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Design and Development of Off Road Vehicle Handling by Active Tubular Stabilizer Bar for Enhancing Yaw Stability

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Abstract:-The stabilizer bar plays an important role in the automotive vehicle, especially in traction and braking condition. Stabilizer bars (also known as Traction bar, Sway bars or Anti-roll bars) are used to stabilize a vehicles from excessive chassis roll when the vehicle running in high traction conditions. Stabilizer bars are generally used on smooth traction conditions. Anti-roll bars improve cornering behavior by reducing body roll.

The aim of the project is to replace "Forged Solid stabilizer rod by using High strength Tubular stabilizer bar" there by reducing the weight of the product and increase the fuel efficiency of the vehicle. The project involves theoretical estimation of torsional stress in the stabilizer bar and validate with finite element analysis and experimental results.

I. INTRODUCTION

The purpose of a vehicle suspension system can be summarised as follows: To isolate the vehicle from the uncomfortable vibrations transmitted from the road through the tyres and to control the transmitted forces back to the tyres so that the driver can keep the vehicle under control. The fact is that vehicles are often designed for off road conditions. They are designed with a high centre of gravity (CG) due to the increased ground clearance required. This report focuses on the improvement of the handling capabilities of an off-road vehicle without sacrificing ride comfort.

A. Roll Stability:

Roll stability impedes the tendency of a vehicle combination to tip over while changing direction typically while turning. The lateral side acceleration creates a force at the center of gravity (CG), pushing the truck or tractor-trailer horizontally.

B. Yaw Stability:

A yaw rotation is a movement about the yaw axis of a vehicle such that it changes the direction of the vehicle which is facing, to the left or right of its direction of motion.

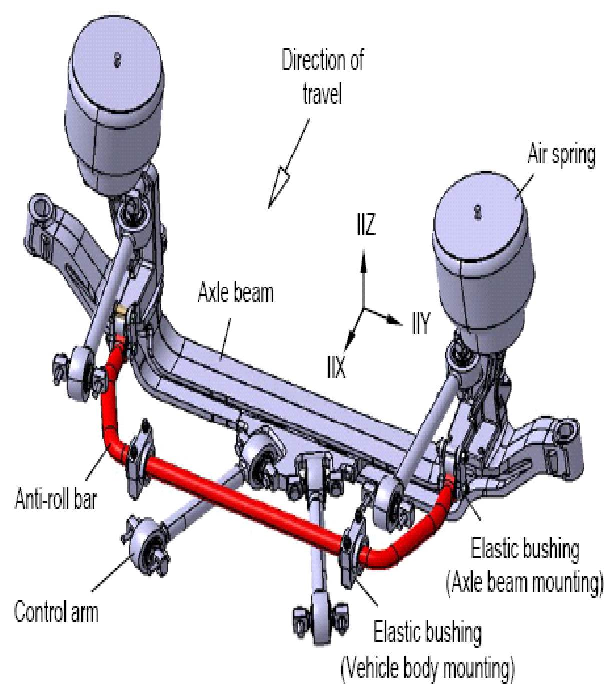

Fig.1: Front Suspension of the Vehicle

C. Anti-Roll

An AntiRoll Bar(ARB) is a round piece of metal,which is either tublar or solid, that connects both the left and the right sides of the suspension together. Generally cars will have one of these bars in the rear and one in the front of the vehicle. The bars react to body roll by twisting. During a corner, the body of the vehicle tries to 'lean' or 'fall' over. As one side of the suspension compresses, the AntiRoll Bar(ARB) resists this compression since it's connected to the other side of the suspension. Essentially you are increasing the overall spring rate or wheel rate of your suspension system during cornering. More spring rate in the sense less body roll. Less body roll means less transition time and a more level tire contact patch.

Fig.2: Modelling of Anti Roll Bar

D. Geometry:

Anti-roll bars might have variable shapes to get around chassis components, or may be much simpler depending on the car. But, whatever the shape of the bar, it can be defined by a single curved bar centerline with a cross section swept along this centerline.

Fig.3: Sample Anti-Roll bar Geometries

E. Connections:

ARB is connected to the chassis components by four attachments. Two of these are the rubber bushings by which the anti-roll bar is attached to the main frame, while the other two attachments are the fixtures between the anti-roll bar ends and the suspension members, either by the use of short links or directly.

F. Bushings:

There are two major types of a anti-roll bar bushings that classified according to the axial movement of the anti-roll bar in bushing. In both the types, the bar rotates freely within the bushing. In the first bushing type, the bar is free to move along the bushing axis while the axial movement is prevented in the second type.

Fig.4: Type-1 Bushing (rubber bushings and metal mounting blocks)

G. Connections to Suspension Members:

rominent connection used between anti-roll bar and the suspension member is the pin joint. Spherical joints are also used to provide this connection.

The good thing about anti-roll bars is that they are very tuneable by changing bar diameters, mixing and matching bushing materials or adjusting the moment arm length.

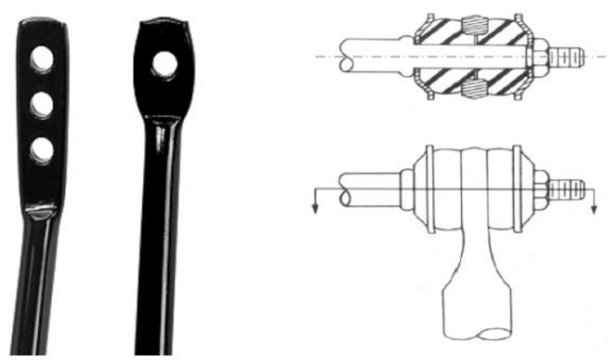

Fig.5: Pinned Connection between Suspension Member and the Anti-Roll Bar (first one is adjustable)

H. Problem Statement:

Preventing body roll is important that most drivers will installed or purchased in order to prevent it. Firstly it disrupts the driver. This is probably the effect that most drivers can see and feel during their own driving experiences. So keeping the driver settled, focused and able to concentrate on the task of driving is a foremost priority for spirited vehicle handling. The most misunderstood effect of body roll upon vehicle handling is the effect of body roll upon the camber and the effect of camber changes upon tire traction. But when the vehicle starts to lean, the tires are also forced to lean or roll to one side.

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So the tire that originally enjoyed a complete and flat contact patch prior to body roll has to operate on only the tire edge while body roll. The resulting loss of traction allows the tires to more easily give way to the forces of weight transfer to the outside edge of the vehicle. When this happens, the vehicle slides sideways, this is generally a bad thing. So this is when the anti roll bars come in.

I. Factors That Determined Stiffness:

Torsional or in other word twisting motion of the bar is actually governed by the equation is,

Twist angle = T.L / J.G

Where,

T – Torque

L – Length

J – Polar moment of Inertia

G – Material Modulus

Torque = Force x Distance

Torsional rigidity is a function of the diameter to the exponent of four. This is why a very small increase in diameter makes a large increase in torsional rigidity.

J. Effective Spring Rate in Sway Bars:

The equation gives you the effective spring rate at the end of the arm where the end link attaches to the sway bar.

$$K_{swaybar\_Puhn} = \frac{5000000 \cdot D^4}{0.4244 \cdot A^2 \cdot B + 0.2264C^3}$$

Where,

A – Length of end perpendicular to B

B – Length of centre section

C – Length of end Section

D - Diameter

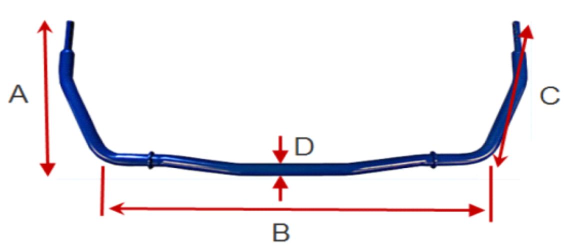


Fig.6: Schematic Arrangement of Anti Roll Bar Actuated

For Solid Round Bars

Polar Moment of inertia (J) = . (D4 – d4) / 32

Moment of Inertia (I) = . (D4 – d4) / 64

Angular deflection of Arm (ϴt) =

The small angle approximation is valid for angles < 15 degrees

Where,

St – deflection from torsion

Definition for the moment in a bar under torsional loading:

The moment is also the applied force times the perpendicular distance

Therefore, M = P.A

Therefore,

Definition of tip deflection of cantilever beam:

Where,

Sb – deflection from bending

Normal values for the Elastic modulus of Stell (E steel) ranges from 27,000,000 – 30, 000, 000 psi (190 – 210 MPa).

Generally, the values for the Shear Modulus of steel (G steel) ranges from 10, 400, 000 – 12, 000, 000 psi (75000 – 80000 Mpa).

The torsional stiffness of a sway bar can be calculated as a function of the applied force and the deflection at the end links comes from the torsional stiffness of the “straight” section and the bending stiffness of each arm.

K. Comparison of Solid and Tube Torsion of An Anti Roll Bar:

The strength of these anti roll bars either of the ultimate strength, yield strength or fatigue strength depends on the maximum stress of the material. In a torsion member (and similarly for the same member under bending) the stress in the material depends heavily on the geometric shape. The stress (shear) that is found throughout the member when applying torque is given by the following formula:

Where,

Ʈ – Shear stress

T – Torque

r – Radius from centre

Ip – Polar moment of inertia

Ip = π . (D4 – d4) / 32

From the above equation it shows that the outside of the member will have the largest stress. The absolute stress value also depends on the Ip value, the greater the Ip value (or diameter of the member) the smaller the stress is. Again this Ip value depends on the diameter to the exponent of 4, it means only a small increase in diameter can give a large increase in the Ip value.

L. Sample Sizes of Anti Roll Bars Given Below:

	Solid	Tube	Units
OD	20	20	Mm
ID	0	16	Mm
Ip	15708	9274	mm4
Torque	100	100	Nm
Stress at OD	64	108	MPa
Stress at ID	0	86	MPa

Table 1: Sample Sizes of Anti Roll Bar

II. FINITE ELEMENT ANALYSIS OF ANTI-ROLL BARS

The procedures in Finite Element Analysis(FEA) are standard,the input data methods, analysis options and result viewing methods shows differences among the different FEA package programs and also among the different versions of the same package program. The analysis of the anti-roll bar is performed with ANSYS. Therefore, the procedures explained in the following sections are valid for this version of the ANSYS program.

A. Design Analysis of Anti-roll bars in ANSYS

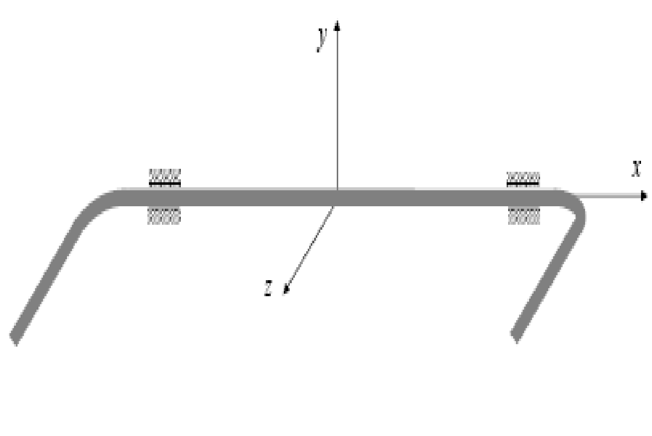


Fig.7: Constraints Applied on the Anti Roll Bar

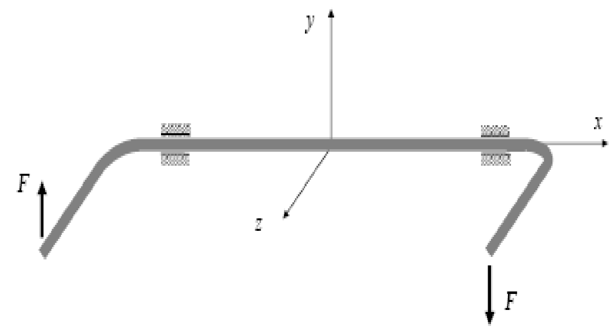
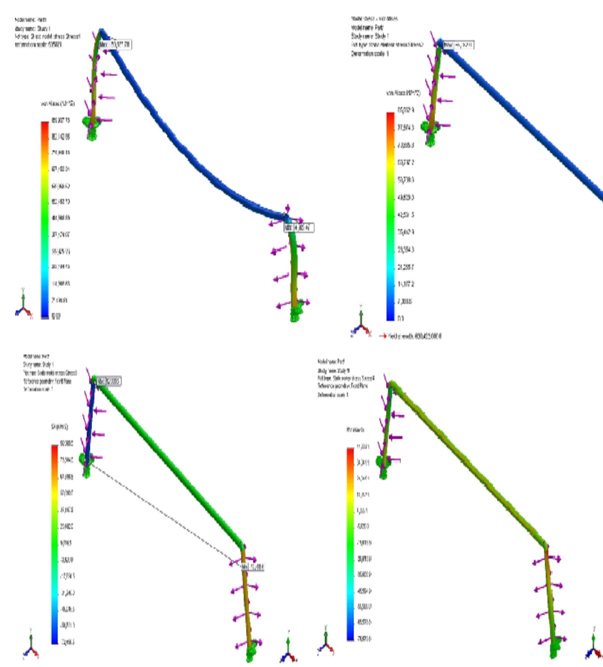
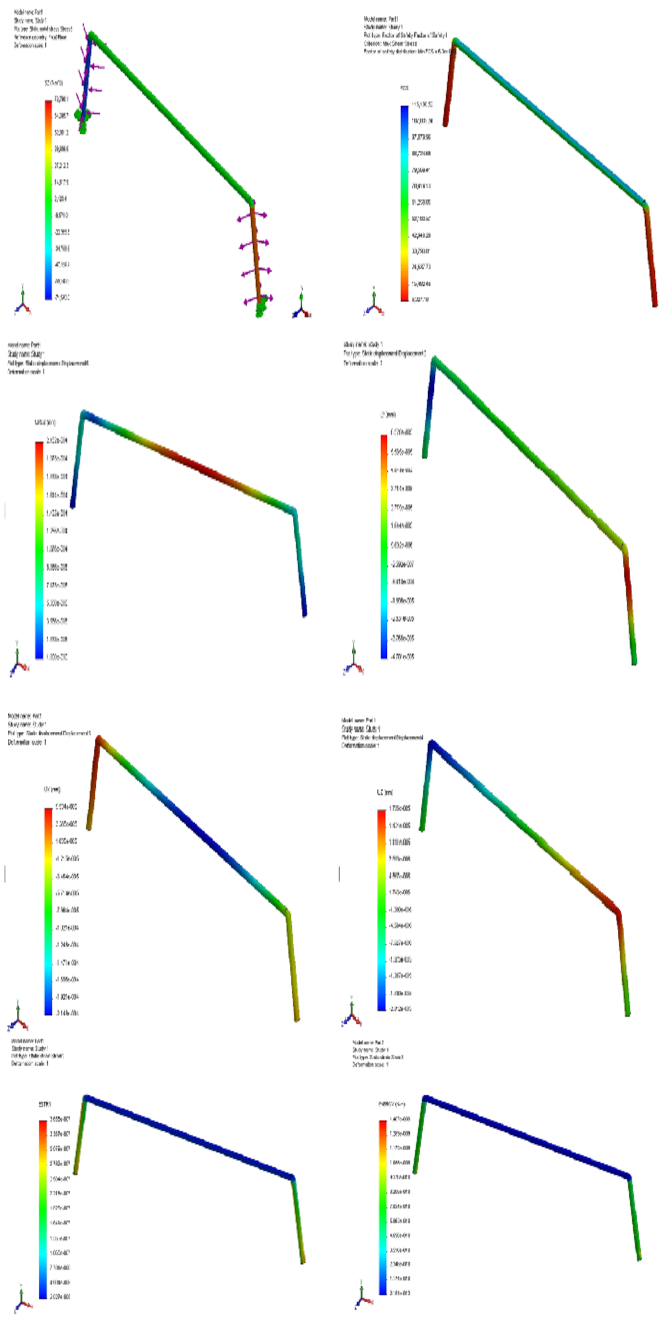


Fig.8: Load Step

A force of 1000 N is applied at the end to make the link as twisted. The loading for the first load step, determination of roll stiffness, is a known force, F, applied to the bar ends, in +Y direction at one end and in –Y direction at the other end.

Fig.9: Meshed Model of an Anti roll Bar





In ANSYS post processer is used for reviewing the analysis results. POST 1 has many capabilities, ranging from simple graphic displays and tabular listing to more complex data manipulations such as load case combinations.

First step in POST 1 is to read the data from the results file into the database. When each load step is solved in the SOLUTION processor, the results of the particular load steps are written into a results file. These results file must be read into database for post-processing process.

So the post-processing is started by reading the results of the first load step. Here, the required output is the deflection of bar ends. This deflection values can be obtained by first plotting the DOF Solutions - UY displacement contour plot and then using the query picker to read displacement value of the node at the bar end. Another method is to list results “DOF Solutions - UY displacement”. These results can be directly read from the printed list, if their node numbers at the bar ends are known. The obtained displacement values are stored for usage in roll stiffness calculations that will be presented in the following section.

Now, the obtained results of the load step of the static analysis can be read to the database. Here, the stress and strain distributions on the bar under maximum load are the consideration. The Principal and Von Misses stresses and strains are important for the failure analysis. Therefore, the contour plots of these stresses and strains must be plotted. Maximum value which occurs in every contour plot is printed as a label on the plot. Thus, this maximum value can be easily stored simply after reading it from the label. However, storing these results is the most difficult part of the post-processing beam elements. ANSYS does not store the maximum or minimum stresses or strains at a beam cross-section. The user can only list all the stress or strain values at the integration points (a cross-section is divided into subsections by the program) of faces and middle section of each beam element. Thus, the maximum values at each section of the beam can be determined outside the ANSYS program after saving these listed results. Deformed shape of the bar should also be plotted and stored in order to see the shape of the bar under loading.

After reading and storing the results of the static analysis, user must exit POST 1 and enter SOLUTION processor to perform modal analysis. After completing the modal analysis and returning again to POST 1, results summary is viewed. This summary shows the first five natural frequencies of the anti-roll bar. Different from the static analysis, here determination of the each natural frequency is

Regarded as a different load step. Thus, in order to see mode shape of the Natural frequency, 3. Load step must read into database. The mode shape can be observed by plotting the deformed shape or animating the deformed shape.

III. CONCLUSIONS

The anti roll bar was modelled in Solidworks and predicted results were obtained in ANSYS. These simulations also provided values for key design variables. The torsional stiffness of the anti roll bar was measured to check the calculations and to determine the torsional stiffness of the anti roll bar.

The suspension designers have the flexibility to tune the handling properties to their exacting standards. This is accomplished by selecting the right combination of diameter and wall thickness. They can increase the stiffness of the bar, without the weight penalties normally associated with a stiffer solid Anti roll bar.

The following handling performance directly effects the vehicle roll

- Adding roll stiffness to the front tends to makes the vehicle more under steering
- Increasing roll stiffness in general tends to increase peak attainable side forces.

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