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WEIGHT REDUCTION OF HEAVY DUTY TRUCK CHASSIS THROUGH MATERIAL OPTIMIZATION

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Abstract— A well-structured and properly built chassis improves crash worthiness, passenger safety and weight efficiency. But there is a need for weight reduction of vehicles for improved fuel economy, performance and emissions. This paper is aimed at weight reduction of a 16 tonne truck chassis through FEA analysis. The chassis was designed and simulated for stresses and displacements using "Altair Hyperworks 13.0". Effects of material change on various factors was studied. The possible areas of material reduction were identified using topology optimization and the chassis was optimized for minimum weight.

Keywords— Truck chassis, FEM, weight optimization, carbon fiber, Hypermesh

INTRODUCTION

When the vehicle is running it is acted upon various loads over the complete course of time it's running like, vertical loading, braking and acceleration loading, cornering forces, torsional forces etc. Out of the all these the vertical load decides the maximum load carrying capacity of chassis. Truck chassis are of ladder type, with two side members connected to each other by lateral cross members to form an integral support structure for all the components and payload. The side members provide vertical rigidity while the cross members provide torsional rigidity.[1]

Vehicle weight is one of the important factor considered while designing. The weight of chassis is the major contributor to the unsprung mass of the vehicle. Improvements are always welcome when the reduction in unsprung mass is considered in order to make the system less bulky. This has to be done by using trial and error method, but doing it on prototype is expensive and time consuming hence finite element methods(FEM) are used.

METHODOLOGY

Weight optimization is carried out in 5 steps.

Step 1 : Modeling and meshing of chassis

A heavy duty truck chassis was modeled using "SolidWorks 2013". The chassis was modeled using surfacing modeling as shown in fig no.1. The meshing was carried out using "Altair Hyperworks 13.0". The side members and cross members were meshed as 2D shell elements where as the axles were modeled and meshed as 1D bar elements.[12]

Figure 2: CAD Model of Chassis

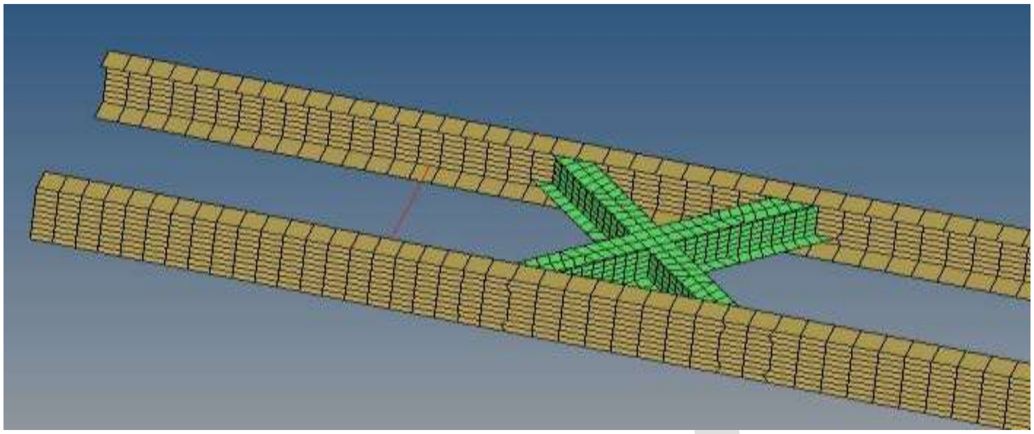

Figure 3: Meshed Model

Step 2 : Application of various loads on chassis

The loads considered are of the unsprung components. The details of the loads and the point of application are as below;[1]

TABLE 1: LOADS APPLIED ON THE CHASSIS

Sr No.	Component	Load (kg)	Distance from front Axle (mm)
1	Radiator	48	576
2	Cabin	619	307
3	Engine + Gear box	650	623
4	Battery	35	1294
5	Fuel Tank	250	1630
6	Payload	11698	1630 onwards UDL

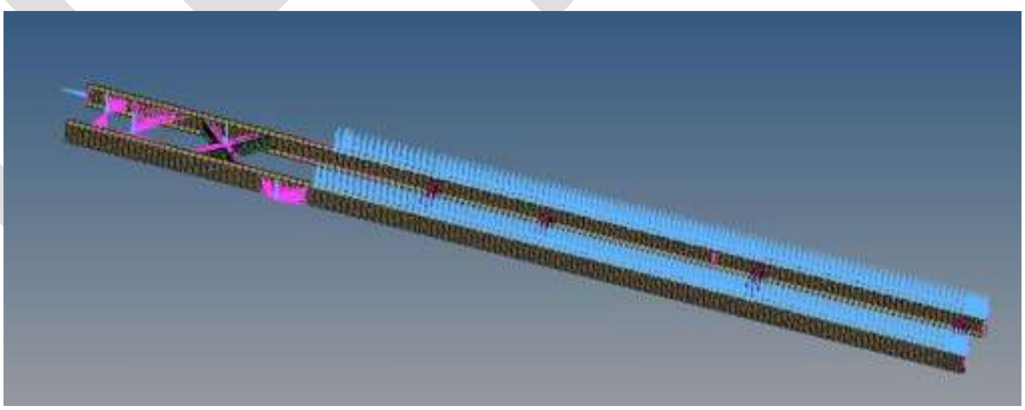

Figure 4: Applied Loads

Step 3: Static analysis

By the use of the Optistruct solver of "Altair Hyperworks 13.0" static analysis was carried out. In this analysis vertical loading i.e. the self wait of all the components attached to the chassis and torsional moment applied at the front end of the chassis is considered.

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Step 4: Topology Optimization

Using the Optistruct module of "Altair Hyperworks 13.0" topology optimization is carried out. Element density is checked and the critical and non critical areas are found out.

Step 5: Material Change

Various combination of materials were used for different components of chassis like side members, cross members etc. and static analysis was carried out to check the structural strength. The various materials which were used are;

TABLE 2: PROPERTIES OF VARIOUS MATERIALS USED [3]-[6]

Sr No.	Material	Yield Strength (MPa)	Density (gm/cc)
1	HLSA350	350	7.79
2	HLSA420	420	7.89
3	HSLA550	550	7.80
4	Aluminium2045-T4	480	2.60
5	Carbon Epoxy	1730	1.60

RESULTS AND DISCUSSION

The static analysis carried out helps in finding out the maximum vertical displacement of the chassis and the bending stresses induced due to the applied static loads. The material used for the primary analysis was steel (Young's Modulus 210MPa; Density 7.9gm/cc). The maximum displacement was found out to be 22.55mm whereas the maximum stress developed was 379.3MPa.

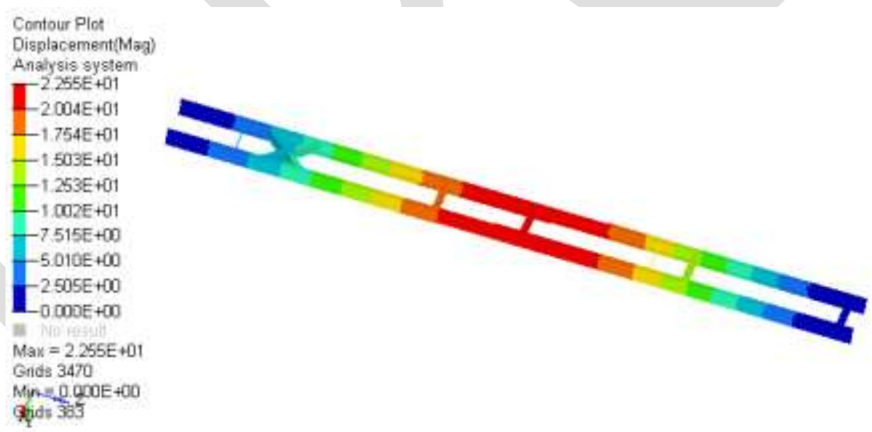

Figure 5: Displacement Plot for steel

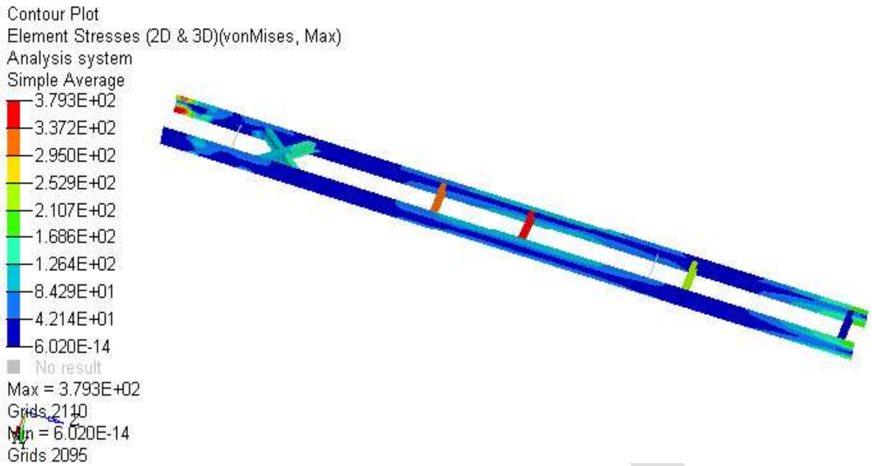

Figure 6: Stress Plot for steel

The mass was calculated using the mass calculate command in "Altair Hyperworks 13.0". To start optimization it is necessary to study the element density cloud. Topology optimization was carried out, where it was seen that the critical areas (i.e. areas with maximum requirement of materials) were the side members, whereas the cross members and axels were less critical. This helps in deciding which material can be used for which components

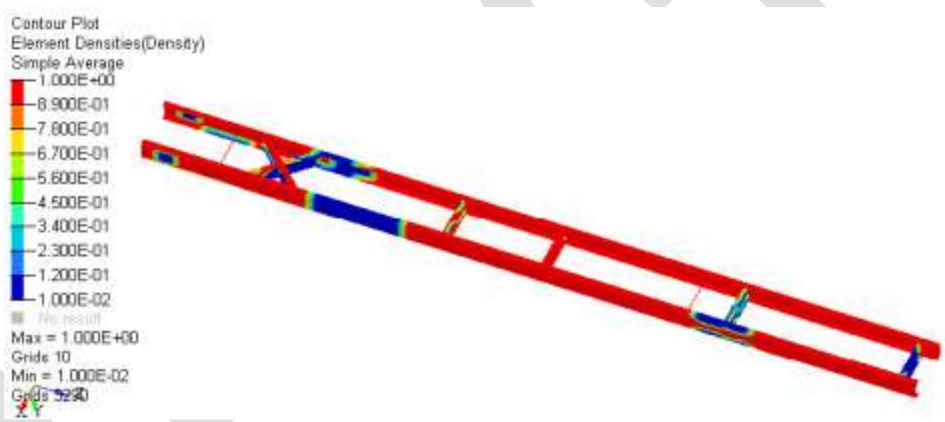

Figure 7: Topology Optimization

Taking this element density cloud into consideration various combinations were tried out for weight optimization. Table 1 shows the different combinations and weight change for all of them.

TABLE 3: RESULT TABLE OF WEIGHT OPTIMIZATION

Sr No.	Side Member	Cross Member	X- Member	Axle	Total Weight (kg)	% Difference
1	Steel				719.393	
2	HSLA 550				710.286	1.266%
3	HSLA 420				718.482	0.127%
4	HSLA 350				709.376	1.392%
5	HSLA 550	Al	Al	HSLA 350	650.23	9.614%
6	HSLA 550	Al	Carbon Fibre	HSLA 350	644.017	10.478%
7	HSLA 550	Carbon Fibre	Carbon Fibre	HSLA 350	637.904	11.327%

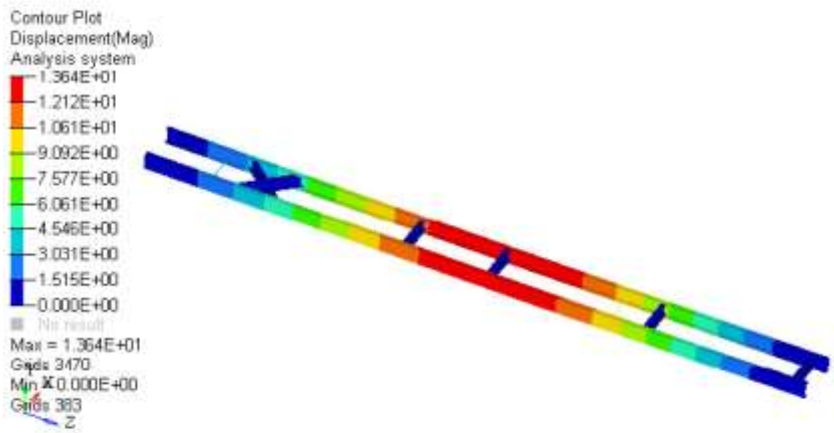

Figure 8 : Displacement Plot for Material 5

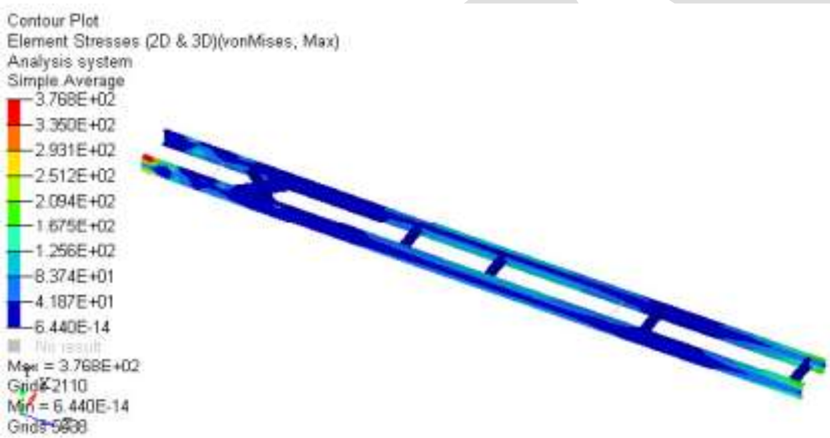

Figure 9: Stress Plot for Material 5

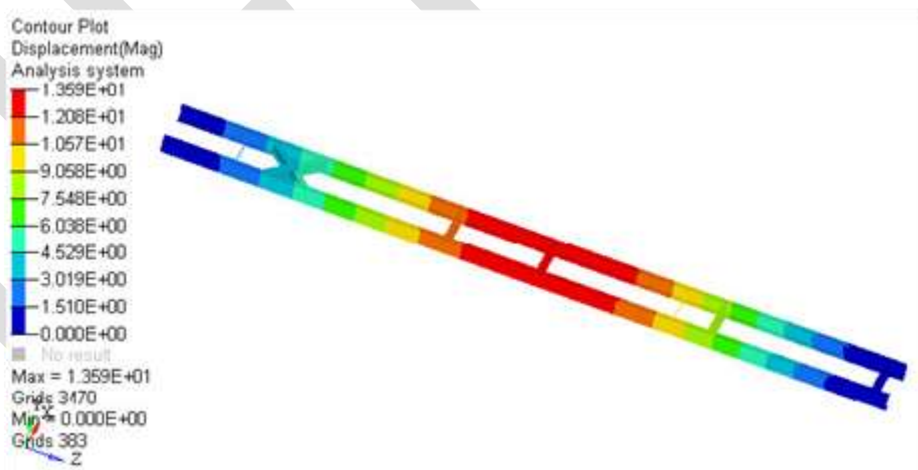

Figure 10: Displacement Plot for Material 7

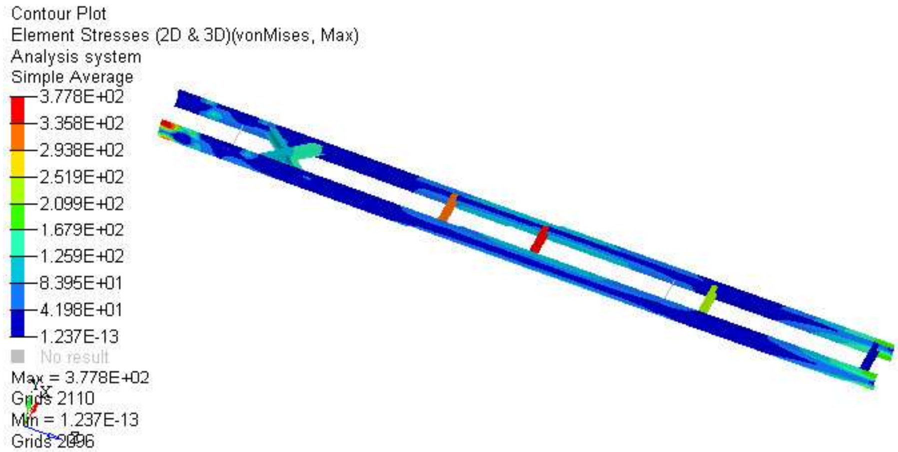

Figure 11: Stress Plot for Material 7

It can been seen that for material combination no 7 maximum weight reduction is possible economically. Also the stress and displacement values were reduced.

CONCLUSION

Static structural analysis of truck chassis was carried out. Chassis model was optimized for decreasing the weight by volume reduction and material change. Critical areas in the chassis were identified using topology optimization, where different materials were tried and simulated for weight reduction while retaining the displacement and stresses within the allowable limits. It was found the changing the materials of side members to high strength steel and cross members to carbon fiber weight reduction of 11% is possible without any reduction in strength of the chassis along with reduction in static displacement of the chassis.

FUTURE PROSPECTS

Carbon fiber is used in the production of race cars since high speed is of the utmost importance. For the use of carbon fiber in commercial vehicles some technical issues need to be resolved. Some of the issues which need to be addressed are;

1. Suitability of carbon fiber for high volume production.
2. Strengthening of composite material for high load bearing capacity.
3. Procedures for joining composites with steel.
4. Composite material process automation, especially for the positioning of reinforcements.

After addressing these issues we can successfully implement the use of carbon fiber in truck chassis.

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