Finite Element Analysis of Automotive Truck Chassis

M D Vijayakumar1, C Ramesh Kannan2, S Manivannan3, J Vairamuthu4, Samuel Tilahun5 and P M Bupathi Ram6

1Department of Mechanical Engineering, Chennai Institute of Technology, Kundrathur, Chennai-600 069, Tamil Nadu, India.
2Department of Mechanical Engineering, PET Engineering College, Tirunelveli, Tamil Nadu, India.
3Department of Mechanical Engineering, Karpagam Academy of Higher Education, Coimbatore, Tamil Nadu, India.
4Department of Mechanical Engineering, Sethu Institute of Technology, Pulloor- 626 115, Kariapatti, Tamil Nadu, India.
5Department of Mechanical Engineering, School of Mechanical and Automotive Engineering, College of Engineering and Technology, Dilla University, Dilla, Ethiopia.
6Centre for Applied Research, Chennai Institute of Technology, Kundrathur, Chennai-600 069, Tamil Nadu, India.

*Corresponding author: vijayakumar.md@citchennai.net

Abstract. The transportation industries at present world play a chief role in field of current commercial economy and developed countries. The usage of trucks is intensely increasing to carry the loads and materials. To enterprise a truck chassis many features to be considered including material selection, packaging, strength-to-weight ratio, stiffness. This paper mostly reviews on most research works and focuses on stress study of the truck chassis using four Finite Element Analysis (FEA) namely ANSYS. The result of this research paper gives the researcher instantaneous solution on modern and present developments in truck chassis field using FEA.

1. Introduction

Chassis is one of the most widely used part in the industrial field. The automotive chassis is the most significant part of providing power and constancy to the vehicle when exposed to various conditions. The chassis support frame for any vehicle that holds the engine body, axle, and powertrain suspension system together. Tie bars are used as fastenings to tie all automobile parts. Ladder chassis is considered one of the oldest styles of automotive chassis. Because the stair chassis has excellent load-bearing capacity, they work in most commercial vehicles, along with most SUVs. The chassis’s high load-carrying capacity offers virtuous driving dynamics and great ride comfort. Therefore, the staircase is preferred over unibody and spine frames. The stair frame frames consist of longitudinal members called cross bars with cross members. The stair frames also serve as a bearing for spring huts with brackets to support the body and dumb iron. Chassis components can be attached to riveted joints, weld joints or bolts. To accommodate the spring action of the suspension system, the ladder frame is built up front and back. The frame is narrow to the front for better steering lock. The several cross sections used in frame construction include channels, boxes, caps, double channels and i-sections. Stress analysis is performed on the frame to find the critical point with maximum pressure.
The critical point is the critical factor that causes the fatigue failure of the chassis frame. Therefore, the life span of a fire truck chassis depends entirely on the size of the pressure. In this paper, model and static structural analysis is performed on the staircase. The investigation of the model involves determining the natural frequency and the mode size. Static Structural Analysis involves the identification of the maximum stress area and the rigidity. The chassis must be firm and strong to absorb vibration generated by the engine, suspension and drive line which is shown in figure 1. The most commonly used materials for the frame are steel and aluminium. However, carbon fibres have been found to be more beneficial than these conventional materials because carbon fibres have greater strength and rigidity and are also lighter in weight. They can be easily made in various shapes. The lightweight chassis reduces the vehicle's fuel consumption, thereby increasing its fuel efficiency. Therefore, an ultra-lightweight carbon fibre chassis is preferred to build chassis to increase the strength and stability of the vehicle.

![Ultra-light weight carbon fibre chassis](image)

*Figure 1.* Ultra-light weight carbon fibre chassis

The magnitude of the pressure can be used to estimate the lifespan of the truck chassis. The accuracy of the expected life of a truck chassis depends on the result of its stress analysis.

2. Experimental set up

Enchanting into account the relative aspects of the economic viability of an early small-scale product; we investigated and adapted a chassis design for an off-road vehicle with appropriate dynamic and structural behaviour. The design of the off-road vehicle chassis is optimized to reduce production costs by means of torsional rigidity, centre of gravity, overall weight of the structure, and general geometry. Investigated the behaviour of the chivanachakorn truss bridge, where an FRP deck replaced an old corrugated concrete deck, using an experimentally validated finite element (FE) model. The numerical results indicate that the fatigue life of the bridge after rehabilitation is more than double that of a reinforced concrete deck system. Based on the estimated truck traffic of the bridge, the FRP deck system has a range of stress in the infinite fatigue life regime, which implies that the fatigue failure of truss and floor systems is never expected in its service life.

We investigated the stability and fatigue behaviour of aluminium box-strainer / web frame connections using finite element analysis (FEA) to provide a connection solution that changes the cutting shapes in the web frame and consequently reduces the weld process. Get enough fatigue strength. FA-based fatigue has been used to determine the critical point of potential crack initiation and to assess life in the door hinge system.
In this study, the stress analysis of the static force loaded heavy duty truck chassis is investigated to determine the critical point of crack initiation as the primary data for assessing the fatigue life of this truck chassis.

3. Modelling of existing chassis frame
To further this study, the dimensions of the framework were assembled Tata 407 Fire Truck Model. The 3D model of the chassis is modelled on the PRO-E. To perform FA analysis of the chassis according to the standard procedure, first the connectivity is required for the assembly to be integrated and the loading and constraint applied; the idealization of the components is also done on the structure which leads to faster analysis. The linked structure is not physical, but it is a sketch with the mechanical properties of the mechanical structure. The existing main frame cross-section is shown in Figure 2.

Cross Section of Main Frame: h = 210 mm, b = 76 mm, t = 6 mm

![Figure 2. Existing main frame cross section](image)

The global vibrational characteristic of a vehicle is related to both its visual and mass distribution. Frequency functions of global bending and torsional vibration modes are generally used as benchmarks for vehicle construction performance. The rigidity of the bending and torsion affects the vibrational behaviour of the structure, especially its first natural frequency whose solid model of fire truck chassis is shown in Figure 3. The mode size of the truck chassis is important to determine the mounting point of parts such as the engine, suspension, transmission and more at certain natural frequency environments. Therefore it is important to include dynamic effects in the design of the chassis.
4. Analysis in ANSYS

Table 1. The Steel and Carbon fibre properties are represented to carry out the analysis

| Material Properties          | Steel     |
|------------------------------|-----------|
| Density (kg/m³)              | 7850      |
| Young’s modulus (MPa)        | 200000    |
| Poisson’s ratio              | 0.3       |
| Yield stress (MPa)           | 250       |

Finite element analysis is carried out on ANSYS workbench to catch equivalent stress, extreme elastic strain and whole deformation with the meshed model in Figure 4.
Figure 4. Meshed model

In this analysis under loading conditions, static forces are applied as loads on the chassis model as shown in Figure 5.

Figure 5. After applying the boundary conditions

5. Results and analysis

5.1. Modal Analysis of truck chassis steel

Boundary conditions are only provided as fixed support for the model analysis of frames. There is no need to give other boundary conditions such as loading and acceleration due to gravity. Model analysis is performed on structural steel and the mode shape is obtained as shown below.

Figure 6. Total deformation of steel chassis frame
Figure 7. Equivalent von Mises elastic strain of steel chassis frame

Figure 8. Equivalent von Mises stress of steel chassis frame
Figure 9. Directional deformation - x axis of steel chassis frame

Figure 10. Directional deformation - y axis of steel chassis frame

Figure 11. Directional deformation - z axis of steel chassis frame
The steel frame was observed to be 144.7 MPa, the extreme stress attained from the analysis of the composite module, which are fewer than the yield strength of the material of 250 MPa. Therefore the design is secure. The extreme total deformation standards of the acquired steel frame are 4.8 mm, respectively, much lower than the deformation limit of the material. But a weight of 456 kg was observed.

5.2. Modal Analysis of truck chassis Carbon fibre

![Figure 12. Total deformation of carbon fibre chassis frame](image)

![Figure 13. Equivalent von-Mises elastic strain of carbon fibre chassis frame](image)
Figure 14. Equivalent von-Mises stress of carbon fibre chassis frame

Figure 15. Directional deformation- x axis of carbon fibre chassis frame
The maximum pressure obtained from the analysis of the carbon fibre chassis composite component is 144.41 MPa, which is lesser than the yield strength of the 200 MPa material. Therefore, the design is secure. The determined total deformation ethics of the achieved carbon fibre chassis are 5.1 mm, respectively, which is much lower than the deformation limit of the material. The table 2. Represents the parameters involved in designing of Chassis frame.

| PARAMETERS                  | STEEL    | CARBON FIBER   |
|-----------------------------|----------|----------------|
| Directional Deformation     |          |                |
| X Axis                      | 4.1799   | 4.4332         |
| Y Axis                      | 2.3966   | 2.5498         |
| Z Axis                      | .060465  | .063553        |
| Total Deformation (mm)      | 4.8253   | 5.1217         |
| Equivalent Stress (MPa)     | 144.66   | 144.41         |
| Equivalent Elastic Strain (mm/mm) | .00072332 | .00076006 |
| MASS                        | 456.9 kg | 91.379 kg     |

6. Conclusion
Model enquiry and stationary mechanical study were carried out on the truck's Tata 407 staircase. From the above results for steel and carbon fiber the maximum shear stress, maximum equal stress and displacement is equal to that of steel. The weight of the product in the automobile industry is a major factor for design and the stress values of carbon fiber are within acceptable limits. Carbon fiber is therefore suitable as a chassis material for vehicles due to its high strength and light weight. For the same load-carrying capacity, carbon fibers are better than steel for building ladder frames, as this reduces the chassis frame by 80% and increases the rigidity of the chassis frame. To conclude, by prodigious FEM software we can optimize the frame weight and conclude that it is suitable for chassis construction.

7. Reference
[1] Chandra M. R., Sreenivasulu S., Hussain S. A., Modeling and Structural Analysis of Heavy Vehicle Chassis Made of Polymeric Composite Material by Three Different Cross
Sections, International Journal of Modern Engineering. Research, Volume 2, Issue 4, July-Aug. 2012, ISSN: 2249-6645.

[2] Juvvi Siva Nagaraju, U. Hari Babu, Design And Structural Analysis Of Heavy Vehicle Chassis Frame Made Of Composite Material By Varying Reinforcement Angles Of Layers, International Journal of Advanced Engineering Research and Studies, Volume 1, Issue 2, January March 2012, ISSN: 2249-8974

[3] Tulasiram N., Charyulu T. N., Design and Analysis of Vehicle Chassis Frame, Indian Streams Research Journal, Volume 2, Issue 7, August 2012, ISSN: 2230-7850.

[4] Seshu P., Textbook of Finite Element Analysis (PHI Learning Pvt. Ltd., May 2009, ISBN: 97881-203-23155).

[5] Patel T. M., Dr. Bhatt M. G. and Patel H. K., Analysis and Validation of Eicher 11.10 Chassis Frame using ANSYS, International Journal Of Emerging Trends And Technology in Comp. Science (IJETTCS), Volume 2, Issue 2, March – April 2013, ISSN 2278-6856.

[6] Patel V. V. and R. I. Patel, “Structural Analysis of a Ladder Chassis Frame” World Journal of Science and Technology, 2012, 2(4):05-08, ISSN: 2231-2587.

[7] Stress analysis of a truck chassis with riveted joints by Cicek Karaoglu*, N. Sefa Kuralay, Department of Mechanical Engineering, DEU Faculty of Engineering, 35100 Bornova, Izmir, Turkey, Finite Elements in Analysis and Design 38 (2002) 1115–1130

[8] TRUCK CHASSIS STRUCTURAL THICKNESS OPTIMIZATION WITH THE HELP OF FINITE ELEMENT TECHNIQUE I. Kutay YILMAZÇOBAN*, Yaşar KAHRAMAN, TOJSAT : The Online Journal of Science and Technology - July 2011, Volume 1, Issue 3

[9] Stress analysis of heavy duty truck chassis as a preliminary data for its fatigue life prediction using FEM. Roslan Abd Rahman, Mohd Nasir Tamin, Ojo Kurdi* Jurnal Mekanikal December 2008, No. 26, 76 - 85