Design and Analysis of Heavy Commercial Vehicle Chassis Through Material Optimization

Sanchit Shrivastava[1], Roopesh Tiwari[2],Suman Sharma[3]
M.Tech. candidate[1],Assitant Professor[2],Professor & Head[3]
Department of Mechanical Engineering, SIRT, SAGE University, Indore, India

Abstract : *Chassis is a French term and was first of all used to indicate the body elements or basic Structure of the automobile. It is the spine of the vehicle. The fundamental role of the chassis body is to safely deliver the most load for all designed working situations.A perfect built chassis improves the crashworthiness, passenger safety, and weight efficiency. Weight reduction is very important in automobile industries, which improved fuel economy, performance, and emissions.This paper is aimed at weight reduction of a 25-tonne truck chassis through Finite element analysis. By material optimization method heavy commercial chassis design will be strengthened. Using different material chassis design can be strengthened. The chassis was designed and simulated for stresses and displacements using "Altair Hyperworks 17.0".*

Keywords : *Truck chassis, Material Optimization, Finite Element Method, Hypermesh, Stress&Deflection.*

I. INTRODUCTION

The chassis is considered to be the most dynamic component of an automobile. It gives the strength and stability to the vehicle under different conditions. It is a skeletal frame of the vehicle on which various mechanical parts such asthe engine, tires, axle assemblies, brakes, and steering are bolted. Vehicle frames provide strength and flexibility to the automobile, it should be strong enough towithstand shock, twist, vibrations, and other stresses.

The magnitude of the stress can be used topredict the life span of the truck chassis. Theresult of its stress analysis shows the accuracyof the prediction life of truck chassis.Automotive chassis is generally made up of a steel frame, which holds the body and motor of the vehicle.Automobile chassis is also made up of light sheet metal, aluminum or composite plastics. It provides strength for supporting vehicular components.[1-3]

The main components of the truck chassis such as front and rearaxles, engine mountings, suspension systems, power train, cabin, trailer. The chassis is considered to be the backbone of thevehicle.[4]

The body of a vehicle is flexibly molded according to the structure of the chassis.The chassis design is resistance to bending and torsional stiffness, chassis have good handling characteristics.[5-6] Under dynamic conditions,the stress distribution of heavy-duty truckand behaviorwas studied.[7]

The chassis structure is mainly divided into three types as Conventional frame, Integral frame, and Semi Integral frame.The conventional frame helps the rivets and joints.The integral frame is mostly used in all forms of cars and light commercial vehicles. Semi Integral frame, half part of the frame is fixed on the front side to which engine gearbox and front suspension are mounted. Sub-frame chassis of a dump truck is used in mining operation.[8-9]

The stress analysis is the crucial factor in fatigue analysis to determine the highest stress point known as the critical point which initiates to probable failure, this critical point is one of the factors that may cause the fatigue failure. The location of critical stress point is thus essential so that the mounting of the components like engine, suspension, transmission can be determined and optimized.[10]

II. METHODOLOGY

A. Finite Element Analysis

The finite element method (FEM) is a numerical technique used to perform a finite element analysis of any given physical phenomenon. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally requires the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations.[11] Finite Element Method (FEM) is one of the methods to locate the critical point.[3,10]

In the solution phase, the governing algebraicequations in matrix form are assembled and the unknownvalues of the primary field variable(s) are computed.Afterthis, we determined the values of bending stresses anddeflection using Optistruct 17.0.

B. Weight Optimization is Carried Out in Three Steps

Step 1: Modeling and meshing of chassis

A heavy-duty truck chassis was modeled using ―CatiaV5. The chassis was modeled using surfacing modeling as shown in fig no.1. The meshing was carried out using "Altair Hyperworks 17.0". The side members and cross members have meshed as 2D shell elements.

Table 1: Properties of Steel Bsk 46 Material

S. No.	Material	Steel Bsk 46
1	Young,s modules	2.1 e^{5} (N/mm^{2})
2	Poisson Ratio	0.3
3	Density	7.9 e^{-9} (N/mm^{3})
4	Yield Strength	460 (N/mm^{2})
5	Tensile Strength	510 (N/mm^{2})

Step 2: Static analysis

By the use of the Optistruct solver of "Altair Hyperworks, 17.0" 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.

Step 3: Topology Optimization

Using the Optistruct module of "Altair Hyperworks 17.0" topology optimization is carried out. Element density is checked and the critical and non-critical areas are found out.

C. Linear Static Analysis

The mass was calculated using the mass calculate command in "Altair Hyperworks 17.0". 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 a 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.

D. *Linear Static Analysis of chassis frame for Different material: The displacement & stress of the chassis are shown in figures.*

a) Steel (Bsk 46)

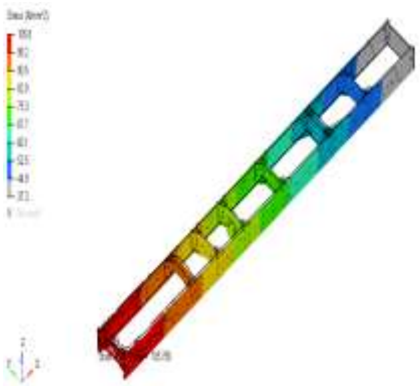

Fig 1: Displacement plot of Steel material Chassis design

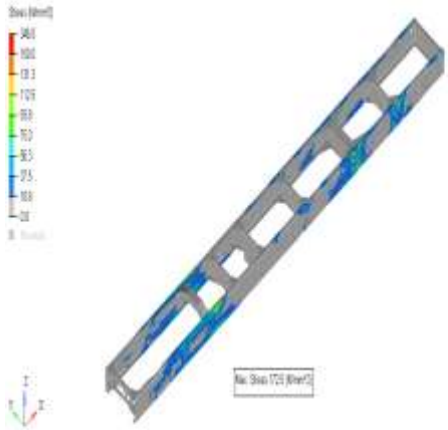

Fig 2: Von misses Stress plot of Steel material Chassis design

b) Aluminium Alloy

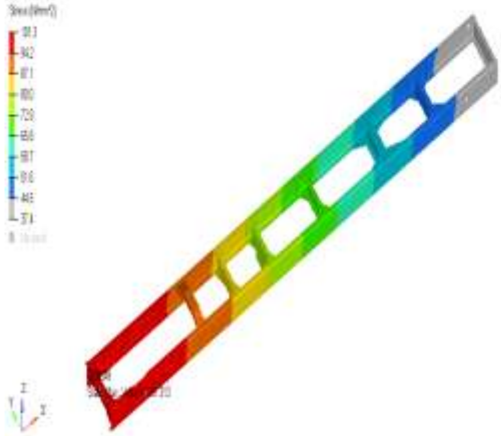

Fig 3: Displacement plot of Aluminium alloy material Chassis design

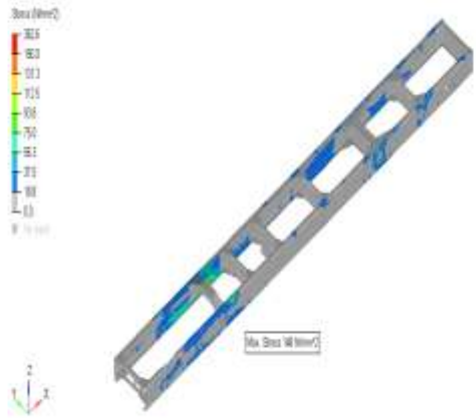

Fig 4: Von misses stress plot of Aluminium alloy material Chassis

c) CarbonComposite

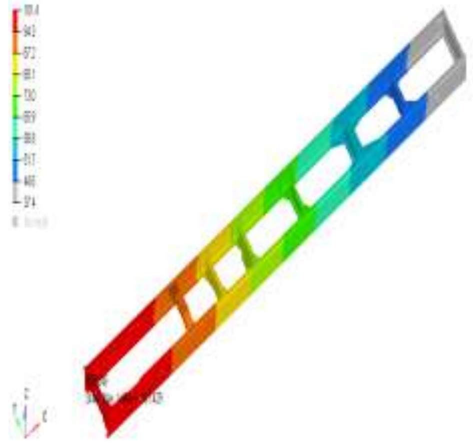

Fig 5: Displacement plot of carbon composite material Chassis design

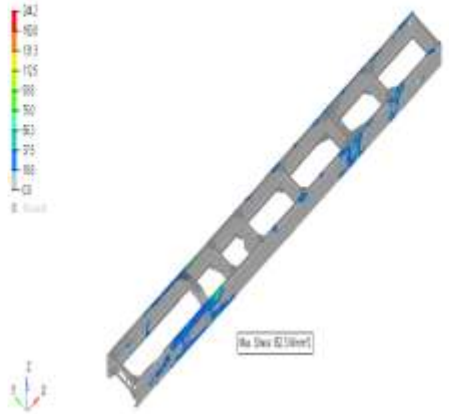

Fig 6: Von misses stress plot of carbon composite material Chassis

In the given diagram figure 1-2 represents the displacement plot and von misses stress plot of steel material chassis design. Figure 3-4 shows the displacement plot and von misses stress plot of aluminum alloy material chassis design. Figure 5-6 shows the displacement plot and von misses stress plot of carbon composite material chassis design.

Table 2: Different materials used and their properties

Property	Structural steel	Aluminum	Carbon-carbon composite
Young's modules	2e5 M pa	7.1e4 M pa	95e3 M pa
Density	7850 Kg /m^3	2770 Kg /m^3	1.7 g /Cm^3
Poisson Ratio	0.3	0.33	0.32

Table 2 shows the different materials like structural steel, aluminum and carbon-carbon composite used and their properties. Table 3 we used three different materials such as Steel, Aluminium allow and Carbon-carbon composite for linear static analysis, linear displacement and maximum stress of chassis.

Table 3: Linear static analysis, linear displacement and maximum stress of chassis

Linear Static Analysis	Material	Weight (Kg)	Maximum Displacement (mm)	Maximum Stress (N/mm^2)	Yield Strength of material (N/mm^2)
Chassis (Long Member)	Steel (Bsk 46)	392.3	**105.0**	**172.5**	**460**
	Aluminium Alloy	138.1	**101.3**	**148.0**	**160**
	Carbon Composite	84.4	**101.4**	**162.3**	**200**

III. RESULTS AND DISCUSSION

The static analysis carried out helps in finding out the maximum vertical displacement of the chassis and the bending stressesinduced due to the applied static loads. The material used for the analysis was steel (Young's Modulus 210MPa; Density 7.9gm/cc).

- The maximum displacement of Steel material chassis is 105.0 (mm) and the maximum stress of existing chassis for steel material is 172.5 (N/mm^2)
- The maximum displacement of Aluminium Alloychassis is 101.3 (mm) and the maximum stress of existing chassis for Aluminium alloymaterial chassis is 148.0 (N/mm^2)
- The maximum displacement of Carbon compositematerial chassis is 101.4 (mm) and the maximum stress of existing chassis for Carbon composite is 162.3 (N/mm^2)

IV. CONCLUSION

Static structural analysis of truck chassis was carried out. Chassis model was optimized for decreasing the weight by volume reduction. Critical areas in the chassis were identified using topology optimization, where the different material was tried and simulated for weight reduction while retaining the displacement and stresses within the allowable limits. It was found that while changing the material from Steel (Bsk 46) to Aluminium alloy the weightreduction is 64.80 %. When we change the material from Steel (Bsk 46) to Carbon-carbon compositethe weight reduction is 78.0% without any reduction in the strength of the chassis.

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