STATIC AND MODAL ANALYSIS OF TRUCK CHASSIS;

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ABSTRACT

A vehicle frame, also known as its chassis forms the backbone to all vehicle.It is one of the important part that used in automobile industry. It is a rigid structure which acts a skeleton to hold all the major parts togetherlike the skeleton of an organism.It principally used for safely carrying the maximum load for all designed operating conditions. Chassis frames should be strong enough to withstand the load and shock.This paper represents the study of the static structural characteristics of the truck chassis at different load condition and the responses of the truck chassis which include the stress distribution and displacement under various loading condition, also observed the modal analysis of truck chassis which include the natural frequencies and mode shapes. Design of the Chassis is carried by using creo3.0 and finite element analysis will be carried out by using ANSYS 14.0.

Keywords: Ansys, Chassis, Creo, Modal Analysis, Static Analysis

I. INTRODUCTION

Chassis forms the structural backbone of a commercial vehicle**.** Until the 1930s, virtually every (motor) vehicle had a structural frame, separate from the vehicle's body. This type of design is known as body-on-frame. Since then, nearly all passenger cars have received unibody construction, meaning their chassis and bodywork have been integrated into one another. However, contrary to cars till date nearly all trucks, buses and pickups continue to use a separate frame as their chassis. The components of the vehicle like Engines, Transmission System consisting of clutch gearbox, propeller shaft and rear axle, Wheels and Tyres, Suspension, Controlling Systems like Braking, Steering, and electrical system parts are all mounted on the Chassis frame. So it is also called as Carrying Unit.

The main functions of a frame in motor vehicles are:-

1. To support the vehicle's mechanical components and body.
2. It give shape to the vehicle body.
3. To deal with static and dynamic loads condition without undue deflection or distortion.These include:

- Weight of the body, passengers, and cargo loads.
- Vertical and torsional twisting transmitted by going over uneven surfaces.
- Transverse lateral forces caused by road conditions, side wind, and steering the vehicle.
- Torque from the engine and transmission.
- Longitudinal tensile forces from starting and acceleration, as well as compression from braking and sudden impacts from collisions.

Types of frames

1. Conventional frame
2. Integral frame
3. Semi-integral frame

Conventional frame**: -** it has two long side members and 5 to 6 cross members joined together with the help of rivets and bolts. The frame sections are used generally. a. Channel Section – Good resistance to bending b. Tabular Section – Good resistance to Torsion c. Box Section – Good resistance to both bending and Torsion

Integral frame: **-** this frame is used now in most of the cars. There is no frame and all the assembly units are attached to the body. All the functions of the frame carried out by the body itself. Due to elimination of long frame it is cheaper and due to less weight most economical also. Only disadvantage is repairing is difficult.

Semi – Integral frame: **-** in some vehicles half frame is fixed in the front end on which engine gear box and front suspension is mounted. It has an advantage when the vehicle is met with an accident the front frame can be taken easily to replace the damaged chassis frame

Ladder Chassis: **-** Ladder chassis is one of the oldest forms of automotive chassis these are still used in most of the SUVs today. It is clear from its name that ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by lateral and cross braces.

Various loads acting on the frame on road.1. Short duration Load – While crossing a broken patch.

2. Momentary duration Load – While taking a curve.
3. Impact Loads – Due to the collision of the vehicle.
4. Inertia Load – While applying brakes.
5. Static Loads – Loads due to chassis parts.
6. Over Loads – Beyond Design capacity

As a truck travels along the road, the truck chassis is excited by dynamic forces induced by the road roughness, engine, transmission and more. Under such various dynamic excitations, the truck chassis tends to vibrate. If any of the excitation frequencies coincides with the natural frequencies of the truck chassis, then resonance phenomenon will occurs as a result the chassis will undergo dangerously large oscillations, which may lead to excessive deflection and failure. The vibration of the chassis will also cause high stress concentrations at certain locations, fatigue of the structure, loosening of mechanical joints, and creation of noise and vehicle discomfort. The chassis structure is the bigger component in the any automobile vehicle. The vehicle shape dependent on this chassis, it provides a means of absorbing energy from frontal, side and rollover impacts. The greater the energy absorbed by the chassis on impact the lower the energy levels transmitted to a vehicles occupants and surroundings, so that lowering the chances of injury. Thus the chassis should be designed in such a way that it is hard, rigid, light-weight and was able to bear the different static and dynamic loading experienced while operating at different operating condition. The objecting of the existing paper is to produce a results which may help to rectify the problems associated with the structures of a commercial vehicle which also may be of significance during design of chassis body structure for the commercial vehicle. In this paper the truck chassis of Ashok Leyland truck were used on which the static and dynamic analysis were carried out and also combined existing theoretical knowledge and advanced analytical methods were done which Identifiesthe points or sections which are highly loaded (stressed) due to the loads by means of which the overall intensity of loading in the structures is assessed.

Then the model analysis were done to determine the natural frequency based on which the truck chassis is design to avoid resonance phenomena to occur and finite element analysis were done on the chassis made up of different Material to the best suitable material for the chassis which gives high strength with low weight and minimum deformation.

II. SPECIFICATIONS OF USED HEAVY VEHICLE

1. Truck model used: - Ashok Leyland 3118il
2. Suspension type: semi elliptical spring at front and rear.
3. Number of gears: 6 forward, 1 reverse gears
4. Maximum engine output: 180bHp@2400 rpm.
5. Maximum engine Torque: 660 Nm @ 1500 rpm
6. Gross Vehicle Weight (GVW): 31000kg.
7. Maximum speed: 78 km/hr.
8. Overall length: - 9745mm
9. Overall width: - 2432mm
10. Wheel base: - 4045mm
11. Frame length: - 6600mm

III. CHASSIS FRAME

The truck chassis used for the study has a narrow body which consists of 2 C-channel side rails and have 5cross members along the 2 side rails. There are some additional members like flat and gusset brackets located at the joint between side rails and cross members to strengthen the joints.

Side bar of the chassis are made from “C” Channels with 230 mm x 76 mm x 6 mm

Front Overhang (a) = 978 mm Rear Overhang (c) = 1620mm

Wheel Base (b) = 4045 mm

Material of the chassis is St 52

E = 2.10 x 105 N / mm2

Poisson Ratio = 0.31

Radius of Gyration R = 230/2 =115 mm

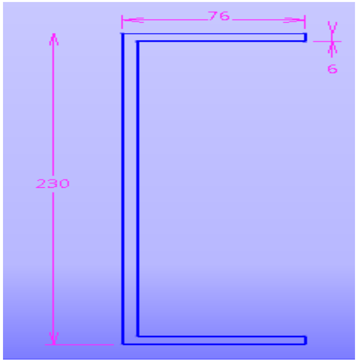

Figure 1 C-frame chassis

IV. THEORETICAL ANALYSIS

In theoretical analysis the truck chassis is consider as the simply supported beam with over hanging on both side of the beam having uniformly distributed load acting upon it. The beam is supported at the axles on front and back of the truck and thus the mathematical theory of beam analysis for determining load and deflections were carried out to determine the bending stress produced due to the load and total shear.

4.1 Load Determination

Total load acting on chassis = Capacity of the Chassis + Weight of body and engine

Total load = (25000+600+400+200)*9.81 = 257022N

Chassis has two beams. So load acting on each beam is half of the Load acting on the single frame

Load acting/beam = 257022 / 2 = 128511 N / beam

For calculation purpose the Chassis is a Simply Supported Beam with uniformly distributed load about axels A and B on both sides and with overhanging on both side of the beam in front and back of the truck chassis.

Load acting on Entire span of the beam is 128511

But Length of the Beam is 6600 mm.

So Uniformly Distributed Load is 128511/ 6600 =19.47N/mm.

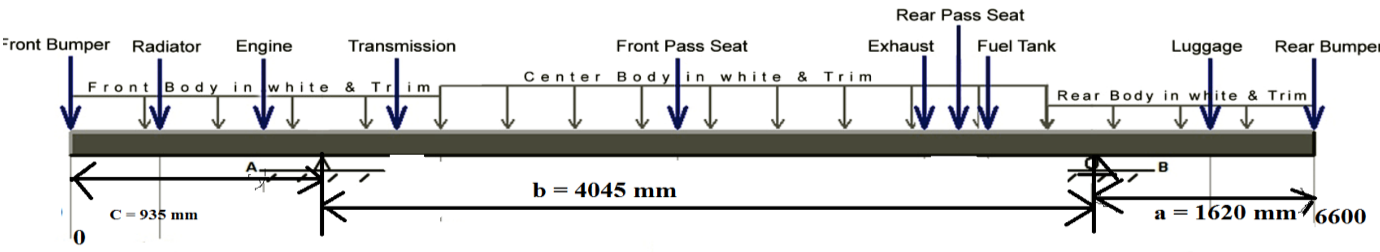

Figure 2 chassis as the simply supported with overhanging

4.2. Determination of Reaction Forces

The reaction forces are forces which acts on the simply supported beam by the supports provided by the axles on front and back side of the truck chassis in the upward direction supporting the load applied due to the uniformly distributed load over the beam. The reaction forces acts on the beam at the point A and point B as shown in the fig 2.

1 ReactionForce atA

The reaction force at the point A is given by equation R_A= WL [L- 2C] / 2b(1)

R_A= 19.47(6600) [6600-2(1620)] / 2(4045)

R_A= 128502[3360] / 8090

R_A= 53370.42 N

2 ReactionForce atB

The reaction force at the point B is given by equation ($R_{B)}$= WL [L- 2a] / 2b (2)

R_B= 19.47(6600) [6600-2(935)] / 2(4045)

R_B= 128502[4730] / 8090’

R_B= 75140.58 N

4.3 Determinationof Shear Forces

The force is the force which acts along parallel to the area consider and in the above beam an attempt is made to find the shear force distribution along the beam by dividing the beam into the different section and find the shear force by considering that the shear force on both side of the beam is equal and opposite in direction.

1 Shear Force at Section-1

The shear force at section 1 is given by equation (F1) =(W*C) N

(3)

F1 = 19.47(935) N

F1 = 18204.4 N

2. Shear Force at Section-2

The Shear Force at Section 2 is given by equation (F2) = (RA – F1) N(4)

F2= (53370.42 – 1820.4) N

F2 = 35165.97 N

3 Shear Force at Section-2

The Shear Force at Section-3 is given by equation (F3) = (W*a)N (5)

F3 = (19.47) * 1620 N

F3 = 31541.4 N

4.3 Determination Of Bending Movement

Bending movement is the reaction movement induced in the beam due to application of the movement on the beam. The present study the taken is simply supported with overhanging on both side of the beam with uniformly distributed load which provides the external movement to the beam. In the present study an attempt was made to find bending movement distribution along the beam so to find the maximum bending movement in order to find the bending stress.

1 Bending Movement at Section-1 (M1) = $(W* C^{2)} / 2$ N-mm (6)

M_1= 19.47*$(935)^2$/ 2 N-Mm

M_1= -8510580.3 N-Mm

2 Bending Movement at Section – 2 (M2) = $(W*a^2) / 2$ N-mm (7)

M_2 = 19.47 * $(1620)^2$ / 2 N-.Mm

M_2 = 25548534N-Mm

3 Bending Moment at Section- 3 (M3) = R_A(RB / 2W – 2c) N-mm (8)

$M_{3=}$ 8862418.107 N-Mm

4.4 Determination Of Moment Of Inertia

Moment of inertia is the moment of moment thus in the present study the moment of inertia of the C-section frame were determine about the X-axis(Ixx) in the rectangular co-ordinate system which will further help in finding the bending stress.

MomentOf Inertia aboutX- Axis $(I_{xx}) = (Bh^3 - B_1h_1^{3)}) / 12$ mm4(9)

$I_{xx=}$ $(70*(220)^3$- $60*(200)^{3)}$ / 12

$I_{xx=}$ 22113333.33 mm^4

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4.5 Determination Of Section Modulus

Section Modulus aboutX – Axis (Zxx) = (Ixx / $Y_{max)}$ (10)

Zxx = (22113333.33 / 220) mm^3

Zxx = 100515.15 mm3

4.6 Determination Of Bending Stress

Bending stress is the stress generated due to the bending couple acts perpendicular to the cross-section area. This bending couple is generated due to lateral forces acts upon the beam due to the load applied on the beam externally.

Bending Stress (S_b) = (Mmax / Ymax) N/mm^2 (11)

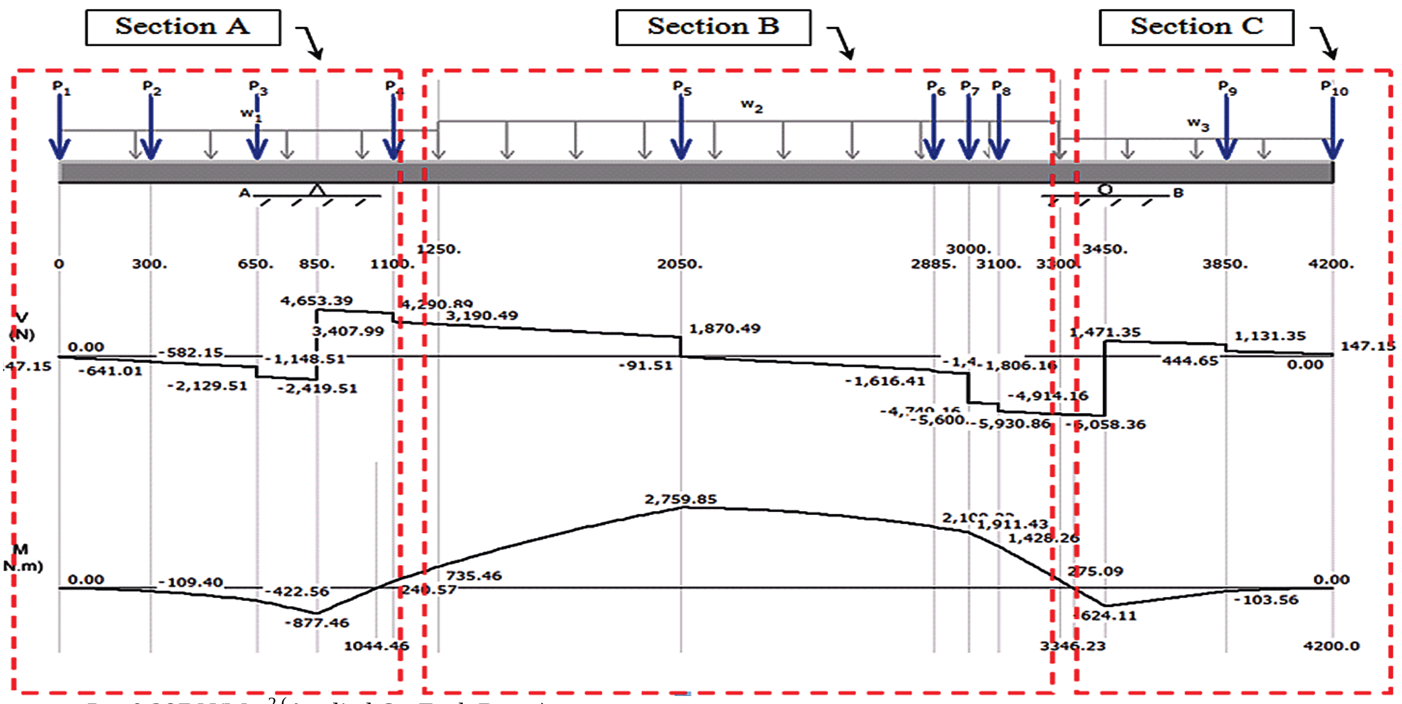
(S_b) = 25548534 / 100515.15 N/mm^2

(S_b) = 50.7 N/ mm^2

4.7 Determination Of Pressure Applied

Total Pressure Applied On A Single Beam (P) = Total Load Applied Pet Beam / Total Area (12)

P = 128511 / (70*6600) N/Mm^2



P = 0.287 N/Mm^2 (Applied On Each Beam)

Figure 3 shear and bending distribution along the beam

V. ANALYTICAL ANALYSIS THROUGH FINITE ELEMENT METHOD.

5.1 Solid Modelling

Fem technique is used for the static structural analysis of the truck chassis through the ansys analysis software for which the 3-D model of the truck chassis was made in the creo 3-d modelling software and then the frame model made was converted into IGES format so that it can be supported by the ansys software and then model is opened in ANSYS Workbench 14.0.for the analysis.

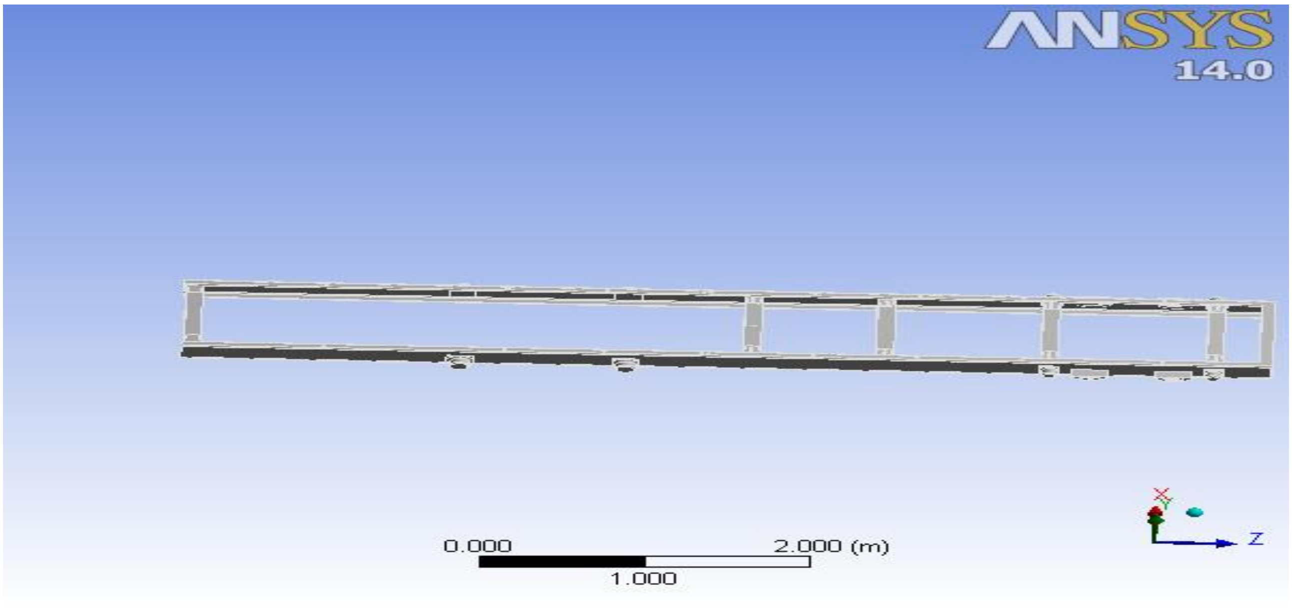


Figure 4 solid model of chassis in ansys for analysis modelled in creo

5.2 Meshing of Chassis Frame

The meshing is done on the model with 2068606 No. of nodes and 1245100 No. of Tetrahedral elements. In order to get a better result, locally finer meshing applied in the region which is suspected to have the highest stress.

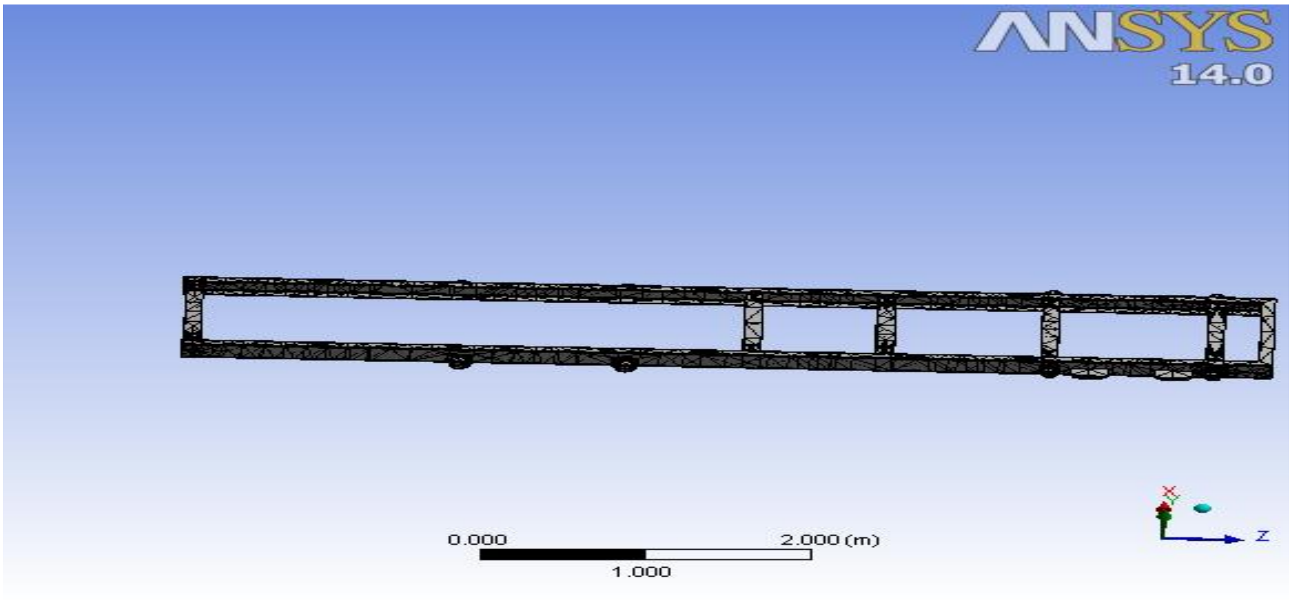


Figure 5 meshing in truck chassis model in ansys

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5.3. Material properties

For the analysis of chassis the material usedis Mild steel. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing

5.4 Loading and boundary condition

The load application is the major part in the analysis of a component. There may be different types of loads like Uniformly Distributed Load, Uniformly Varying Load and Point Load. The present frame carries the UDL throughout its length. The truck chassis model is loaded by static forces from the truck body and cargo. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between cargo and upper surface of chassis

As the frame supports the body by its two side frames,

The load on each side member = 257022/2 = 128511 N

.The total area on which the UDL is placed = 6600 × 70 = 462000 mm2

Total pressure applied = Total load /Total area = 128511/462000 = 0.287 N/mm2

There are 4 boundary conditions of model; the first two boundary conditions are applied in front of the chassis, the second and the third boundary conditions are applied in rear of chassis, in this, rear and front end of the chassis are kept fixed.

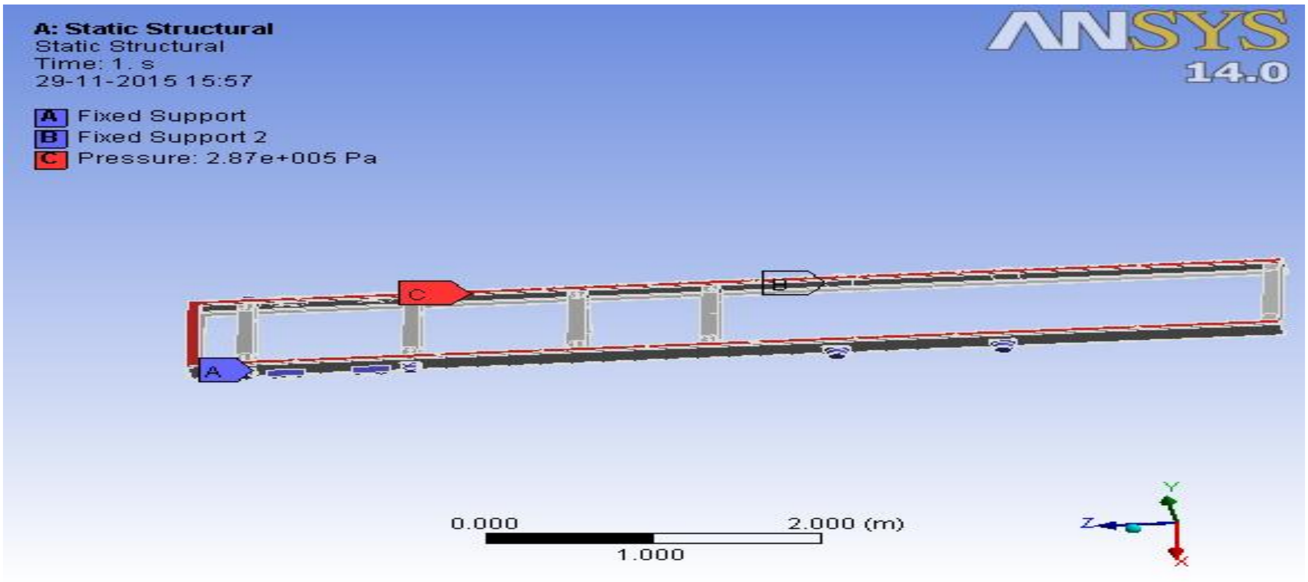


Figure 6 loading and boundary condition applied on model of truck chassis

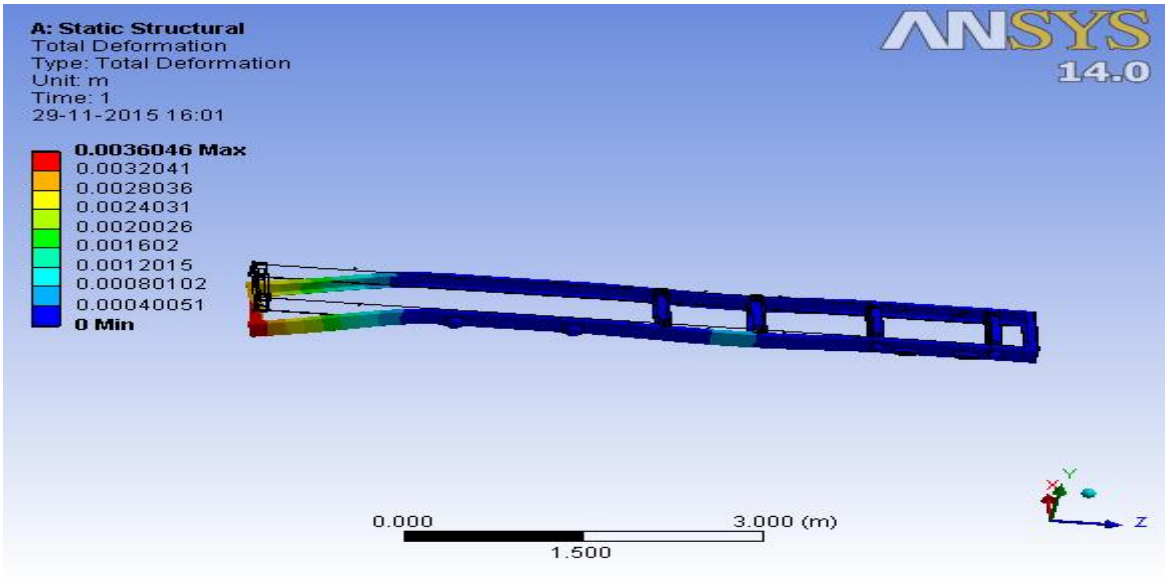


Figure 7 fem analysis result showing total deformation under static loading

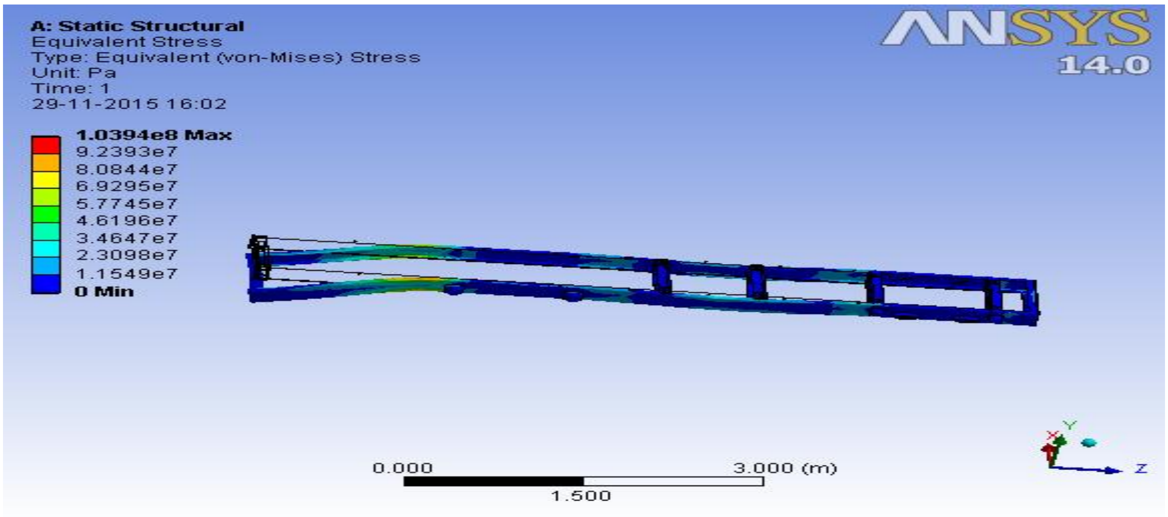


Figure 8 fem result showing Equivalent stress (von misses) under static loading

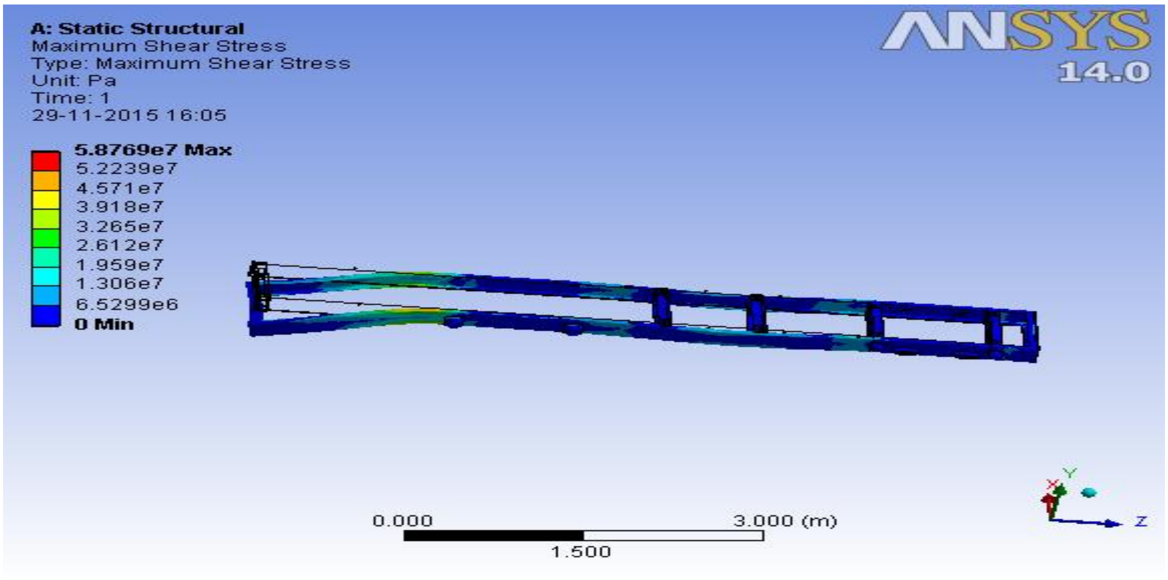


Figure 9 fem result showing maximum shear stress

5.5 Result

The location of maximum Von Misses stress and maximum shear stress are at corner of side bars
The Von Misses stress magnitude of critical point is 103.9 MPa and the
Maximum shear stress magnitude is 58.7 MPa.

VI. MODAL ANALYSIS OF CHASSIS UNDER STATIC LOADING CONDITION

Static analysis does not consider the variation of load with respect to time. Variation in variables with respect to time couple is predicted through dynamic analysis. Dynamic analysis can predict these variables with respect to time/frequency. Natural frequency of component is the basic design property. Natural frequency information is also helpful for avoiding resonance, reducing noise and as an important meshing check (free-free run).When the excitation frequency is close to natural frequency of component, there would big difference in static and dynamic results and led failure of the component. Thus it is important to find the natural frequency of the body for the design purpose and to avoid any failure in the component.

6.1 loading condition for the modal analysis

The boundary and loading condition were same for the modal analysis as for the static analysis. The modal analysis were done till 20 modes and the natural frequency were found out for each mode through analysis and the equivalent stress and total deformation were also determined.

6.2 Model Analysis Result for the 20th Mode.

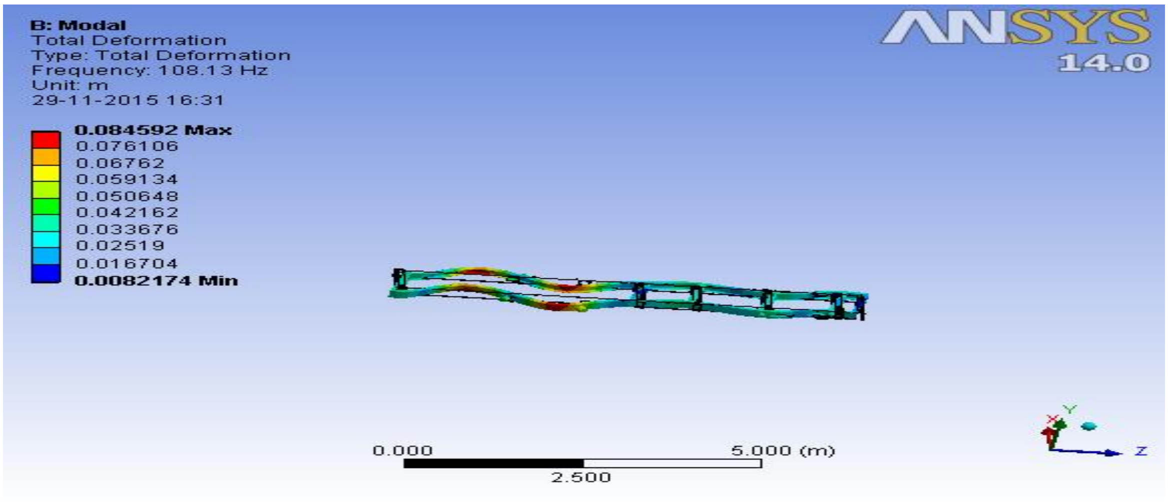


Figure 10 total deformation at mode 20

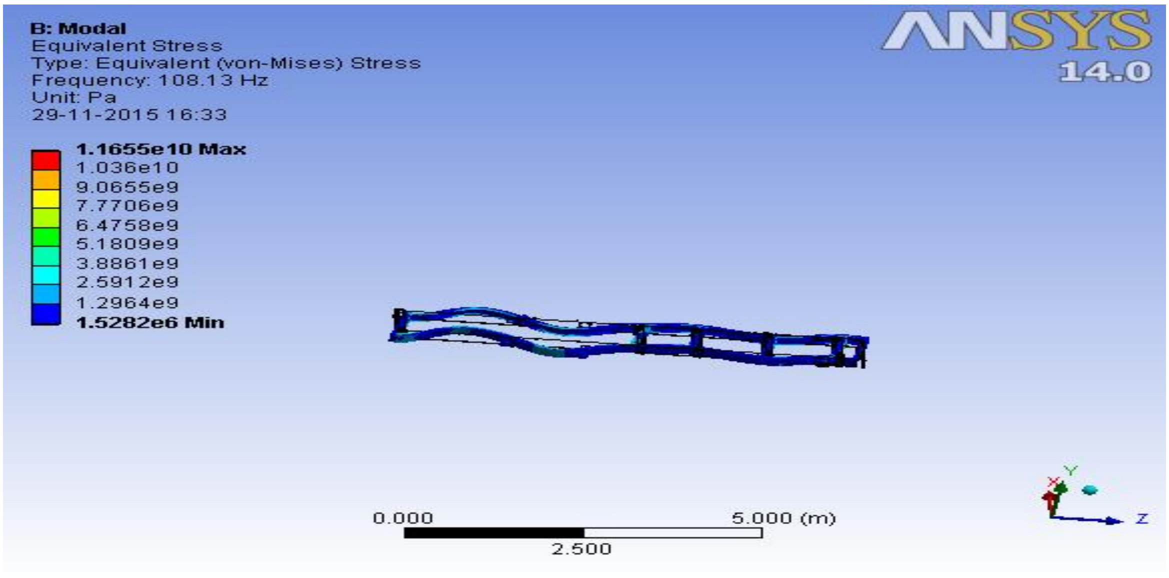
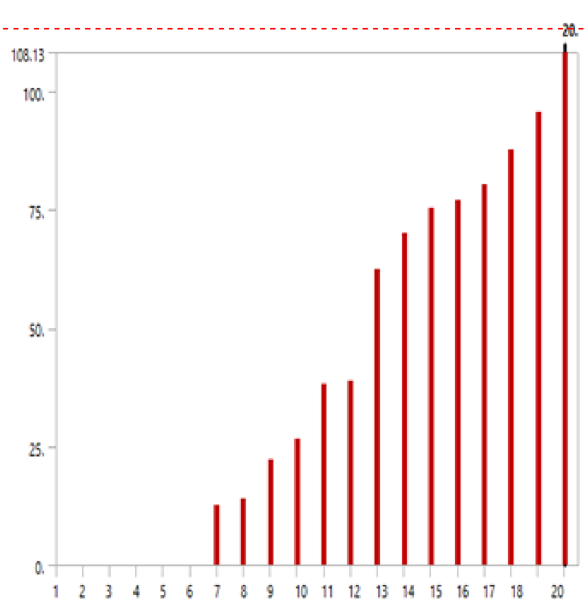


Figure 111: Fem result showing equivalent stress at the 20th mode

Table 1: Frequency at different modes

Mode	Frequency [Hz]
1.	0.
2.	
3.	
4.	3.375e-004
5.	1.7368e-003
6.	2.285e-003
7.	12.52
8.	13.935
9.	22.207
10.	26.635
11.	38.129
12.	38.787
13.	62.283
14.	69.91
15.	75.185
16.	76.962
17.	80.128
18.	87.725
19.	95.555
20.	108.13



VII STRUCTURAL ANALYSIS OF CHASSIS MADE OF POLYMERIC COMPOSITE MATERIAL

A composite material is defined as a material composed of two or more materials combined on a macroscopic scale by mechanical and chemical bonds. Unique characteristic of many fibre reinforced composites is their high internal damping capacity. This leads to better vibration energy absorption within the material and results in reduced noise transmission to neighbouring structures. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of metallic materials. The fatigue strength to weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fibre composites have emerged as a major class of structural material and are either used or being considered as substitutions for metals in many weight-critical components in aerospace, automotive and other industries.

7.1 The different composite material used for analysis are:

1 Carbon/ Epoxy

Carbon-Fibre-Reinforced Polymer, Carbon-fibber-Reinforced Plastic or Carbon-fibre- Reinforced Thermos Plastic (CFRP, CRP, CFRTP or often simply carbon fibre, or even carbon) is an extremely strong and light fibre-Reinforced Polymer which contains carbon fibres. CFRPs are commonly used in the transportation industry; normally in cars, boats and trains, and in sporting goods industry for manufacture of bicycles, bicycle components, golfing equipment and fishing rodsformula One racing and wherever high strength-to-weight ratio and rigidity are required such as sailing boats and rowing shell hulls, top-end bicycles

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Composition: Bisphenol-based epoxy 60-90%, Amine-based curing agent 1-30%, Imidazole-based curing catalyst 0.1-3% and Carbon Black 1-10%.

Mass of Frame:Mathematical equation for mass is Mass = Volume × Density

Density of Carbon/Epoxy = 1600 kg/m3

Volume of frame = 4.9104×10^{-2} m³

Total mass of frame = 1600 × 0.049104 = 79 kg (Approx.)

2 E-glass/ Epoxy

An individual structural glass fibres are both stiff and strong in tension and compression, along its axis. Although it might be assumed that the fibre is weak in compression, it is actually only the long aspect ratio of the fibre which makes it seem so i.e., because a typical fibre is long and narrow, it buckles easily. On the other hand, the glass fibre is weak in shear that is, across its axis. Therefore if a collection of fibres can be arranged permanently in a preferred direction within a material, and if the fibres can be prevented from buckling in compression, then that material will become preferentially strong in that direction.

Composition: 54% SiO_2 - 15% Al_2O_3 - 12% CaO

Mass of frame:Mass = Volume × Density

Density of E-glass/Epoxy = 2600 kg/m3 \

Volume of Frame = 4.9104×10^{-2} m³

Total mass of Frame = 2600 × 0.049104 = 127.67 kg

3. S-glass/ Epoxy

The manufacturing process for glass fibres suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals to liquid form. Then it is extruded through bushings, which are bundles of very small orifices (typically 5–25 micrometers in diameter for E-Glass, 9 micrometers for S-Glass). These filaments are then sized (coated) with a chemical solution. The individual filaments are now bundled together in large numbers to provide a roving. The diameter of the filaments, as well as the number of filaments in the roving determines its weight. Common uses of S-glass include high performance aircraft (gliders), boats, automobiles, baths, hot tubs, septic tanks, water tanks, roofing, pipes, cladding, casts, surfboards and external door skins.

Composition: 64% SiO_2- 24% Al_2O_3- 10% MgO

Mass of Frame:Mass = Volume × Density

Density of S-glass/ epoxy = 2495 kg/m3

Volume of frame = 4.9104×10^{-2} m³

Total mass of frame = 2495 × 0.049104 = 123 kg (Approx.)

7.2 FEM analysis on different materials

The finite element analysis were done on different composite material as mention above by applying the same static loading and boundary condition as was done earlier and thus found the equivalent stress and corresponding total deformation of all the material which reveal’s how strong the structure is and thus able to determine the best composite replacement of the conventional steal which is light weight and having high strength so as to withstand the large load applied on chassis during the operation.

Table 2: Result of fem analysis

Material	Mass (kg)	Max. equivalent stress (MPa)	Max. Deformation (mm)
Carbon/ Epoxy	134	114.79	2.8
E-glass/ Epoxy	217.77	104.15	8.48
S-glass/ Epoxy	208.98	109.16	8.2

VII CONCLUSION

The truck chassis were analysed theoretically by assuming the chassis as simply supported beam with distributed load provided by the truck component like engine etc. and the simply supported beam by supported by the axles in front and back on both side of the truck and the bending stress were and deformation were found out and then the finite element method analysis were done with the help ANSYSfea software and from above it was concluded that

1. The area of induced maximum Von Misses stress and maximum shear stress is at the corners of side bars
2. The results of the analytical shear stress is little bit less than then the finite element and the difference is of 13.33% less. This difference occurred as the fine meshing of the component gives more accurate results. By increasing the meshing the accuracy of the results increases.
3. In Modal Analysis the total deformation and equivalent stress of truck chassis frame for 20 different modes and natural frequencies for each modes were determined which helps while designing the truck chassis. The natural frequency were important while designing the truck chassis in order to avoid the resonance of natural frequency with chassis frequency which led to high amplitude vibration and ultimately result in fracture.
4. We have also considered polymeric composites like Carbon/Epoxy, E-glass/Epoxy and S- glass /Epoxy for chassis material. By employing a polymeric composite heavy vehicle chassis for the same load carrying capacity, there is a reduction in weight of 70% to 80%. And after doing the finite element analysis through ANSYS fea software it was concluded that Carbon/Epoxy polymeric composite heavy vehicle chassis has superior strength, less deformation and less weight compared to steel, E-glass/Epoxy and S- glass /Epoxy. So it is better to use Carbon/ Epoxy as a material for frames of heavy vehicle chassis. So that the fuel consumption decreases for the vehicles and can bear the large load with minimum deformation.

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