



Safety and Comfort of Hybrid Anti Roll Bar System for Improved Cornering Stability

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ABSTRACT: Stiffness and stability are of high importance for vehicles. Existing suspension systems reworking for vehicle stability increasing and they are not limited to own. One of the stability increases extra elements is the anti-roll bar. The anti-roll bar is a suspension system supporter in vehicles. However, bar stiffness plays a critical role in vehicle stability. Bar stiffness can be managed on the predefined limitations.

Therefore, a light, effective, and reliable vehicle system can be obtained. Aluminum metal matrix composites are widely used in various applications because of their higher mechanical and physical properties when compared with their base Al alloy. Metal matrix composites are fabricated by metal as a matrix material and metal, organic compound or ceramic as reinforcement.

This experiment focuses on the changes in mechanical properties of LM6 reinforced with Boron carbide, Fly ash and Silicon carbide. Fabricate will be using stir-casting method. For this purpose, matrix of LM6 combined with various reinforcement weight percentages has been planned. (B₄C-2.5%), (FA-2.5%) & (SiC-2.5%). The mechanical behavior such as Hardness, Tensile strength, Compressive strength will be evaluated.

The optical properties will be evaluated through SEM analysis. Various stress analysis evaluated through Solid works with and without reinforcements.

KEYWORDS: vehicle stability, AL alloys ceramic as reinforcement, Compressive strength, Metal matrix, SEM analysis.

I. INTRODUCTION

Designing a suspension system for a car, the aim is to maximize comfort for passengers on uneven roads, increase vehicle stability, improve wheel alignment with the road surface and also reduce 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 without losing their characteristics. When the car accelerates, rotate and stops suspension system is responsible for the stability of the car, so a lot of attention is paid to that. Anti-roll bar or sway bar is one of the suspension elements that improves ability or align in gone wheel with the other one and controlling the rollover of the automobile.

The anti-roll bar is used to connect one wheel against another wheel i.e. when riding on an uneven road surface, and one-wheel ride on unevenness and the other wheel stays on a level road surface, then it transfer torsion force from one wheel to the opposite wheel and provides stability to body and control rollover of the automobile. Designing the anti-roll bar is very important because of its geometric parameters, which determine its rigidity, and the comfort or stability of the automobile is determined from its stiffness. So, its main function is by improving the stiffness of the suspension system reduces the rollover of the vehicles due to the irregularities of the road surfaces or in the case of cornering.



WORKING ANTI-ROLL BAR: Anti-rollbar, also called a stabilizer bar, is a rod or tube, which connects suspension members of the opposite wheel together to resist the roll of the vehicle which occurs during cornering or due to road irregularities, usually made of steel. The bar's torsion stiffness which is nothing but resistance to twist determines its ability to reduce body roll and is termed as "Roll Stiffness". An anti-roll bar also improves the handling of a vehicle by increasing stability during cornering.

Most vehicles have front anti-roll bars and anti-roll bars at both the front and the rear wheels can reduce roll further. A spring rate increase in the front anti-roll bar will produce an oversteer effect. So, anti-roll bars are used to improve directional control and stability of the vehicle. Also, one more benefit of the anti-roll bar is that it limits the change in the chamber angle caused due to body rolling and improves traction. The geometry of anti-roll bars can differ from vehicle to vehicle, it may have irregular shapes of it around chassis components, or may be much simpler depending on the vehicle. So, two important parameters to consider while designing the anti-roll bar are first, stiffness of the anti-roll bar which shows the direct influence on handling characteristics and second, bar geometry which totally depends on the arrangement, space available and location of chassis components.

GEOMETRY AND CONNECTIONS: There are three types of cross-sections normally used in anti-roll bars: solid circular, hollow circular and solid tapered. Hollow and tapered are improved versions of the solid bar as they reduce the weight of the bar. At four locations anti-roll bar is attached to the other chassis components. Generally, use rubber bushings through which an anti-roll bar is mounted to the mainframe. The material of the bushing is also an important parameter to reduce stress concentration.

Commonly used materials for bushing are rubber, nylon, polyurethane. Here care must be taken to locate correct attachment points to avoid interference with the suspension motion. Different types of attachments are: Bar and bayonet type link, bar with rubber insulated eye, bar with eye type link, bar with trapped rubber and washer, bar with rubber insulator block, bar with silent block bush eye.

GEOMETRY AND CONNECTION OF ANTI-ROLL BAR IN A VEHICLE: The anti-rollbar can have in different geometries which include several bends and curves which is specific to the kind of vehicle and the application. For example, race car needs a different suspension because they have low ground clearance and the wheel swing is lesser in comparison to a commercial vehicle. The weight of a commercial vehicle is high, and it has large wheel swing.

The anti-rollbar must be installed via a rubber bush which restricts the degree of freedom and allows only rotational. This helps in equal application of torque on both wheels. If there is any offset alignment while installing the anti-roll bar, it disturbs the distribution of force and leads to uneven torque application on wheels. The ends of anti-roll bars have a pin joint which is attached to suspension, knuckle or sometimes to the control arm. Also, one disadvantage of the anti-roll bar is that when the vehicle travels on bumps, the anti-roll bar tends to lift the other wheel. This causes instability in vehicles. Also, this force is impulsive and has a large magnitude which induces a large torque on the anti-roll bar. So, the anti-roll bar should have sufficient torsional stiffness to sustain the impact during bumps.

FORMULATION OF STIFFNESS FOR ANTI-ROLL BAR The stiffness of the anti-roll bar generally depends on the following parameters mentioned in Fred Puhn's Sway Bar Stiffness Formula.

$$Q = \frac{500000 \cdot (OD^4 - ID^4)}{(0.4244 \cdot R^2 \cdot 2L) + (0.2264 \cdot S^2)}$$

Parameter	Dimensions	FIAT 500 (Hatchback)	Honda Accord	Chevrolet Trax (SUV)
OD	Outer Diameter	1.45	1.45	1.5
ID	Inner Diameter	1.15	1.25	1.15
R	Effective Arm Length	14	12	15
L	Half Length of Bar	13	11	10
S	Length of Arm	17	16	16
Q	Sway Bar Stiffness	407.86	435.57	715.95



In this study, 3 samples of anti-roll bars were taken from different 2016 FIAT 500 (Hatchback), 2016 Honda Accord (Sedan) and 2016 Chevrolet Trax (SUV) categories of vehicles. The Fred Puhn's Sway Bar Stiffness Formula was used to calculate the stiffness (Q value). In case of Hatchback and Sedan, the stiffness value was almost similar but in case of SUV the stiffness value was very high due to the large mass of the vehicle. To meet the requirements of high-performance vehicles, the sway bar should be manufactured with higher stiffness to sustain large dynamic loads. To meet this demand, conventional manufacturing methods should be altered to enhance the manufacturing so that the performance of the anti-roll bar is improved. The sway bar stiffness (Q value) obtained from Fred Puhn's Sway Bar Stiffness Formula was later used in the Torsion Rigidity criteria to obtain angle of twist for different materials which has modulus of rigidity similar to the high strength steel.

According to Torsion bar equation,

$$\frac{T}{Jp} = \frac{\tau}{R} = \frac{G\theta}{L} \quad (2)$$

According to Rigidity Criteria condition

$$\frac{\tau}{R} = \frac{G\theta}{L} \quad (\text{which is equal to } Q \text{ obtained from Fred Puhn's Formula})$$

$$\text{Therefore } Q = \frac{G\theta}{L} \Rightarrow \theta = \frac{QL}{G} \quad (3)$$

These calculations Table 3 shows that the angle of twist for anti-roll bars of different categories. The angle of twist is low in case of hatch back and in case of sedan it's slightly high because of the large mass and same is the case with SUV. This is the common angle of twist value for anti-roll bars which either needs to be reduced in case of Sedans and SUV since the large mass of the vehicle exerts a large torque on the vehicle.

Also, at this high torque the material experiences large fatigue load and can result in development of creep or cracks and can lead to failure. To prevent this, the manufacturing process should be enhanced to obtain good torsional strength and at the same time material should be free from defects to avoid catastrophic failure of the component.

II. LITERATURE REVIEW

Sachin Sunil Kelkar [1] et al [2021] were studied explains a coherent flow for designing, manufacturing, analyzing, and testing a tunable anti-roll bar system for a formula student racecar. The design process starts with the analytical distribution in conjunction with suspension geometry. Then, the materials election for the design, i.e. Aluminum 7075 T6 is made based on parameters such as density and modulus of rigidity. A MATLAB program is used to iterate deflection vs load for different stiffness and shaft diameter values. This is then checked with kinematic deflection values in Solid works geometry. To validate with the material deflection, 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 on-track 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 deflection were determined and validated.

Merve Alpar [2] et al [2024] were found Stiffness and stability are of high importance for vehicles. Existing suspension systems are working for vehicle stability increasing and they are not limited to own. One of the stability increases extra elements is the anti-roll bar. The anti-roll bar is a suspension system supporter in vehicles. However, bar stiffness plays a critical role in vehicle stability. Bar stiffness can be managed on the predefined limitations. Therefore, a light, effective, in the and reliable vehicle system can be obtained. In this study, an urban electric bus anti-roll bar optimization was conducted numerically. For optimization, the bar diameter was changed between 25mm and 40mm. S235, 50CrV4, AISI 1065,



Sagar B. Deshmukh Patil [3] et.al [2021] were found an anti-roll bar or sway bar is one of the suspension elements that improve the stability or aligning one wheel with the other one and controls the rollover of the automobile while cornering or on the rough road surface. Basically, it is a U-shaped bar having two short lever arms that connect suspension members of the opposite wheel and two more points, it attached to vehicle chassis with rubber bushings. Reviewed different materials used for manufacturing anti-roll bar. In this present work, effects are investigated by changing conventional steel material with composite glass fiber epoxy. Response surface optimization technique used for the optimization of various parameters such as internal and external diameter, cornering radius, bushing distance for the composite bar. Results obtained by performing finite element analysis using ANSYS Composite Prep Post (ACP) software.

Yonghua Li and Zhe Chen [4] et.al [2024] were ordered to ensure the comfort of passengers and the smoothness of two-system pendant suspension system also brings the problem of insufficient vehicle anti-roll stiffness. In order to solve the above problems, the addition of an anti-roll torsion bar system can be used. As an important suspension component of a rail vehicle, the accurate calculation of the anti-roll stiffness value of the anti-roll torsion bar system is an important guarantee to make it meet the design requirements. In the traditional design process of anti-roll torsion bar, the main calculation method is the combination of finite element simulation calculation and the cortical calculation. However, the existing theoretical calculation method has the disadvantage of insufficient accuracy, and the design redundancy is large to ensure safety and increase the weight of anti-roll torsion bar.

III. RESEARCH METHODOLOGY

This study employs a systematic literature review methodology to analyse the advancements in AI-powered Intrusion Detection Systems (IDS) developed in 2024. This review aims to identify emerging trends, evaluate the effectiveness of various AI techniques, and highlight the challenges and future directions in the field.

The literature search was conducted across several academic databases, including IEEE Xplore, SpringerLink, Science Direct, and Google Scholar, using keywords such as "AI-powered IDS," "machine learning," "deep learning," "generative adversarial networks," "reinforcement learning," and "explainable AI".

Each selected study was analysed to extract key information, including the AI techniques employed, the datasets used, the evaluation metrics reported, and the reported outcomes. A comparative analysis was conducted to assess the strengths and limitations of different approaches and to identify common trends and gaps in the existing literature.

The findings from the literature review were synthesized to provide a comprehensive overview of the current state of AI-powered IDS, emphasizing the advancements made in 2024.

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IV. RESULTS AND DISCUSSION

The requirement of composite material has gained popularity these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Fly ash is one of the least expensive and low-density reinforcement available in huge quantities as solid waste by-product in ceramic plants. The Hardness strength will also be taken into consideration. For the achievement of the above, an experimental setup is prepared where all the necessary inputs will be made. In this work a composite is developed by adding Boron carbide, Fly ash & silicon carbide in LM6 aluminum alloy metal by mass ratio with some percentages. The composite has to be prepared by crucible casting technique and has to be analyzed various mechanical properties.

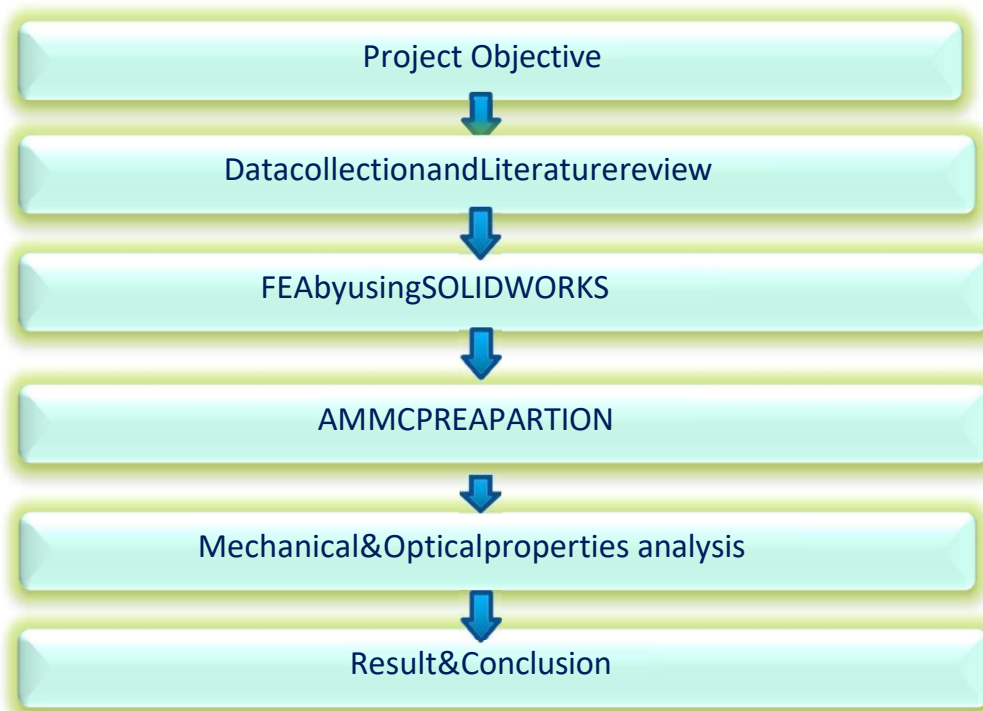


FIG: 1

V. CONCLUSION

From solid work antiroll bar an analysis is vanishes stresses; equivalent strain and resultant displacement were evaluated .Finally found LM6AMMC produced minimum $(1.489 \times 10^4 \text{N/m}^2) \geq 1.709 \times 10^3 \text{N/m}^2$ stress and strain compared to UN reinforcement LM6 alloys. Composite materials, especially LM6 and various reinforcements were purchased for casting.

In PHASE 1 the material and the casting ratio were selected, based on the literature survey and getting some ideas from the experts. Materials were purchased, according to the requirement of castings.

Analysis have been found minimum $(1.489 \times 10^4 \text{N/m}^2) \geq 1.709 \times 10^3 \text{N/m}^2$ stress and strain compared to Un-reinforcement LM6 alloys. So, it is very suitable for Anti roll bar devices

InPhase-II, the following test has been evaluated to check the mechanical characteristics of the material. Below mentioned test has analyzed. Sand casting, tensile test, compression test, hardness test, optical property analysis.

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