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Finite Element Analysis of Truck Chassis Frame

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Abstract - *Chassis is one of the important part 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. This can be achieved by static and dynamic analysis, combining existing theoretical knowledge and advanced analytical methods. Design of a Chassis is carried by using CATIA .And finite element analysis will be carried out by using ANSYS.*

Keywords*: Chassis,CATIA,ANSYS*

Introduction - 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. The main function of the chassis is not only support the components and payload mounted upon it including engine, body, passengers and luggage, but also to maintain the desired relationship between the suspension and steering mechanism mounting points. Along with a vehicle chassis provides safety to occupants of the vehicle and outside parties. The chassis is subjected to stress, bending moment and vibrations due to road roughness and components that mounted on it. When the truck travels along the road, Stress acting on chassis is varies with the displacement, the behaviour of the chassis that always subjected to stress (moving or not),to overcome this failure chassis requires appropriate strength, stiffness and fatigue properties of the components to be able to stand these loads or stresses. modal updating technique also important in order to create a good model for analysis. From the global torsion analysis, it has been found that the torsion load is more severe than bending load. In order to overcome this problem, a cross bar and material selection are very important to consider during design stage

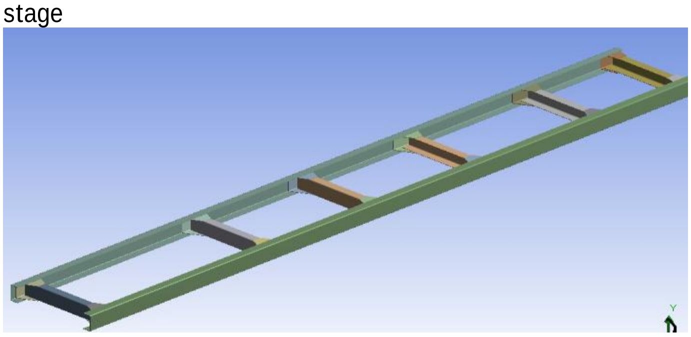


Fig:- Ladder chassis frame

Objective- The objective of the study is to produce results which may help to rectify problems associated with structures of a commercial vehicle and which also may be of significance during design of chassis body structure of the vehicle after carrying out static and dynamic analysis, combining existing theoretical knowledge and advanced analytical methods. identify points and sections which are highly loaded (stressed) due to the loads by means of which the overall intensity of loading in the structures is assessed. Shape optimization or weight reduction of chassis

Case consideration Technical specifications

For the analysis of the chassis used truck model of TATA 1612. It gives the Constant research and development and unrelenting efforts to meet the customers need has created this marvel. More power, more torque, more reliability and ofcourse more productivity. There is a choice of body size, type as well as wheel base for different application.

Data for the vehicle:

1)Suspension type: Parabolic spring at front and semi elliptical leaf spring at rear.
Option 2: semi elliptical spring at front and rear.
2)Number of gears : 6 forward , 1 reverse gears
3)Maximum engine output: 135 Kw181 Hp@2500 rpm.
4)Maximum engine Torque: 685 Nm @ 1400 rpm

Performance of Vehicle:

- Gross Vehicle Weight (GVW): 25000kg.
- Gross Combined Weight (GVW + Payload): 26200kg.
- Maximum Gear speed: 78 km/hr.

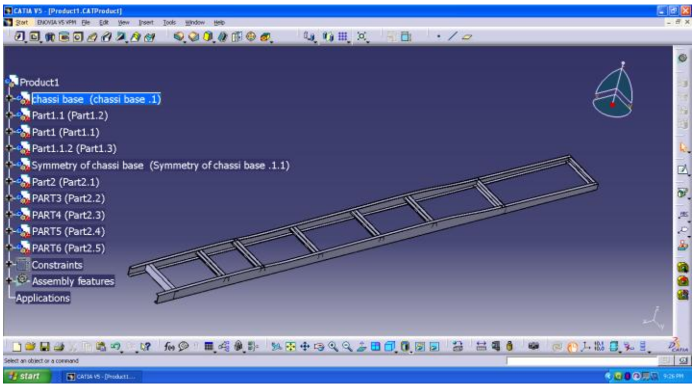
- Frame: Ladder type heavy duty frame, Depth-285mm, width-65mm, frame width-884mm.
- Weights (kg):

Max. permissible GVW = 25000
Max. permissible FAW = 6000
Max. permissible RAW = 19000

Basic calculation for chassis frame
Model No. = Tata 1612
Side bar of the chassis are made from "C" Channels with116mm x25mm x5 mm
Front Overhang (a) = 740 mm
Rear Overhang (c) = 1400 mm
Wheel Base (b) = 6670 mm
Material of the chassis is St 52 E = 2.10 x 105 N / mm2
Total load acting on chassis = Capacity of the Chassis + Weight of body and engine= (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 = 257022 / 2
= 128511 N / Beam
Chassis is simply clamp with Shock Absorber and Leaf Spring. So Chassis is a Simply Supported Beam with uniformly distributed load. Load acting on Entire span of the beam is 128511 Length of the Beam is 8810 mm.
Uniformly Distributed Load is 128511/ 8810 =14.58 N/mm

Fig: Chassis as a simply supported beam with overhang
Stress generated
M –max = 72022530.91N-mm
Moment of inertia around the x-x axis = 1266840 mm^4
Section of modulus about X-X axis = 21842.06897 mm^3stress produced on the beam = 3297.422 N/mm^2
Material used
for the analysis of chassis used Mild steel. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing.

Solid Modeling of Truck chassis
The modeling of chassis is done with CATIA



Static Analysis of Chassis without Chassis Load
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. In this, rear and front end of the chassis are kept fixed. As chassis is divided into 3 parts, pressure is applied on all these parts at each side. The pressure applied on first part is 290321.9248 N/m2 ,pressure applied on the second and the pressure applied part is 129362.6374 N/m2 and the pressure applied on third part is 244740.1247 N/m2
Meshing

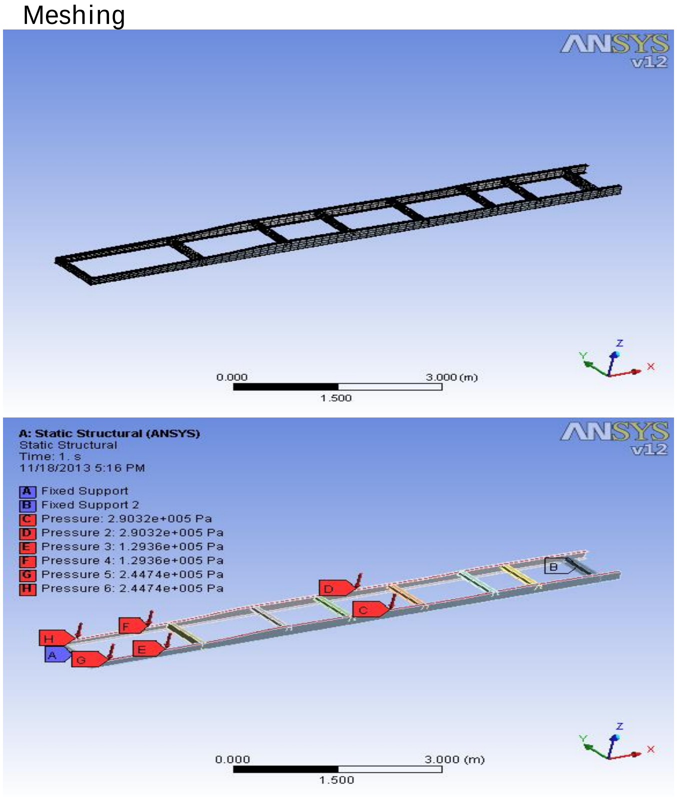


Figure :-Meshing and Loading and Boundary Condition for chassis without load.

Total Deformation And Directional Deformations for chassis without load

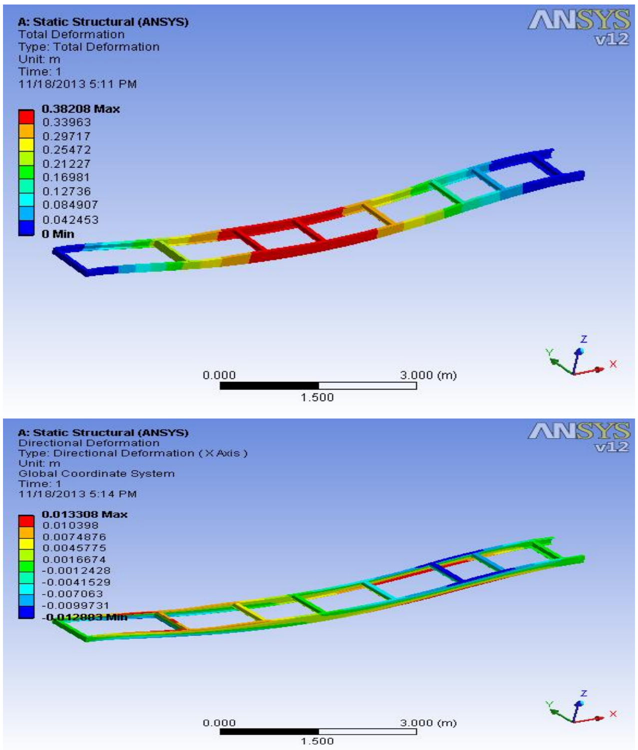


Figure:- Total Deformation Directional Deformation for Chassis without load

Static Analysis of Chassis with Chassis Load:

Loading and Boundary Conditions for with chassis load:

In static bending with chassis load both rear and front ends are kept fixed and different loading and boundary conditions are applied as shown in the figure given below. For bending it is assumed that the forces are acting at both side of the chassis in upward direction. It is also considered that the chassis load is also acting. In figure H and I denote the forces which are acting in upward direction whereas remaining are the chassis load acting in the downward direction. A and J denotes the fixed support.

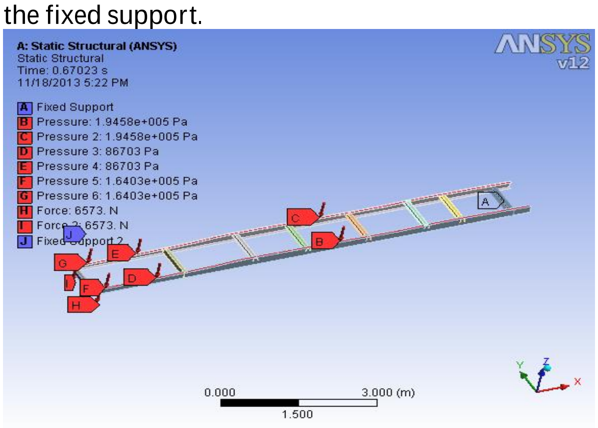
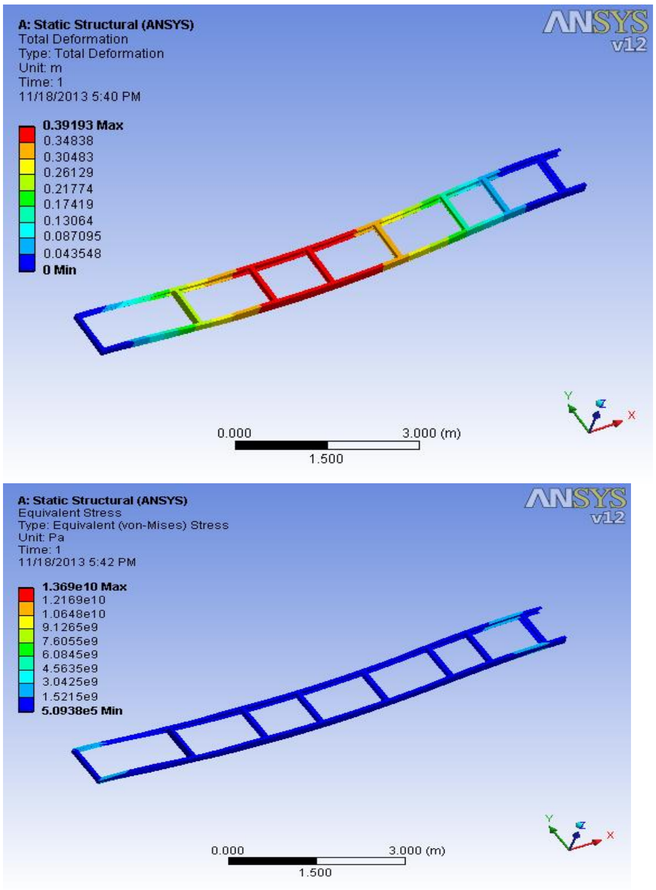


Figure: Loading and Boundary Condition for with chassis load

Total Deformations And Equivalent Stress for with chassis load.



Dynamic analysis

Static analysis does not take into account variation of load with respect to time. Output in the form of stress, displacement etc. with respect to time couple is predicted by dynamic analysis. Dynamic analysis can predict these variables with respect to time/frequency. To determine natural frequency of component it is 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.

Modal Analysis of Static Bending With Chassis Load:

Loading and Boundary Condition:

In static bending with chassis load both rear and front ends are kept fixed and different loading and boundary conditions are applied as shown in the figure given below. For bending it is assumed that the forces are acting at both sides of the chassis in upward direction. It is also considered that the chassis load is also acting. In figure H and I denote the forces which are acting in upward direction whereas remaining are the chassis load acting in the downward direction. A and J denotes the fixed support. Then the analysis is made to find out different mode shapes and natural frequencies.

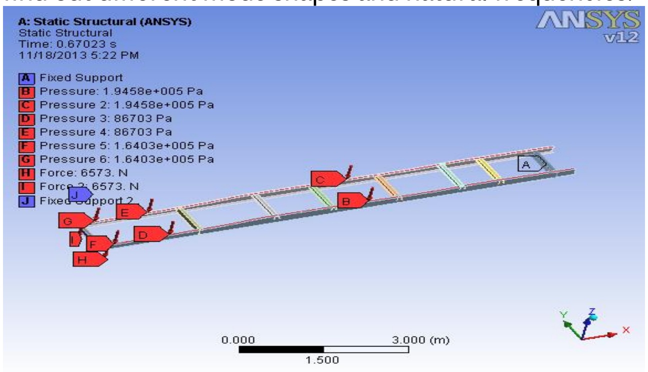


Fig: Loading & Boundary Condition for model analysis of static bending with chassis load

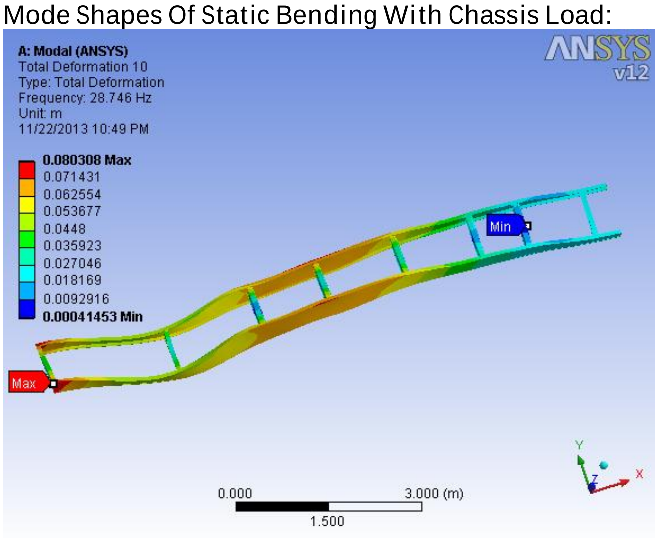
Eight natural frequencies were calculated for the mode analysis and are tabulated in Table below. It is observed that frequencies were varying from 16.89 Hz to 46.31 Hz.

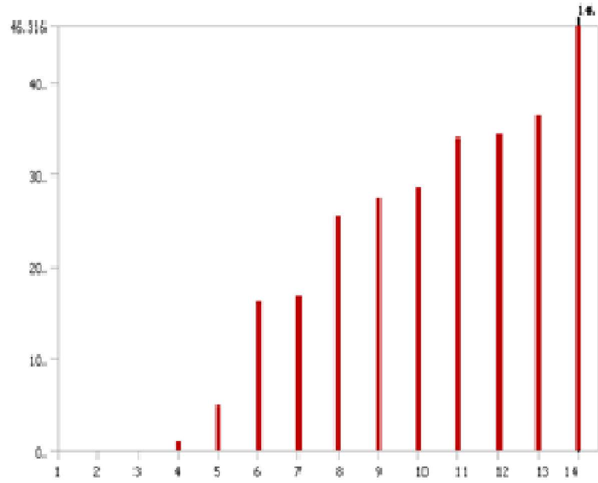
Table: Mode shapes, Frequencies and displacement for Static Bending with Chassis Load Truck Chassis

Different mode shapes and their displacement natures are find out at these frequencies.

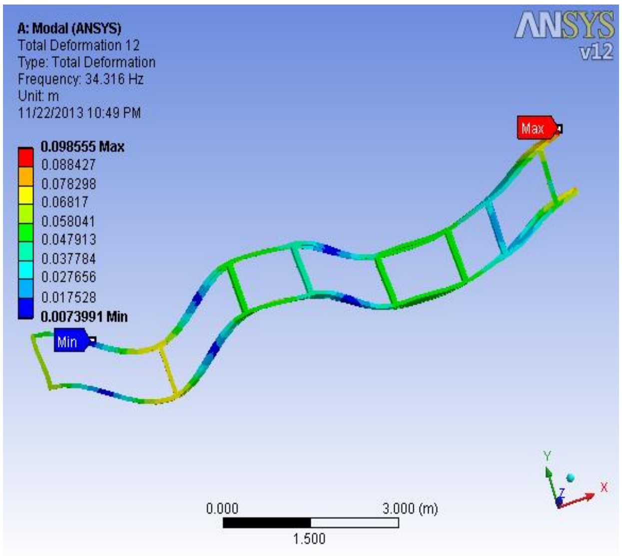
Sr No.	Mode no.	Frequency	Displacement
1	1	16.894	Twisting about X-axis
2	2	25.537	Bending about Y-axis
3	3	27.427	Deformation about X-axis and Bending about Y-axis
4	4	28.746	Twisting about X-axis &Bending about Y-axis
5	5	33.971	Twisting about X-axis
6	6	34.316	Deformation about X-axis and Bending about Y-axis
7	7	36.564	Deformation about X-axis and Y-axis
8	8	46.316	Deformation about X-axis

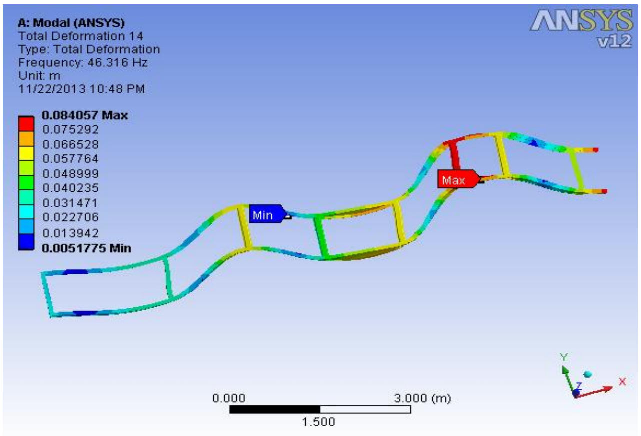
Mode Shapes Of Static Bending With Chassis Load:





Graph : Frequencies at different modes for Static Bending with Chassis Load Truck Chassis





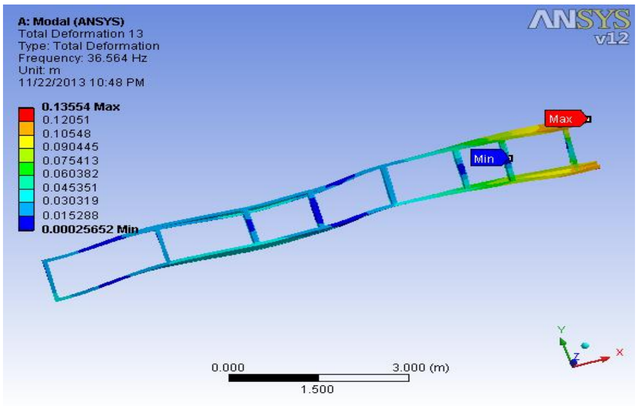


Figure: Different Mode Shape for Static Bending With Chassis Load of Truck Chassis.

Dynamic bending with chassis load

In this case the rear end is kept fixed and different loading and boundary conditions are applied as shown in the diagram given below. As the case is of bending it is assumed that the forces are acting at each side of the chassis in upward direction as the both wheels are experiencing sudden bump. In figure H and I denotes the forces which are acting in upward direction whereas remaining are the chassis load acting in the downward direction. A denote the fixed support. Then the analysis is made to find out different mode shapes and natural frequencies.

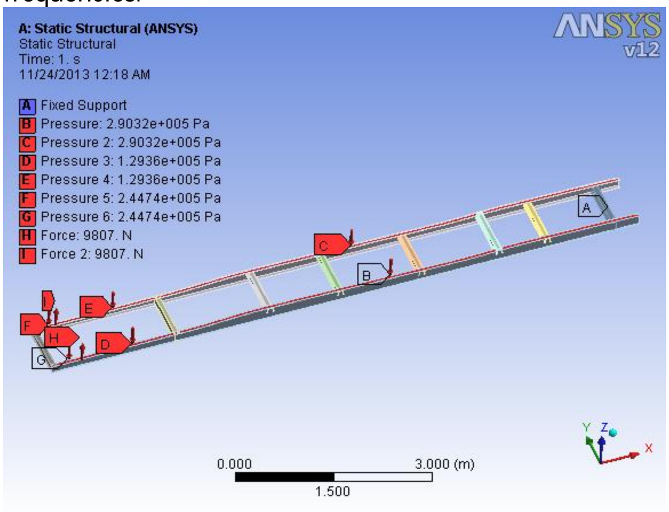


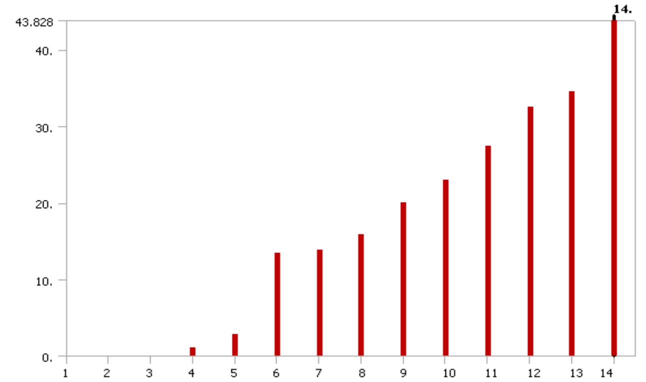
Fig: Loading and Boundary Condition For Dynamic Bending With Chassis Load of Truck Chassis.

There were eight natural frequencies calculated for the normal mode analysis and are tabulated in Table below. It is observed that all the natural frequencies varying from 13 Hz to 50 Hz.

Table: Mode shapes, Frequencies and displacement for Dynamic Bending With Chassis Load of Truck Chassis.

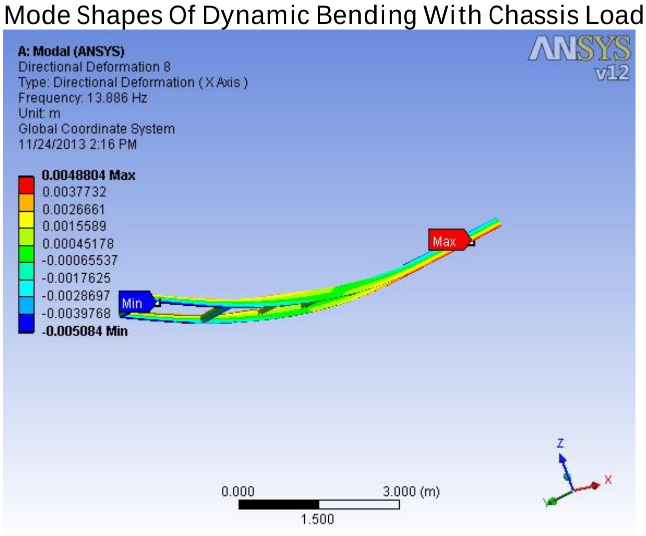
Sr No.	Mode no.	Frequency	Displacement
1	1	13.886	Twisting about X-axis
2	2	15.819	Bending about Y-axis
3	3	20.065	Deformation about X-axis and Bending about Y-axis
4	4	22.957	Twisting about X-axis &Bending about Y-axis
5	5	27.388	Twisting about X-axis
6	6	32.598	Deformation about X-axis andBending about Y-axis
7	7	34.601	Deformation about X-axis and Y-axis
8	8	43.828	Deformation about X-axis

Different mode shapes and their displacement natures are find out for the above frequencies.



Graph: Frequencies at different modes for dynamic bending With Chassis Load Truck Chassis

Mode Shapes Of Dynamic Bending With Chassis Load



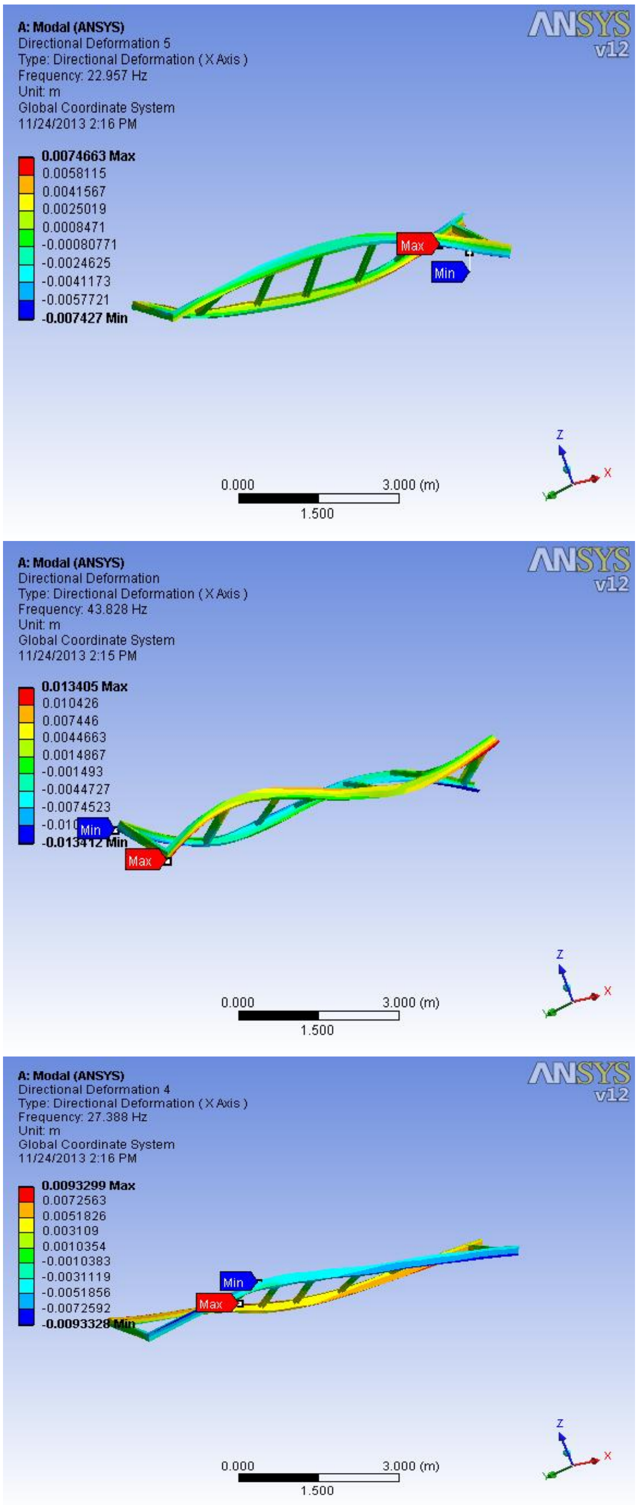
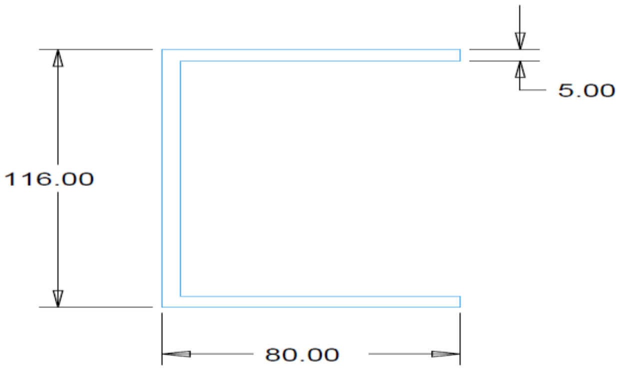


Figure: Different Mode Shape for Dynamic Bending With Chassis Load of Truck Chassis.

Shape optimisation of chassis

In the case of chassis we can reduce the weight of chassis frame by reducing its thickness, but it will increase the deflection as well as the shear stress. To omit this problem the sensitivity analysis will be helpful to reduce thickness of cross section of chassis frame.

Analytical Calculations cross bar



1) Area 1(a1) = 0.8x0.005 =4x10^-3 m^2
2)Area 2(a2) = 0.106x0.005 = 5.8x10^-4 m^2
Area 3(a3) = Area 1(a1)
3)d1 = 0.884length of cross member

Total volume of the cross member = 8.2212x10^-3 m^3

Total mass of 6 cross member = 6x64.53642 = 387.21 kg

Now, reducing the height of cross member in10 mm

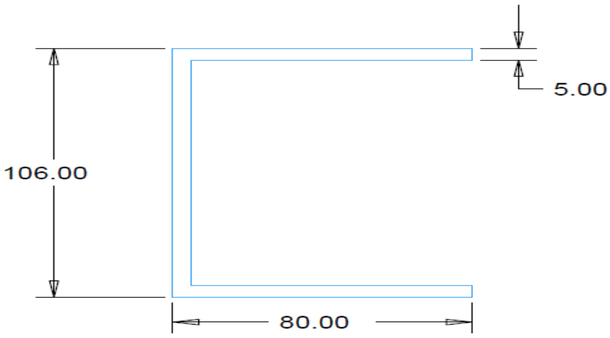


Figure: Reduced "C" Cross Member

The area a1 and a3 are same but the area a2 will change.

Results after Optimization in FEA:

Optimization of design has been achieved There has been considerable decrease in weight of chassis Optimization has been achieved by reducing the thickness of chassis C-section wherever less load is acting and where there are less deformations.

Results	
Original Mass	401.55 kg
Marginal Mass	1.3766 kg
Optimized Mass	366.76 kg

Results and discussion

Comparative Result for Shear Stress:

In static analysis shear stresses are important so that it is calculate by FEA and then compare with analytically. FEA value is 13.33% greater than analytical value; this difference may be occurred due to simplification in FEA modeling.

Table: Comparative Result for Shear Stress

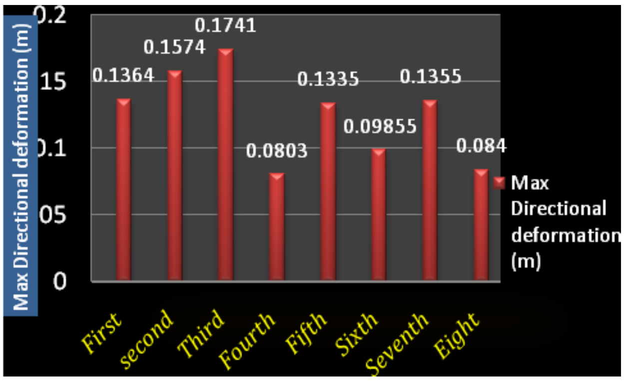
PARTICULAR	FEA	ANALYTICAL	DIFFERENCE
SHEAR STRESS	3805.2 (MPa)	3297.4(MPa)	13.33 (%)

MODEL ANALYSIS:

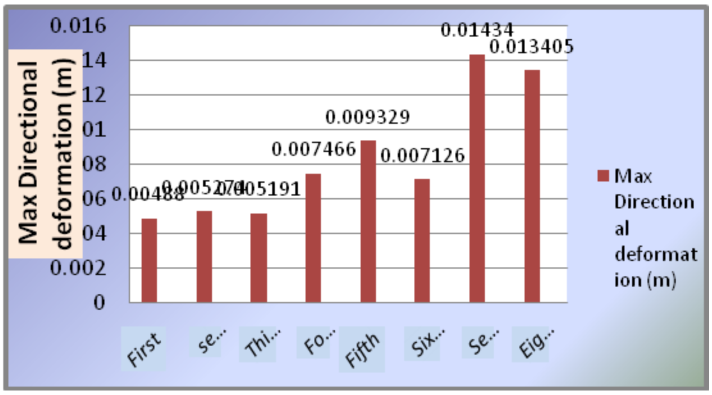
Table: Mode shape of static, dynamic bending with chassis load.

MODAL ANALYSIS

Mode Shape	STATIC BENDING WITH CHASSIS LOAD		DYNAMIC BENDING WITH CHASSIS LOAD	
	Frequency	Max Directional deformation (m)	Frequency	Max Directional deformation (m)
First	16.894	0.1364	13.886	0.00488
second	25.537	0.1574	15.819	0.00527
Third	27.427	0.1741	20.065	0.00519
Fourth	28.746	0.0803	22.957	0.00746
Fifth	33.971	0.1335	27.388	0.00932
Sixth	34.316	0.09855	32.598	0.00712
Seventh	36.564	0.1355	34.601	0.01434
Eight	46.316	0.084	43.828	0.01340



Graph: Mode shape Vs Max Directional deformation (m)for static bending with chassis load



Graph: Mode shape Vs Max Directional deformation (m)for Dynamic Bending With Chassis Load.

In Modal Analysis we can determine the total deformation of truck chassis frame at a different frequency range. From the above analysis results, the frequency range of Modal Analysis for Free-Free Condition is 16.89 Hz to 46.316Hz. Also frequency range of Modal analysis due to applied load on truck chassis is 13.886 Hz to 43.828.Hz (i.e. for Static Bending with Chassis Load).The Frequency range of both Modal Analysis for Free-Free Condition and Applied load on truck chassis are in the range 10 to 50 Hz. Almost all of the truck chassis designed were based on this frequency range to avoid resonance during operating conditions, so that the design of truck chassis is safe.

Comparative Results for Mass:

In the case of chassis we can reduce the weight of chassis frame by reducing its cross member height, the existing height of "C" section is 116mm and it is reduced by 10mm

Existing Height of "C" SECTION[mm]	Reduced height of "C"SECTION[mm]	Difference [%]	Existing weight of cross bar in FEA	Analytical Weight of cross bar	Optimize Mass by FEA	Optimize mass by analytical	Difference [%]
116	106	8.66	401.2	387.5	366.42	366.22	8.72

Conclusion

As conclusion, this study has achieved its core objectives.

In Static Analysis, we can determine highly stressed area of truck chassis due to applied load, and analytical shear stress is 13.33% less than FEA values.

In Modal Analysis we can determine the total deformation of truck chassis frame at a different frequency range. From the analysis results, the frequency range of Modal Analysis for Free-Free Condition is 16.89 Hz to 46.316Hz.

Also frequency range of Modal analysis due to applied

load on truck chassis is 13.886 Hz to 43.828.Hz (i.e. for Static Bending with Chassis Load).
The Frequency range of both modal analyses for Free-Free Condition and Applied load on truck chassis are in the range 10 to 50 Hz.
Almost all of the truck chassis designed were based on this frequency range to avoid resonance during operating conditions, so that the design of truck chassis is safe.
By reducing the height of the cross-member of chassis by 8.6%, the weight reduction of chassis is found to be reduced by 8.72%.

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