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Analysis of Anti-Roll bar to Optimize the Stiffness

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Abstract-The objective of this paper is to analyze stiffness of anti-roll bar by varying the various geometric condition of the anti-roll bar. The stiffness of anti-roll bar can be calculated by using the Finite Element Software ANSYS. Analysis of anti-roll bar is especially important as cases are reported about the fracture of anti-roll bar after a 1, 00,000 km of travel. Stiffness per weight is the basis for the comparison of different types of anti-roll bar. Improving the stiffness of bar with small increase in weight will result in improving the roll stability of the vehicle. The anti-roll bar having more ratio of stiffness per weight can be used in the vehicle.

Keywords-Stiffness, FEA, anti-roll bar, stability, roll angle

I. INTRODUCTION

Anti-roll bar is one of the inventions in the automobile industry which is also called as sway bar or stabilizer bar. Vehicle anti-roll bar is part of an automobile suspension system. Structure of such anti-roll bar are U shaped bar which connect two wheel that is left and right wheel and bar is fixed to the chassis of the vehicle by bush. Anti-roll bar may be solid or hollow tube. The main function of anti-roll bar is reducing body roll motion when the vehicle is at the cornering condition. An anti-roll bar improves the handling of a vehicle by increasing stability during cornering. Body roll condition occurs due to the load transfer and changes takes place in the camber of vehicle which directly affect the steering behavior of the vehicle and vehicle loses its stability therefore to eliminate the roll effect in case of under steer and over steer anti roll bar is used. Anti-roll bar gives comfort in driving condition and safety in case of such roll situation. One more benefit of anti-roll bar is that, it improves traction by limiting the camber angle change caused by body roll.

The Anti-roll bar provides the advantage that it allows to use the less stiff spring therefore it can absorb uneven road shocks giving ultimate comfort to passengers [1]. The antiroll bars can be used in front suspension, rear suspension or in both suspensions irrespective of type of suspension. Anti-roll bars may have irregular shapes to get around chassis components, or may be much simpler depending on the car. When the anti-roll bar is used in the vehicle then it reduces the body roll by 48.4% which gives the stability to the vehicle. By the use of finite element method stiffness of the anti-roll bar is found and it is shown that lowest stiffness to the weight ratio is achieved by using the shortest length of side length of bar [2].A typical anti-roll bar is shown in fig 1.

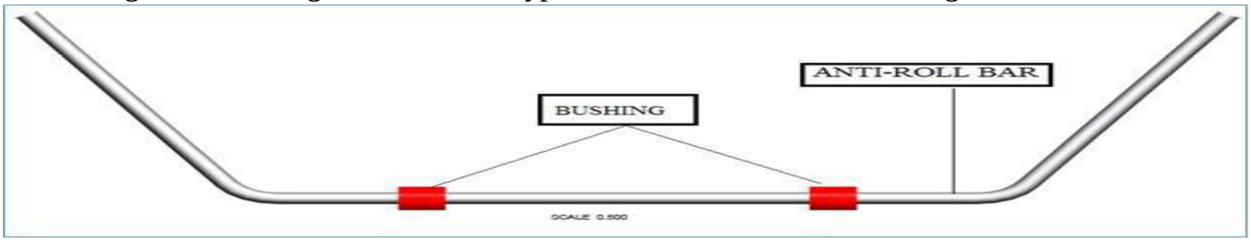

Fig1: Typical Anti-roll bar with bush

II. METHODOLOGY

In this paper we have considered the use of anti-roll bar at the rear suspension of vehicle. We have done different geometrical variation in anti-roll bar. We have varied the length of bar and the distance between the bush of the bar. Simple geometry of the bar is used for the purpose of analysis and stiffness of the bar is calculated with the finite element method that is by using the software. We have used the Ansys workbench 14 for simulation and analysis of anti-roll bar.

A. Stiffness of the bar

Roll stiffness can be calculated by using software. For calculating the roll stiffness only static analysis is considered and the effect of dynamic condition is completely eliminated. The anti-roll bar is considered to be made up of Steel. Properties of steel used are density, modulus of elasticity and Poisson's ratio. The linear load of 1 KN is applied at one end of the bar and in one direction but for the other end we have applied the same load in opposite direction. The results can be determined with help of deflection found in the software. As we have considered simple bar for analysis, hence obtained result and actual result may vary.

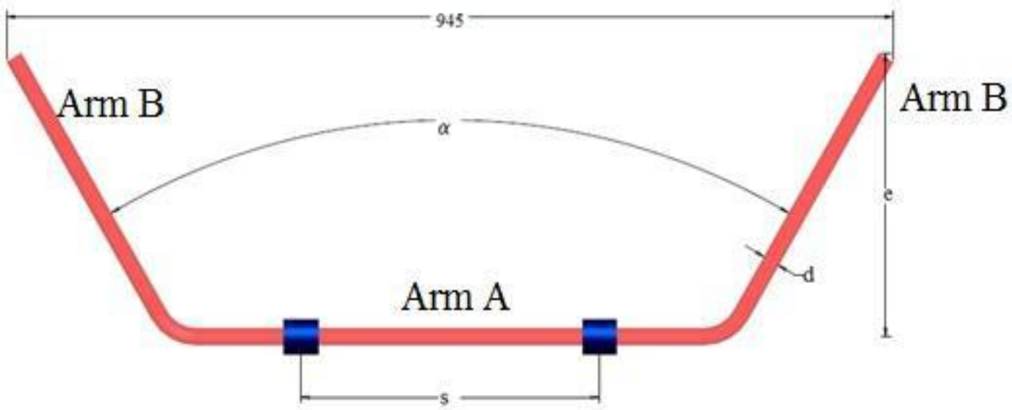

Fig 2: Parameters of Anti-roll bar

A.1 Variation in the distance between horizontal arm and end of bar, 'e'

The variation is done as shown in the table below

Table 1: Variation in 'e'

Anti-Roll Bar	1	2	3	4	5
e (mm)	420	370	320	270	220

For this Case following parameters are kept constant

1) $\alpha = 60^0$
2) Distance between the bush, S = 350 mm
3) Area, $A_0 = 314.2\ mm^2$
4) Moment of Inertia, $I = 7854\ mm^4$
5) Polar moment of inertia, $J = 15708\ mm^4$

The weight of the anti-roll bar decreases due to decrease in the length of anti-roll bar.

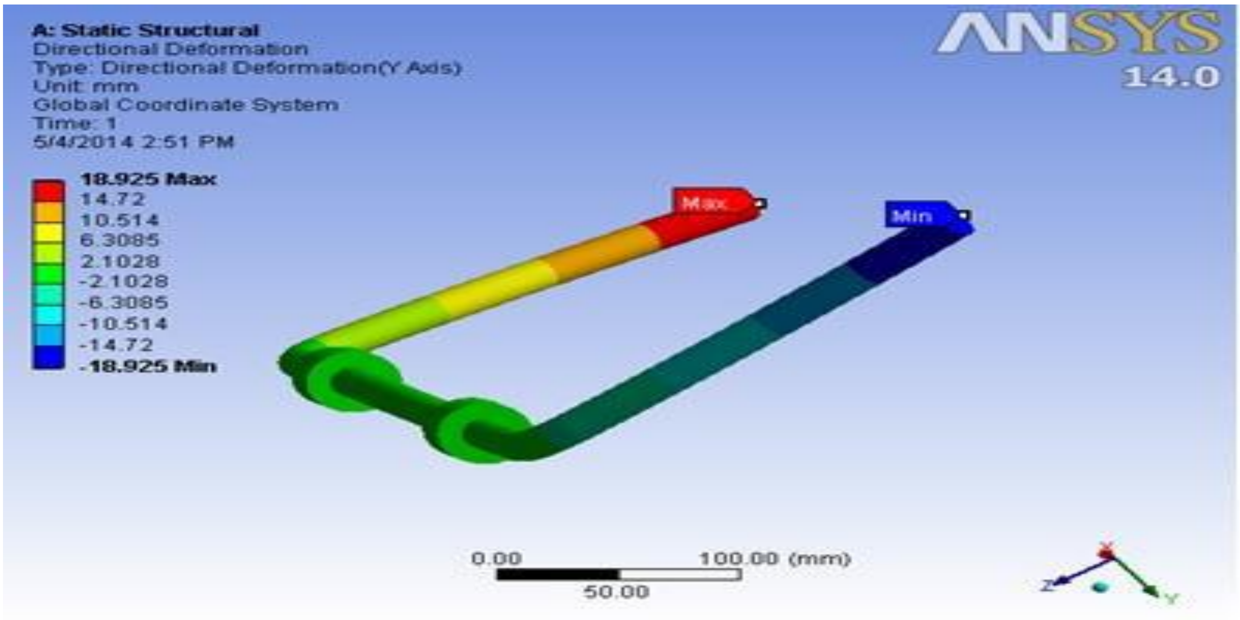

Fig 3: Deformation in Anti-roll bar

A.2 Variation of the distance between bushes, 'S'

Bushes are attached to the chassis and used to provide support to the anti-roll bar. We have varied the distance between the bushes. The information about the variation is given in the following table.

Table 2: Variation in 'S'

Anti-roll bar	6	7	8	9	10
S (mm)	300	250	200	150	100

For this case following parameters are kept constant

1) e = 420 mm
2) $\alpha = 60^0$
3) Area, $A_0 = 314.2\ mm^2$
4) Moment of Inertia, $I = 7854\ mm^4$
5) Polar moment of inertia, $J = 15708\ mm^4$
6) Weight of anti-roll bar, W = 40.14 N

B. Roll Angle Calculation

Roll angle calculation is carried out by the method suggested by Leal, L., Rosa, E, Nicolazzi, L.,Uma [3] in this paper they have put forth the technique to calculate the roll angle. According to them roll angle of the vehicle body is calculated by the following equation

$$\boldsymbol{\varphi} = \frac{\boldsymbol{M_{RO}} + \boldsymbol{M_{R1}} + \boldsymbol{M_{R2}}}{\left(\frac{t_f^2}{2}\right)\boldsymbol{K_f} + \left(\frac{t_r^2}{2}\right)\boldsymbol{K_r} + \left(\frac{t_f^2}{2}\right)\boldsymbol{K_{Ef}} + \left(\frac{t_r^2}{2}\right)\boldsymbol{K_{Er}}}$$

Where,

M_{RO} = Momentum caused due to the suspended mass = $\mu_s \times W \times h_o$

μ_S = Static Coefficient of friction = 0.7

W = Weight of suspended masses = 1903.14 N

h_o = Distance of the C.G. of the suspended mass to the roll axis = 480.3 mm

M_{R1} = Momentum caused due to non-suspended mass of the front axle = $\mu_s \times W_{nf} \times r_d \times \left(1 - \frac{m}{P_f}\right)$

r_d = Dynamic radius of the tire = 240 mm
W_{nf} = Weight of non-suspended masses on the front axle = 274.68 N
m = Height of the front roll center = 192.1 mm
P_f = Height of front reaction point = -731.9 mm

M_{R2} = Momentum caused due to the non-suspended mass of the rear axle = $\mu_s \times W_{nr} \times r_d \times \left(1 - \frac{m}{P_r}\right)$

W_{nr} = Weight of non-suspended masses on the rear axle = 274.68 N
P_r = Height of rear reaction point = 275.0 mm

t_f = Front Axle Width = 1420 mm
t_r = Rear axle Width = 1150 mm
K_f = Spring constant in the extreme of the front arm = 7.2 N/m
K_r = Spring Constant in the extreme of the rear arm = 6.6 N/m
φ = Roll angle in degrees

RESULT

In order to decrease the rolling effect of the body it is necessary to obtain higher value of stiffness to weight ratio.
Results are plotted on the graph as well as table when different geometrical variations are done on Anti-roll bar. Value of stiffness to weight ratio is important to find the best suitable anti-roll bar.

C. Variation in the arm length, 'e'

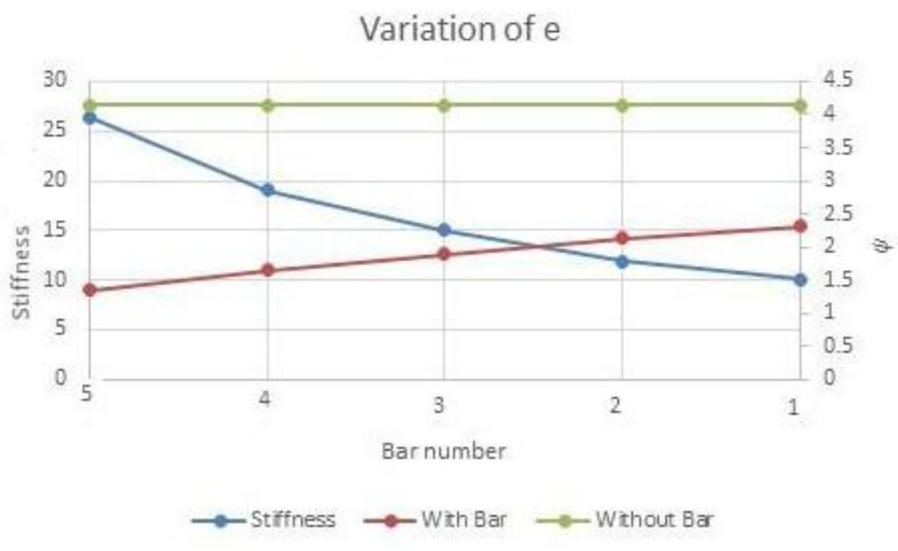

Fig 4: Variation of length of arm

Table 3: Result of varying the arm Length

Anti-roll bar	1	2	3	4	5
e (mm)	420	370	320	270	220
Weight (N)	40.14	38.74	37.35	35.95	33.42
Stiffness (N/m)	10.02	11.92	14.99	19.07	26.42

Stiffness / Weight	0.25	0.31	0.40	0.53	0.79
φ (^{0})	2.31	2.13	1.89	1.65	1.34

From the above graph it is clear that as the length of arm, 'e' is decreased stiffness to weight ratio is increased and because of this roll angle is also decreased. And as a result roll of the body is also decreased.

Hence it is clear that bar no 05 gives the best performance which provides greatest reduction in roll angle when compared to the other bars.

D. Variation of the distance between the bushes, 'S'

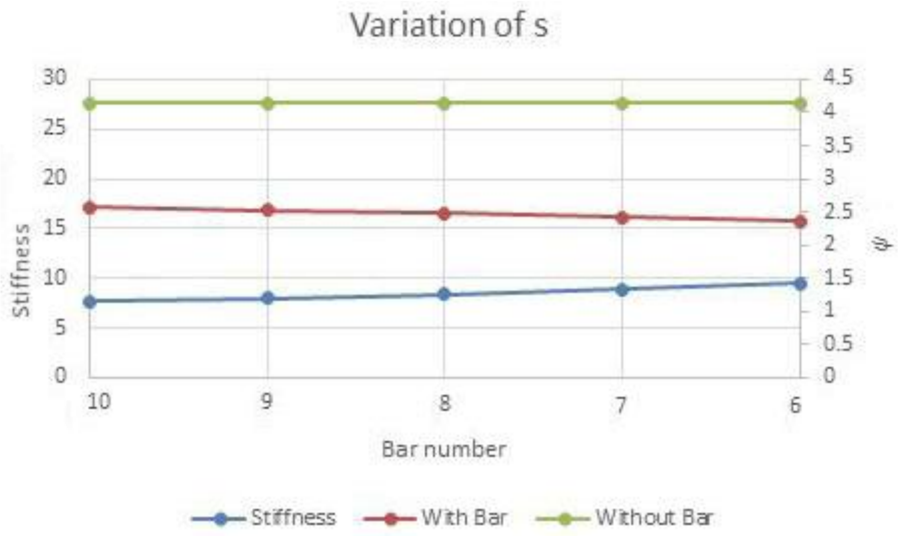

Fig 5: Variation of Distance between bushes, 'S'

Table 04- Result of Varying the Distance between bushes

Anti-roll bar	6	7	8	9	10
S (mm)	300	250	200	150	100
Weight (N)	40.14	40.14	40.14	40.14	40.14
Stiffness (N/m)	9.51	8.92	8.42	8.00	7.64
Stiffness / Weight	0.24	0.22	0.21	0.20	0.19
φ (^{0})	2.36	2.43	2.48	2.53	2.58

When the bushing is far the stiffness of the bar is increased and so the rigidity if the bar. And the arrangement does not add extra weight to the vehicle.

The best stiffness to weight ratio is given by the bar no 06 when compared with the values of other anti-roll bar.

CONCLUSION

In this paper we found the stiffness of the bar using the CAD software and for angle we have used the method suggested by Literature review author. The results obtained above by using the simple geometry of anti-roll bar are found to be satisfactory. The lowest value of the roll angle is obtained with the bar having minimum length of arm, 'e'. Though there is increase in the stiffness to weight ratio but it can be neglected in comparison to the roll angle of vehicle. Also it is been concluded that the distance between the bushes should be greater as less portion of the bar will be subjected to bending their by improving the stiffness of the anti-roll bar.

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