Stress Reduction of Cross Member of Rear Axle for Car

T. A. Jadhav
Department of Mechanical Engineering,
Sinhgad College of Engineering, Vadgaon (Bk), Pune
411041, Maharashtra, India

A. N. Mudalgikar
Department of Mechanical Engineering,
Sinhgad College of Engineering, Vadgaon (Bk), Pune
411041, Maharashtra, India

***Abstract* - Axles are the solid lateral connection between two wheels. Later the rigid connection between wheels was replaced with the help of independent suspension system which feature wheels that are mounted to a steerable wheel carrier. This wheel carrier is part of kinematic linkage which connects wheels to the axle. The rear axle cross member serves as support to differential as well as corner modules. Loads imposed due to vehicle's parts such as engine, transmission, body etc. are transmitted to roadway via cross member and suspension linkage. Also irregularities and vibrations from the roadway are transmitted to passengers via cross member and suspension. This paper includes the design and analysis of cross-member of rear axle by FEA. The FEA results are within permissible limit, thus design of cross member is satisfactory.**

Keywords: Cross member, Rear Axle, Suspension, Finite Element Analysis

I. INTRODUCTION

Axles were defined as rigid lateral connections two wheels which could be steered together. This type of axle benefits in rolling stability and simplifies assembly by giving a connection between the wheels and body. Now a day's term "axle" is sometimes defined as the whole system, including the independent suspension and wheel carrier. In other cases, suspension linkage and wheel carrier are considered a separate assembly known as a corner module in addition to the axle and sub-frame. We used the second definition, as the first is based on the concept of rigid axles, which are increasingly irrelevant for passenger vehicle design. Modern passenger vehicle axles are pre-assembled and attached to the body using four bolts in a final assembly step. The assembly consist of Sub-frame, steering gear, stabilizer, differential and corner module

Over the years many engineers and designers have worked on the design and development of axle of the vehicle. Ashpiz E.S. et al. [1], studied the problem of strengthening of the subgrade located on the sections that have the interchange of cars with the axle load of 25 tonne and more. The problem of the subgrade behaviour were observed on the example of the Eastern test site. Mohd Azizi Muhammad Nor et al. [2], carried out modelling, simulate and perform the stress analysis of an actual low loader structure consisting of I-beams design application of 35 tonne trailer designed. The scope of this study issue on structural design and data gathering. Stress and displacement contour are later constructed and the maximum deflection and stress are determined by performing stress analysis. Calculated results are then linked to analytical results, where it is found that the location of maximum deflection matches with theoretical approximation but differs on the magnitude aspect. Safety factor for the low loader structure has also been calculated. Cicek Karaoglu et al. [3], studied stress analysis of a truck chassis with riveted joints was performed for reducing the magnitude of stress near the riveted joint of the chassis frame, side member thickness, and connection plate thickness and connection plate length were varied. Analytical results showed that stresses on the side member can be reduced by increasing the side member thickness. Jean Abry et al. [4], A FE seam weld model has been built for advanced fatigue structural stress analysis. The vehicle structure is mainly built with steel sheets and the assembly is performed by seam welding. The FEA results are post processed and each appropriate tensor component is taken into account. Longitudinal shear stress in weld and at weld toe as well as weld longitudinal normal stress calculations are detailed. Finally, vehicles built during the last decade are inspected back from the customers experience field. Observed crack types and locations are compared to fatigue analysis predictions. Min Zhang et al. [5], the unsafe area of beam is determined, which gives a certain base for structure modification. A combined fatigue simulation of multi working conditions is carried out. The influence of different conditions on fatigue life is studied. Fatigue life of front axle containing crack is analysed for the effect of crack parameters such as length and depth on fatigue life. Mohd Hanif Mat et al. [6], developed a lightweight chassis that can safely withstand the required loads. A steel space frame was chosen for the design since it is the most effective and cost efficient structure and commonly used for single seater car. FEA was used to determine the strength and rigidity of the chassis subjected to the required loads. Results showed that chassis was able to withstand the required loads with minimal deflections. Chunguo Xu et al. [7], studied the forming process of the integer rear axle on numerical simulation and experiment. The simulation result shows that it can greatly increase the necking coefficient. Based on theoretical analysis and numerical simulation, the forming process of rare axle with integrated structure were studied, experiment were done and the sample of rear axle were obtained. The deformation and wall thickness increase law of necking process was obtained. The new forming process by end heating with temperature gradient was presented. Zhang et. al. [8], two beam elements chassis/suspension models with rigid vehicle body representation and finite element tires were studied under

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

proving ground conditions. Several proving ground road surfaces were modelled and used in the analysis. Also analysed were the low speed driveway-ramp and (relatively) high speed lane-change cases. The proving ground simulation results, and system compliance results as well, were compared between the two models. The differences revealed the importance and necessity of using finite element model include the component flexibility in conducting vehicle chassis/suspension dynamic analysis. M.M. Topac et. al. [9], observed a failure that occurs before the expected load cycles while performing vertical fatigue tests of a rear axle housing prototype. In these tests, crack mainly originated from the same region. Using these data, stress and fatigue analyses were done by FEA. Results from tests were compared with the FEA result. Design modification were proposed to increase the fatigue life of the prototype. Above literature review shows that many researchers have worked on the design of axle for various types of vehicles such as passenger car, commercial vehicles, motorbike etc. The main focus was to develop the stable cross member system which is verified under standard load cases.

The main objective of work is to analyse the existing cross member for stress and deflection parameters. Based on these results the new design of cross member is proposed with suitable modification in the geometry. Further analysis of modified cross member is carried out with identical conditions and results are verified with baseline results available in company.

II. DESIGN OF CROSS MEMBER

The Computer Aided Drafting is one of the most important stage for initial development of the project. This consist of finalizing the basic shape or form of the design which will withstand under design conditions.

After finalizing the basic shape of the axle, we used the CATIA (modelling software) to design the 3D model. As it was required to manufacture the model by sheet metal, the surfacing workbench is used for drafting.

Figure 1 shows the CAD model of Cross member.

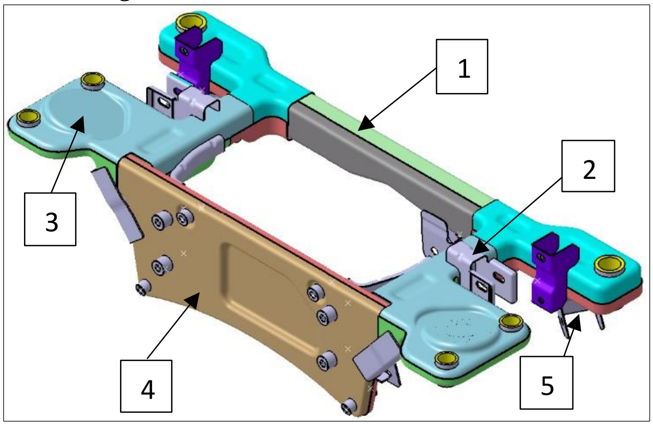

Figure 1 – Cross Member - (1) Front Member, (2) UCA Bracket, (3) Spring Seat, (4) Rear Member, (5) LCA FRT Bracket

III. FEA OF CROSS MEMBER

After modelling Finite Element Analysis of the cross member is carried out. The aim of FEA is to perform linear FE-Analysis on the cross member to check the strength of the parts.

In the early stages of chassis and suspension design, wheel loads are often unavailable or are measured using prototypes. As a result, instead of real load cases, standard load cases are used which are based on standard driving manoeuvres. These manoeuvres are assumed to be quasi-static, i.e. time-independent. The resulting standard load cases are used to determine cross-sectional loads for quasi-static FE calculations (structural stiffness, durability).

Similar standard load cases are used by a large number of vehicle manufacturers. The wheel loads are given either as wheel accelerations or as numerical force or moment values.

Thirteen load cases have been analysed, however only critical load cases results are presented in this paper.

From FEA results it is found that the stresses are more than ultimate tensile strength of the given material thus it is decided to modify the design and perform the FEA on modified cross member with identical conditions.

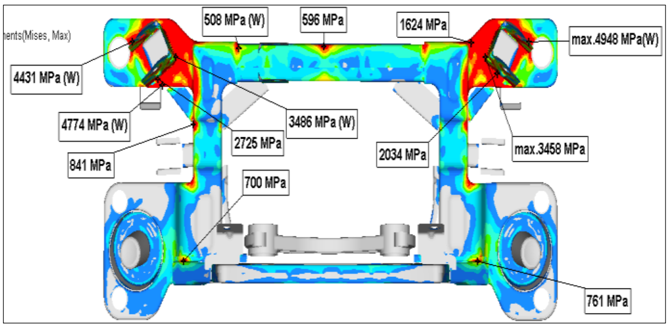

Figure 2 – Cross member Load Case 5: Longitudinal Acceleration

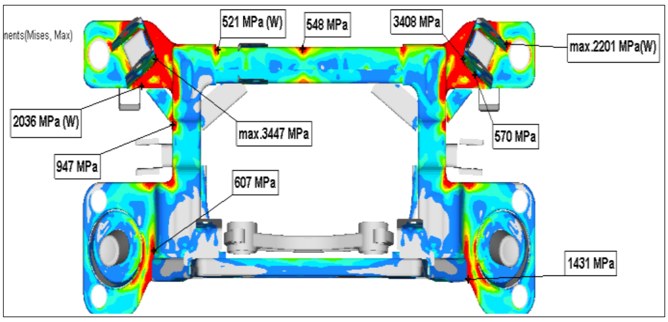

Figure 3 – Cross member Load Case 9: Braking Backwards

IV. DESIGN OF MODIFIED CROSS MEMBER

After FEA of Cross member I, it is clear that stresses induced in the cross member are high and need to be modified or reduced. So cross member is modified to eliminate those high stresses regions. Following figure 4 shows the modified design of cross member.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

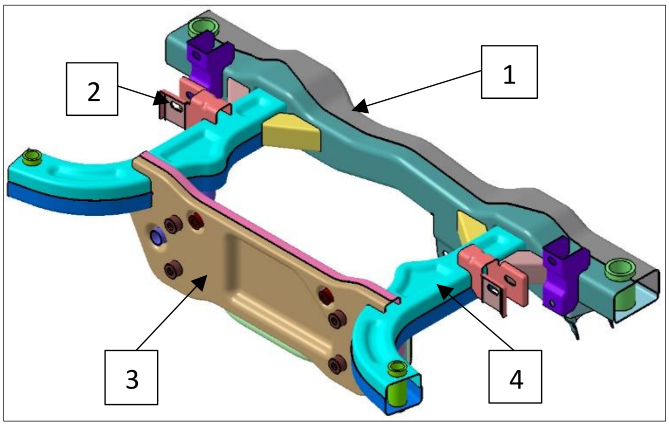

Figure 4 – Modified Cross Member – (1) Front Member, (2) UCA Bracket, (3) Rear Member, (4) Side Member

V. FEA OF MODIFIED CROSS MEMBER

After modification of Cross member, Finite Element Analysis of this modified cross member is carried out. Same load cases as previous cross member are used for FEA.

Thus for comparison of both FEA results same load cases as previous cross member are shown in Figure 5 and Figure 6.

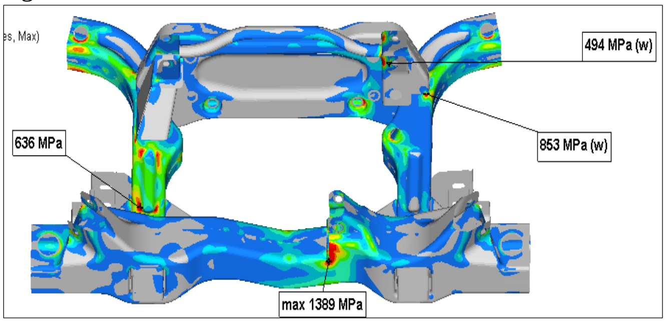

Figure 5 – Modified Cross member Load Case 5: Longitudinal Acceleration

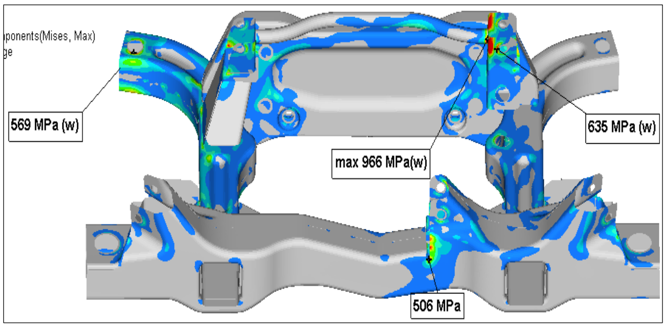

Figure 6 – Modified Cross member Load Case 9: Braking Backwards

VI. RESULTS

In this chapter, the design comparison of Cross member I and modified Cross Member is done. While comparing the both design as well as analysis aspects are taken into consideration. The stresses on the cross member were leading to failure of the part thus it is required to modify the cross member to reduce the stresses coming on the part.

A. Modification in Design

To eliminate or to reduce the stresses coming on the Cross member I it is required to modify the design. But the mounting of the cross member on the ladder frame of the vehicle cannot be modified. Also the hard point where various other part to be mounted are fixed. In following figures 7, 8, 9 and 10, left side shows cross member and right side shows modified cross member.

Therefore Following modifications are done on the cross member I:

1. *The removal of spring seat from the cross member.*

From the FEA results of Cross Member it was clear that, spring force was creating a moment arm on the cross member and causing high stressed area on the parts. So it was decided to remove the spring seat from cross member design, which will help to reduce the stresses on the parts. First of all it was necessary to find the alternate mounting position for the spring seat. The best alternate position for spring seat is on the ladder frame of vehicle.

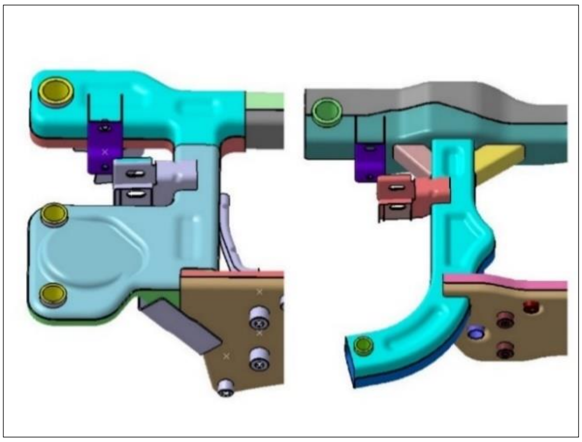

Figure 7 – Modified side member without spring seat (Right)

2. *Modified cross member with reduced weld area.*

Another highly stressed area was front bracket of Lower Control Arm (LCA). From FEA results the stress is high in welded area, thus solution for this problem is to reduce the welding area. Thus to achieve this the bracket is removed and mounting of LCA is integrated in the front member.

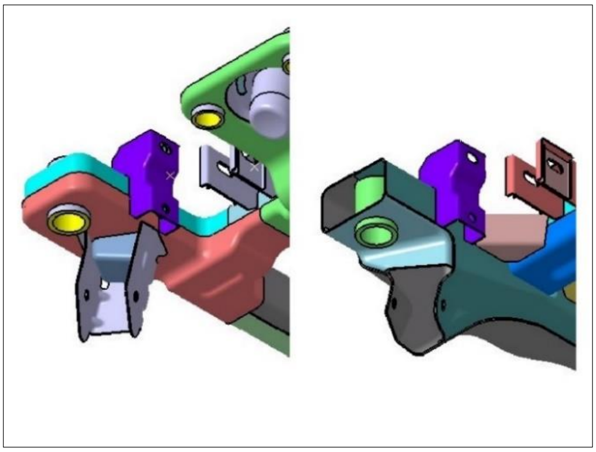

Figure 9 – Modified front member with reduced weld area (Right)

3. *Integrated torque restrictor bracket into Front member:*

While designing the new front member, the torque restrictor bracket (TR) is also integrated. This helps to reduce welding of the parts which leads to reduction in the stresses.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

Also the thickness of sheet metal used for the front member design is increased to 2.5mm from 2.0mm, which increased the strength of part.

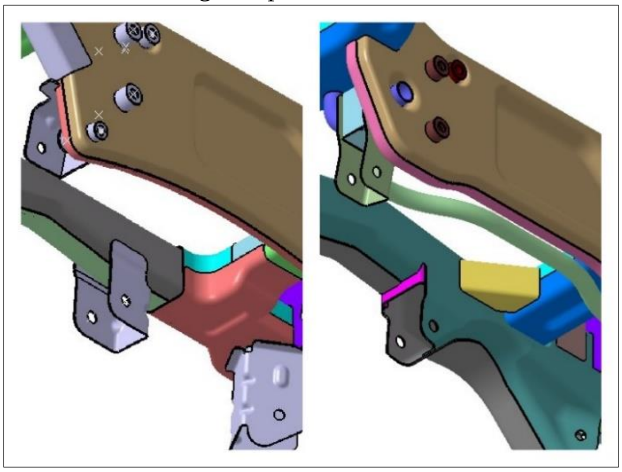

Figure 8 – Modified cross member with integrated TR bracket (Right)

4. *Strengthening of Lower Control Arm rear mounting bracket:*

The rear LCA bracket of cross member was very weak and highly stressed. Thus this bracket is redesigned to reduce the stresses. While redesigning two tubular structures are used. One is attached to the side member and bracket while another is attached from left hand bracket to right hand bracket.

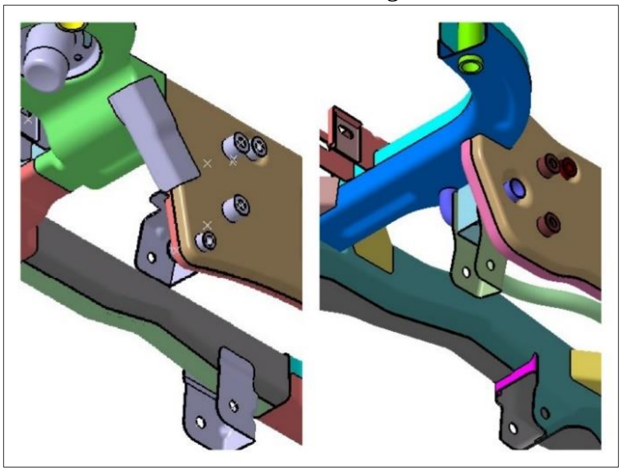

Figure 10 – Modified cross member with strengthened LCA bracket (Right)

B. Finite Element Analysis Comparison

FEA results of cross member and Modified cross Member are compared and reduction in the stresses is observed. For the reduction only in max stress is observed.
Here are the comparison of both FEA results:
Figure 11 shows the max stress of each load case in both cross members. It can be observed that stresses are reduced in every load case.

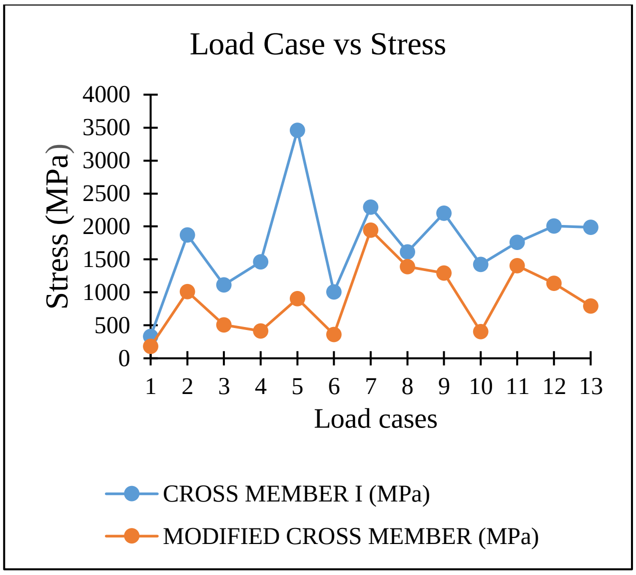

Figure 11 – FEA Result comparison of both cross members

Following figure 12 shows the percentage of reduced stress in the modified cross member. The average percentage of reduction in stress in 48%.

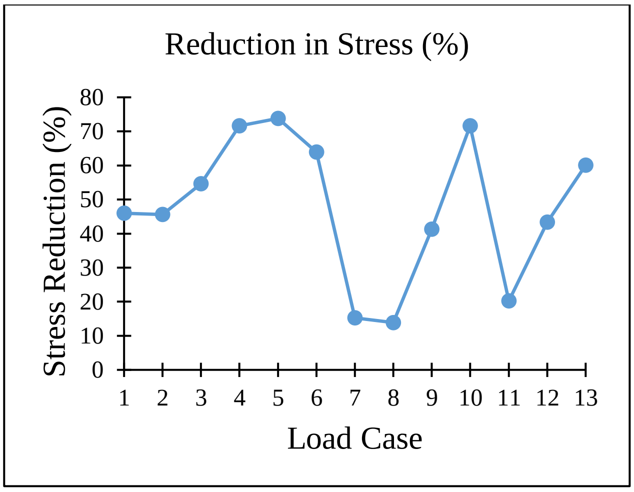

Figure 12 – Load Case wise reduction in stresses

VII. CONCLUSION

In this paper, from the design perspective, number of parts are reduced which is significant in minimizing the manufacturing and assembly cost of the product.
Reduction of parts also leads to reduction of weight of whole cross member. Therefore reduction in weight as well as stress in achieved successfully. The stresses in the modified cross member are significantly reduced which can easily identified by the comparison of both FEA results. This proves that modified cross member has more strength and can sustain given loads than cross member.

REFERENCES

[1] Ashpiz E.S., Zamukhovskiy A.V., Subgrade Strengthening on the Sections for Cars Interchanging with Axle Load of 25 T and More, *Procedia Engineering 189 (2017)*, pp. 874 – 879
[2] Mohd Azizi Muhammad Nora,b, Helmi Rashida, Wan Mohd Faizul Wan Mahyuddinb, Mohd Azuan Mohd Azlanc, Jamaluddin Mahmuda, Stress Analysis of a Low Loader Chassis, *International*

Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012), Procedia Engineering 41 (2012), pp. 995 – 1001

[3] Cicek Karao glu, N. Sefa Kuralay, Stress analysis of a truck chassis with riveted joints, *Finite Elements in Analysis and Design 38 (2002)*, pp. 1115–1130

[4] Jean Abrya, Christophe Mittelhaeusera, Sébastien Wolfa, Didier Turliera, Enhanced fatigue structural stress analysis of a heavy vehicle seam welded steel chassis frame, *Procedia Engineering 213 (2018)*, pp. 539–548

[5] MinZhang, XiangfeiJi, LijunLi, A research on fatigue life of front axle beam for heavy-duty truck, *Advances in Engineering Software 91 (2016)*, pp. 63–68

[6] Mohd Hanif Mat, Amir Radzi Ab. Ghani, Design and Analysis of 'Eco' Car Chassis, *International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012) Procedia Engineering 41 (2012)*, pp. 1756 – 1760

[7] Chunguo Xu, Guangsheng Ren, Yongqiang Guo, Weiwei Ren, Ya Zhang, Tube necking extrusion principle and forming process of trailer rear axle, *Procedia Engineering 81 (2014)*, pp. 634 – 640

[8] Yuan Zhang, Paul Xiao, Tim Palmer and Akbar Farahani, Vehicle Chassis/Suspension Dynamics Analysis – Finite Element Model vs. Rigid Body Model, *Developments in Tire, Wheel, Steering, and Suspension Technology*

[9] M.M. Topac , H. Gunal , N.S. Kuralay, Fatigue failure prediction of a rear axle housing prototype by using finite element analysis, *Engineering Failure Analysis 16 (2009*), pp. 1474–1482

[10] Christianah O. Ijagbemia,, Bankole I. Oladapob, Harold M. Campbella, Christopher O. Ijagbemi, Design and simulation of fatigue analysis for a vehicle suspension system (VSS) and its effect on global warming, *Procedia Engineering 159 (2016)*, pp. 124 – 132

[11] Zoran Odanovic, Analysis of the railway freight car axle fracture, *Structural Integrity Procedia 04 (2016)*, pp. 056–063

[12] T.A.Jadhav, N.V.Chavann Modal Analysis of Lower Wishbone Arm with experimental validation, Emersing trends in Automobile Industry.