Design and Analysis of Antiroll Bars for Automotive Application

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Abstract-Anti-roll bar, stabilizer or sway bar, is a rod or tube, usually made of steel, that connects the left and right wheels members together to resist roll or swaying of the vehicle which occurs during cornering or due to road irregularities. An anti-roll bar improves the handling of a vehicle by increasing stability during cornering or evasive manoeuvres. The bar's tensional stiffness (resistance to twist) determines its ability to reduce body roll, and is named as “shear stress or Rolling Stiffness”. More vehicles have front anti-roll bars. Anti-roll bars at both the front and the rear wheels can reduce roll further. The other function of anti-roll bars is to tune the handling balance of a car. Under steer or overseer behaviour can be tuned out by changing the proportion of the total rolling stiffness that comes from the front and rear axles. The stabilizer bars contribute thus considerably to the improvement of comfort of the motor vehicles.

Keywords-*Anti-sway bar, stabilizer bar, tensional angle, ,FEA, Automotive Design, Stress Analysis, Torsion Stiffness, Anti Roll Bar, Design Parameters, Bushing position, Rolling stiffness, Deflection*.

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I. INTRODUCTION

1.1 Introduction to Anti-roll bar

Anti-roll bar, sway bar, is a rod or tube, usually made of steel, that connects the right and left of the vehicle which occurs during turning. The bar's torsion stiffness (resistance to twist) decides its ability to eliminate body roll, and is named as “shear stress or Rolling (SSOR) Stiffness”. An anti-roll bar improves the handling of a vehicle by increasing capacity during cornering or evasive manoeuvres. More vehicles have front Anti-roll bars. Anti-roll bars at both wheels can reduce rolling further. Properly chosen (and installed), anti-roll bars will reduce vehicle roll, that in turns leads to good handling and increased driver confidence. A spring rate increase in the front or rear anti-roll bar will produce under-steer effect while a spring rate increase in the rear bar will develop uncontrolled steer effect. Thus, sway bars are also used to improve directional control and stability. One more benefit of that, it improves traction by limiting the camber angle change caused by body roll. Anti-roll bars may have not regular shapes to get around chassis components, or may be much simpler depending on the car. There are two possible facts to be considered about the sway bars within the presented and second, the geometry of the bar is dependent on the shape of other chassis components, the anti-roll bar is a rod or tube that connects the right and left spring

Members. It is used in front suspension, rear suspension or in both suspensions; don’t matter the suspensions is rigid axle type or independent type.

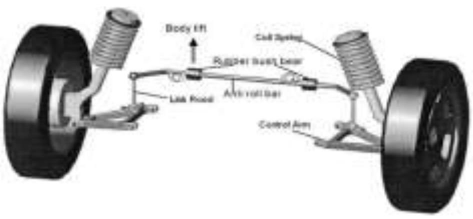

Figure 1.1 Anti roll bars with control Arm

A typical anti-roll bar is shown in Figure 1.1information. First, the anti-roll shear stress of the bar has direct effect on the handling characteristics of a vehicle.

The main goal of using anti-roll bar is to reduce the vehicle roll. Body roll occurs when a vehicle deviates from straight-line motion. The line joining the roll centres of wheels suspensions forms the roll axis of a body. Centre of gravity of a vehicle is generally above this roll axis. Thus, while turning the centrifugal force creates a roll moment about the roll axis, which is equal to the develop centrifugal force with the distance between the roll axis and the CG. Anti-roll bars serve two or more key functions. First they reduce roll of body, as explained above, and second provide a way to again spreading cornering loads between the both wheels, which in turns, given the capability of modify handling characteristics of the vehicle.

1.2 Principles:

Anti-roll bar is also a torsion spring that resists body roll motions. It is usually constructed out of a steel bar, formed into a "U" shape that join to the body at two points, and at the both sides of the suspension. If the both wheels move together, the bar rotates about its mounting points. When the wheels move relative to each other, anti-roll bar is subjected to torsion and forced to roll. Each end of the bar is connected to last link through a movable joint. The sway bar end link join in turn to a spot near a wheel or axle, transferring forces from a maximum loaded axle to opposite side.

Due to that forces are transferred:

1. from the maximum-loaded axle
2. To the jointed last link via a bushing
3. To the anti-roll (torsion) bar via a

Flexible joint

4. To the jointed end link on the opposite side of the body
5. To the opposite axle.

The bar resists the torsion through its shear stress. The stiffness or shear stress of an sway bar is proportional to the stiffness of the material, the 4th power of its radius, and the inverse of the length of the arms(lever) (i.e., the shorter the arm(lever), the stiffness of bar is high). Stiffness is related to the geometry of the mounting points and rigidity of the bar's sway. The increases stiffness of the bar, the more force required to move the wheels relative to both. This increases the amount of shear stress required to make the body roll.

In a turn the spring mass of the vehicle's body produces linear force at the centre of gravity (CG), proportional to linear acceleration. Because the centre of gravity is usually not on the roll axis, the linearly force creates a moment about the rolling axis that tends to roll the body. (The rolling axis is a line that connects the rear and front roll centres (SAEJ670e)). The moment is called the rolling couple. Roll couple is resist by the suspension rolling stiffness, which is a function of the spring rate of the vehicle's springs and of the anti-roll bars. The uses of anti-roll bars allows designers to eliminate roll without making the suspension's springs develop stiffness in the vertical plane, which allows develop body control with less compromise of quality. One effect of body lean, a typical suspension geometry, is positive camber on the outside of the turn and negative on the inside, which reduces their cornering grip (specific with cross ply tires).

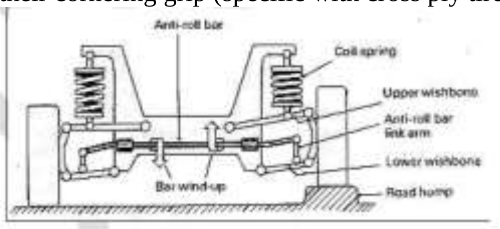

Figure 1.2.1Basic Properties of Anti-Roll Bars

1.5 Connections

Sway bars are connected to the other chassis (body) components via 4 attachments. Two of these are the rubbers bushings through which the sway bar is attached to the frame. And the other two attachments are the fixtures between the suspension members and the sway bar ends, either through the use of directly.

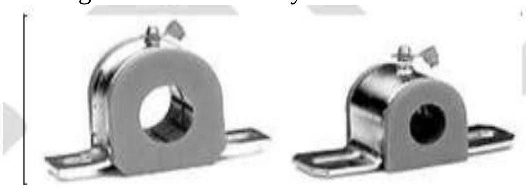

Figure 1.5.1Rubber bushings

There are two major types of anti-roll bar bushings given according to the axial movement of the sway bar in the bushing. In both types, the bar is free to rotate in the bushing. In the first bushing type, the sway bar is usually free to move along bushing axis while the axis movement is prevented in the second type.

The bushing material is other important parameters. The material of bushings is commonly rubber, nylon or polyurethane, but even metal bushings are used in some race cars. The main goal of using anti-roll bar is to reduce the body roll. Body roll occurs when a vehicle deviates from straight-line motion. Centre of gravity of a vehicle is normally above this roll axis. Thus, while turning the centrifugal force creates a roll (swing) moment about the roll axis, which is equal to the product of centrifugal force with the distance between the roll axis and the (CG) centre of gravity. This moment causes the inner suspension to extend and to compress the outer suspension, thus the body roll occurs.

1.6 Purpose and Operation

An anti-sway or anti-roll bar is subjected to force each side of the vehicle to lower, or rise, to similar heights, to reduce the sideways tilting (roll) of the vehicle on sharp corners, or large bumps. With the bar removed, a vehicle's wheels can tilt much larger distances (as shown by the SUV image). Although there are many variations in design, a common function is to force the cross wheel's shock-absorber, spring or suspension rod to lower, or rise, to equal level as the other wheel. In a rapid turn, a vehicle tends to drop closer onto the outer wheels, and the sway bar soon forces the opposite wheels to usually 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 chassis (body). After the fast turn, then the downward pressure is reduced, and the paired wheels can return to their normally height against the vehicle, kept at similar levels by the connecting sway bar.

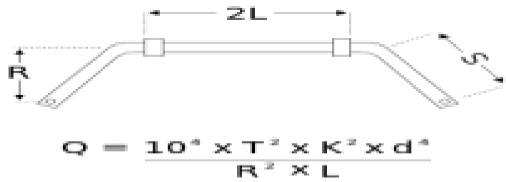

Figure 1.6.1SUV

One way of estimating antiroll bar stiffness:

T=Vehicle track width (inches)
K=Fractional lever arm ratio (movement at rolls bar / movement at wheels)
d=Bar diameter (inches)
R=Effective arm length (inches)
L=Half-length of bar (Inch)
S=Length of arm(lever) (inches)
Q=Stiffness (lb*in per degree)

Because each pair of wheels is cross-connected by anti-roll bar, the combined operation causes all wheels to generally offset the separate tilting of the others and the body tends to remain level against the general slope of the terrain. A negative side-effect of joining pairs of wheels is that a bump to one wheel tends to also jar the opposite wheel, causing a big impact applied across the whole width of the vehicle. Other suspension techniques can delay or dampen this effect of the connecting bar, as if hitting small holes that momentarily jolt a single wheel, whereas larger holes or larger tilting then tugs the bar with the opposite wheel.

1.7 Main Functions

Anti-roll bars provide 2 main functions. The first function is the eliminate of body lean. The reduction of body lean is dependent on the total rolling stiffness of the vehicle.

Increasing the total rolling stiffness of a vehicle does not change the steady state total load (weight, mass) transfer from the inside to the outside wheels, it only reduces body lean. The total lateral load transfer is determined by the Centre of Gravity height and track width. Other function of anti-roll bars is to tune the driving balance of a car. Steering behaviour can be tuned out by changing the proportion of the total rolling 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 (weight) 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 low slip angle, which is an under steer effect. Increasing the proportion of roll stiffness at the back axle has the opposite effect and decreases under steer.

The function of stabilizer bars in motor vehicles is to reduce the body roll during cornering. The body roll is influenced by the occurring wheel load (weight) shift and the change of camber angle.

II. LITERATURE REVIEWS

Prof. Laxminarayan Sidram Kanna1, Prof. S. V. Tare2,Properly chosen (and installed), stability bar will reduce body roll, which in turns leads to good handling and increased driver confidence. Stability bar analyses in the past were performed using analytical methods. In general, this good stability bar analyses are multi-disciplinary, including calculations related to the stresses. Failures such as like wear or scoring. In this trying to design stability bar to resist external force or bending, shear failure. As computers have become higher or more powerful, people have direction to use numerical reaches to develop theoretical models to predict the purpose of whatever is studied. This has improved stability bar analyses and computer simulations. Numerical (FEA) methods can potentially provide more accurate solutions since they normally require much less restrictive assumptions. [1]

Cristiano Antonio de Andrade1, André Chaves de Jesus2, It was obtained the mechanical properties in hardness of the sway bar material. The structure was characterized by optical microscopy. The observation microstructures were ferrite,partite. The steel used in the bar (stabilizer) has been classified by chemical and analytical analysis as SAE 1045. The analytical calculation of the stresses and stiffness acting at critical points of the sway bar was performed to check the displacement range that the bar (stabilizer) support without reaching the yield strength of the material. Occurs on both sides of the bar, being result of the folding process used. [2]

Husen J. Nadaf Prof. A. M. Naniwadekar, All suspension systems have a common goal, which is to develop the ride in terms of comfort, handling, and safety. This is accomplished by influencing the motions affected by road irregularities (bad) to the wheels and axles while minimizing their effect on the vehicle body and frame (body). Sway bars used in ground vehicle to reduce bodyrolling by resisting any un-even vertical motion between the pair of wheels right and left suffer from fatigue and tough failure. In this study, several structural analyses of an anti-roll bar of passenger car were carried out by means of finite element (FEA) technique to determine stress distributions and torsion stiffness (shear stress). The results of FEA analyses indicated that, there is difference [3]

P. M. Bora1, Dr. P. K. Sharma2,The aim of this paper is to report the analysis of Vehicle anti-roll bars (stabilizer bars)used for suspension components limiting body roll angle using the finite element analysis tool ANSYS. Vehicle anti-roll bars have a direct effect on the handling characteristics of the vehicle. Ride comfort, handling and road holding are the three aspects that a vehicle suspension system has to provide compromise solutions. type of end connection final anti-roll bar properties are estimated at varying load.[4]

Dariusz Bojczuk, Anna Rębosz-Kurdek, The problem of maximization of the buckling load and the problem of maximization of the natural vibration frequency under or over a condition imposed on the global cost is discussed. Cross-sectional areas of sway bar structures and number of elastic and plastic supports, their positions and stiffnesses (or the number and positions of rigid (tough) supports) are selected as design parameters. The proposed here algorithm of optimization of bar structures with their supports and helps is applied for analysis of some optimization problems.[5]

MPravin Bharane, Mr. Kshitijit Tanpure,The objective of this paper is to analyze the main or good geometric parameter which affects rolling stiffness of Anti-Roll bar. By the optimization of good geometric parameter, we can increase or develop the rolling stiffness and reduce the mass of the bar. Changes in design of anti- roll bars are quite common at various or long area steps of vehicle production and a design analysis must be performed for each change.. Locating the bushings closer to the center of the bar increases the stresses at the bushing locations which results in rolling stiffness of the bar decreases and the max Von mises stresses increases.[6]

Manoj Purohit, Shailesh Kadre, This paper presents an approach of FEA and correlation of the results with the test results and helps the design to move to the next level of concept quickly. The approach includes the [7]

P.Senapathi, S.Shamasundar, G. Venugopala Rao and B.M.Sachin, Durability of automobile stabilizer bar is assessed in the present study. Finite element analysis of the bar (stabilizer) is performed based on the experimental observations. Fatigue analysis is performed under and over cyclic loading. Effect of shot peening have been taken into account. Fatigue cycles are defined for the maximum loading conditions. Custom built fatigue testing equipment is used to simulate the fatigue life of [8]

III. PROBLEM DEFINITION

The stress field at the bar (stability) will be analyzed using a three-dimensional finite element (FEA) solid model. There are two various important facts to be considered about the stability bar that first, the anti-rolling stiffness of the bar has direct effect on the handling (turning) characteristics of a vehicle (body). And second, the geometry of the bar (stabilizer) is dependent on the geometry of other chassis components.

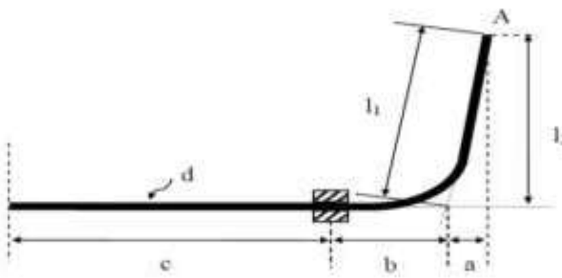

Figure 3.1 SUV

3.1 INPUT PARAMETERS

INPUT PARAMETERS	VALUES
Cross-section type Solid round cross-section	Solid round cross-section
Section radius	15.5 mm
Bushing type	1
Bushing locations	± 300 mm
Bar material	Alloy steel(chromium-molybdenum)
Modulus of Elasticity	$2.1x10^5$Mpa

The loading is applied at point A, inward to or outward from plane of the page. The roll stiffness of such a bar can be calculated as:

L= a+b+c (L: Half Track Length)

fA =[(P(l13-a3) + (L/2 *(a+b)2) + (4l22 (b+c))/3EI] (fA :- Deflection of point A)

KR = (P*L2) / 2fA ……..

KR: Roll Stiffness of the bar Max shear stress = T*R/J ……..

T= Torque R= outer radius of bar J= Polar Modulus

IV. METHOLODOLOGY (ANALYTICAL METHOD)

4.1 Design of anti-roll bar

1) On the basis of comparative shear stress of solid and hollow anti-roll bar of different diameter

This chapter deals with the analytical analysis of stability bar, where design equations are developed and calculation of load acting, moment, torque transmitted, polar moment of inertia has been calculated. However the following points discuss the same.

4.1.1Design of solid stability bar

4.1.2Design of hollow stability bar

Let us discuss the points one by one:

Design of solid stability bar:

Shear stress of solid bar with different diameter

The bar Max shear stress = T*R/J

for 30 dia= Z= 174. 98 N/mm

for 31 dia= Z= 153.54 N/mm2

for 32 dia= Z= 145.47 N/mm2

Design of Hollow stability bar:

Shear stress of hollow bar with different diameter

For 30 dia= Z= 179.73 N/mm2

For 31 dia= Z= 162.42 N/mm2

For 32 dia= Z= 147.20 N/mm2

Here, the analysis of solid stability bar is carried out in three different cases, by considering, Solid bar with 30mm diameter,31mm and 32mm and correspondingly design calculations such as load acting, moment, torque transmitted, polar moment of inertia and shear stress has been calculated.

4.2 Analysis of hollow anti rolls bars in ANSYS (Numerical method)

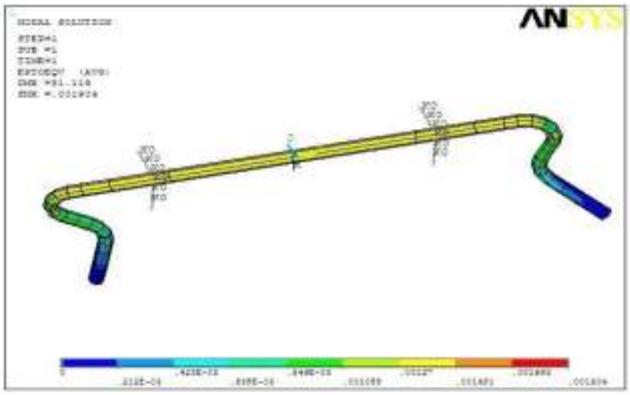

Figure 4.2.1a (solid)

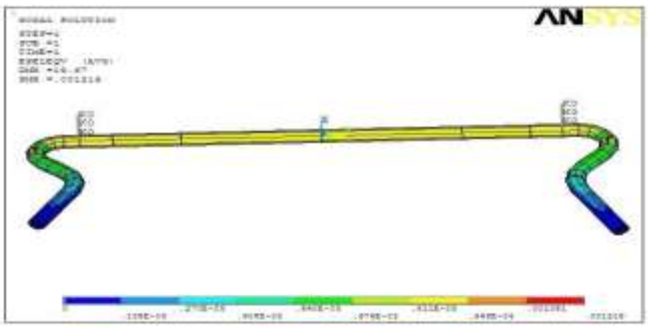

Figure 4.2.2b (solid)

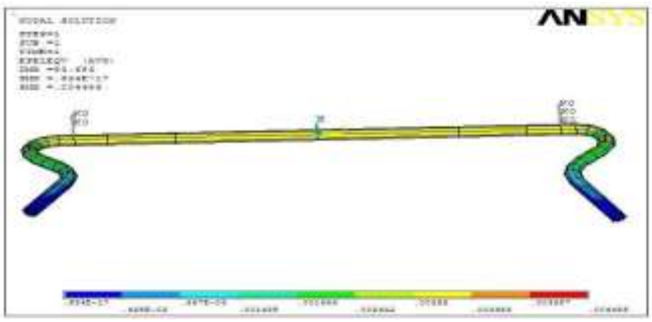

Figure 4.2.3c (solid)

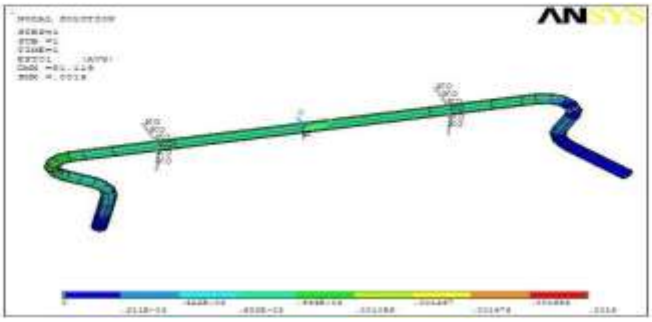

Figure 4.2.4d (Hollow)

Figure 4.2.5e (Hollow)

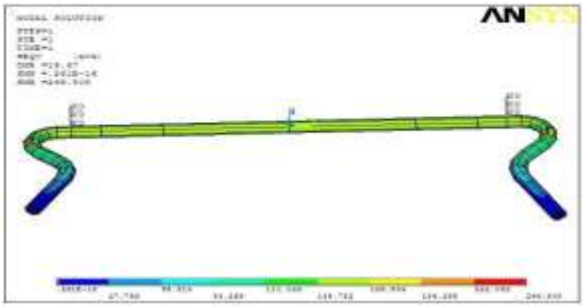

Figure 4.2.6f (Hollow)

Table 4.1INPUT PARAMETERS

INPUT PARAMETERS	VALUES
Cross-section type Solid round cross-section	Solid round cross-section
Section radius	15.5 mm
Bushing type	1
Bushing locations	± 300 mm
Bar material	Alloy steel(chromium-molybdenum)
Modulus of Elasticity	$2.1x10^5$Mpa

4.3 Comparison between max. Prin. Stress, for different diameter:

The bar Max shear stress = T*R/J

for 30 dia= Z= 173. 98 N/mm

for 31 dia= Z= 152.54 N/mm2

for 32 dia= Z= 144.47 N/mm2

Design of Hollow stability bar:

Shear stress of hollow bar with different diameter

For 30 dia= Z= 178.73 N/mm2

For 31 dia= Z= 160.42 N/mm2

For 32 dia= Z= 146.20 N/mm2

V.RESULTS & DISSCUSSION

After extensive study it has been observed that shear stress is predominant in the analysis of stability bar. Also it has been observed that by varying the dimensions for solid and hollow the shear stress goes on decreasing, the following table shows the same.

5.1ANALYTICAL RESULT

Dimensions	Solid Stability bar (shear Stress) (N/mm2)	Hollow stability bar(shear Stress)(N/mm2)
For 30 mm	174.98	179.73
For 31mm	153.54	162.42
For 32mm	145.47	147.20

5.2 NUMERICAL RESULT (ANSYS)

Dimensions	Solid Stability bar (Shear Stress) (N/mm2)	Hollow stability bar(shear Stress)(N/mm2)
For 30 mm	173. 98	178.73
For 31mm	152.54	160.42
For 32mm	144.47	146.20

There is 0.1 % difference between mathematical and numerical results

It has been observed from the above table that, for same dimensions the rate of shear stress is maximum for hollow stability bar. It is also interesting to note down the point that, the rate of shear stress is goes on decreasing as the dimensions increases for both the cases of solid and hollow stability bar. It can be discussed from the above table; there is considerable Percentage increase in shear stress for hollow stability bar as compared with solid bar.

Also this rate of percentage will goes on reducing as the dimensions are increased from 30mm to 32mm.

VI.CONCLUSIONS

1) Parametric optimization obtaining reduction in stress at corner bends stabilizer bar

2) It is important that the target weight reduction is greater than 60 to70 % of the weight of comparable solid stabilizer bar.

3) Increases stiffness with diameter

4) Increases shear stress with diameter

5) By increasing the bushing stiffness or shear stress of Anti-roll bar, increases Anti- roll stiffness, also increasing the stresses induce in the bar

6) A stability bar improves the handling of a vehicle by increasing stability during cornering or evasive manoeuvres. Conveniently chosen (and installed), stability bar will reduce body roll, that in turns leads to good handling and increased driver confidence.

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