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Structural Analysis of Pick-Up Truck Chassis using Fem

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Abstract : One of the major components in vehicle system is the Truck chassis. Chassis acts as a base upon which various parts of the vehicle can be mounted. The most important requirement of any vehicle chassis is to provide good load-bearing characteristics along with less weight. In this research work, an attempt to investigate the static characteristics and also the fatigue life prediction of the chassis frame will be made. Static analysis involves determining the location in which maximum stress occurs and to evaluate torsional stiffness of the chassis frame. Torsional stiffness of the chassis frame was determined. Predicted values were validated with the results available in the literature and the maximum value of error was found to be 7.83%.Dynamic characteristics of the chassis frame were also evaluated to determine the natural frequencies and mode shapes.
Keywords : Truck Chassis, torsional stiffness, Modal Analysis, FEM.

Introduction

The automotive frame is subjected to different type of loads during in its life time , the two parameter that influence for the design of the chassis frame structural integrity and durability the various loads that frame can take Bending , Torsion , combined bending and torsion , lateral loading and fore and aft loading. There are different types of chassis frame used for automotive application they are broadly classified into Ladder frames , Cruciform frames , Torque tube backbone frame , Space frames and integral structures .In this paper we investigated the ladder chassis frame which is subjected to torsional loading[1] optimized the chassis of off road vehicle with appropriate dynamic and structural behavior ` taking into aspects ,they presented a methodology to measure the torsional stiffness of the chassis they conducted an experimental investigation in the chassis frame and validated with the finite element model results ,results showed that 6% increase in the total weight in the structure and 75%increase in the torsional stiffness than that of the original structure after the optimization.[2] conducted a study on ladder type chassis frame in that they analyzed three types of stiffness **i.e. Vertical stiffness, Lateral stiffness, Torsional stiffness** using the finite element analysis ,in this a truck model was modeled using a commercial CAD package PRO-E and preprocessed with the HYPER MESH and three stiffness was calculated further they have conducted the parametric study by changing the design variables that affects the stiffness the result showed that lower wheel base, optimum thickness ,narrow frame , larger section width and addition C section will have desirable effect on the truck[3] investigated the frame side member (FSM) which is subjected to the vertical loads (Bumps) ,a theoretical bending stress calculation was calculated and finite element modeling and numerical analysis was carried out using MSC NASTRAN and results were post processed with Altair/HYPERVIEW , the result showed that bending stresses are more in the FE modeling when compared with theoretical bending stress calculation this is due to the different section modulus used for both the numerical analysis and the theoretical calculation , in numerical analysis low section modulus used when compared with the theoretical stress calculation. [4] conducted a finite element analysis on a low ladder structure of a semitrailer ,they conducted the stress analysis in the structure the numerical results was compared with the analytical results there is difference between the analytical and numerical result this is due to geometry model of 3D is complex when compared with the simple 2D model for theoretical analysis[5] studied the stress analysis of truck chassis using ANSYS ,the truck chassis are usually made of C Section (side members) .The side members ,cross members and connection plate are connected through rivets a numerical analysis was studied by them the result showed that increasing in the thickness of the side member can reduce the stresses on the joint areas and to compensate the overall weight increase due to increase of the thickness local plate is used which will prevent the overall weight increase of the frame and it will reduce the stresses in the frame[6] conducted an experimental and a numerical analysis of the ladder chassis frame, torsional stiffness was calculated from the experimental procedure and compared with the numerical results which was carried out using ANSYS , modal analysis of the ladder frame was also experimentally conducted and compared with the numerical results obtained FEA analysis the results are good in agreement with the results obtained from experimental procedure. [7] studied the static and dynamic load characteristic of a truck chassis they conducted static and stress analysis in truck chassis in ANSYS and optimized the truck chassis and modal analysis was carried out to find the natural frequencies of the truck[8] investigated the structural strength of the ladder chassis frame used in agricultural truck agricultural trucks are subjected to bending and torsion so, these two deformation modes are investigated to investigate these modes one wheel ramp and two wheel ramp test was conduction and simulations was carried out using Finite element analysis both the experimental and the simulations results was compared for the validation good agreement was found in the lateral strain under torsional loading[9] investigated the ladder chassis frame LCV truck, After the comprehensive they made cost saving frame by deleting the box plate and tubular cross members and they compared the existing frame and cost saving frame the result showed that bending stiffness was increased to 9.15% when compared with the existing frame and torsional stiffness was on par with the existing frame

Numerical Simulation of Chassis

The objective of the numerical simulation is to evaluate the deflection of the chassis frame when subjected to torsion which in turn can be used to evaluate the torsional stiffness (q) of the chassis frame

The chassis frame structure was modelled using Solid Works 15.0 as per the dimensions given in the literature[6]. Chassis frame consists of side members and cross members. Side members are rectangular in shape and the cross members are tubular in shape. Designed model is then converted into parasolid format in solid works and it was imported to the ANSYS Workbench 15.0.

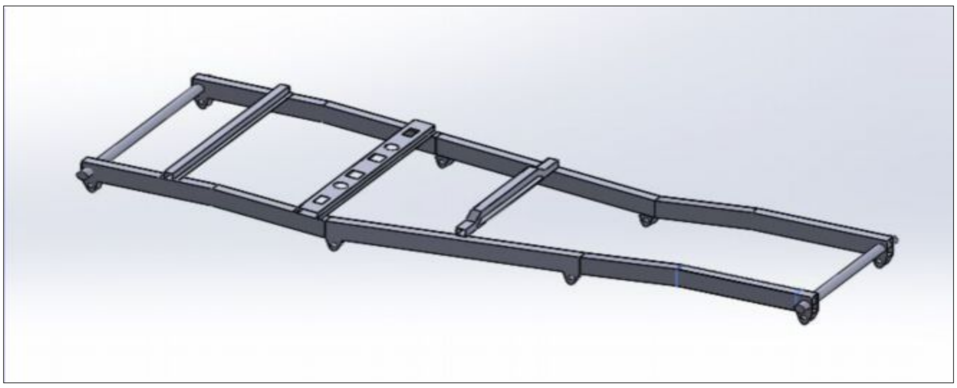


Figure.1 CAD Model of the Chassis Frame

In ANSYS WORBENCH 15.0 static structural analysis was selected to carry out further simulation study , the material and elemental properties of the chassis frame are listed below in a tabular column.

Table.1 Material Properties of the Chassis

Material	Structural Steel
Modulus of Elasticity	200GPa
Mass Density	7850 kg/m
Poisson's ratio	0.3

After specifying the material properties of the chassis frame, the frame was meshed using the tetrahedral mesh the faces of the frames was selected to give controlled sizing on them after specifying the sizing the entire frame was meshed the total nodes and elements are given below.

Total Nodes: 67,561

Total Elements: 32,856

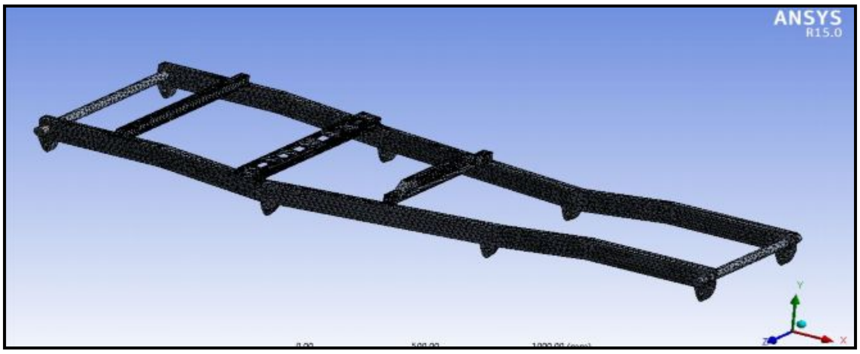


Figure.2 Meshed Model of the Chassis Frame.

The quality of mesh (Aspect ratio) was checked using the mesh metric in the workbench .

For evaluating the deflection of the frame under torsion conditions, the chassis was fixed at the rear end. Loads are applied on the front end of the frame in opposite directions of the magnitude 9807N. The current setup was then solved for deflection. The value of the deflection was found to be 48mm, the load setup case for the frame is given below.

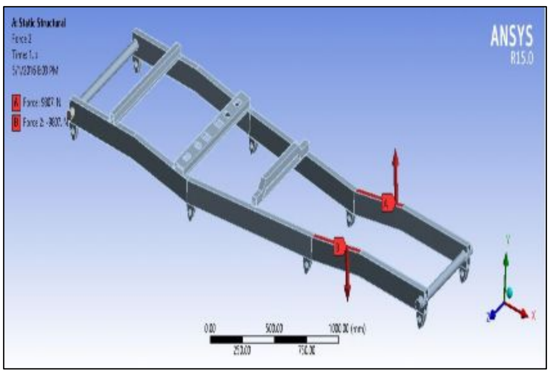


Figure.3 Load Case Setup in ANSYS

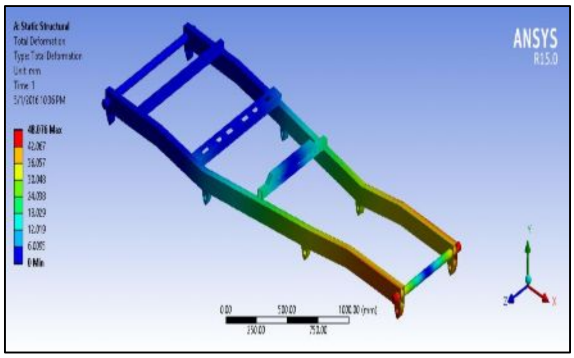


Figure.4 Total Deformation

The value of deflection evaluated from the FEM tool can be used to determine the torsional stiffness of the chassis frame.

Based on the experimental data available in the literature for the chassis frame, several parameters of the chassis frame are listed below.

Table.2 Parameters relating to Torsion Testing of Chassis

S.No	Parameter	Value (m)
1	L_f	0.65
2	L_s	0.65
3	L_t	0.91
4	δ	0.05
5	δ_d	0
6	δ_e	0
7	F_d& F_e	9807N

The values of $\delta_{d\ and}$ δ_e are zero because the chassis was fixed at the right and left sides at the back end of the frame.

Angle of twist (θ) of the structure was calculated using the relation,

$\theta_{twist} = \theta_f = 2\delta/L_f$
θ_{twist} =2*0.048/0.65
=0.1476rad

Torque (T) of the chassis was calculated using the following expression,

$T= [(F_d/2) + (F_e/2)]* L_s$
T=[(9807/2) + (9807/2)]*0.65
T=6374.32Nm

Torsional Stiffness (q) is defined as the ratio of the torque of the chassis frame to the angle of twist of the frame under torsional loading conditions.

q=T/θ
=6374.32/0.1476
=43186.45 Nm/radian

Validation of Results:

The value of torsional stiffness obtained from numerical simulation has been validated against the result available in the literature and the maximum value of error was found to be 7.83%.This shows that the result of numerical simulation agrees well with the literature[6].

Table.3 Validation of Results

Comparison	Torsional Stiffness(Nm/radian)	Maximum Deflection(mm)
Literature	40700	50
Numerical	43186.45	48
Error(%)	7.83	4

The chassis frame is further improved by incorporation of a X-type member in the already available chassis frame.X-type member with minimum thickness is embedded in the hollow side members to account for better characteristics of the chassis frame. Static tests were performed with the modified chassis frame as same as done at the start.

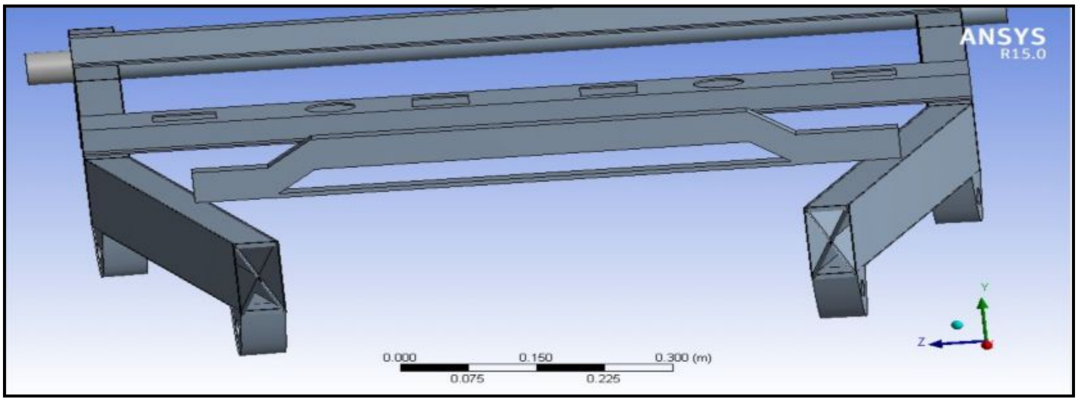


FIG.5. Model 7 Cut Section View of the X-Member Inside the Ladder Chassis

Boundary conditions are imposed on the chassis frame in the following manner. The rear end of the chassis frame is made as a fixed support whereas at the front end , force of the magnitude 9807N are applied in opposite directions.

Current setup is solved for deflection. Results show that, by the incorporating a new X-member within the side member of the chassis frame, overall deflection of the chassis frame is reduced. Value of deflection was measured to be 41mm.

The value of torsional stiffness is then calculated.

Angle of twist (θ) of the structure was calculated using the relation,

$\theta_{twist} = \theta_f = 2\delta/L_f$
$\theta_{twist} = 2*0.041/0.65$
$= 0.1261$rad

Torque (T) of the chassis was calculated using the following expression,

$T = [(F_d/2) + (F_e/2)]* L_s$
$T = [(9807/2) + (9807/2)]*0.65$
$T = 6374.32$Nm

Torsional Stiffness (q) is defined as the ratio of the torque of the chassis frame to the angle of twist of the frame under torsional loading conditions.

$q = T/\theta$
$= 6374.32/0.1261$
$= 50549.7224$ Nm/radian

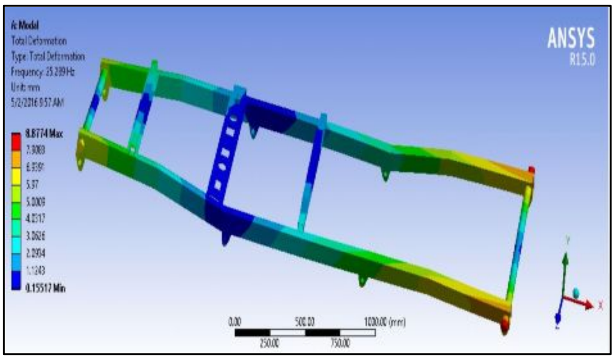
The value of torsional stiffness was found to be 50549.7224Nm/radian which is greater than the torsional stiffness of the root model as 43186.45 Nm/radian.

Table.4 Comparison of Torsional Stiffness before modification and after modification

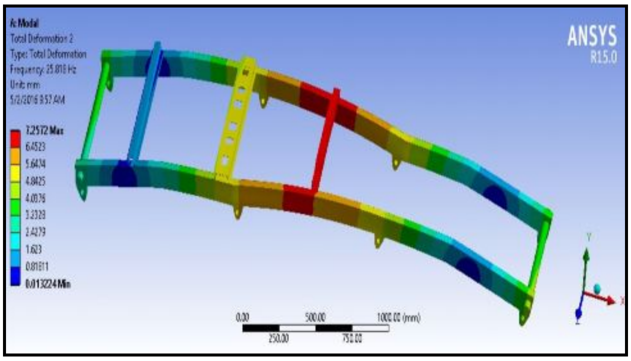
Models	Torsional Stiffness(Nm/radian)
Root Model	43186.45
Updated Model	50549.7224
Percentage (%)	+17.05

Modal Analysis

Modal Analysis of the chassis was also performed to evaluate the dynamic characteristics of the chassis. Free-free boundary condition has been imposed on the chassis to observe the behaviour of the chassis frame without any external load and forces . It means that front end and rear end of the chassis are not constrained. This boundary condition was selected to study the behaviour of the chassis while moving on extreme conditions such as bumpy roads and high gradient roads. Since the frequency range of the beam varies between 20Hz and 90Hz, these were the initial conditions applied on the FEM.



MODE 1



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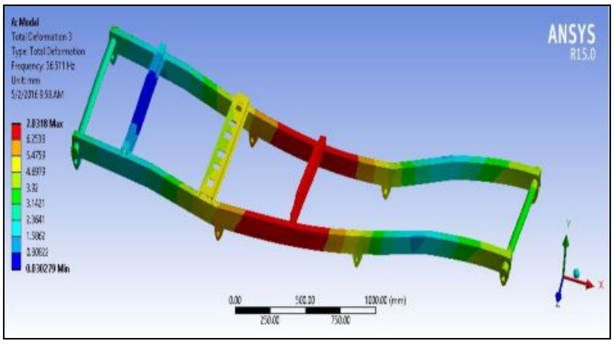
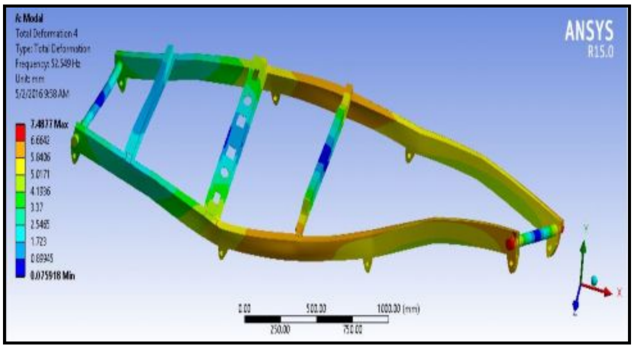
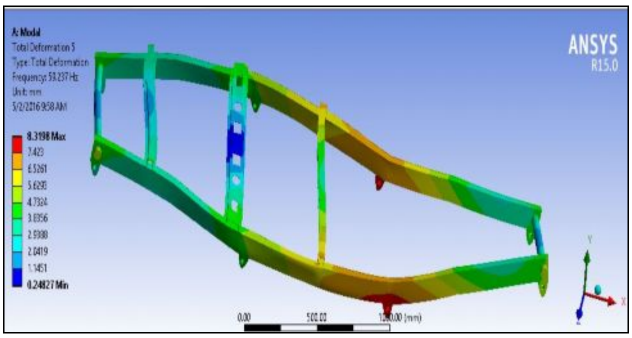


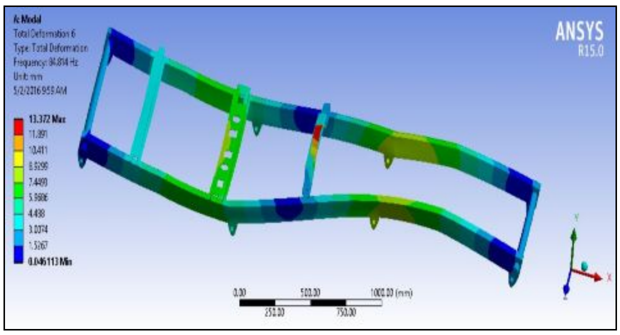
MODE.3



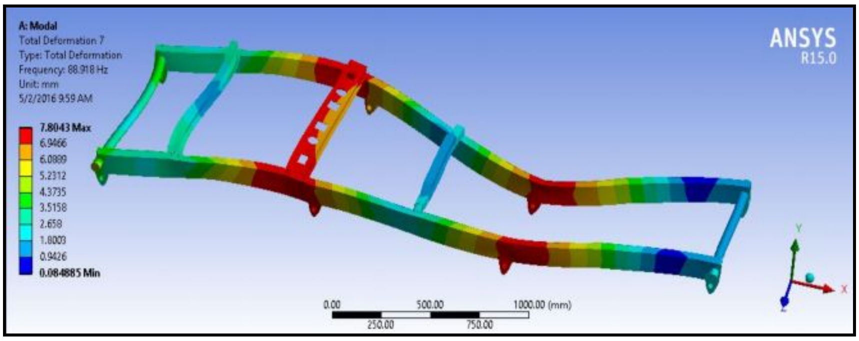
MODE.4



MODE.5



MODE.6



MODE.7

Table.5 Modal Analysis of Existing frame

Mode	Natural frequency (Hz)
1	25.289
2	25.818
3	36.511
4	52.549
5	59.237
6	84.814
7	88.918

Modal analysis of modified frame is also conducted and the results are shown in table.6

Table.6 Natural Frequencies of the Updated Frame

Mode	Natural frequency(Hz)	Percent variation of natural frequency from existing model
1	24.318	-3.839
2	28.658	-11.00
3	36.571	+0.16
4	50.81	-3.328
5	57.257	-3.768
6	83.944	-1.0257
7	85.621	-3.708

Results and Discussion

Finite Element Root model of the chassis was created which represents the real structure of the chassis in the ANSYS Workbench 15.0.After modelling , the finite element mesh of the structure was generated. Torsion analysis of the chassis frame was performed which showed a deflection of 48mm and then torsional stiffness of the structure was evaluated. Value of torsional stiffness was **43186.45 Nm/radian**. Results were validated against the results available in the literature and the maximum error was found to be 7.83% which is under acceptable limits .Design modification of the chassis frame was done by incorporating a X-type member within the side members. Torsion testing of the updated chassis frame yielded a deflection of 41mm which shows 14.5% less deformable than the root model under same loading conditions. Torsional stiffness of the chassis was calculated as **50549.72 Nm/radian** which is 17.05% stiffer than the root model of the chassis. Higher value of torsional stiffness is an indication of the better load carrying capability of the chassis and chassis is less flexible.

Conclusions

Structural analysis of the chassis frame has been conducted. Results show that the maximum value of deflection was found to be 48mm.With this value of deflection, the torsional stiffness of the chassis was evaluated and its value is 43186.45Nm/radian. This value was validated with the result available in the literature.

Design modification of the chassis frame was proposed by incorporating an X-type member within the side member and the deflection value is 41mm.This updated chassis is 14.5% less deformable compared to the actual chassis. Torsional stiffness of the updated chassis frame showed 17% improvement over the actual chassis. Dynamic characteristics of the chassis frame such as natural frequencies and mode shapes were determined. The scope for future work is to carry out a fatigue study of the chassis frame and determine the fatigue strength under cyclic loading conditions.

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