Design and Analysis of Strut Bar for Achieving Maximum Performance of Vehicle

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Abstract – *This research focuses on the integral automotive structural component known as a strut bar or strut brace. It provides additional support and stability to a vehicle's chassis. It's typically a metal bar that connects the top of the front struts or shock absorbers, enhancing rigidity and reducing chassis flex during cornering or uneven road conditions. This can improve handling, steering responsiveness, and overall performance by reducing body roll and enhancing traction. It enhances the rigidity of the vehicle's chassis, ensuring that the suspension system functions properly. In this paper, we will analyze strut bars and how the different load conditions act on them, in different conditions, how materials can affect its rigidity and more. The design of strut bar is made with the SOLIDWORKS software. The analysis part is done in ANSYS.*

***Key Words*: Strut Bar, Stability, Rigidity, Load Conditions.**

1.INTRODUCTION

In this era where every vehicle is running at high speed, we have recorded numbers of accidents, from which some of them occurs due to turning at high speed. These events leave a huge impact on automobile and manufacturing industries as an impact and with the increasing demands in driving dynamics, safety and comfort the manufacturers and designers nowadays are using an innovation known as "STRUT BARS". Strut bars has come up as a valuable component in terms of vehicle handling and stability. These rigid, sometimes adjustable structure plays a vital role in minimizing chassis flex and torsion. It also plays a crucial role in terms of safety during cornering and at a high-speed turning and has enhanced the performance of vehicle not only in terms of control or handling but in terms of safety also. Due to high-speed driving and too much driving under braking, the ride usually feels stiffer in F1 Race Car. The amount of body roll, the driver feels can be frustrating sometimes, as a solution use of strut bars in F1 cars can be beneficial.

This research on Strut bars will have an aim on Effectiveness of strut bar in vehicles and to provide some valuable information into the Engineering and Automotive applications of strut bars.

This research will have an aim on how different types of materials and design of strut bar can be beneficial to overall performance of a vehicle.

1.1. DESIGN CRITERIA FOR STRUT BAR

When considering the strut bar, there are several criteria to keep in mind to ensure its effectiveness.

The design architecture of the strut bar significantly influences its rigidity. The geometry, cross-sectional shape, and dimensions of the strut bar are important determinants of its structural integrity. A strut bar featuring a solid or tubular design tends to manifest enhanced rigidity due to an efficient distribution of forces along its structure. Furthermore, the length of the strut bar should be commensurate with the width of the vehicle's engine bay, ensuring optimal rigidity and stability. A basic strut bar typically ranges in length from 30 to 50 inches (76 to 127 cm), depending on the specific make and model. The width and diameter of the bar can vary, but they are generally around 1 to 1.5 inches (2.54 to 3.81 cm). The dimensions can vary according to the application and design.

1.2 MATERIAL PROPERTIES AND RIGIDITY

The material composition of the strut bar is important in determining its rigidity. Materials with high tensile strength, such as aluminum alloys or steel, manifest superior rigidity due to their inherent resistance to deformation. The Young's Modulus, representing a material's resistance to elastic deformation, is a crucial factor affecting the strut bar's rigidity. Consequently, materials with higher Young's Modulus values exhibit enhanced rigidity, contributing to an effective suspension system.

1.3 COMPABILITY AND RIGIDITY

Ensuring compatibility between the strut bar and the vehicle's chassis is imperative for achieving the desired rigidity. The attachment points of the strut bar to the strut towers or chassis should be carefully designed to establish secure connections. A well-aligned strut bar, easily integrated within the vehicular framework, supports its rigidity by effectively reducing chassis flex and increasing overall structural stability.

1.4 IMPORTANCE OF STRUT BAR

It can be used in various types of vehicles such as cars, trucks, SUVs, and even some performance-oriented motorcycles. Especially they are used in sports cars and high-performance vehicles, where the priorities are handling and reducing chassis flex. Additionally, it can also be used for customized vehicles or modified vehicles to enhance their suspension systems and overall stability.

There are types of strut bars like single straight strut bar, X-type strut bar, H-type strut bar, and triangulated design strut bar, that can be used according to our need.

In sports cars, strut bars are commonly used to enhance vehicle's handling, overall performance, improving chassis rigidity, reduction in body roll, better steering response, optimized suspension geometry. You'll often find front strut bars and rear strut bars being used in sports cars. Front strut bar is installed at the front of the vehicle, connecting the top of front strut towers. It helps in reducing flex and movement between front strut towers during cornering or rapid changes in direction. This leads to improved front-end stability and steering response. Rear strut bars are installed at the rear of the vehicle, connecting the top of the rear strut towers. They serve a similar purpose to the front strut bars, providing stability and reducing flex in the rear suspension. This helps in maintaining traction and stability, especially during acceleration and cornering.

1.5 SOLID TO HOLLOW RATIO IN STRUT BAR

	Aluminum	Steel	Carbon Fiber
Solid	6766.5	19332.86	52198.72
Hollow	6343.59	18124.55	48936.30

Table -1: Chart representing Stiffness of Strut bar of 1.3-meter length of different material with different cross-section

"Average of Young's modulus of carbon fiber is considered here for the values"

To calculate the stiffness of a Strut bar, we would typically use the formula for the stiffness of a beam. The formula is:

$$K=(E\times I)/L$$

The formula of Stiffness depends on some parameters like:

"E" is Young's Modulus of elasticity of the material of Strut bar

"I" is the moment of inertia of the cross-section of the Strut Bar

"L" is the length of the Strut Bar

"K" is stiffness of Strut Bar

: - Generally, "I" (Moment of Inertia) depends on the specific shape and dimensions of the cross-section of the Strut Bar. Mostly, strut bars are used as circular cross-sectional shape.

All measurements are in meters

1.6 HOW LENGTH OF STRUT BAR OF DIFFERENT MATERIALS AFFECTS ITS STIFFNESS

Every material has its own property which is useful for a component's serviceability, life, hardness and stiffness and many more. Strut bars are usually made up of 'Aluminum', 'Steel', 'carbon fiber' and many more. Mostly of them are used of 'Aluminum' and 'steel'. To enhance the performance of strut bar it is important to analyze strut bars of different materials and with different lengths. In this paper there will be an analysis of how Aluminum and Steel strut bars with different lengths affect its stiffness.

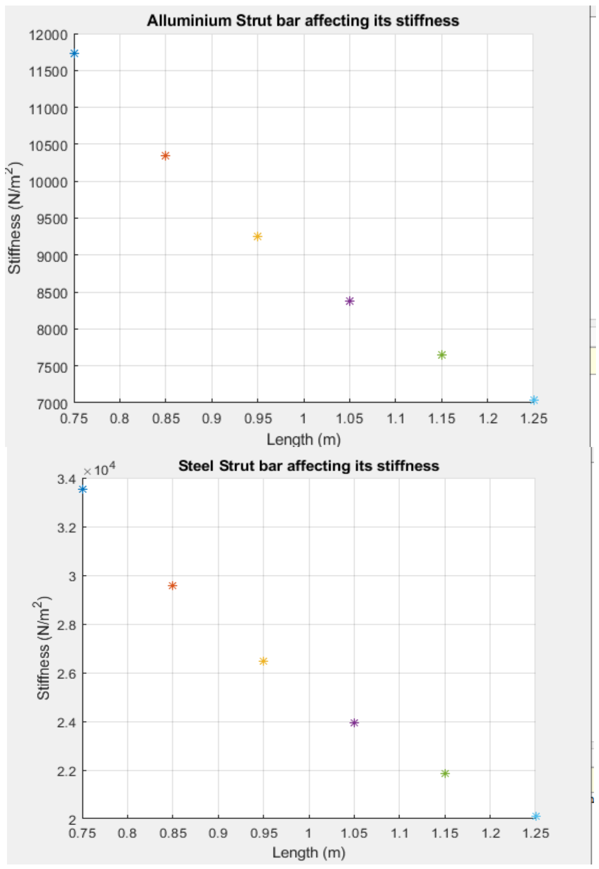

Chart -1: Graphs representing Length of ALUMINUM and STEEL strut bar affecting its Stiffness

The above graphs clearly show that the Aluminum strut bar with bigger length has lower stiffness than Steel strut bar.

The calculation of stiffness for steel strut bar and the above graph were done and generated on MATLAB R2023b

2. DESIGN & LOAD CONDITIONS ON STRUT BAR

There are lot of loads acting on a strut bar like tensile load, compressive load, torsional load & shear load. The effect on the strut bar usually depends on the material of it. The load that acts on strut top is combination of both tensile and compressive. The rear strut bar experiences torsional loads (twisting force) around an axis. The harness eyelet bush typically experiences shear and compressive loads.

Figure 1. Front view of the bar

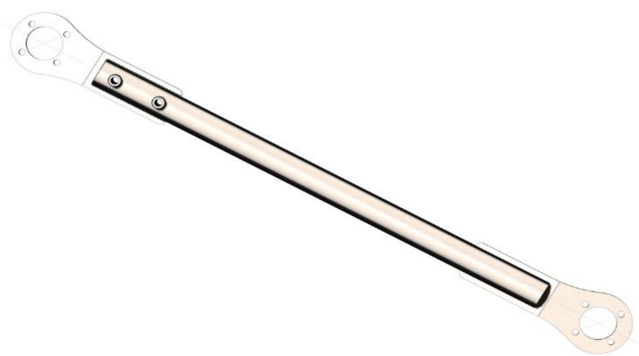

Figure 2. SolidWorks design of strut bar (Hollow)

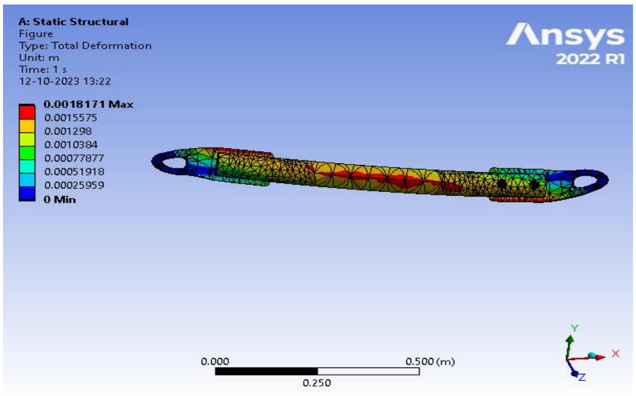

Figure 3. Total Deformation of strut bar.

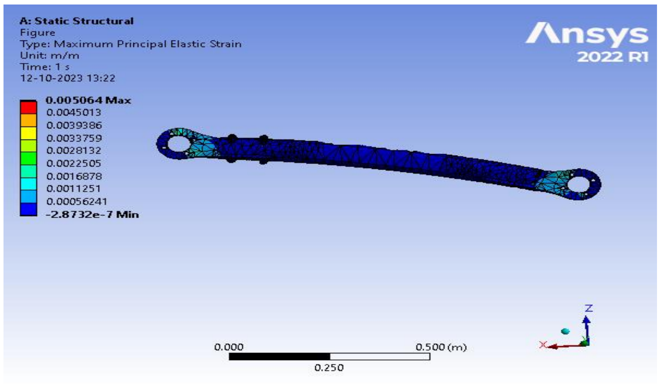

Figure 4. Maximum principal elastic strain

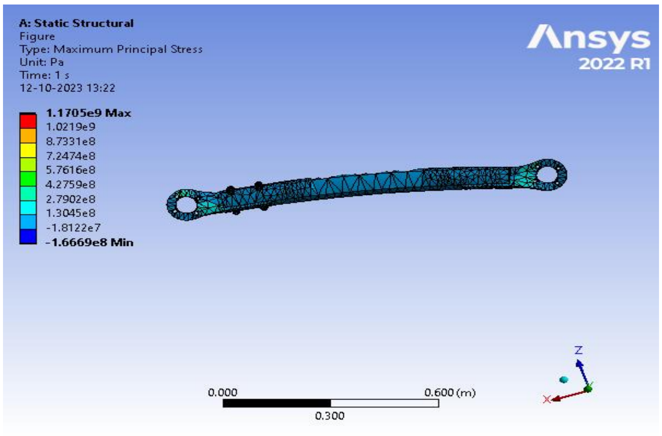

Figure 5. Maximum principal stress

The above images show the effects on strut bar in loading conditions using the ANSYS software. For the analysis purpose, average values are taken as consideration.

2.1 SPECIFICATIONS OF THE BAR

The material used here is stainless steel. The mass of the bar is 4049.363 grams, volume of bar is 5.158 x 10^5 mm^3, area of bar is 3.494 x 10^5 mm^2, density is 0.008 g/mm^3. The values are taken into consideration from the FUSION 360 software. The bar contains total of 5 components here that includes 1X REAR BAR, 2X STRUT TOP, & 2X HARNESS EYELET BUSH. The strut bar experiences a total of eight forces during its operation. Among these, there are two tensile forces applied to the strut top, including the compressive forces on strut top. A moment is generated on the rear bar affecting its structural stability and equilibrium. Furthermore, there are two compressive forces acting on the harness eyelet bush, influencing its mechanical behavior and interaction with the strut bar. It's important to note that the strut bar is fixed at the end where it connects to the strut towers, ensuring its structural integrity and functional performance.

3. DRAWBACKS OF STRUT BARS

While beneficial for enhancing vehicle handling and stability, strut bars do have some disadvantages or drawbacks.

It has limited effectiveness. The impact of a strut bar is marginal, especially in modern cars with advanced suspension systems. The extent of handling enhancement might not align proportionally with the investment, depending on the vehicle and its existing suspension system. The installation cost of strut bar can be relatively high. The ratio of cost and benefit may not always be favorable, particularly if the vehicle is primarily used for daily commuting rather than performance-focused driving.

Installing a strut bar might be challenging for someone and may require professional assistance or specialized tools. This complexity in installation can increase both the cost and effort associated with integrating the strut bar into vehicle's chassis. Strut bars may not be applicable for all vehicles, as certain vehicles lack mounting points or structural design that limit the extent of handling improvement achievable through strut bar.

If installation of strut bar is not done properly, it can lead to an overly stiff ride. This can compromise ride comfort and traction, especially on uneven or irregular road surfaces. Though strut bars are lightweight, it still adds some weight to the vehicle. In high performance scenarios, every pound matters, potentially affecting the overall performance.

4. CONCLUSION

In this paper, Strut bar was studied for its functionality, handling and vehicle stability. Chart was prepared of Stiffness in different materials of different cross-section and the results show that ALUMINUM HOLLOW strut bar has the lowest stiffness and is more suitable for use. Stiffness was calculated from a typical Stiffness Formula. If the purpose is to prioritize fuel efficiency and reduce overall car weight a HOLLOW strut bar can be used, on the other hand, if the purpose is to prioritize reducing chassis flex and enhancing stability in high-performance applications a SOLID strut bar can be used. The graphs and the results show that use of ALUMINUM strut bar with a larger length than a STEEL strut bar will prove to be more beneficial to the overall performance of a vehicle. Aluminum Strut bar has low stiffness as compared to the Steel Strut bar. Due to low stiffness the Aluminum Strut bar will be able to absorb more force and will work for a longer time as compared with the steel strut bar.

Design of a strut bar which is taken as reference was created to find Deformation of strut bar and to find the amount of Stress and Strain acts on the Strut bar. Due to analysis on ANSYS software it will be a smooth work to find the locations of the Maximum Stress and strain affected areas and to work on those areas to improve the performance of bar and vehicle. The value of maximum deformation in the bar was found to be 0.0018171 meters. Most deformed part in the strut bar was in the middle. Maximum principal strain and Minimum principal strain in the strut bar was found to be 0.005064 and -2.8732×10^{-7} respectively. Maximum principal stress and minimum principal stress in the strut bar was found to be 1.175×10^{9} N/m^2 and -1.6669×10^{8} N/m^2 respectively.

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