VEHICLE ANTI-ROLL BAR ANALYZED USING FEA TOOL ANSYS

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ABSTRACT

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. Ride comfort requires insulating the vehicle and its occupants from vibrations and shocks caused by the road surface. In this study, the effects of anti-roll bar design parameters such as diameter of anti-roll bar, type of bushing, bushing location, type of end connection final anti-roll bar properties are estimated at varying load.

Keywords: FEA, Anti-Roll Bar, Sway Bar, Stabilizer Bar

I. INTRODUCTION AND LITERATURE

Anti-roll bar, also referred to as stabilizer or sway bar, is a rod or tube, usually made of steel, that connects the right and left suspension members together to resist roll or swaying of the vehicle which occurs during cornering or due to road irregularities. The bar's torsional stiffness (resistance to twist) determines its ability to reduce body roll, and is named as "*Roll Stiffness*". An anti-roll bar improves the handling of a vehicle by increasing stability during cornering or evasive maneuvers. Most vehicles have front anti-roll bars. Anti-roll bars at both the front and the rear wheels can reduce roll further. Properly chosen (and installed), anti-roll bars will reduce body roll, which in turns leads to better handling and increased driver confidence. A spring rate increase in the front anti-roll bar will produce under-steer effect while a spring rate increase in the rear bar will produce over-steer effect. Thus, anti-roll bars are also used to improve directional control and stability. One more benefit of anti-roll bar is that, it improves traction by limiting the camber angle change caused by body roll. Anti-roll bars may have irregular shapes to get around chassis components, or may be much simpler depending on the car.

There are two important facts to be considered about the anti-roll bars within the presented information. First, the anti-roll stiffness of the bar has direct effect on the handling characteristics of a vehicle. And second, the geometry of the bar is dependent on the shape and location of other chassis components,

The anti-roll bar is a rod or tube that connects the right and left suspension members. It can be used in front suspension, rear suspension or in both suspensions, no matter the suspensions are rigid axle type or independent type. A typical anti-roll bar is shown in Figure 1.

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. The line connecting the roll centers of front and rear suspensions forms the roll axis of a vehicle. Center of gravity of a vehicle is normally above this roll axis. Thus, while cornering the centrifugal force creates a roll moment about the roll axis, which is equal to the product of centrifugal force with the distance between the roll axis and the center of gravity.

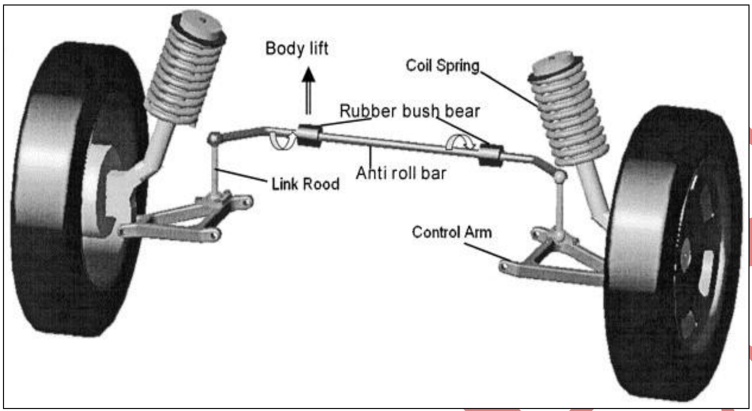

Figure 1 - A typical anti-roll bar

Anti-roll bars serve two key functions. First they reduce body roll, as explained above, and second provide a way to redistribute cornering loads between the front and rear wheels, which in turns, gives the capability of modifying handling characteristics of the vehicle.

A lot of work has been reported and lot of needs to be done towards standardizing the design and analysis of the sway bar. A brief review of some selected references is presented below:

J. Marzbanrad, A. Yadollahi [1]: investigated about "Fatigue Life of an Anti-Roll Bar of a Passenger Vehicle." Under this research they studied, Fatigue life assessment of an anti-roll bar component of a passenger vehicle. A stress analysis is also carried out by the finite element technique for the determination of highly stressed regions on the bar. M. Murat TOPAÇ, H. Eren ENGİNAR, N. Sefa KURALAY [2]: published their work on "Reduction of Stress Concentration at the Corner Bends of the Anti-Roll Bar by Using Parametric Optimization." They have discussed about the reduction of stress concentration at the corner bends of an anti-roll bar that is designed for an intercity passenger bus by optimizing the shape of the critical regions. M. Cerit, E. Nart, K. Genel [3]: published their work on "Investigation into effect of rubber bushing on stress distribution and fatigue behavior of anti-roll bar."P.H. Cronje´, P.S. Els [4]: published their work on "Improving off-road vehicle handling using an active anti-roll bar."

II. DESIGN ANALYSIS OF ANTI-ROLL BARS IN ANSYS

A typical ANSYS analysis has three distinct steps:

1. Build the model.
2. Apply loads and obtain the solution.
3. Review the results.

These 3 steps are performed using pre-processing, solution and post-processing processors of the ANSYS program. Actually, the first step in an analysis is to determine which outputs are required as the result of the analysis, since the number of the necessary inputs, analysis type and result viewing methods vary according to the required outputs. After determining the objectives of the analysis, the model is created in pre-processor. The next step, which is to apply loads, can be both performed in pre-processor or the solution processor. However, if multiple loading conditions are necessary for the required outputs and if it is also necessary to review the results of these different loading conditions together, solution processor must be selected for applying loads. The last step is to review the results of the analysis using post-processor, with numerical queries, graphs or contour plots according to the required outputs. The parameters of anti-roll bar design are: Bar geometry, bar cross-section, bar material and Stiffness of the bushing material.

2.1 Analysis

The first thing to be done in the pre-processor is to define the element types. Two different element types are required for modeling the anti-roll bar with its bushings. The bar will be meshed with BEAM189 (BEAM189 is a quadratic (3-node) beam element in 3-D) elements while the bushings will be modeled by COMBIN14 elements (COMBIN14 is a spring-damper combination element that has longitudinal or torsional capability in one, two, or three dimensional applications). Actually, the anti-roll bar can be analyzed with solid, beam or shell elements (in case of hollow cross-section). However in this study beam elements are preferred. Beam elements are used to create a mathematical one-dimensional idealization of a 3-D structure. They offer computationally efficient solutions when compared to solid and shell elements.

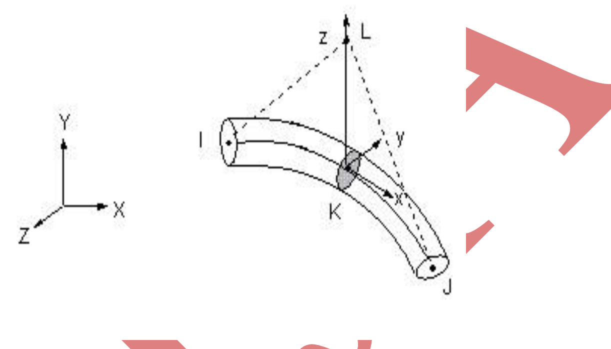

Figure 2 – ANSYS BEAM189 element

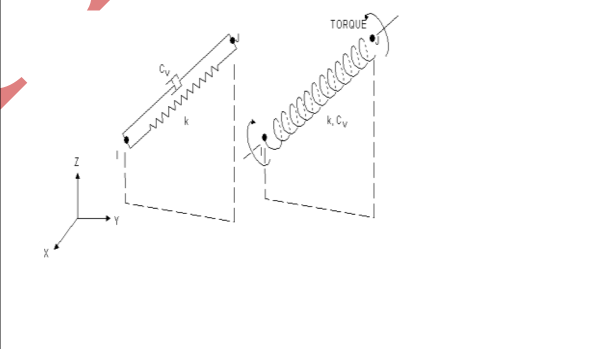

Figure 3 – ANSYS COMBIN14 element

Since the aim of the study is to create an automated design, computational efficiency is very important. Also control of the meshing operation is easier when using beam elements. 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 as shown in Figure 4

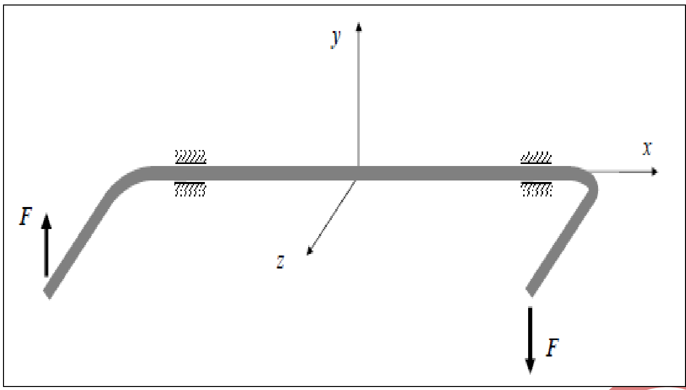

Figure 4 - Load Step1

For the first two loading cases given in the previous section, analysis type is *static,* since the loading is steady. The analysis type is selected as *modal* for the third case since the natural frequencies are to be determined.

The first step of solution is to choose the analysis type based on the loading conditions and the required outputs. For the first two loading cases given in the previous section, analysis type is *static*, since the loading is steady. The analysis type is selected as *modal* for the third case since the natural frequencies are to be determined.

Second decision is to determine whether the analysis will be linear or non-linear. A static analysis can be either linear or nonlinear. Some types of nonlinearities in a model are: large deformations, plasticity, creep, stress stiffening, contact (gap) elements, hyper elastic elements etc. In the anti-roll bar problem, only large deformations can create non-linearity.

2.2 Roll Stiffness Calculation:

Supposing that the load “*F*” that was shown in Figure 3.11 caused a deflection “f_A“ at the bar ends, the roll stiffness of the bar can be calculated using the geometry presented below. Figure 5 shows the new orientation of the line that connects the bar ends. In case of rigid axle suspensions the movement of the bar ends is equal to the wheel movement, thus the vehicle body rolls with an angle “ψ”. If the suspension is independent type, suspension members which are connected to the anti-roll bar ends move the same amount with the bar ends. Thus the ratio of the wheel travel to the suspension member travel is required for calculating the body roll angle for independent suspensions.

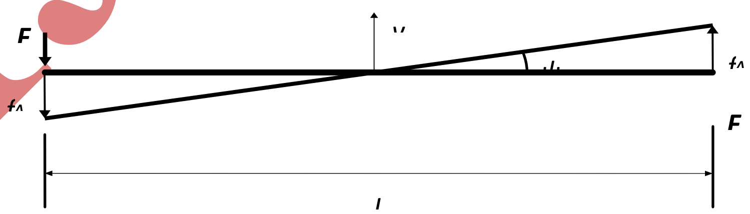

Figure 5 – The orientation of the line connecting bar ends, before and after deformation.

Assuming rigid axle suspension, the anti-roll stiffness (k_R) can be calculated with three different units as follows:

$$k_R = \frac{FL}{f} \quad \left(\frac{Nm}{mm}\right) \qquad k_R = \frac{F}{f} \quad \left(\frac{N}{mm}\right) \qquad k_R = \frac{FL}{\tan^{-1}\left(\frac{f}{L/2}\right)} \quad \left(\frac{Nm}{deg}\right)$$

All these three units are used in the literature for expressing the anti-roll bar stiffness.

2.3 Geometry and loading conditions for the Anti-roll bar

The design of the Anti-roll bar is developed by using CATIA Software by considering the below mentioned geometrical and material properties

Table 1 : Input variables for Anti-roll bars

	Input	Value		Input	Value
1	Cross-section type	Solid round cross-section	2	Section radius	15.5 mm
3	Bushing type	1	4	Bushing locations	± 300 mm
5	Bushing length	40 mm	6	Bushing Stiffness	1500 N/mm
7	Bar material	SAE 5160	8	Modulus of Elasticity	206 GPa
9	Density	7800 kg/m^3	10	Y	0.27
11	Yield stress	1180 MPa	12	Ultimate stress	1400 MPa
13	Number of elements	100	14	Loading	±2000N on both sides

Figure 6a-6d : Equivalent and principal strain across the var and at hollow section

Figure 7a-7d: Equivalent and principal stress across the var and at hollow section

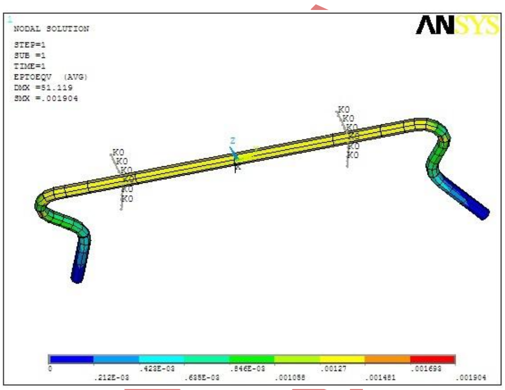

Figure 6a

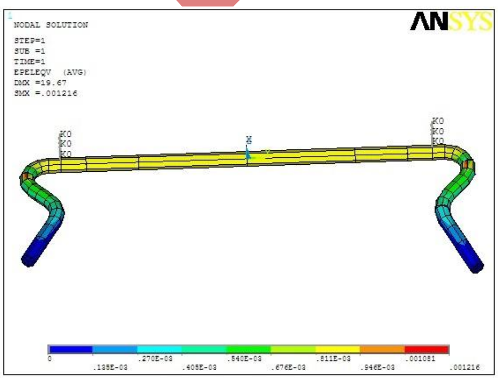

Fig 6b

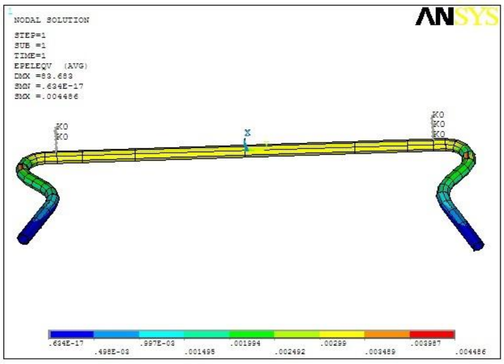

Fig.6c

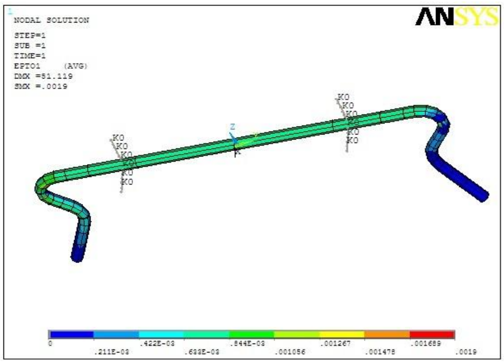

Fig 6d

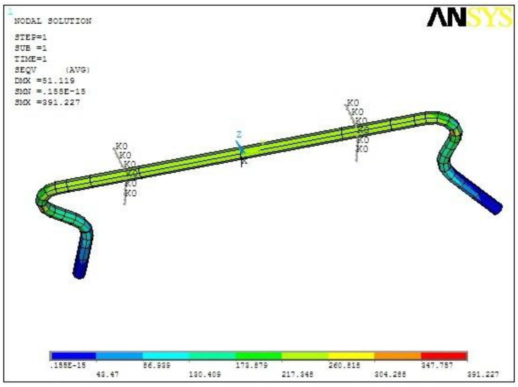

Figure 7a

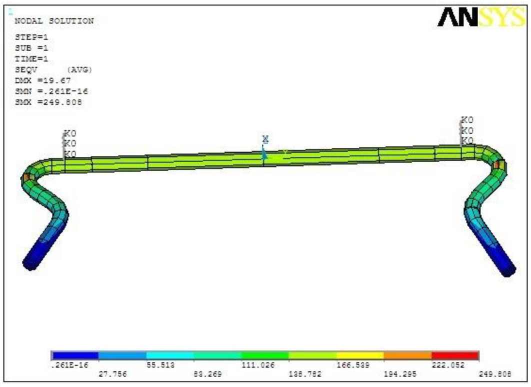

Fig.7b

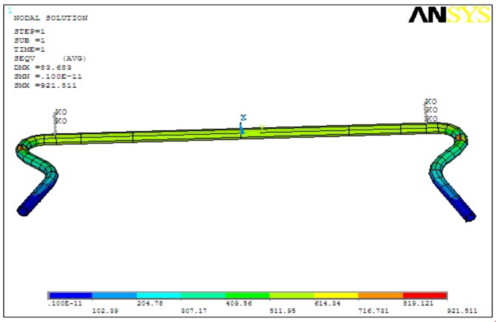

Fig 7c

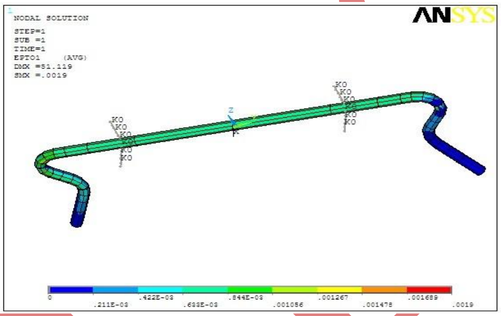

Fig 7d

Table no. 2 Comparison between max. Prin. Stress, max. Prin. Strain and deflection for different forces:

From Table it can be observed that the values of max. Prin. Stress, max. Prin. Strain and deflection are increasing with increase in load.

Sr. No.	Parameter	F=1000N	F=1500N	F=2000N	F=2500N	F=3000N
1.	Max. Prin. Stress (Mpa)	195.353	293.43	390.705	488.3	586.05
2.	Max. Prin. Strain	0.09503	0.1425	0.19	0.2375	0.285
3.	Deflection (mm)	25.56	38.64	51.119	63.09	76.68

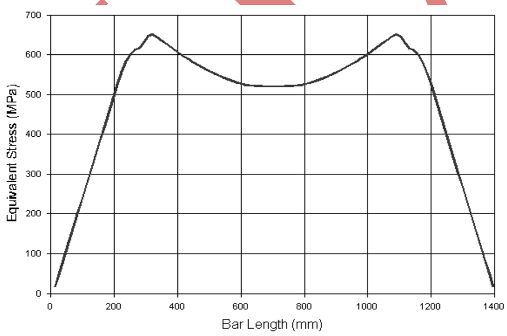

Fig.8 a –Variation of Equivalent Stress along bar length

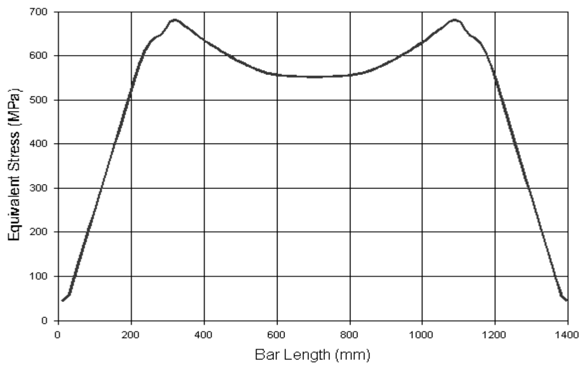

Fig.8 b – Variation of Equivalent stress along bar length(Hollow cross- section)

Figure 8-9 depicts the law of modulus of elasticity that the stress is directly proportional to the load hence as the load or force increases the stress is also increases.

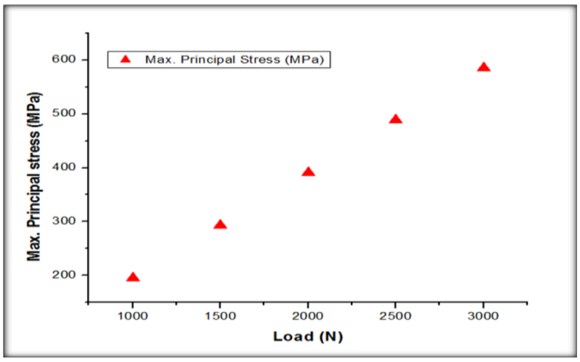

Fig. 9a

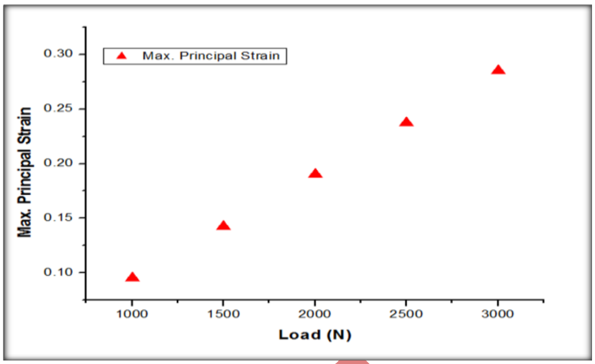

Fig. 9b

Figure 9: Variation in Stress and strain wrt. load

III. CONCLUSION

Following conclusions are derived about anti-roll bar design parameters from FEA: -

1. As the load on bar increases, deflection, stresses and strain on the bar increases correspondingly.
2. Increasing the cross-sectional diameter of an anti-roll bar will increase its roll stiffness and decreases deflection and stress.
3. The weight of the hollow anti-roll bar is less than the solid bar, while the stresses on the hollow bar are higher for the same load conditions.
4. In Hollow bar, as the thickness increases, stress, strain and deflection decreases while weight of bar increases. (Here for 2mm thickness bar fails).

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