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# DESIGN AND SIMULATION OF TORSION BAR(ARB) FOR FSAE USING MATLAB

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***Abstract* - Formula SAE is a student design competition organized by SAE International (previously known as the Society of Automotive Engineers, SAE). The concept behind Formula SAE is that a fictional manufacturing company has contracted a student design team to develop a small Formula-style race car. The prototype race car is to be evaluated for its potential as a production item. Each student team designs, builds and tests a prototype based on a series of rules, whose purpose is both ensuring on-track safety and promoting clever problem solving. An anti-roll bar is a part of automobile suspensions that helps reduce the body roll of a vehicle during fast cornering or over road irregularities. It connects opposite wheels together through short lever arms linked by a torsion spring. A sway bar increases the suspension's roll stiffness—its resistance to roll in turns, independent of its spring rate in the vertical direction. In this research paper, calculation for the anti-roll bar mechanism will be simpler, and more accurate than hand calculations. Calculation was done using MATLAB and further analysis using FEA in ANSYS.**

*Keywords*- **Anti Roll Bar; FEA; MATLAB; Sway Bar; Torsion; FSAE**

## I. INTRODUCTION

An anti-sway or anti-roll bar is intended to force each side of the vehicle to lower, or rise, to similar heights, to reduce the roll of the vehicle on curves, sharp corners, or large bumps. With the bar removed, a vehicle's wheels can tilt away by much larger distances. Although there are many variations in design, a common function is to force the opposite wheel's shock absorber to the same level as the other wheel. For example, in a fast turn, a vehicle tends to drop closer onto the outer wheels, and the sway bar soon forces the opposite wheel to also get closer to the vehicle. As a result, the vehicle tends to "hug" the road closer in a fast turn, where all wheels are closer to the body. After the fast turn, then the downward pressure is reduced, and the paired wheels can return to their normal height against the vehicle, kept at similar levels by the connecting sway bar.

Because each pair of wheels is cross-connected by a bar, the combined operation causes all wheels to generally offset the separate tilting of the others and the vehicle tends to remain level against the general slope of the terrain.

Anti-roll bars provide two main functions. The first function is the reduction of body lean. The reduction of body lean is dependent on the total roll stiffness of the vehicle. Increasing the total roll stiffness of a vehicle does not change the steady state total load transfer from the inside wheels to the outside wheels, it only reduces body lean. The total lateral load transfer is determined by the CG height and track width.

The other function of anti-roll bars is to tune the handling balance of a car. Understeer or oversteer behavior can be tuned out by changing the proportion of the total roll stiffness that comes from the front and rear axles. Increasing the proportion of roll stiffness at the front increases the proportion of the total load transfer that the front axle reacts to—and decreases the proportion that the rear axle reacts to. In general, this makes the outer front wheel run at a comparatively higher slip angle, and the outer rear wheel to run at a comparatively lower slip angle, which is an understeer effect. Increasing the proportion of roll stiffness at the rear axle has the opposite effect and decreases understeer.

## II. CALCULATION

3 cases have been considered, with the material as our variable. Result will be considered based on the torsion bar which has the least torsional shear stress values when compared with the max. tortional shear stress. The main objective is to calculate the diameter of the torsion bar (hollow), and to compare the theoretical shear stress calculated with the values of max. shear stress of the material, and with results from ANSYS simulations.

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To begin with, an assumption for the length and thickness of the 'pin-joint' has been taken (Ref. to Figure 1).

*Figure 1 : Pin-Joint*

At this point, the length of the torsional bar required, is from the kinematic diagram which is already designed. The forces which will act upon the bell-crank of the vehicle have to be calculated/retrieved, which will lead to the result of the torsion acting on the 'torsion bar' of the anti-roll bar mechanism. Using the thickness and length of the pin-joint, the angle is found at which the polar moment of inertia is acted upon. At this point, all the factors are available for calculating the polar moment of inertia acting on the torsion bar. From this value, calculation of the diameter of the tube is done. As a hollow tube is feasible as the torsion bar, this diameter will be considered as the outer diameter of the torsion bar. Following this, the inner diameter will be retrieved. Finally, the theoretical torsional shear stress of the tube can be retrieved. Also, design of torsion bar on DSS Solidworks and analyze for torsional shear on ANSYS, which will be the equivalent torsional shear. In order to utilize this torsion bar, both the torsional shear values must be less than the maximum torsional shear stress value of the material.

In our cases, the length of the torsion bar is 530.678mm. Thickness of pin-join is 5mm. Length of pin-joint is 92mm. Force exerted on bell crank is 872N. The Young's Modulus and Poisson's ratio varies, according to the material.

## III. CODE

```
clc
clear all
syms pi J D T L G t l F R E v
L=input('Enter length of torsion bar(mm): ')
t=input('Enter thickness of pin-joint(mm): ')
l=input('Enter length of pin-joint(mm): ')
F=input('Enter force exerted on bell crank(N): ')
E=input('Enter Youngs Modulus (Modulus of Elasticity) (GPa): ')
v=input('Enter Poissons Ratio: ')
G=(E/(2*(1+v)))
T=F*(l/1000)
R=t/l
o=atan(R)
J=((T*L)/(G*o))
pi=3.1415
D=((32*J)/pi)^0.25
D=input('RoundD : ')
d=((D^4)-((32*J)/pi))^0.25
d=input('Round(d): ')
t=((16*T)/(pi*((D^3)-(d^3))))*1000
```

1.3.1 Case (i) :

Material = AISI 4130 Steel (E = 200 GPa, v = 0.3)

Maximum torsional shear stress = 265 MPa

Enter length of torsion bar(mm): 530.78

L = 530.7800

Enter thickness of pin-joint(mm): 5

t = 5

Enter length of pin-joint(mm): 92

l = 92

Enter force exerted on bell crank(N): 872

F = 872

Enter Youngs Modulus (Modulus of Elasticity) (GPa): 200

E = 200

Enter Poissons Ratio: 0.3

v = 0.3000

G = 76.9231

T = 80.2240

R = 0.0543

o = 0.0543

J = 1.0195e+04

pi = 3.1415

D = 17.9517

Round D : 18

D = 18

d = 5.7886

Round(d): 6

d = 6

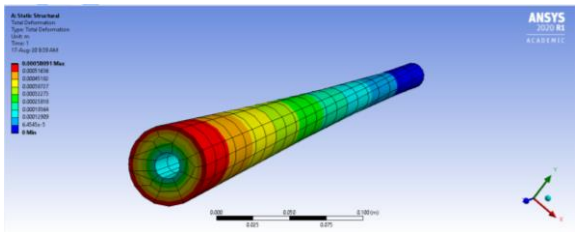
t = 72.7545

As observed, the theoretical torsional shear stress is 72.75 MPa

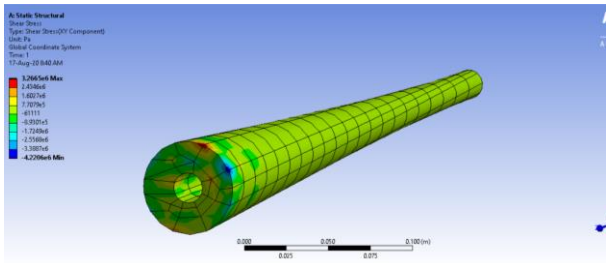
ANSYS Simlutaion:

Mesh Quality → Smoothing → Fine. The only parameter altered

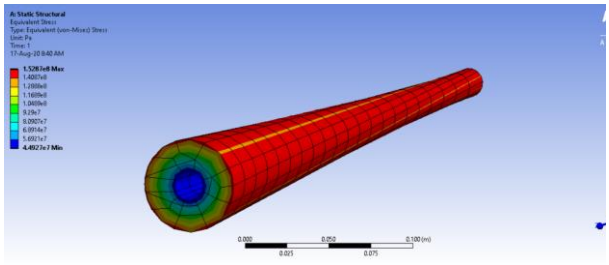
From above MatLAB output, Torque (T) = 80.224 Nm.



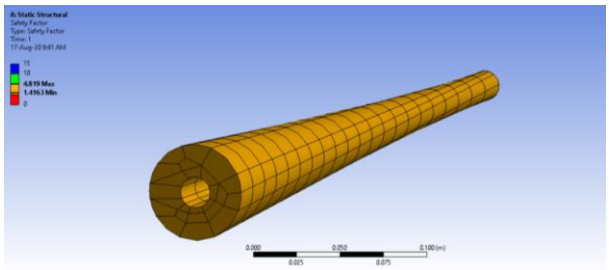
*Total deformation*



*Shear stress*



*Equivalent stress*



*FOS*

1.3.2 Case (ii):

Material: Ti-6Al-4V (E = 114 GPa, v = 0.342)

Maximum torsional shear stress = 575 MPa

Enter length of torsion bar(mm): 530.78

L = 530.7800

Enter thickness of pin-joint(mm): 5

t = 5

Enter length of pin-joint(mm): 92

l = 92

Enter force exerted on bell crank(N): 872

F = 872

Enter Youngs Modulus (Modulus of Elasticity) (GPa): 114

E = 114

Enter Poissons Ratio: 0.342

v = 0.3420

G = 42.4739

T = 80.2240

R = 0.0543

o = 0.0543

J =1.8465e+04

pi = 3.1415

D = 20.8252

RoundD : 21

D = 21

d = 8.9429

Round(d): 9

d = 9

t = 47.8891

>>

As observed, the theoretical torsional shear stress is 47.89 MPa

ANSYS Simulation:

Mesh Quality → Smoothing → Fine. The only parameter altered

From above MatLAB output, Torque (T) = 80.224 Nm.

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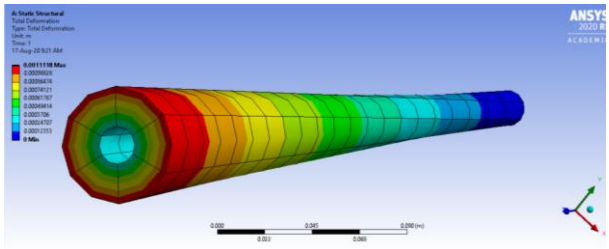
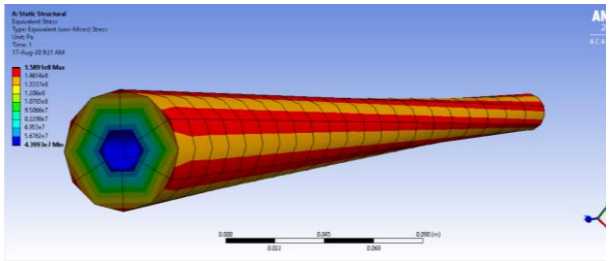
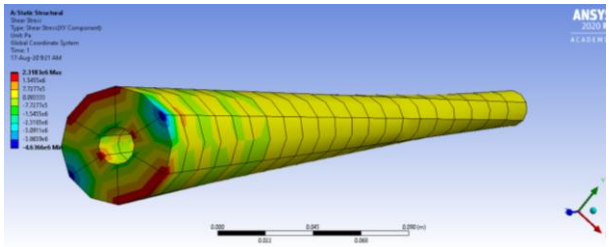


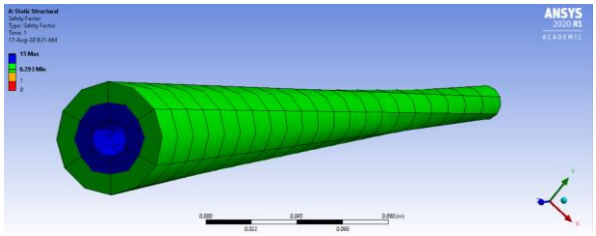
*Total Deformation*



*Equivalent Stress*



*Shear Stress*



*FOS*

## IV. RESULTS

| | **AISI 4130** | **Ti-6Al-4V** |
|---|---|---|
| **Theoretical Torsional Shear Stress** | 72.75 MPa | 47.88 MPa |
| **Total Deformation** | 0.588 mm | 1.11 mm |
| **Equivalent Stress** | 152 MPa | 158 MPa |
| **Shear Stress** | 3.226 MPa | 2.31 MPa |
| **FOS** | 1.4 – 4.8 | 6.293 |

## V. CONCLUSION

The function of the ARB is to withstand the torsional moment actuated on it, in order to transfer energy within the wheels, which balances the overall ride of the vehicle. From the above table, Ti-6Al-4V material is more feasible than AISI 4130, in manufacturing the ARB.

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