WEIGHT OPTIMIZATION AND FEA ANALYSIS OF TRUCK CHASSIS

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Abstract: Automobile chassis usually refers to the lower part of the vehicle including the tires, engine, frame, driveline and suspension. Out of these, the frame gives necessary support to the vehicle components placed on it. Also the frame should be so strong to resist impact load, twist, vibrations and other bending stresses

During the conceptual design stage, when changes to the design is easy to implement and have less impact on overall project cost, the weight and structural characteristics are mostly unknown since detailed and overall vehicle information is not available at the early stage . The vehicle design starts up with conceptual studies to define size, number and location of undriven and drive axles, type of suspension, engine power, transmission, tire size and axle reduction ratio, cab size and auxiliary equipment. The selected configuration has to be more precise and accurate for the considered transportation tasks and should match the existing production line. In general, there are two approaches to analyze truck chassis: one is stress analysis to predict the weak points and the other is fatigue analysis to predict life cycle of the frame. This overview selectively and briefly discusses some of the recent and current developments of the stress analysis of truck chassis. A number of analytical, numerical and experimental methods are kept in mind for the stress analysis of the heavy duty truck frames.

Conclusion of the stress analysis in the vehicle chassis has been reported in literature. Finally, the scope of future work has been discussed after concluding on the obtained results.

Introduction:

Automobile chassis usually refers to the lower part of the vehicle including the tires, engine, frame, driveline and suspension. Out of these, the frame gives necessary support to the vehicle components placed on it. Also the frame should be so strong to resist impact load, twist, vibrations and other bending stresses. The chassis frame consists of side rails attached with a number of cross members.

Along with the strength, an important consideration in the chassis design is to increase the bending stiffness and torsion stiffness. Proper torsional stiffness is required to have good handling characteristics. Commonly the chassis are designed on the basis of strength and stiffness. In the conventional design procedure the design is based on the strength and is then focused to increase the stiffness of the chassis, with very small consideration to the weight of the chassis. This design procedure involves the adding of structural cross member to the existing chassis to improve its torsional stiffness. As a result, weight of the chassis increases. This increase in weight of the chassis fuel efficiency is reduced and increases the overall cost due to extra material. The design of the chassis with proper stiffness and strength is necessary. The design of a vehicle structure is of fundamental importance to the overall vehicle performance. The vehicle structure plays an important role in the reliability of the vehicle. Generally, truck is a heavy motor vehicle which is designed for carrying the attached weights, such as the engine, transmission and suspension as well as the passengers and payload. The major focus in the truck manufacturing industries is to design vehicles with more payload capacity. Using high strength steels than the conventional ones are possible with corresponding increase in payload capacity. The chassis of truck which is the main part of the vehicle that combines the main truck component systems such as the axles, suspension, power train, cab and trailer etc.

Literature Survey:

Anurag, Amrendra Kumar Singh, AkashTripathi, Aditya PratapTiwari, Nitishupadhyay, ShyamBihari La, "DESIGN AND ANALYSIS OF CHASSIS FRAME", IJRE, Vol. 03 No. 04, April 2016, ISSN 2348-7852 (Print) | ISSN 2348-7860 (Online).This overview selectively and briefly discusses some of the recent and current developments of the stress analysis of truck chassis. A number of analytical, numerical and experimental methods are kept in mind for the stress analysis of the heavy duty truck frames. This paper presents the study of the stress developed in chassis as well as deformation of chassis frame. The stress and deformation has been calculated for the chassis frame and the analysis has been done for the validation on the chassis frame. The model of the chassis has been developed in Creo (Pro-E) 2.0 and static structural analysis has been done in ANSYS WORKBENCH 15.0.

S. Dheeraj and R. Sabarish, "Analysis of Truck Chasis Frame Using FEM", Middle-East Journal of Scientific Research 20 (5): 656-661, 2014, ISSN 1990-9233.In this project, an attempt is made to find the stresses in a tipper truck frame. We are analyzing stress concentration points where the displacement and frequencies are high at the time of loading and unloading. The software used for modeling and analysis is ANSYS 10.

Mukesh Patil, RohitThakare, Aniket Bam. "Analysis of a tanker truck chassis", International Journal on Mechanical Engineering and Robotics, ISSN (Print): 2321-5747, Volume-3, Issue-6, 2015. This report presents an analysis of the static stress acting on the upper surface of the truck chassis. Critical parts that will lead to failure are also observed. The method used in this numerical analysis is finite element analysis (FEA). Finite element analysis helps in accelerating design and development process by minimizing number of physical tests, thereby reducing the cost and time for analysis. 3-D model of the truck chassis is made using Creo Parametric and analyzed in ANSYS Workbench. The results show that the road excitation is the main disturbance to the truck chassis as the chassis natural frequencies lie within the road excitation frequency range. The mode shape results determine the suitable mounting locations of components like engine and suspension system. Some modifications are also suggested to reduce the vibration and to improve the strength of the truck chassis.

Hirak Patel, Khushbu C. Panchal, Chetan S. Jadav,"Structural Analysis of Truck Chassis Frame and Design Optimization for Weight Reduction", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-4, April 2013.

This report is the work performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis. Structural systems like the chassis can be easily analyzed using the finite element techniques. A sensitivity analysis is carried out for weight reduction. So a proper finite element model of the chassis is to be developed. The chassis is modeled in PRO-E. FEA is done on the modeled chassis using the ANSYS Workbench.

Conclusion from literature survey:

- Review of literature shows that many authors have reported the design to find best configuration of the Chassis in terms of the geometry and they also study on modification of geometry and strength to withstand sudden change in stress while in operating.
- The incidence of failure needs to be brought down. Analysis is done to check the effect of variable design parameter with some boundary condition.
- Also, finding the effective design which will reduce the weight of structure without compromising on strength.
- Therefore it is important to determine the factors like stresses, deformation, force etc. which influences the failure, finding the alternate design which will comprise of rib structure to reduce the weight of the Chassis.
- New design must be able to withstand all of the loads it is going to undertake.

Objectives of Project:

Iterative FEA approach for selection of different loading conditions as given above on truck chassis and optimizing through selection of different cross section suitable to withstand loads with maximum factor of safety, like I or C or sq. section profile and thus ensuring weight reduction without compromising in mechanical strength by topology optimization. Followed by fabrication and experimental validation

Scope:

1. We are going to do the optimization of the chassis members.
2. Optimization will contribute to reduction of weight without compromising over the strength of the chassis.

Methodology:

CAD Model Generation

- Getting input data on dimensions of chassis from market.

- Creating 3D model in CATIA.

Determination of loads:

Determination of different loads and boundary condition acting on the component by studying various ref papers, and different resources available.

Testing and Analysis

- Meshing the CAD model and applying the boundary conditions.

- Solve for the solution of meshed model using ANSYS.

Re-Design, Analysis and Results

- Making changes in CAD model for optimization.

- Carrying different iteration by removing material or changing topology based on ANSYS results.

- Check the maximum stress ensuring it is well within the safe region.

Fabrication, Experimental validation and Result

- Fabrication of prototype.

- Suitable experimentation and comparison with present chassis.

- Validation of result by comparing with software results.

Fig.Cad Model of Truck Chassis Fig. – Meshing of Chassis in Hypermesh

(Shell 63 – 2D Mesh)
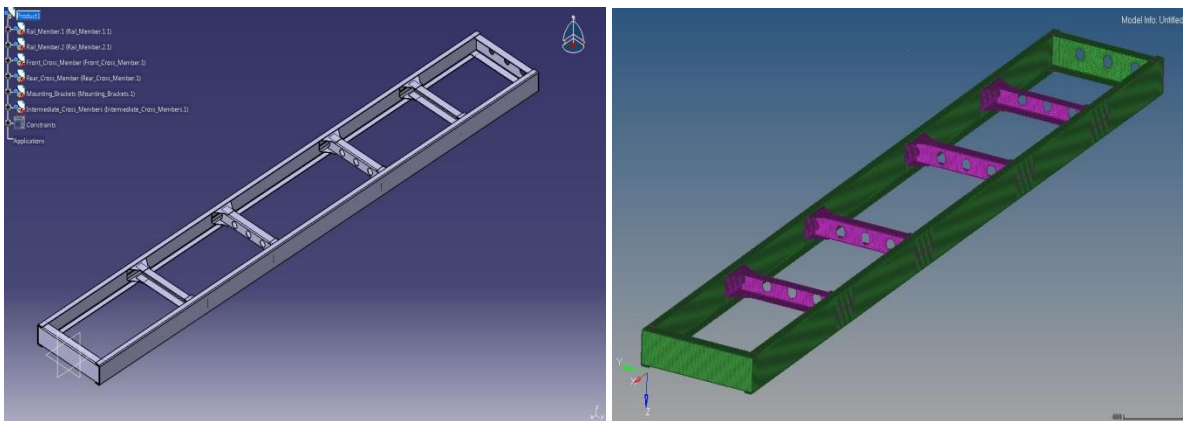
The CAD model for Eicher 10.80 truck chassis is ready, which is created in CATIA V5. Now in the further part we are going to perform the calculation of boundary conditions (forces acting on chassis) and then the FEA of chassis in Hypermesh.

Meshing:

Initially the igs file is imported to the meshing software like Hypermesh. The CAD data of the chassis is imported and the surfaces were created and meshed. As all the dimensions of blade are not comparable the element for meshing the chassis is shell element (Shell 63) (2D Mesh Element Type)

Table: Meshing Details:

Element Type	Shell 63 (2D element)
Number of Nodes	88453
Number of Elements	87088

Force calculations:

Eicher 10.80 Specifications:

- Gross Vehicle Weight (GVW) = 8250 kg
- Wheel base = 3750 mm
- Overall width = 2005 mm
- Overall Height = 2340 mm
- Load body length = 4300 mm
- Load body width = 2005 mm
- Load body height = 1590 mm
- Engine Displacement = 3298 cc
- Maximum Power = 95 PS @ 3200 rpm
- Maximum Speed = 92 km/hr.
- Location of CG: (from CATIA)
  - CG from front axle = b = 2654 mm
  - CG from rear axle = c = 1096 mm
  - CG height from ground = h = 1755 mm

Now for calculation of forces we consider different cases for analysis viz.

1. Case 1 – Gross vehicle weight as UDL
2. Case 2 – Bump force
3. Case 3 – Torsional force due one side bump
4. case 4 - roll over bending moment

Case 1 – Gross vehicle weight as UDL:

UDL = GVW x Gravitational acceleration………... (1)

 = 8250 x 9.81

UDL = <u>80932.5 N</u>

Case 2 – Bump force:

$$FB = \frac{3}{2} \ x \left(\frac{W \ x \ c}{L} + \frac{m \ x \ a \ x \ h}{L} \right) … … … … … … … … … (2)$$

Where, W = 80932.5 N

c = 1096 mm

m = 8250 kg

h = 1755 mm

L = 3750 mm

a = average acceleration

To calculate acceleration, we have

$$a = 550 \text{ x} \left(\frac{g}{V} \text{x} \frac{HP}{m}\right) ft/s2 \text{ ... ...} (3)$$

Where, g = 9.81 m/s^2 = 32.2 ft/s^2

V = max. speed = 92 km/hr = 83.85 ft/s

HP = 95 PS = 93.7 HP

m = 8250 kg = 18188.14 lb

Putting above values in equation (3), we get,

a = 1.0881 ft/s^2 = 0.332 m/s^2

Now substituting required values in equation (2), we get,

F_B = 37403.6 N ~ 37404 N

Now this bump force is acting on complete front axle. We must calculate force acting on each wheel and then force acting on each leaf spring mounting.

Bump force acting on each front wheel = F_B / 2 = 18702 N .... (4)

Bump force acting on each leaf spring mounting = 18702 / 2 = 9351 N.

Case 3 – Torsional force due to one side bump:

For torsional case of the chassis, the bump force will be acting on one side only.

Hence from equation (4), we have,

Bump force acting on one front wheel (say left) = 18702 N

This force will act in vertically upwards direction on left front wheel and same magnitude force will act on right front wheel but in vertically downwards direction.

Torsional force acting on chassis = 18702 N

Torsional force acting on each leaf spring mounting = 18702 / 2 = 9351 N

For roll over we need to understand the velocity first at which tipping starts hence
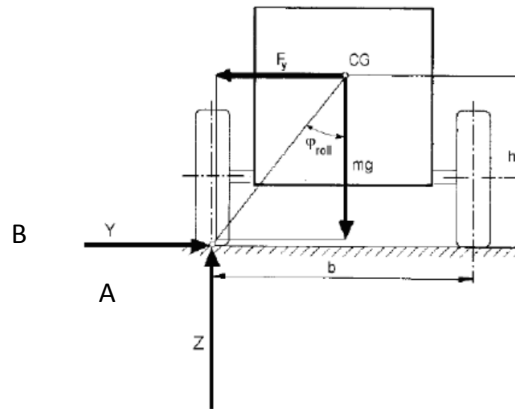
taking moment about point A

Z is the reactional force which is W/4= 80932.5/4 = 20233 N

mg at CG id 80932.5 N

Fy is centrifugal force which is $1/2 \times m \times r^2$

h = 1755mm

b/2 = 2005/2 = 1002.5 mm

putting in equilibrium

mg x b/2 + Fy x h = Z x b

81134831.25 + Fy x 1755 = 20283582.5

Fy = 34673N

1. Finite Element analysis of Existing Chassis

To perform the FEA of the Existing Chassis, continuum (Chassis model) is discretized into finite number of elements through meshing process and then boundary conditions are applied to the system. Fixed supports are applied to chassis where it comes in contact with the leaf spring systems.

Roll over bending moment along with Existing UDL
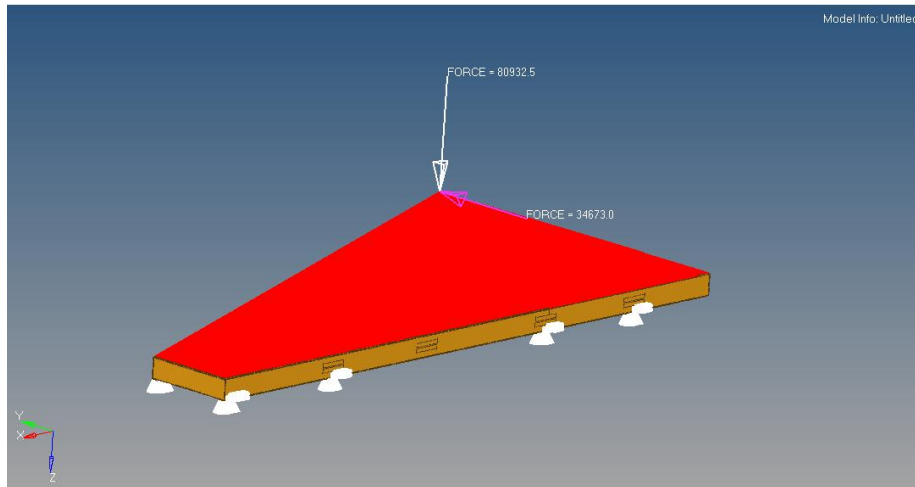
Applied forces and boundary conditions

Deformation plot Stress Plot
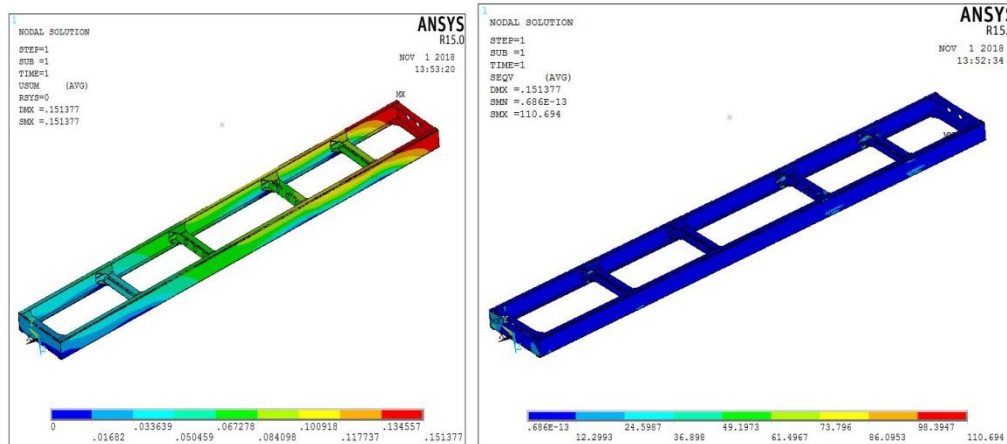
Maximum displacment of**0.151 mm**. Maximum Stress of of **110.6Mpa**

OPTIMIZATION OF TRUCH CHASSIS It uses highly advanced optimization algorithms; OptiStruct can solve the most complex optimization problems with thousands of design variables in a short period of time. OptiStruct advanced optimization engine allows users to combine topology, topography, size and shape optimization methods to create better and more alternative design proposals leading to structurally sound and lightweight design. Manufacturing requirements can also be defined as input to the simulation to create design proposals that are easier to interpret and to manufacture. As per above discussion topology optimization is done by removing material from the low stress region from von mises stress results
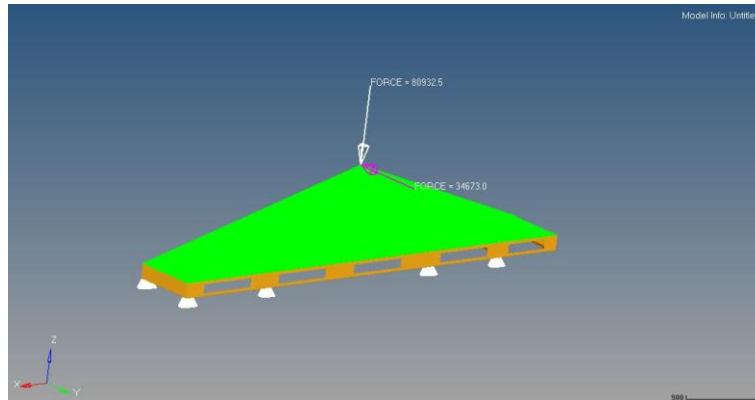
Fig. Meshed model with boundary conditions.

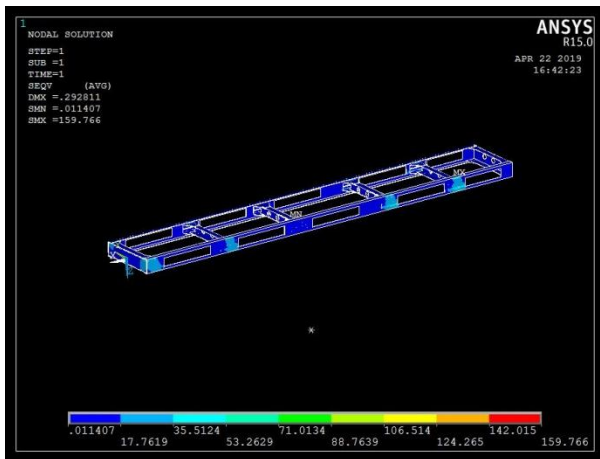**Von mises stress Result for displacement**

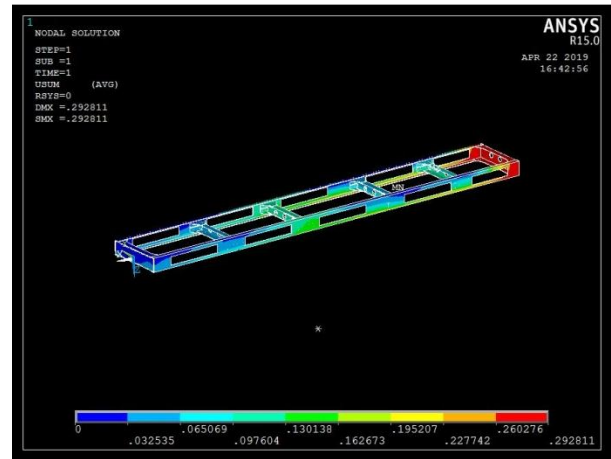Fig: von-mises stress for truck chassis   Fig.Displacement result for truck chasis

Maximum Stress of **159.766 Mpa.** Deformation is 29 mm is observed.

So we will stop here because further increase in optimization increases stress value near to critical limit. So iteration process is stop here. And this model is selected for manufacturing and testing.

Comparison for Stress and Deflection

Sr. No.	Von mises stress in Mpa	Deformation in mm	Weight in kg
Existing	110.6	0.15	192.672
Iteration 1	137.655	0.164	177.166
Iteration 2	139.818	0.168	173.103
Iteration 3	159.766	0.29	152.257

Percentage weight reduction = (Existing weight – final weight) / Existing weight

= (192.672 – 152.257) / 192.672

= 40.415/192.672

= 20.97 %

Fabrication and testing

Manufacturing drawing

A one forth scaled prototype is fabricated using mild steel material for testing purpose. The prototype is fabricated in KK Engineering, Katraj, Pune.

Experimental validation

The experimental investigation is performed on fabricated model on universal testing machine at Praj Metallurgical Lab, Kothrud, Pune. Compression test has been performed on the model produced. The input conditions are recreated in the lab while the component is being tested. The loading and the boundary conditions are matching the practical working conditions in which the vehicle is expected to perform. As the fabrication of truck chassis is done in one fourth scaled ratio. Therefore force is also reduced to one forth for testing. And from separate analysis of vertical force and roll over force it clear that vertical force produces maximum effect. Hence testing will be performed by applying only vertical force. Original vertical force applied on truck chassis is 80932.58 N.So for testing force is equal to 20233.125 N.

Observations Displacement is measured for the prototype from the test and a load vs deformation graph is obtained.
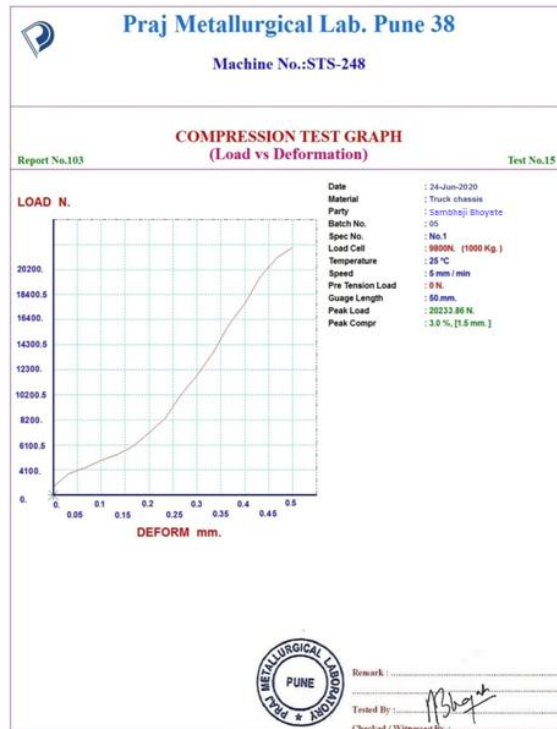
Conclusion:

➤ The FEA analysis of truck chassis is carried out over conventional model.

➤ A comparative study of FEA and Experimental results was made.

➤ From the results it can be concluded that the validation of results show close resemblance with a % error of 2.22 %

➤ Also the weight optimization of 20.97 % achieved without compromising strength of skateboard

➤ The natural frequencies of existing truck chassis are analyzed using FEA.

- The frequencies of vibration of optimized truck chassis in six different modes are lower than that existing truck chassis with Steel.
- Hence the comparison shows that there is no negative effect of optimization on natural frequency of truck chassis.

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