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Design and Analysis of Anti-Roll Bar in Formula Vehicle

K Madhukumar[1], M Tinku Rajkumar[2], Ayush Vishvakarma[3], Rajat Pokale[4]
[1]*Assistant Professor,* [2, 3,4]*U G Scholar, Department of Mechanical Engineering, Sir M. Visvesvaraya Institute of Technology, Bangalore*

***Abstract:** This study explains a coherent flow for designing, analyzing, and testing a tuneable anti-roll bar system for a formula student race-car. The design process starts with the analytical calculation for roll stiffness using constraining parameters such as CG (Centre of Gravity) height, total mass, and weight distribution in conjunction with suspension geometry. Then, the material selection for the design i.e., Aluminium 7075 T6 is made based on parameters such as density and modulus of rigidity.*
A MATLAB program is used to iterate defection vs load for different stiffness and shaft diameter values. This is then checked with kinematic defection values in FUSION 360s geometry. To validate with the material defection, finite element analysis is performed on ANSYS workbench.
Manufacturing accuracy for the job is checked using both static analysis in lab settings and using sensors on vehicles during ontrack testing. The error percentage is found to be 4% between the target stiffness and the one obtained from static testing. Parameters such as moment arm length, shaft diameter and length, and defection were determined and validated. This paper shows the importance of an anti-roll bar device to tune the roll stiffness of the car without interfering with the ride stiffness.

I. INTRODUCTION

When designing cars, attention is given to the comfort and safety of the passenger, therefore, when designing car racks, the aim is to maximize comfort for passengers on uneven roads, improve wheel alignment with the road surface, increase vehicle stability, reduce or completely remove the potential impacts of moving suspension elements in the body of the car. A lot of attention is given to reducing the weight of the suspension elements, but the suspension elements cannot lose their characteristics. Also, a lot of attention is paid to the car suspension system, which is responsible for the stability of the car, it needs to balance the car when it rotates, stops and accelerates.

One of the suspension elements is the anti-roll bar or sway bar that improves the comfort, stability or fixing of the car with the road and control the rollover of the car. The anti-roll bar usually connects the one-axle wheel with the other side of the wheel. The anti-roll bar holds one wheel against another wheel, i.e. when riding on an uneven road surface, and one-wheel rides on unevenness - the other wheel stays on a level road surface, inhibits the movement of the opposite wheel. Designing the anti-roll bar is very important for its geometric parameters, which determine its rigidity, and from the stiffness - the comfort or stability of the car. The stabilizer is usually made of spring steel, but in order to reduce its mass, the development of the stabilizer production from carbon fibre and aluminium has begun.

While the vehicle wheel movie with respect to each other, the anti-roll bar is applied to torsion and forced to roll, the anti-roll bar is a torsion spring that protects them from vehicle body roll motions. The anti-roll bar end is attached to join in turn to a spot near a wheel or axle, transferring forces from a maximum load axle to opposite side. In the final master's thesis, the withstand and displacements of a simple structure anti-roll bar are calculated. Anti-roll bar dimensions are also gauged which affect the stiffness of the anti-roll bar.

A. Working Principle

An anti-roll bar is usually a torsion spring that resists body roll motions. It is usually constructed out of a cylindrical steel bar, formed into a "U" shape, that connects to the body at two points, and at the left and right sides of the suspension. If the left and right wheels move together, the bar rotates about its mounting points. If the wheels move relative to each other, the bar is subjected to torsion and forced to twist. Each end of the bar is connected to an end link through a flexible joint. The anti-roll bar end link connects in turn to a spot near a wheel or axle, transferring forces from a heavily loaded axle to the opposite side.

II. LITERATURE REVIEW

Mr Pravin Bharane, Mr Kshitijit Tanpure, Mr Ganesh Kerkal says "Optimization of Anti-Roll bar using Ansys Parametric Design Language (APDL) say that the main goal use for the anti-roll bar is to reduce the body roll. The objective of the researcher analyses the main geometric parameter which involves affecting the rolling stiffness. All the analyses are carried out using Ansys Parametric Design language. The Judgement of this paper is that by locating the bushing near to the bar centre can in increase the stress, the rolling stiffness of bar is decreased. Anti-roll bar stiffness increases by increasing the bushing stiffness, it also increases the stress induced in the bar.

Amol Bhanage and Padmanabhan says "Static and fatigue Simulation of Automotive Anti-Roll Bar" Before DBTT, show that the fatigue life of the antiroll bar is compared with four materials. The fatigue life in setting up by using ANSYS Software, Fatigue model were calculated using ANSYS n code Design life software. shows higher fatigue life for SAE 5160 with a comparison to AISI 1020, SAE 4340 and SAE 9262. By using the same load condition above ductile to brittle transition temperature is found out. The Conclusion is that the fatigue life of SAE 5160 is high compared with AISI 1020. The AISI 1020 is best to use in Anti-Roll Bar.

The research study was done by J. Marzbanrad, A. Yadollah "Fatigue life of a passenger car, says that as the principal organizer, a few adjustments are proposed to some current weariness disappointment models. Numerous clues that might be considered to create general weakness disappointment models for three-dimensional pressure fields with arbitrary, nonproportional loadings are specified. At that point, exhaustion life of an against move bar segment of a traveller vehicle is explored by the numerical strategy lastly, the examination is made among the aftereffects of the FEM investigation, consequences of the current speculations, aftereffects of the altered adaptations of the hypotheses, and additionally the trial comes about.

The study was done by Hubert, K. and Kumar, A., "Anti-Roll Stability Suspension Technology," Studied and explained anti-roll bars are usually manufactured from SAE Class 550 and Class 700 Sheets of steel. The steels included in this class have SAE codes from G5160 to G6150 and G1065 to G1090, respectively. Operating stresses should exceed 700 MPa for the bars produced from these materials.

The research was done by Mohammad Durali and Ali Reza Kassaiezadeh "Design and Software Base Modeling of Anti- Roll System" say that, examined and proposed the primary objective of utilizing hostile to move bar is to lessen the body roll. Body roll happens when a vehicle goes amiss during straight-line movement. The line interfacing the move focuses on the front and back suspensions shape the move pivot move hub of a vehicle. The focus of gravity of a vehicle is regularly over this move pivot. In this way, while cornering the radiating power makes a moving minute about the move hub, which is equivalent to the result of divergent power with the separation between the move hub and the focal point of gravity.

The study done by Birudala Raga Harshits Reddy "A Review on Anti-Roll Bar used in Locomotives and Vehicles" has studied about all research paper done by the different researcher on Anti-roll bar. By reading the different paper the researcher gave the details review about the anti-roll bar like Material, Manufacturing, Function and Development. The reviewer concluded that the anti-roll bar has a direct effect on car performances, then the reviewer says that by changing the parameter of the bar, the properties can have improved.

III. PROBLEM DEFINITION

Increasing One of the most unrecognised parts but yet important component hiding under the vehicles is the anti-roll bar bushings. Located on the chassis of the vehicle and used to reduce road noise, absorb bumps and cracks in the road and deliver a softer ride, the anti-roll bar is fixed with rubber bushings that keep the vehicle's body from rolling as it manoeuvres turns. When it is properly lubricated and maintained, the anti-roll bar bushings can bring excellent driving conditions for many years. At the point when the bar begins to weakness, the alert signs can go from subtle noises to significant problems with steering and handle this potentially leading to a vehicle accident and other safety concerns.

Inactive in vehicle handling

Since when driving the car routinely. It's likely that we can have an unmistakable comprehension of how the car handles the road. Simple way to identify problem with the anti-roll bar bushings are the point at which when the handling seems inactive or respond slowly, mainly when the vehicle makes a sudden turn and during take turn near the corner, the vehicle appears to be less steady than it has been beforehand, this is likewise a caution of bushings has been worn out and need to be restore to new bushings.

Rattling under the chassis of the car

The anti-roll bar is found specifically under the car. At the point when bushings are worn out, exhausted or totally breakout, the antiroll bar itself will end up flexible and cause a rattling or thumping sound while we are driving.

The turbulence will get continuously louder when you steer the car in either direction or when you are driving on the hard road. Mostly the noise will come from the front end of the vehicle, near the feet on the floor area and are very easily notable.

Squeaking Sound from under the vehicle

Not quite the same as a shake or thumping sound, the squeaking commotion originating from under the car is a potential cautioning sign that the bushings are beginning to wear. This sound is detectable while you are rolling over knocks, making forceful swings to one side or right, or an event that you crash into the garage. This noise is normally caused by an anti-roll bar bushing that isn't appropriately greased up because of metal-on-metal contact.

Type of Suspension System

Vehicle suspension - is a system that needs to maintain the body at a certain height above a road and transmit forces generated by driving over bumps or when braking when cornering. No less important is the ride comfort, which is ensured by vibration and shock damping. The suspension comprises rigid and flexible elements connecting the vehicle wheels with the bodywork. Constructor to align the many, often conflicting functions were developed different solutions.

McPherson's Suspension

McPherson strut suspension is used in the methodology of depreciation on vehicles with front-wheel drive. This decision deserves special attention because in many cases, the front suspension is used McPherson suspension. The lower-class cars, it is almost the only applicable solution. McPherson suspension column significantly simplified, as cushioning, supporting and steering functions of the elements have been merged into a single system. In addition, it takes up little space, which is particularly important in front wheel drive case at the transverse drive system layout. The main elements of the column are a shock absorber and helical spring. The upper shock absorber fastening element bearing column gives the possibility to rotate around its axis turn the wheels. The column is rigidly connected to the swing bracket (bracket) and swing arm ball joints (joints) is connected to the lever.

IV. DESIGN AND ANALYSIS

A. CAE Tools

CAE tool is broadly utilized as apart of vehicle industry. Accordingly, the car manufacturer has lessened item advancement cost and time while enhancing security, solace, and sturdiness of the vehicle they deliver. The prescient capacity of CAE apparatuses has advanced to the point where a great part of the plan confirmation is presently done utilizing computer re-enactments as opposed to physical model testing. Tools utilize as a part of this investigation are quickly clarified beneath.

System Analysis

The computer and data innovation are a necessary piece of the advanced enlightened world. The computer has turned into a vital apparatus and architect. Be that as it may, until further notice, he cannot supplant what is called designing reasoning. Looked with another issue, the designer must finish the assignment, utilizing the notable standards of material science, arithmetic and different sciences. The computer can just complete human-customized directions. He does this rapidly and precisely. The human concern is to furnish the computer with revised information. A computer can perform estimations productively, however, it cannot autonomously, without human mediation, details an undertaking, assemble a count plot, check presumptions, select the fitting strategies for choosing and condition, check whether the outcome is sensible, reach determinations and make suggestions.

Up until this point, there is just a single step in building investigation methodology, which is in a perfect world suited for the computer for the calculation. As it has just been said, different computer programming can be utilized for computer analysis. Notwithstanding, such fundamental project is utilized that depend on finite element method. The market offers various bundles of this compose, so the inquiry is which one to look over. On the planet, a standout amongst the most famous and most adaptable computer project of this write is Ansys. Understanding crafted by this program can without much of a stretch be connected to an arrangement of analysis tasks.

B. Ansys Simulation

For finite element analysis, ANSYS Workbench programming is utilized. ANSYS is a computer-aided engineering software which is utilized to decide finite element, structural analysis, Computational Fluid Dynamics analysis, Explicit and Implicit method. For our case, static structural is done to decide the disfigurement of the structure and different parameters, for example,

the pressure and vitality consumed by the structures. These figurines are then checked with the hypothetical computations to decide the quality of the superstructures. Infinite element investigation, the entire anti-roll is discretized into smaller element called as finite element and the analysis is done. The precision of the components relies upon the meshing. Ansys software is used as simulation program.

C. Model Description

The standard model of the anti-roll is chosen the model is drawn as per the spring design manual. The anti-roll bar with a hollow circular section for geometrical has been considered important parameter that is used to draw the model in SOLIDWORKS software is listed in the below table,

Table.4.1 Physical Properties

Property	Values
Density	7850 kgm^{-3}
Tensile Yield Strength	2.5E+08
Compressive Yield Strength	2.5E+08
Tensile Ultimate Strength	4.6E+08
Poisson Ratio	0.3

D. SOLIDWORKS Model

SOLIDWORKS is used as a design software to model the chosen anti-roll bar. The SolidWorks is a designing software was created by the French company Dassault System. It is one of widely-used software in aerospace and automotive industries. Only the anti-roll is designed as per the specifications. The designed CAD model of the anti-roll bar is shown below Fig.4.1

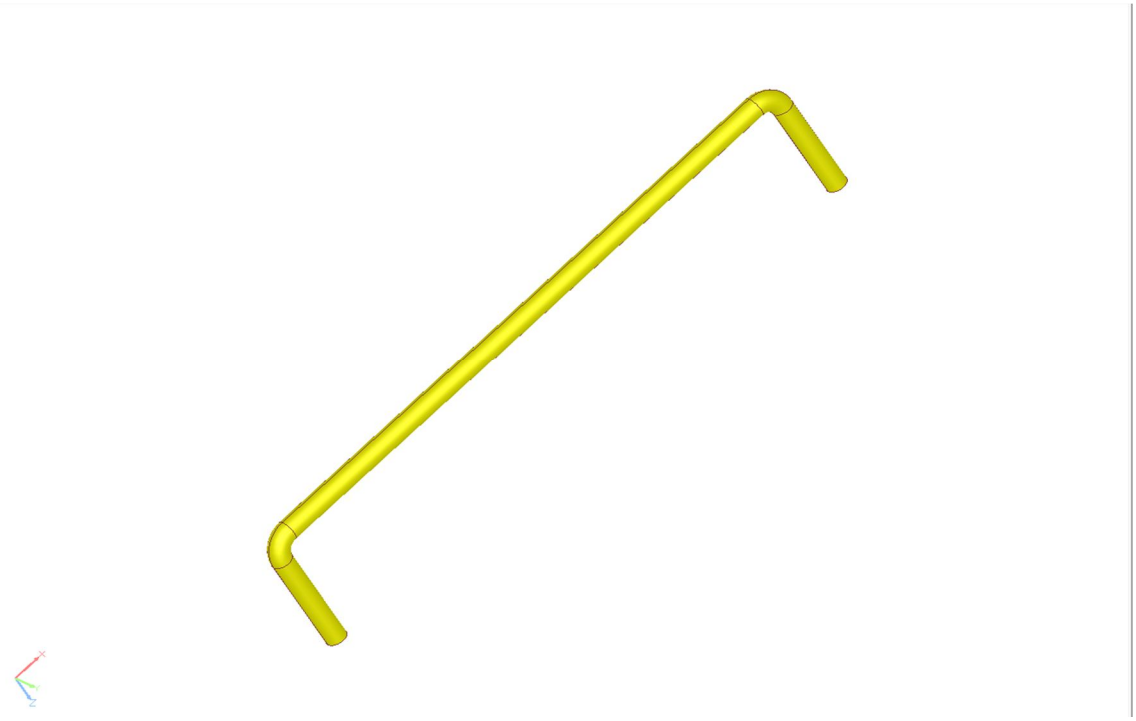

Figure. 4.1 Anti-roll Bar in CAD Model

V. ADVANTAGES AND DISADVANTAGES OF ANTI ROLL

The core benefit of anti-roll bars can be observed while cornering a vehicle. It provides an additional spring force that reduces the car body leaning in one direction. Moreover, this force also increases the vehicle's controllability while turning a vehicle.

The major con of a stiff anti-roll bar is the transfer of force incurred on one tyre onto another. This can cause a jarring movement and reduces ride quality on a bumpy road. In extreme conditions, it can also damage the suspension system of a car.

VI. RESULTS AND ANALYSIS

After the calculation are done for the bar and the model is imported in the ANSYS workbench, the investigation is done to find the total deformation of the bar and the results are obtained. In this section discusses those outcomes and it impacts on the rolling stiffness is also analysed

Analysis of Anti-roll in finite element analysis result The anti-roll bar of the car is analysed in ANSYS with the given load as shown in section 5.4.3. Two solutions are required for anti-roll bar are obtained from the finite element analysis are shown below

1) Total Deformation

Deformation is one most critical analysis the anti-roll bar deformation is obtained is shown in the Fig. The maximum displacement occurs in the workbench program is 34.577 mm by using the load 1000 N

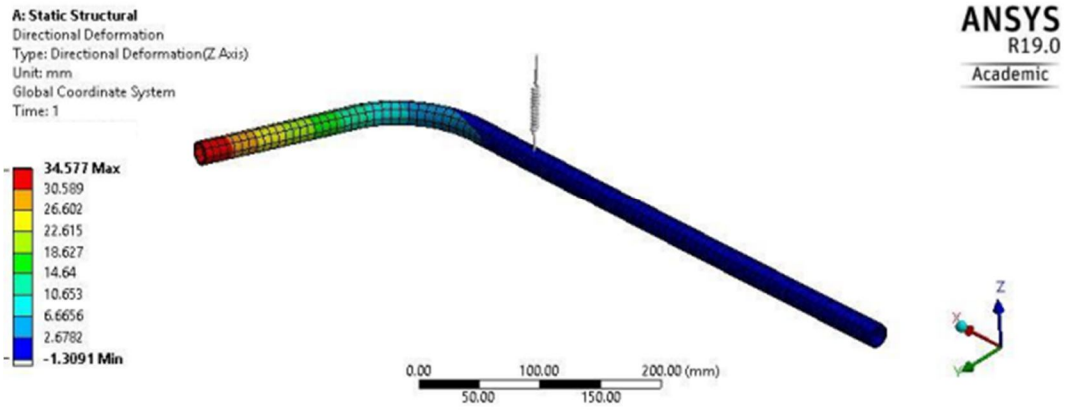

Figure. 6.1 Anti-roll bar Total displacement in ANSYS Workbench

2) Equivalent Stress

The Figure.6.2 shown the equivalent stress that is analysed the maximum stress obtained is 600MPa, for the applied load 1000 N. Which is less than the working stress 700MPa has per the spring design manual.

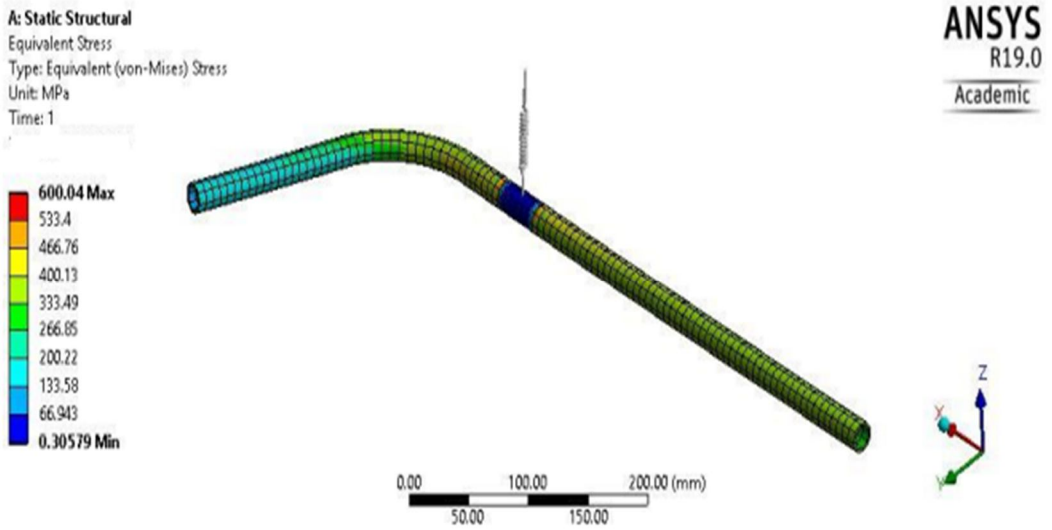

Figure.6.2 Equivalent Stress

Analyser Numerical analysis with APDL

Anti-roll bar was selected to examine the software package APDL. Creating a conceptual model selected the appropriate finite element type properly expressing the structural behaviour. Using APDL program to calculate the stresses and displacement anti-roll bar was used bolt element. The code written in the APDL program for calculating the anti-roll bar characteristics. The below figure.6.3 illustrates the geometric model of the anti-roll bar which is created by the APDL program.

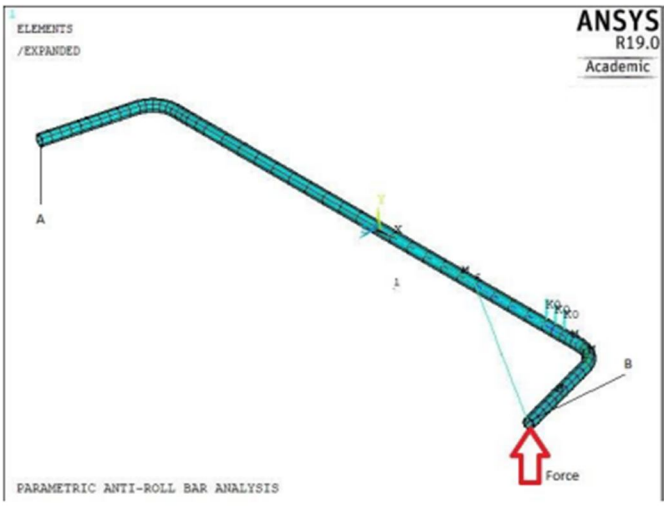

Figure.6.3 Geometric of Anti-roll bar in ANSYS APDL

The above figure shows that the anti-roll bar the point A is constrained in some direction. At the point A, the anti-roll bar cannot move in the z-axis, but it can move smoothly in y-axis and x-axis. In addition, to that, the point A the anti-roll bar cannot rotate about y-axis and z-axis, but it can smoothly rotate in the x-axis. The upward force is also applied at the point A.

At the point B, the anti-roll bar can translate in the y-axis, but it cannot move in x-axis and z-axis. Similar to that the Point B can rotate around the x-axis and z-axis. The downward force is also applied at the point B When the modelling the anti-roll bar, it was necessary to take into account the fact that the anti-roll bar is fastened with bushings.

Spring with a rigidity of 1500 N/mm was used to simulate locally space bushings. Such spring stiffness is closest to the rigidity of rubber bushing. The results of the equivalent stresses and total displacement obtained by linear analysis are shown in figure 6.4 and 6.5 respectively

The highest displacement values are 28.7267mm of the anti-roll bar is shown in Figure.6.4, When the anti-roll bar is applied with 1000 N

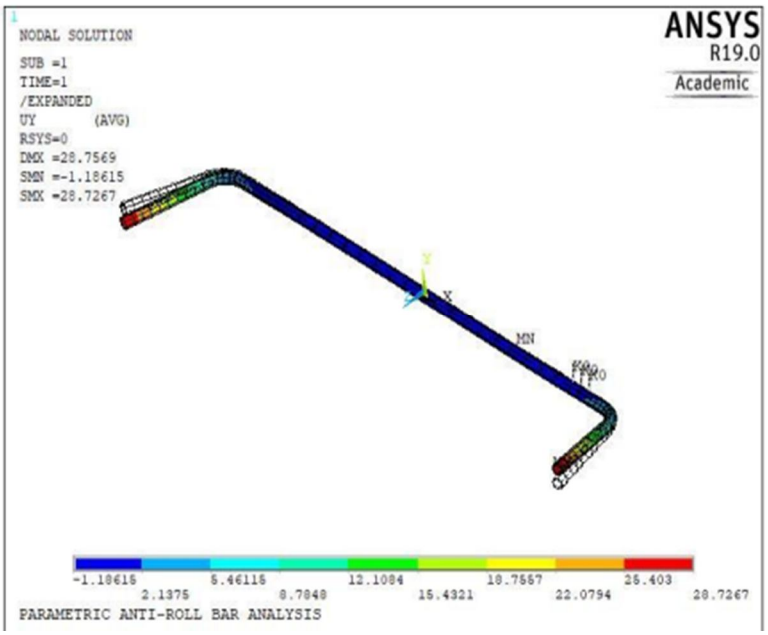

Figure.6.4 Anti-roll Bar Displacement in ANSYS APDL

The shows the maximum equivalent stresses values are 395.134 MPa of the anti-roll bar is shown in Figure.6.5 when the bar is applied with a load of 1000N.

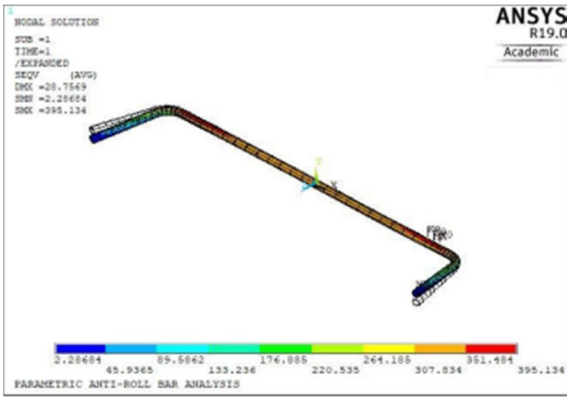

Figure.6.5 Anti-roll Bar Equivalent stress in ANSYS APDL

VII. CONCLUSION

The design of the anti-roll bar is carried with help of SOLIDWORKS. Then the analysis is carried in ANSYS Workbench. An ANSYS APDL program also created for the particular model. The dynamic strength of the anti-roll bar is a program. Perform computation using different sort of finite element strategies and the total displacement, equivalent stress is estimated. The Numerical computation was carried out in ANSYS program. The result is shown is in table.6.1. The comparison showed that the difference between the percentage various between 1.01 % up to 1.27. By chance, the parameter of the anti-roll bar there strongly effects on the vehicle performance. Most of the vehicle uses hollow type circular anti-roll bar. By locating the bushing closer to centre this may increase the stress and this resultant in decrease rolling stiffness. The value obtained in ANSYS workbench and ANSYS APDL program are displacement value is 34.577 and 28.73 mm particular to load of 1000 N. The stress value for the both is 600 MPa and 395.134 Mpa corresponding for the load of 1000 N. The value for stress is comparatively less than allowable stress which is mentioned in the Spring Design Manual. A linear status, Pearson correlation also found between the parameter and it was found that the external parameter of the diameter increases as the displacement parameter decrease gradually. When the external diameter increase, the mass of the bar increases gradually. It found that there is an interlink statistical relationship between the values. When performing the response surface optimization, it shows that external parameter of the diameter increases as the displacement parameter decrease gradually. When the external diameter increase, the mass of the bar increases gradually. It found that there is an interlink statistical relationship between the values.

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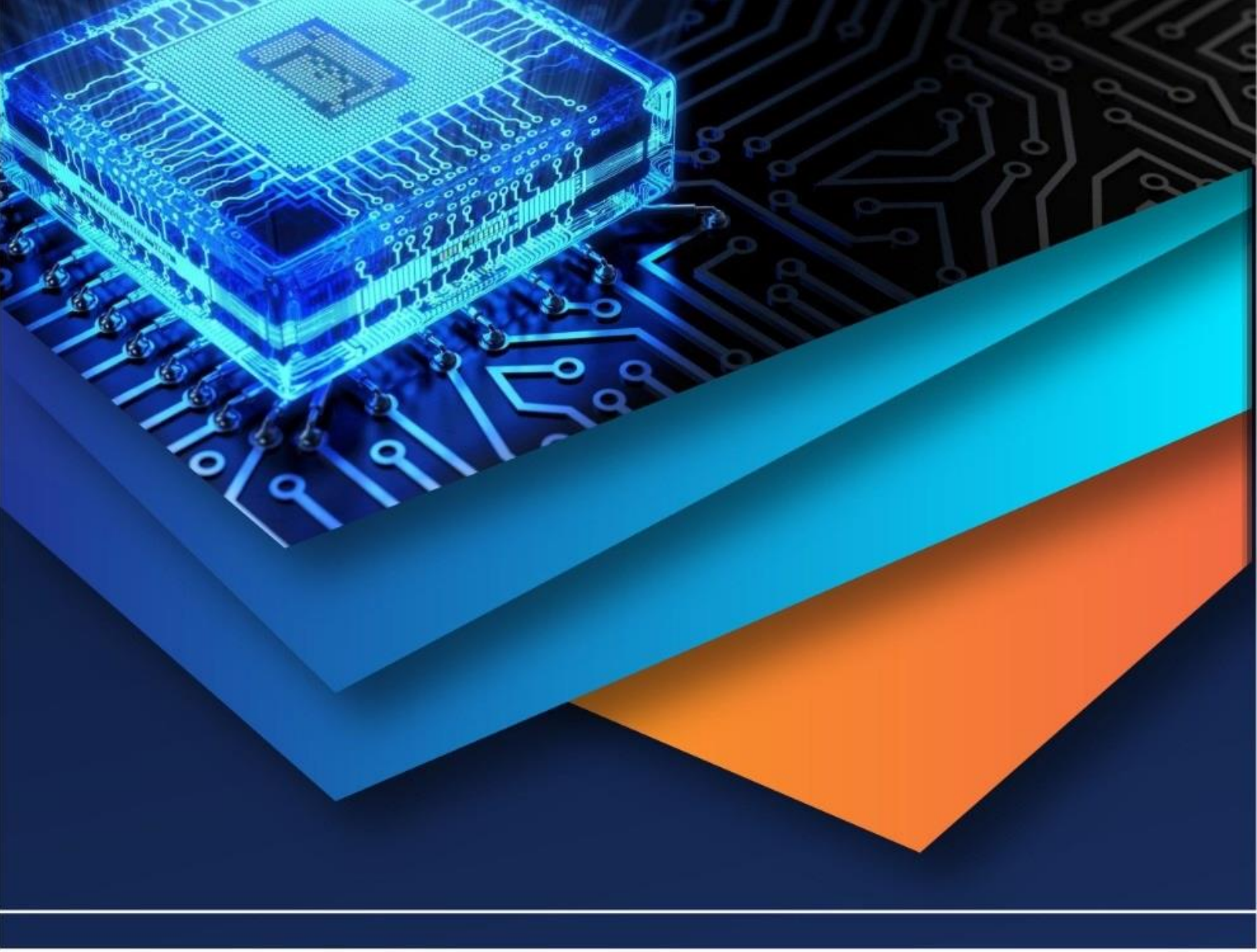

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