*0.01=0.14mm

Y'=0.14-0.045=0.095mm

Mt=100\*0.5\*9.807=490.35N.mm

ᶲexp=Y'/S=0.095/57.3=0.016579406 rad

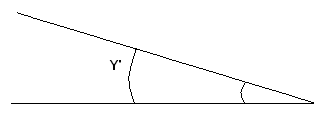
ᶲtheo=Lf/R\*(Fn/G)\*(16\*100/∏\*d^3)

ᶲ=400/5\*(9.805\*0.5/26950)\*(16\*100/∏\*10^3)

ᶲ=7.4132\*10^-3 rad

**Discussion of the work done**

The major cause of the error was the inherent distortion of the apparatus it was corrected by a factor "Di" that was provided by the appendix "B" by the manufacturer each value of weight has a respective value of "Di" that was subtracted from the value of the arc of twist. In addition the inability to fix the rod in the shuck perfectly which increase the probability to rotate the shuck without rotating the rod.



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In order to determine ג which is the arc of twist in terms of Y' the angle of twist ᶲ should be calculated hence ᶲ=Y'/S and ג=R\*ᶲ this implies that ג = d/2\*Y'/S

As for comparing the different values of the arc of twist for different rods this comparison can't happen without varying one criteria and fixing all the others

Taking the first option of the first part where one type of material is used having same length but different radius from the calculated values the value of the arc of twist decreases as the radius increase for a 10mm radius ג=0.062 for an 8mm radius

In the second option aluminum was used having 10mm radius having different length and from the tables the value of the arc of twist decreases as the length decreases for a 636mm aluminum bar ג=0.120 for 536mm ג=0.104

In the third option the four different materials were used but having the same length and same diameter from the tables for the steel rod the arc of twist is 0.011 as for the aluminum rod ג=0.037 this shows that as the modulus of rigidity decreases the arc of twist increases.

In the second part an aluminum rod of 400mm length with 10mm radius the results showed that as the load increases the arc of torsion increases for a o.5kg the arc is 0.035 for a 1.5kg load the arc is 0.082

Finally we can conclude that that the angle of twist is proportional to the force, length, and disproportional to the modulus of rigidity and the cross section.

**Procedure followed**

First the length of the bar is measured than the rod is fixed to the drill shucks keeping the loading arm at mid position then the free length is measured which is the distance between the clamps of the two shucks the dial gage is set to zero then the load is applied and the value of the torsion is recorded corrected to take account for the apparatus torsion the angle of torsion is calculated then the same procedure is repeated for the several cases.

**Tables and data sheet**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Experiment#8** | |  |  |  |  |  |  |
| *Part I* |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| **Option A:** | Arc of twist with respect to d | | |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Material: Brass; G=48,000N/mm2; L=400mm; F=1kg; s=57.3 mm | | | | | | | |
| d (mm) | Lf (mm) | Y (mm) | Y '(mm) | Mt (N.mm) | λexp (mm) | λtheo (mm) | %error |
| 5 | 337.5 | 8.845 | 8.755 | 980.7 | 0.382 | 0.350 | 9.052 |
| 6 | 337.5 | 5.23 | 5.14 | 980.7 | 0.269 | 0.203 | 32.759 |
| 8 | 337.5 | 2.0875 | 1.9975 | 980.7 | 0.139 | 0.086 | 63.058 |
| 10 | 337.5 | 0.805 | 0.715 | 980.7 | 0.062 | 0.044 | 42.496 |
|  |  |  |  |  |  | avg % error: | 36.841 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **OptionB:** | Arc of twist with respect to Lf | | |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Material: Aluminum; G=26950N/mm2; Diameter =10 mm; F=1kg; s=57.3 mm | | | | | | | |
| L (mm) | Lf (mm) | Y (mm) | Y '(mm) | Mt (N.mm) | λexp (mm) | λtheo (mm) | %error |
| 636 | 580 | 1.46 | 1.37 | 980.7 | 0.120 | 0.108 | 11.180 |
| 536 | 481 | 1.28 | 1.19 | 980.7 | 0.104 | 0.089 | 16.449 |
| 435 | 380 | 1.02 | 0.93 | 980.7 | 0.081 | 0.070 | 15.195 |
| 402 | 346 | 0.935 | 0.845 | 980.7 | 0.074 | 0.064 | 14.952 |
|  |  |  |  |  |  | avg % error: | 14.444 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Option C:** | Arc of twist with respect to G | | |  |  |  |
|  |  |  |  |  |  |  |
| Diameter =12 mm; L=336 mm; Lf=282 mm; F=1kg; s=57.3 mm | | | | | | |
| Material | Y (mm) | Y '(mm) | Mt (N.mm) | λexp (mm) | λtheo (mm) | %error |
| Steel | 0.195 | 0.105 | 980.7 | 0.011 | 0.017 | 36.888 |
| Aluminum | 0.447 | 0.357 | 980.7 | 0.037 | 0.052 | 28.473 |
| Brass | 0.275 | 0.185 | 980.7 | 0.019 | 0.037 | 47.049 |
| Copper | 0.22 | 0.13 | 980.7 | 0.014 | 0.029 | 53.610 |
|  |  |  |  |  | avg % error: | 41.505 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Part II* |  |  |  |  |  |  |  |  |
| Angle of twist with respect to Mt | | |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Aluminum; d=10 mm; Lf=400mm; G=26,950 N/mm2; s=57.3 mm | | | | | | | | |
| F (kg) | Mt (N.mm) | Y (mm) | Y '(mm) | φexp (rad) | φtheo (rad) | % error | λexp (mm) | λtheo (mm) |
| 0.1 | 98.07 | 0.14 | 0.13 | 0.002 | 0.001 | 37.550 | 0.010 | 0.007 |
| 0.2 | 196.14 | 0.22 | 0.2 | 0.003 | 0.003 | 0.000 | 0.015 | 0.015 |
| 0.5 | 490.35 | 0.44 | 0.395 | 0.007 | 0.007 | 3.715 | 0.035 | 0.036 |
| 1 | 980.7 | 0.715 | 0.625 | 0.011 | 0.015 | 25.035 | 0.055 | 0.073 |
| 1.5 | 1471.05 | 1.09 | 0.935 | 0.016 | 0.022 | 25.184 | 0.082 | 0.110 |
| 2 | 1961.4 | 1.45 | 1.245 | 0.022 | 0.029 | 25.284 | 0.109 | 0.145 |
|  |  |  |  |  | avg % error: | 19.461 |  |  |

**Conclusion**

In many engineering applications we see that most parts that are under high torque have a bit small cross section taking as example the crank shaft of an engine have a radius of 10mm the axles of a car which is the link between the gear box and the wheels does not exceed 7mm this part which receives the highest load in the car this proves that we can have parts that can receive high torques can have small cross sections without affecting their strength that proves that increasing the modulus of rigidity can help in decreasing the arc of twist under the effect of torsion.

From the formula used in the calculation of the theoretical angle of twist we can derive a general formula:

ᶲ=Lf/R\*(Fn/G)\*(16\*100/∏\*d^3)

Taking 100\*R\*Fn as the torque applied T

Expanding (∏/d^3) into ∏\*(2R)^3

This become ∏\*8R^3 replacing in the above formula we get

T\*L/(G\*R)\*(16/∏\*8R^3) this can be reduced to

T\*L/G\*((∏/2)\*R^4)

ᶲ=T\*L/GJ with J=∏/2\*R^4