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Structural Analysis of front Control ARM

Lokesh Yadav[1]*, Imraan Siraj[2]

[1] Research Scholar, IITM Group of Institutions, Murthal (Haryana)

[2] Associate Professor, IITM Group of Institutions, Murthal (Haryana)

Abstract - The vehicles are controlled by the lower extremities of the automotive suspension system located at the front. The primary aim of this study is to evaluate the structural integrity of the lower control arm under specific loading conditions using finite element analysis techniques. The ANSYS simulation software is utilized for conducting Finite Element Analysis (FEA) simulations and modeling of the lower control limb. The finite element analysis (FEA) simulation yielded significant results, including contour diagrams that visually represented deformation, equivalent stress, and shear stress. The arm's corner region exhibited the maximum equivalent stress magnitude, measuring 153 MPa, in contrast to the support region which experienced the minimum stress level.

Keywords - Front control lower arm, FEA

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1. INTRODUCTION

The suspension system of a vehicle is commonly perceived as a critical component that contributes to both the safety and comfort of driving. This perception stems from its role in supporting the vehicle's body and facilitating the transfer of forces between the body and the road surface. Active and semi-active constituents are employed to enhance these factors.

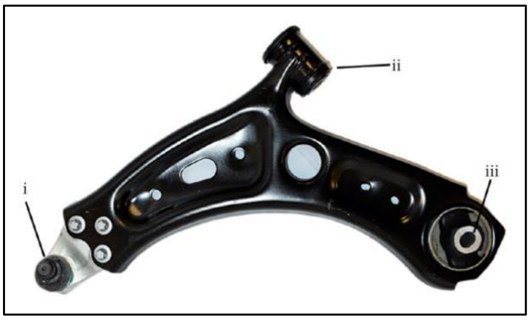

Figure 1: Lower Control Arm [7]

The lower control arm holds significant importance within the front suspension system. The “wheel's function encompasses the regulation of its movement and the transmission of the load imposed by the road onto the wheel to the vehicle's chassis” [7]. The suspension control arm exhibits various suspension configurations, such as wishbone and double wishbone designs. The nomenclature "A-type control arm" is derived from its visual appearance. The suspension system of an automobile is not an independent entity. In order to “achieve optimal performance, the system necessitates components that are both dependable and efficient. The primary function of the lower control arm is to regulate the movement of the wheels relative to the body or chassis of the automobile” [7]. The lower control arm holds significant importance as a crucial component in the operation of all automobiles currently in use. In the absence of this component, the vehicle may exhibit abnormal vibrations and exhibit erratic driving behaviour, thereby inducing anxiety in the driver and potentially resulting in a collision.

2. LITERATURE REVIEW

M.H.A. Rahman and several individuals [1] The “primary objective of this study is to employ a topology optimization methodology in order to investigate the design of a lightweight front lower control arm for a C-segment automobile. According to this concept, the initial weight of the lower control arm has been reduced by 25% compared to its previous value” [1]. The newly designed cast-aluminum lower control arm exhibits a novel configuration that demonstrates ingenuity and aligns seamlessly with the prevailing business strategy. The findings indicate that the utilization of the I-bar cross-sectional shape enhances the structural rigidity of the components, thereby enabling them to withstand higher levels of bending moment.

The authors of the study, A. R. Kale et al., [2] This study presents visual representations of the Lower Control Arm's structural response to varying loads. There exists a possibility that the limb exerting control may experience deformation when subjected to such a magnitude of weight. The lower control arm is non-functional. The issue of weight reduction in the automotive industry is widely recognized as a critical concern. Once the structure has been enhanced, the revised lower control arm undergoes a static evaluation. The findings of the evaluation primarily relied on the extent to which the construction adhered to the minimum yield standards. The construction exhibits a high level of proofing, as evidenced by the quality of the output.

Kim Do-Hyoung, along with other individuals. [3] This study employed a reduced-scale algorithm to investigate its impact on the static load capacity and stiffness of a lower arm. This action was “undertaken in order to enhance the loading aggregation of the composite layer, as evidenced by the lower arm” [3]. The significant reduction in weight, by 50 percent, of the lower limb composed of standard steel material was a matter of considerable importance. Ultimately, “it was determined that the hybrid lower arm exhibited a weight reduction of 50% compared to a conventional steel lower arm” [3]. Moreover, it demonstrated superior stiffness and significantly enhanced shape retention capabilities.

Mohd Viqaruddin and his companions [4] This study demonstrates the application of the Radioss software in conducting static analysis and torsional research on the control limb. The enhancement of the control arm's durability and weight reduction can be achieved through modifications to its physical dimensions and other characteristics. The advancement of topology has facilitated the ability to optimise material properties based on their anticipated usage and failure locations. Additionally, the reduction in weight of the Control arm can be attributed to the utilization of ALTAIR RADIOSS SOFTWARE for material selection determination.

Liang Tang and several individuals. [5] The primary objective of this study is to propose a model aimed at enhancing the topology of the Control Arm. The proposed model is derived from empirical observations of the elastic properties exhibited by rotating accessories and bushings. Additionally, it incorporates a methodology for effectively managing multiple heaps. This is undertaken in order to achieve the desired levels of stress, stiffness, and characteristic frequency.

3. METHODOLOGY

During the initial phase of analysis, the lower control limb is simulated using the Creo design software. The lower limb model is integrated into a design modeller, wherein it undergoes examination for surface imperfections and anomalies. The design of the lower control arm is illustrated in Figure 2.

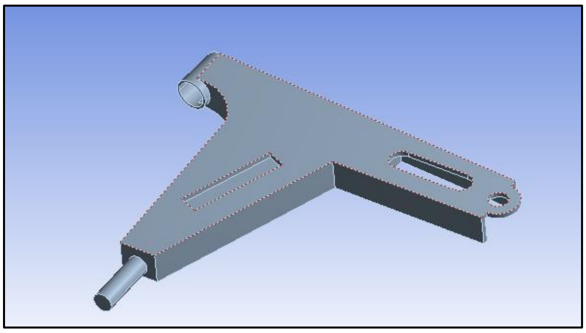

Figure 2: CAD model of lower Control Arm

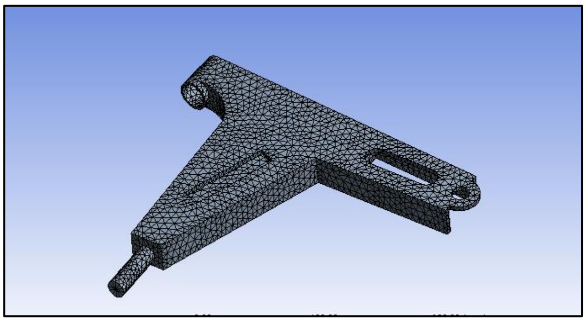

Figure 4: Meshed model of lower Control Arm

The model of lower control arm is discretized under fine relevance and normal inflation. The growth rate is for meshing is set to 1.2. The transition ratio is set to .271 with number of layers set to 5.

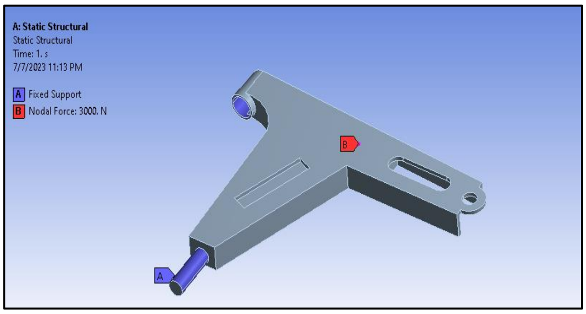

Figure 5: Loads and boundary condition on lower Control Arm

Figure 5 illustrates the implementation of structure boundary conditions on the lower control limb subsequent to the process of discretization. The structural boundary conditions include fixed support at the cylindrical zone as represented in dark blue color and force on specific node as represented in red colored region. After applying structural boundary conditions, the simulation in run. The simulation process involves formulation of elements and nodal calculations of front control lower arm.

4. RESULTS AND DISCUSSION

After running FEA simulation, the contour plots of equivalent stress, deformation plot and shear stress plots are obtained.

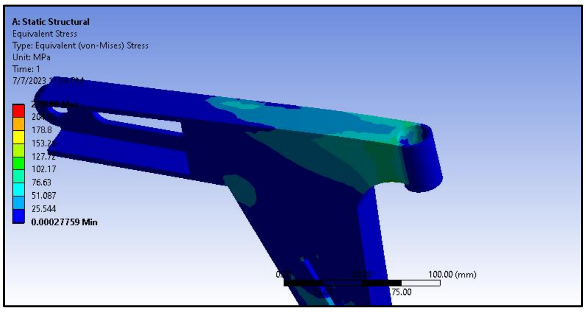

Figure 6: Equivalent stress on lower Control Arm

Figure 6 depicts the stress distribution of the lower control arm. At the highest point, the tension reaches a maximum value of 153 MPa. The equivalent stress is minimal at the holding region of lower control arm.

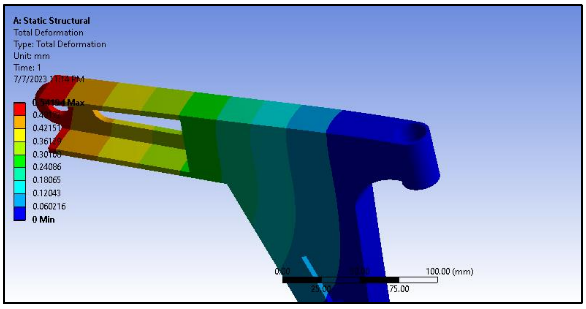

Figure 7: Total deformation on lower Control Arm

Figure 7 shows the displacement plot of the lower control arm. The curvature is most noticeable at the end of the limb that is not held down, where it is bigger than 0.421mm. The deformation is minimum at the rear end of the arm.

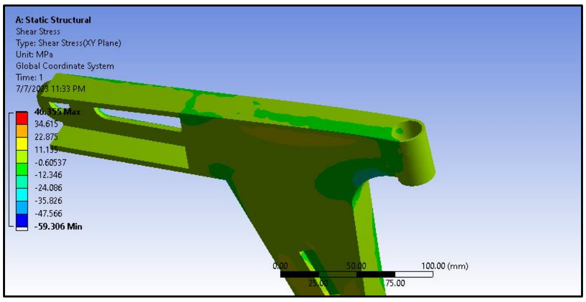

Figure 8: Shear stress distribution plot on lower Control Arm

Figure 8 depicts the shear stress distribution plot for the lower control arm. The higher shear stress is obtained at the corner edges of lower control arm wherein the magnitude of shear stress is nearly 22.8MPa.

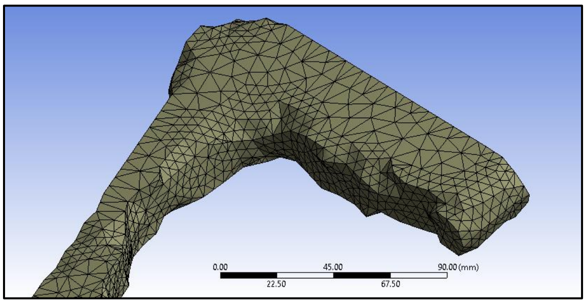

Figure 9: Topology optimized design of front control lower arm

The design of front control lower arm is then optimized using topology optimization technique. The topology optimized design of front control lower arm is developed with reduced mass density as shown in figure 9.

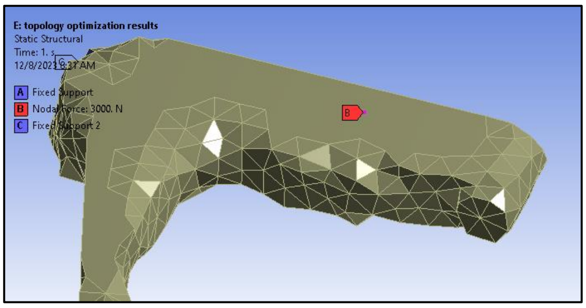

Figure 10: Structural boundary conditions on front control lower arm

After generation of topologically optimized design of front control lower arm, the model is applied with fixed support at two regions. A point load is also applied with specific magnitude as shown in figure 10.

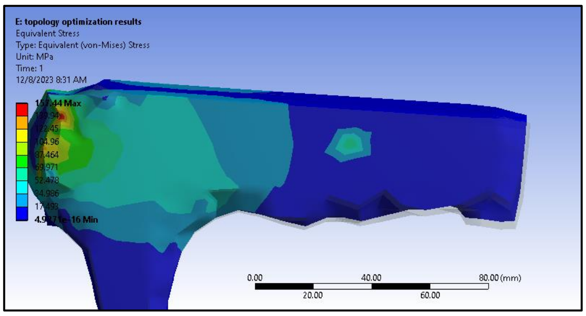

Figure 11: Equivalent stress on front control lower arm

The equivalent stress distribution plot is obtained for front control lower arm wherein the maximum stress is obtained at front left zone with magnitude of 145MPa and is lower on other regions of arm.

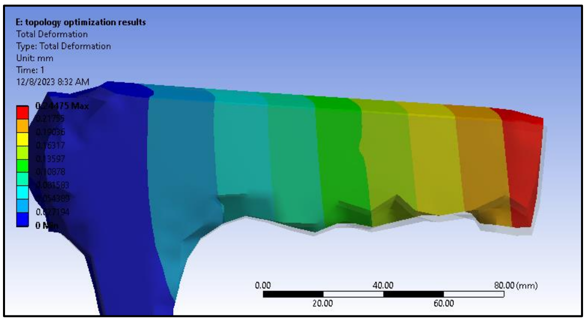

Figure 12: Total deformation on front control lower arm

The total deformation plot is obtained for topologically optimized design of front control lower arm as shown in figure 12. The deformation is maximum at the free end of the arm with magnitude of more than 0.23mm.

5. CONCLUSION

The FEA simulation yielded valuable results, including contour plots of equivalent stress, deformation, and shear stress. The maximum equivalent stress was observed at the corner region of the arm with a magnitude of 153 MPa, while the minimum stress occurred at the holding region. The deformation plot indicated maximum displacement at the free end of the arm, exceeding 0.421 mm, while minimal deformation was observed at the rear end. According to the shear stress data, the corner edges of the lower control arm experienced shear stresses that peaked at approximately 22.8 MPa. These results provide essential information on the structural behavior of the lower control arm under the specified loading conditions, steering design modifications for enhanced performance and strength. The structural analysis is conducted on front control lower arm using FEA. The critical regions of high stresses and deformation are identified from FEA results. Significant mass reduction of front control lower arm is achieved using lattice structure technique and topology optimization technique. Using lattice design, the mass reduction of front control lower arm obtained is nearly 5% as compared to generic design. The topology optimization technique has able to reduce the mass of front control lower arm by nearly 45%.

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Corresponding Author

Lokesh Yadav*

Research Scholar, IITM Group of Institutions, Murthal (Haryana)