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Design and analysis of hollow torsion bar

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***Abstract*—This paper describes role torsion bar suspension in battle tank. The role of suspension system in a vehicle is much important and also it is much efficient than previous design. In existing torsion bar suspension failure occur due to more angle of twist in rod during heavy load applied. Here the project is comparison of solid and hollow bar suspension in Main Battle Tank. We have found the diameter of the solid rod based on the material properties. For this project spring steel is chosen. Load calculation for the arm and off set angle is found by using axial and tangential forces. By using bending equation arm is designed. For various loads bending stress and axial stress of the rod is found. After designing the arm and solid rod, shear stress and angle of twist for the solid rod is found. For the same volume and material shear stress and angle of twist of hollow rod is found for the various loads. By varying the torque, angle of twist and shear stress is gradually increased. By comparing the both values in hollow bar and solid bar, hollow bar is efficient. Because angle of twist and shear stress is reduced.**

From the result we have cleared that hollow torsion bar is more preferable than solid bar. Battle tanks are used for purpose of defense and the whole system of the tank is must be comfortable. Hence the suspension needs more flexible.

***Index Terms*— torsion bar, shear stress, design, hollow bar.**

I. INTRODUCTION

The suspension system of the vehicle must be flexible. Nowadays torsion bar suspension is used in battle tank. Battle tanks are used in defense field in various countries. In each tank torsion bar suspension system is used. In existing suspension system failure occur when sudden load applied. During sudden load applied, angle of twist of the rod is increased and it crosses the limit. So we need to reduce the angle of twist of the rod. If the complete solid rod is changed to hollow bar, it becomes more efficient. So we choose the hollow rod for suspension in battle tanks. To find the shear stress and angle of twist for the hollow and solid rod. Both rod having same volume and material properties. After finding this both rods of shear stress and angle of twist has to be compared. At end of work which rod having less angle of twist and shear stress for same volume, that design will be chosen as an efficient design

When the horizontal volute springs were to be positioned during the process of compression by either the initial or back bogie wheel arm, the load was transmitted to the back of the arm. This would be kept tension on the track

Figure 1. Photo of volute springs

Figure 2. Photo of horizontal springs

A volute spring is a compression spring in the form of a cone (a volute). Under compression the coils would slide over each other, affording longer travel. An independently suspended front system with torsion bars mounted lengthwise would have one end of the bars anchored to the car frame and the other end attached to the lower control arms. The existing torsion bar type of suspension system is shown in Figure 3.

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Figure 3. Photo of existing torsion bar

This project mainly concerned with the reduction of angle of twist in torsion bar by using hollow rod. Current battle tank having failure in suspension system. Further development is requiring to rectify the failure. For the alternate of solid bar suspension system, hollow bar is used. And also reduce the shear stress of hollow rod. To compare the angle of twist and shear stress of both rods. After comparing the values opted design will be chosen.

II. FORCE CALCULATION

Axial and tangential forces

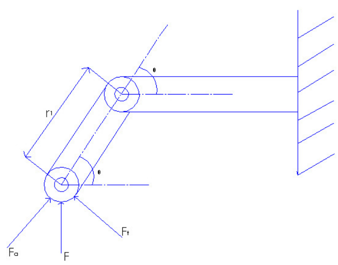

Figure 4. Line diagram indicating axial and tangential forces.

Total weight of tank = 50T

Total number of wheels = 10

Pay load per wheel $F_p = 50/10 = 5T$

$F_p = 5\times104$ N

(θ>0 to 90, increment θ=10)

$F_a = F \sin\theta$ & $F_t = F \cos\theta$

The values have been shown in Table 1

Table 1- Tabulation indicating tangential and axial forces

θ, degree	$F_a \times 10^4$ N	$F_t \times 10^4$ N
0	0	10
10	1.736	9.848
20	3.42	9.396
30	5	8.66
40	6.427	7.66
50	7.66	6.427
60	8.66	5
70	9.396	3.42
80	9.848	1.736
90	10	0

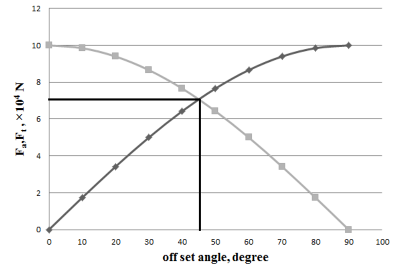

Figure 4. Indication of offset angle with force

Arm Design

(Take w=150mm and r=300mm)

$$\frac{M}{I} = \frac{c}{y}$$

$M = F_t \times r = 10\times10^4 \times 0.3 = 3\times10^4$ Nm

$$I = \frac{(t\times b^3)}{12} = \frac{(t\times 0.15^3)}{12} = t\times2.81\times10^{-4}\ m^4$$

$\sigma = 250\times10^6$ N/m^2

$$y = \frac{W}{2} = \frac{150}{2} = 75mm = 0.075m$$

$$\frac{3\times10^4}{t\times2.81\times10^{-4}} = \frac{250\times10^5}{0.075}$$

Thickness of arm, t = 0.032 m ≈ 32 mm

Design validation

F_T VS Bending stress & F_a vs compressive stress:

For minimum load: bending stress:

$$\frac{M}{I} = \frac{\sigma_b}{y}$$

$M = F_t \times r = 0.25\times10^4 \times 0.3 = 750$Nm

$$I = \frac{(t\times b^3)}{12} = \frac{(0.032\times 0.15^3)}{12} = 9\times10^{-6}\ m^4$$

$$y = \frac{W}{2} = \frac{150}{2} = 75mm = 0.075m$$

$$\frac{750}{9\times10^{-6}} = \frac{\sigma_b}{0.075}$$

$$\sigma_b = 6.25\times10^6\ N/m^2$$

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III. ANALYSIS OF SOLID TORSION BAR

Design of Solid Bar has been done. The force diagram has been indicated in Figure 5

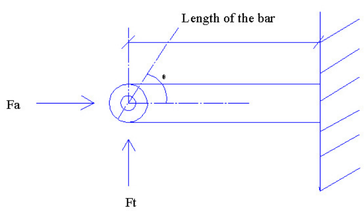

Figure 5. Force diagram for solid bar

Total load of tank =50T

No of wheels =10

Load on wheel =5T

$$\tau = \frac{\sigma_u}{2} = \frac{990}{2} = 495\ N/m^2$$

$$[\tau] = \frac{\tau}{fos} = \frac{495\times10^6}{2} = 200\times10^6\ N/m^2$$

Torque = $3.5\times10^4\times0.3$=10500 Nm

$$\frac{\pi d^3}{16} = \frac{T}{[\tau]}$$

$$\frac{\pi d^3}{16} = \frac{10500}{200\times10^9}$$

d=0.068 m

Diameter of the rod, d=68mm

$$\tau = \frac{\sigma_u}{2} = \frac{990}{2} = 495\ N/m^2$$

$$[\tau] = \frac{\tau}{fos} = \frac{495\times10^6}{2} = 200\times10^6\ N/m^2$$

Torque = $3.5\times10^4\times0.3$=10500 Nm

$$\frac{\pi d^3}{16} = \frac{T}{[\tau]}$$

$$\frac{\pi d^3}{16} = \frac{10500}{200\times10^9}$$

d=0.068 m

Diameter of the rod, d=68mm

Torque vs shear stress has been indicated in Figure 5 and the angle of twist with torque has been shown in Figure 6.

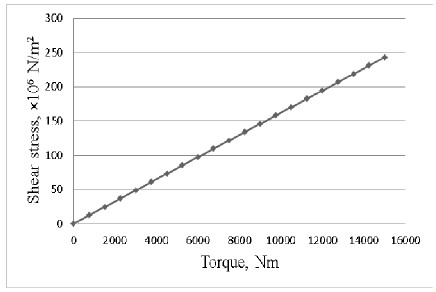

Figure 5 - Torque vs shear stress

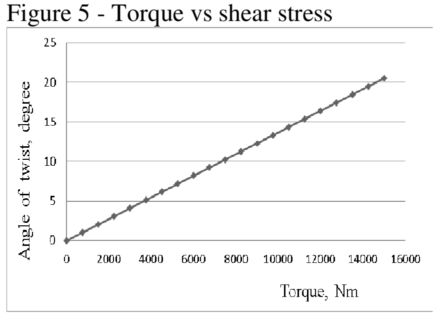

Figure 6 - Angle of twist with torque

IV. ANALYSIS OF HOLLOW TORSION BAR

Diameter of section 1

d = 68mm

Diameter of section 2

d_o=85mm

d_i=71mm

Diameter of section 3

d_o=102mm

d_i=93mm

Diameter of section 4

d_o=119mm

d_i=113mm

Diameter of section 5

d_o=136mm

d_i=132mm

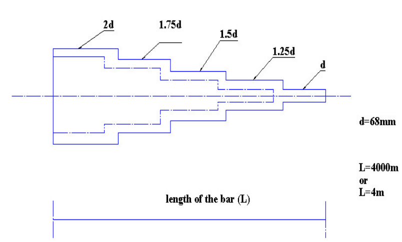

Figure 7 – Hollow bar

TOTAL ANGLE OF TWIST IN THE ROD

FOR MINIMUM TORQUE

T=750Nm

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$$\theta = \frac{32T}{\pi C}\left[\frac{l1}{d^4} + \frac{l2}{16d^4} + \frac{l3}{15d^4} + \frac{l4}{255d^4} + \frac{l5}{240d^4}\right]$$

$$= \frac{32\times750}{\pi\times80\times10^9}\left[\frac{0.64}{0.068^4} + \frac{0.84}{16(0.085)^4} + \frac{0.84}{15(0.102)^4} + \frac{0.84}{255(0.119)^4} + \frac{0.84}{240(0.136)^4}\right]$$

θ =0.172 degree

FOR MAXIMUM TORQUE

T=15000Nm

$$\theta = \frac{32T}{\pi C}\left[\frac{l1}{d^4} + \frac{l2}{16d^4} + \frac{l3}{15d^4} + \frac{l4}{255d^4} + \frac{l5}{240d^4}\right]$$

$$= \frac{32\times15E3}{\pi\times80\times10^9}\left[\frac{0.64}{0.068^4} + \frac{0.84}{16(0.085)^4} + \frac{0.84}{15(0.102)^4} + \frac{0.84}{255(0.119)^4} + \frac{0.84}{240(0.136)^4}\right]$$

θ = 3.44 degree

4.2 TORSIONAL BEHAVIOR OF HOLLOW BAR
SECTION 1
SHEAR STRESS:
FOR MINIMUM LOAD:

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\frac{750}{2.099\times10^{-6}} = \frac{\tau}{0.034}$$

τ = 12148642.21 N/m^2

FOR MAXIMUM LOAD:

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\frac{15000}{2.099\times10^{-6}} = \frac{\tau}{0.034}$$

τ = 242972844.2 N/m^2

COMPARISON OF SOLID & HOLLOW BAR

load, Tons	Torque, Nm	solid	hollow bar
0	0	0	0
0.25	750	1.02	0.17
0.5	1500	2.05	0.34
0.75	2250	3.07	0.52
1	3000	4.09	0.69
1.25	3750	5.12	0.86
1.5	4500	6.14	1.03
1.75	5250	7.17	1.21
2	6000	8.19	1.38
2.25	6750	9.22	1.55
2.5	7500	10.24	1.72
2.75	8250	11.27	1.89
3	9000	12.29	2.07
3.25	9750	13.31	2.24
3.5	10500	14.34	2.42
3.75	11250	15.36	2.5
4	12000	16.39	2.75
4.25	12750	17.41	2.92
4.5	13500	18.43	3.1
4.75	14250	19.56	3.27
5	15000	20.48	3.44

V. CONCLUSION

We have designed the solid bar and hollow bar of battle tank suspension system. We have found out the shear stress and angle of twist for both rod for the same volume and properties of spring steel material. In existing torsion bar suspension failure occur due to more angle of twist in rod during heavy load applied. We have found the diameter of the solid rod based on the material properties.

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