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Weight Optimization & FEA Analysis of Truck Chassis

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Abstract - This dissertation work deals with the elaborate design optimization technique for truck chassis with FEA method. Chassis is one of the important parts that used in automobile industry. It is a rigid structure that forms a skeleton to hold all the major parts together. Chassis frames are made of "steel section" so that they are strong enough to withstand the load and shock. Chassis must be light in weight to reduce dead weight on the vehicles. Major challenge in today's automobile vehicle industry is to overcome the increasing demands for higher performance, lower weight in order to satisfy fuel economy requirements, and longer life of components, all this at a reasonable cost and in a short period of time. The study is to produce results to rectify problems associated with structures of a commercial vehicle such as strength, stiffness and fatigue properties along with stress, bending moment and vibrations 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.

After manufacturing of truck chassis, analytical results are validated experimentally by stress analysis of truck chassis with the help of universal testing machine (UTM). The process of validation for this method is Followed by fabrication and experimental.

Key Words: CAD, Chassis, FEA, Anys etc.

1. 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.

Fig -1: Chassis

1.1 Objectives

1. To determine the torsion stiffness and static and dynamic mode shape of the truck chassis by using torsion testing, modal analysis, and finite element method.
2. To improve the static and dynamic behavior of the truck chassis by changing the geometrical dimension and structural properties.
3. To develop a new truck chassis.

1.2 Problem Specification

Chassis behavior and resistance plays a very important role in overall vehicle rigidity and strength, the more optimized the chassis, the less prone to failure due to uneven loading conditions, hence less impact of connecting members in sprung and un sprung mass, moreover an optimized chassis with less weight will increase the power to weight ratio which is desired by every automotive industry.

2. METHODOLOGY

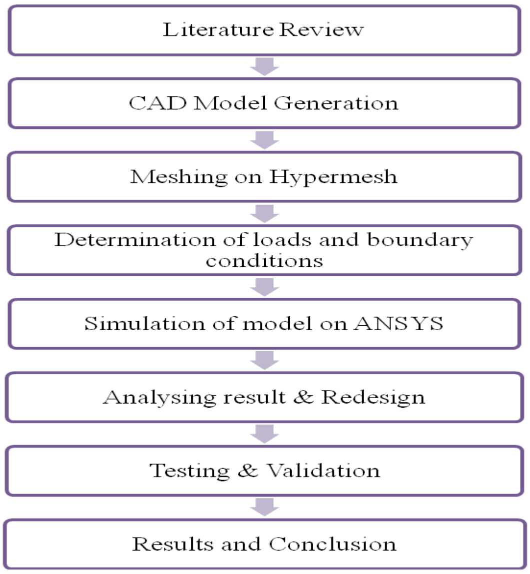

Fig -2: Flow Chart

3. FORCE CALCULATIONS

3.1 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

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

Case1- Gross vehicle weight as UDL

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

= 8250 x 9.81

UDL = 80932.5 N

Case2- Bump force

$$F_B = \frac{3}{2} \times \left(\frac{W \times c}{L} + \frac{m \times a \times h}{L} \right) \quad \text{.....................} (2)$$

$$a = 550 \times \left(\frac{g}{V} \times \frac{HP}{m} \right) ft/s2$$

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

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) = 18702N

Torsional force acting on chassis = 18702 N

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

4. DESIGN & ANALYSIS OF CHASSIS

Design and Analysis of truck chassis of dissertation includes design and analysis of existing truck chassis of Eicher 10.80. Dimensions of the existing truck chassis have been measured from market and CAD model of a truck chassis have been prepared in CATIA V5. The finite element analysis is carried out by using Hypermesh and ANSYS as post-processor.

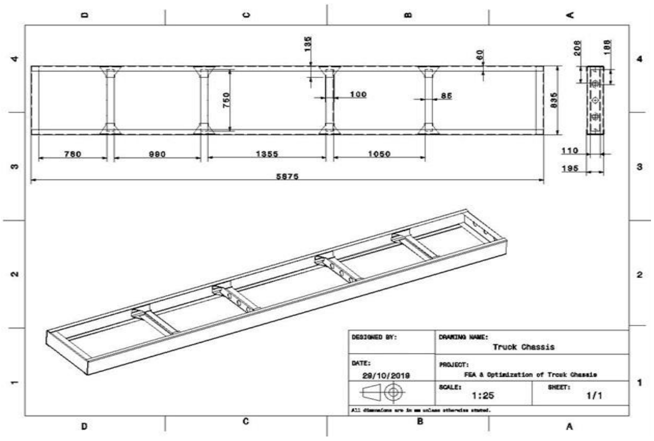

Fig -3: Chassis Drafting

4.1 Catia Model

Computer Aided Three dimensional Interactive Application (CATIA) is a software from Dassault systems, a France based company. CATIA delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product.

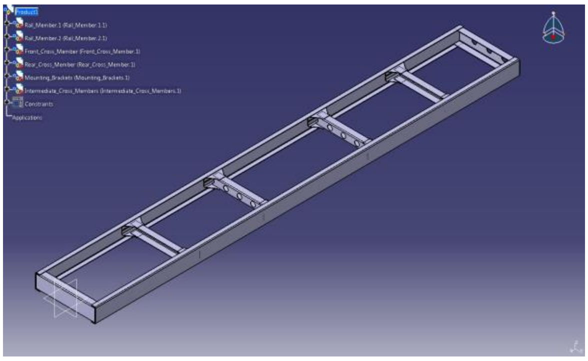

Fig -4: CAD model

4.2 Analysis of Chassis

Analysis is done by selecting appropriate solver and carrying out the operations in various stages to obtain solution

Meshing of Model

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.

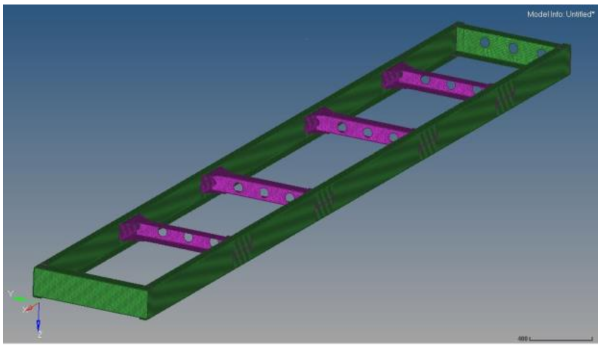

Fig -5: Meshing of Chassis in Hypermesh

4.3 FEA Flow Chart

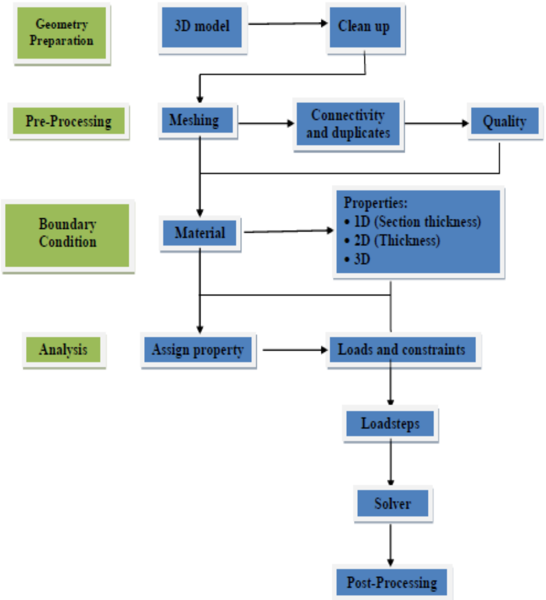

Fig -6: FEA Flow Chart

4.4 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.

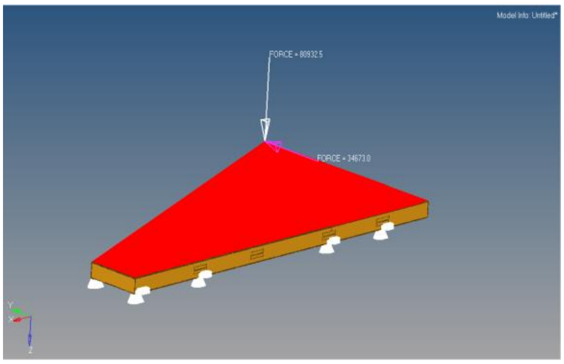

Fig -6: Applied forces and boundary conditions

1. Deformation plot

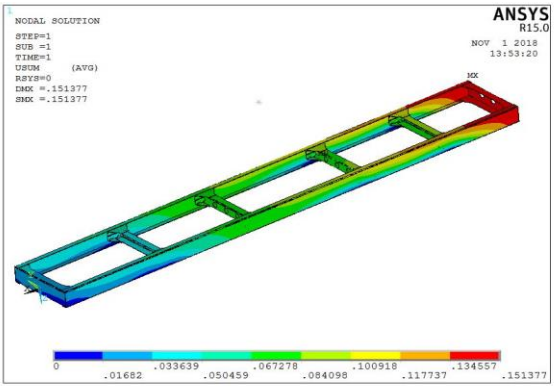

Fig -7: Deformation plot

Maximum displacement of **0.151 mm** is observed.

2. Stress plot

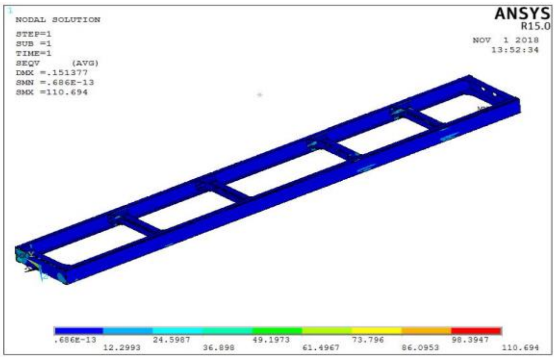

Fig -8: Stress plot

Maximum Stress of **110.6Mpa** is observed.

4.5 OPTIMIZATION OF TRUCK CHASSIS

Optimization methods were developed to have lighter, less cost and may have better strength

Weight reduction is done using optimization software OPTISTRUCT. The weight reduction is done using Topology optimization by meeting the strength, safety factor targets. And the corresponding weight reduction is analyzed.

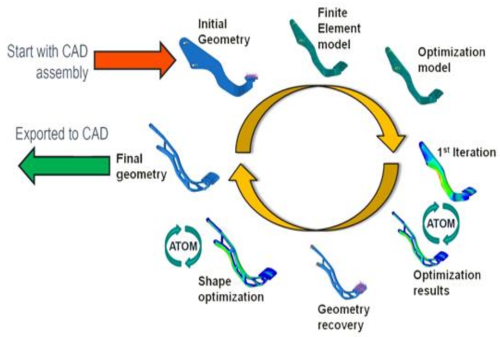

Fig -9: Loop of topology optimization

1. ITERATION-1 OF FEA

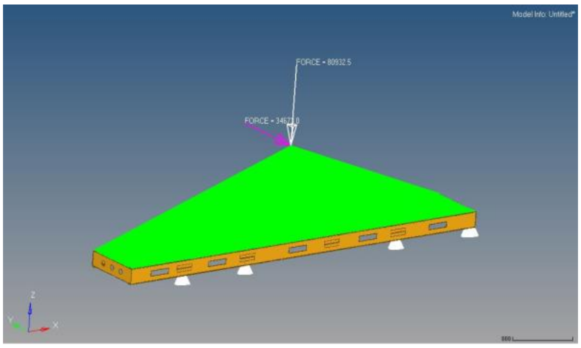

Fig -10: Meshed model with boundary conditions

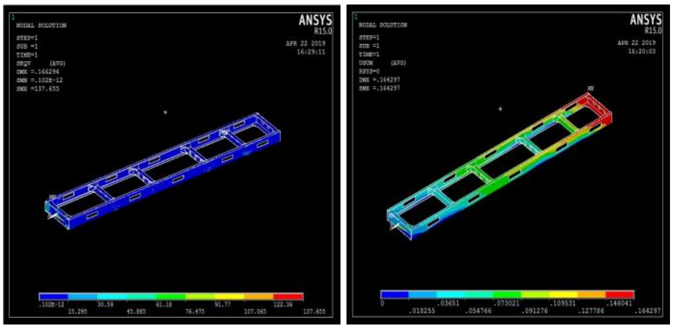

Fig-11: (a) Von mises stress (b) displacement

From fig.11 (a) Maximum Stress of 137.655 Mpa is observed & (b) it can be seen that the deformation is 0.164 mm

2. ITERATION-2 OF FEA

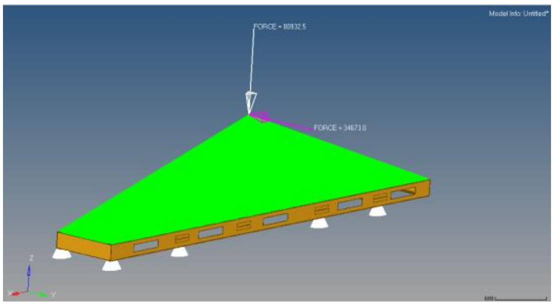

Fig -12: Meshed model with boundary conditions

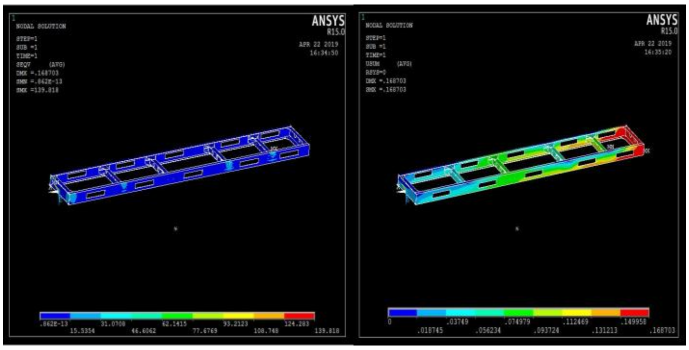

Fig-13: (a) Von mises stress (b) displacement

From fig.13 (a) Maximum Stress of of **139.818 Mpa** is obsreved& (b) it can be seen that the deformation is **0.168 mm**

3. ITERATION-3 OF FEA

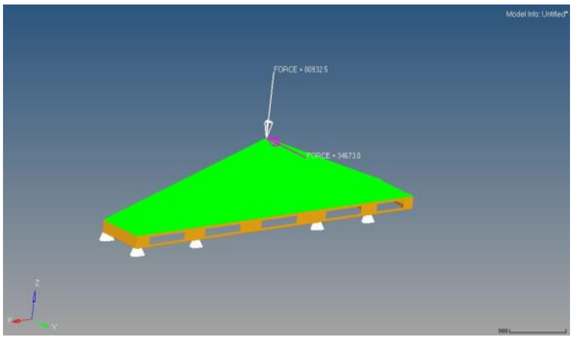

Fig -14: Meshed model with boundary conditions

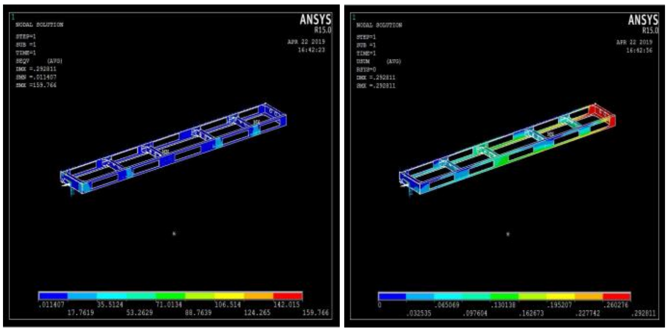

Fig-15: (a) Von mises stress (b) displacement

From fig.15 (a) Maximum Stress of of **159.766 Mpa** is obsreved& (b) it can be seen that the deformation is **0.29 mm**

4.6 COMPARISON FOR STRESS AND DEFORMATION

Table -1: Obtained Values

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 %**

4.7 Optimized Truck chassis drawing

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

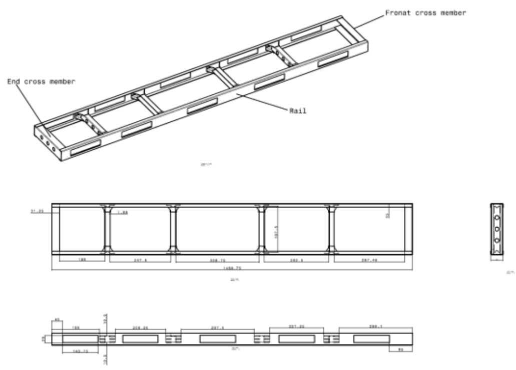

Fig-16: Optimized truck chassis drawing

Fig-17: Fabrication of truck chassis

5. EXPERIMENTAL VALIDATION

Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

The experimental investigation is performed on fabricated model on universal testing machine at Praj Metallurgical Lab, Kothrud, Pune.

Fig-18: UTM machine

6. RESULT AND DISCUSSION

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

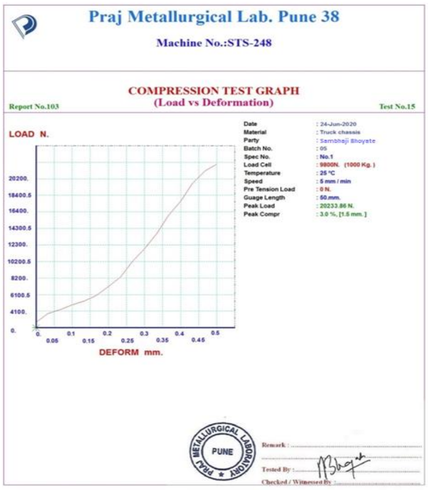

Fig-19: Testing report

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

RESULT COMPARISION

Percentage Error = (Experimental - FEA) / Experimental
= (0.45 - 0.44) / 0.45
= 0.01/0.45
= 2.22 %

Percentage weight reduction = (Existing weight – final weight) / Existing weight
= (192.672 – 152.257) / 192.672
= 40.415/192.672
= 20.97 %

3. CONCLUSIONS

1. The study carried out in this dissertation work mainly concerned with the weight optimization of truck chassis. Intially model of truck chassis is created in catia V5 by reverse engineering and optimize the weight of truck chassis without compromising its strength.
2. The FEA analysis of truck chassis is carried out over conventional model. The design is safe in conventional model and there is scope for optimization. Then FEA analysis is done on optimized model. We selected the optimized model which is safe within the limit.
3. 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.
4. A comparative study of FEA and Experimental results was made.
5. From the results it can be concluded that the validation of results show close resemblance with a % error of 2.22 %
6. Also the weight optimization of 20.97 % achieved without compromising strength of truck chassis

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