DESIGN AND OPTIMIZATION OF SUSPENSION ROCKER (BELL-CRANK)

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Abstract -*Formula society of automotive engineers offers design events for undergraduates to enhance their practical knowledge and provides a wide scope for innovative ideas. In the Formula student vehicle, the suspension geometry plays a very important role. The main objective of this project is to make a more optimized Rocker (Bell-crank) that can give more efficient spring travel while resisting all the forces acting on it. The whole component is manufactured in a proper systematic manner where firstly the hard points of the rocker are evaluated from LOTUS shark suspension analyser software. According to the hardpoints and dimensions, the CAD modelling was done on SOLIDWORKS software. Theoretical, as well as analytical calculations of forces were done and by applying those forces on components in ANSYS Workbench software the factor of safety was calculated.*

Key Words: Rocker, Bell-crank, LOTUS shark, Suspension Geometry, Topology optimisation, Forces on rocker.

1. INTRODUCTION

Formula student vehicles consist of suspension systems connected in two different geometries either directly actuated or Push/Pull rod type actuation. In this project, we propose a pushrod suspension system in which the rocker is the important component that is attached to the chassis and connects the pushrod with dampers. The rocker has three mounting points in which the first one is connected to the chassis. The second where, rocker to damper point provides mounting for the dampers and third where, rocker to pushrod point provides mounting for the pushrod. As it connects the two main components it must be well designed which absorb all the forces in dynamic conditions considering the lateral and longitudinal direction and the forces that come from the pushrod should be transferred efficiently to the dampers to get desired motion ratio.

2. Material Selection

A Rocker (Bell-crank) must be designed in such a way that it should give high output on spring travel. Considering its weight for the motion on the force of wheel travel the material Al7075 T6 is used. While selecting the material, the major focus was on the strength to weight proportion of material.

For material selection, we compared the materials having some desired properties and after comparing the materials shown in Table 1, Al 7075 T6 was found to be the best suitable material.

Materials	Al 7075 T6	Al 6061 T6	Mild Steel
Young's Modulus (GPa)	71.7	68.9	200
Density (g/cc)	2.81	2.7	7.8
Shear Modulus (GPa)	26.9	26	79.3
Poisson's Ratio	0.33	0.33	0.26
Ultimate Tensile Strength	572	310	500
Yield Tensile Strength	503	276	250

Table 1: Material Comparison [3], [4]

The composition of Aluminium 7075 T6 is 5.6–6.1% Zinc, 2.1–2.5% Magnesium, 1.2–1.6% Copper, and some other materials which are very less in composition like SILICON, IRON, MANGANESE, TITANIUM, CHROMIUM etc. The specific strength of Al 7075 is very high. Al 7075 offers a better strength for the suspension Rocker component. As in the table given, we can see that yield and tensile strengths are higher than compared to other materials. It is one of the aluminium alloys with the highest strength. [4]

The composition of Al 6061 T6 is Magnesium 0.80 - 1.20%, Silicon 0.40 - 0.80%, Iron 0.0 - 0.70%, Copper 0.15 - 0.40%, Chromium 0.04 - 0.35%, Zinc 0.0 - 0.25%, Titanium 0.0 - 0.15%, Manganese 0.0 - 0.15 %, etc. It offers better weldability but for Rocker we need material with good machinability. It is not as strong as Al 7075. It has no problem of corrosion as having less amount of copper. [4]

The composition of Mild Steel A36 is Carbon 0.25- 0.29%, Copper 0.20%, Iron 97%, Manganese 1.03%, Phosphorous 0.04%, Silicon 0.2%, Sulphur 0.05%. It is one of the cheapest materials on the list. The material is easily available on market. It is very heavy and the strength to weight ratio is very poor as compared to Al 6061 T6 and Al 7075 T6. [3]

3. Calculations

Theoretical calculations were done with all the forces that come on the component directly and indirectly in the dynamic state of the vehicle. Majorly, the Bump force comes from the wheel to the rocker through a push rod.

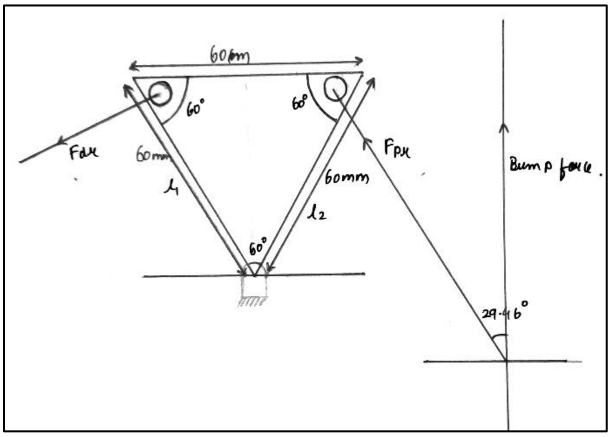

Fig-1: Forces on Rocker

Wheel rate = Spring rate × Motion ratio [1]
spring rate = 78.80 N/mm [6]
Motion ratio = 0.899
= 78.80 × $(0.899)^2$
Wheel rate = 63.6962 N/mm

Front Bump force =wheel rate × Travel due to bump [1]
Travel due to bump = 30mm
=38.9727 x 30
Bump Force = 1910.586 N

Force at Pushrod rocker end = Bump force × cos Ɵ [5]
= 1910.586 x cos (29.46)
F_{PR} = 1663.035 N

Rocker Motion Ratio (RMR) = (L1/L2) × sin Ɵ [5]

L1=60mm, L2= 60mm, Ɵ=60°

RMR = (60/60) × sin (60)
= 0.866

Force on Rocker Damper end (F_{DR}) = F_{PR} x RMR
= 1663.035 x 0.866
= 1440.188 N

4. Design Procedure

The design of components should be in a very precise manner. The SOLIDWORKS software is used for the designing of rocker where the dimensions were taken from the hard points iterated in LOTUS shark suspension analyser software. Taking the weight of the component into consideration, major focus was to make an optimized rocker with no excessive material in it [1]. The thickness of each plate is 3mm and in between maximum weight reduction is done. The two Aluminium plates are attached with a tube-shaped of the same material in which spherical roller bearing is used for proper movement of rocker.

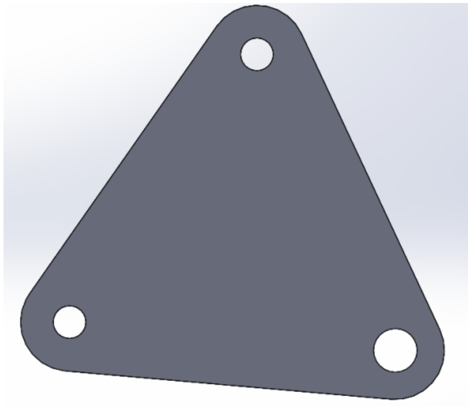

Fig-2: Rocker without Topology

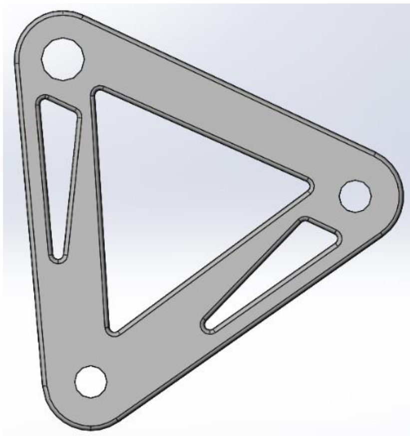

Fig-3: Rocker with Topology

5. Analysis

Software analysis is done on ANSYS Workbench Software by applying all the physical properties including its material. The Tetrahedron mesh is better suited to represent complex geometries and bending deformations. Therefore, Tetrahedron mesh is applied to get high accuracy in the analysis result of the component. After the final analysis of optimised design, the value of nodes and elements were found to be 98508 and 61034 respectively.

After performing analysis on basic design, it was found that the design has 8.2829 value of Factor of Safety which depicts that the component has excessive material in it. Whereas, on analysis of optimized design it came down to 1.2512 with approximately 20 g of material reduction.

5.1 Analysis Results

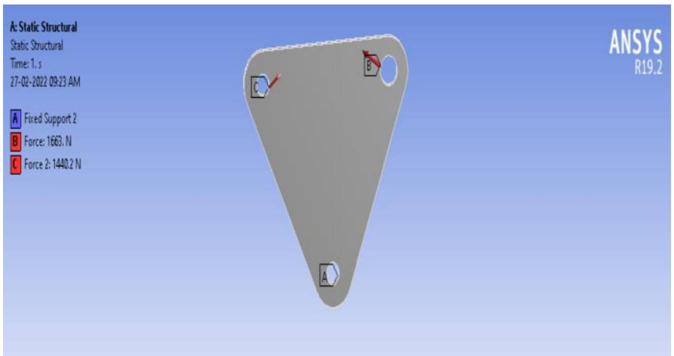

Fig-4: Forces

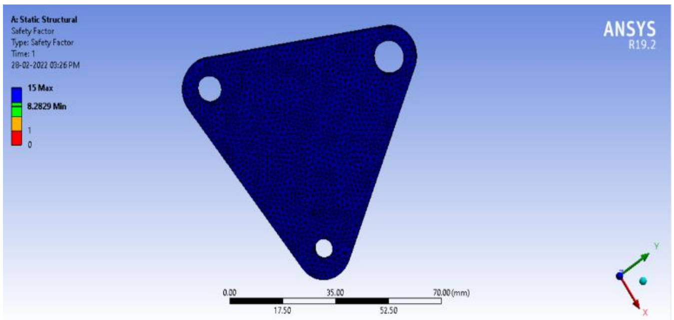

Fig-5: Factor of safety without Topology

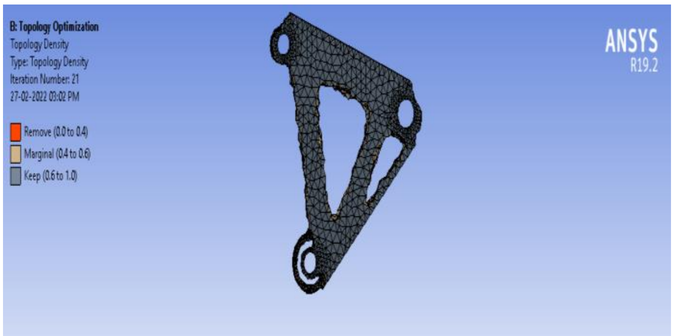

Fig-6: Topology Optimization

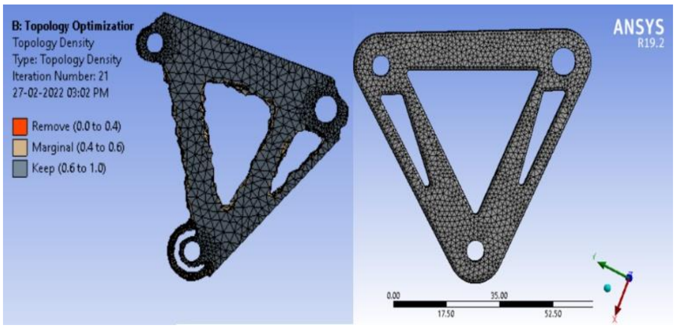

Fig-7: Optimised design

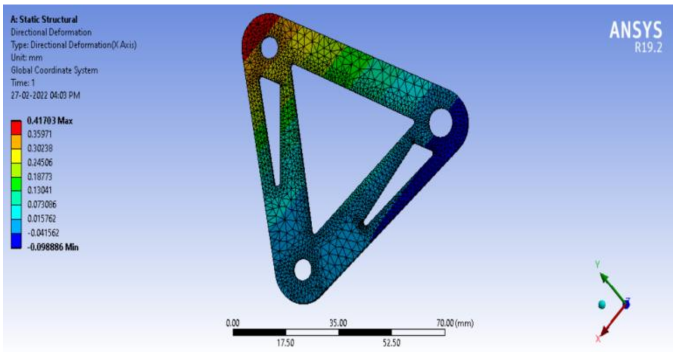

Fig-8: Directional deformation

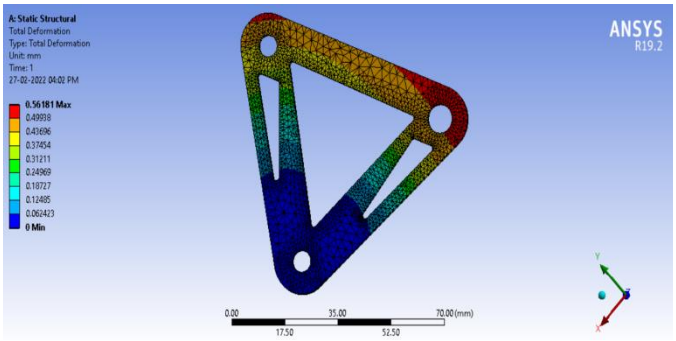

Fig-9: Total deformation

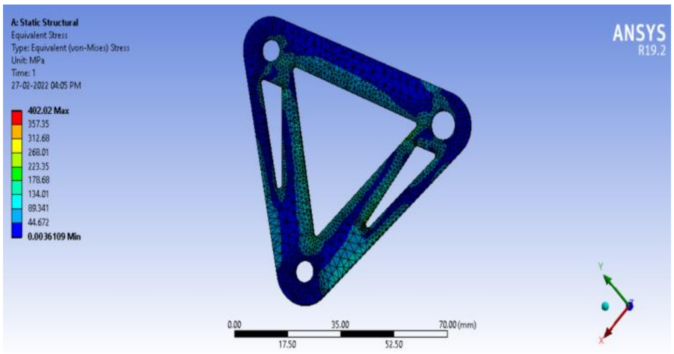

Fig-10: Equivalent stress

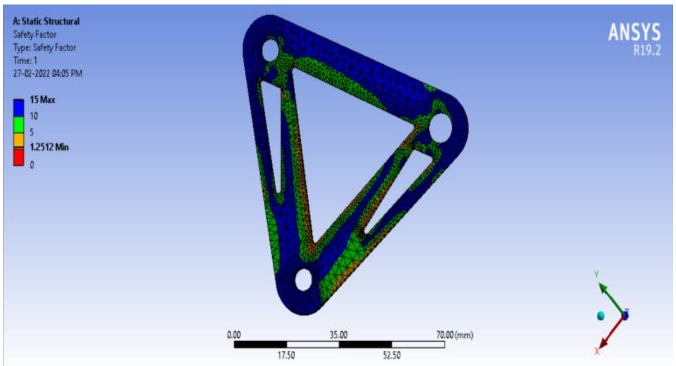

Fig-11: The factor of safety on Topology

6. CONCLUSION

The main objective of this project was to make the more efficient and optimised rocker to improve the functionality in the suspension system. The aim was to focus majorly on the weight to strength ratio and considering all the force calculations the material was selected. The weight of the rocker before Topology Optimization was 62.82g and thereafter, it is found to be 43.01g. Significantly, 19.81g of weight is reduced and the analysis results show that on applying all the necessary forces the component can withstand those forces with the given material, therefore the objective of this project is achieved.

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