

Truck Chassis Frequency Analysis with Different Simulation Conditions

Dr. Prashanth A.S, Amith Kumar S N, Dr. Vishwanth M, Dr. T N Raju

Dept of Mechanical Engineering,
Dr. Ambedkar Institute of Technology, Bengaluru, India

Abstract- The chassis of a truck is the backbone of the vehicle, incorporating the majority of component systems such as axles, suspension, gearing, cab and trailer, and is typically subjected to the load of the cabin, its contents, and inertia forces induced by rough road surfaces, among other things (i.e. static, dynamic and cyclic loading). In fatigue research and component life prediction, strain analysis is critical for determining the best stress point, also known as the juncture that leads to likely failure. One of the causes that contributes to fatigue loss is this juncture

Index Terms- High strength, CATIA V5, ANSYS workbench

I. INTRODUCTION



Fig 1: Heavy Truck



Fig 2: Schematic sketch of Chassis

The foundation of automotive chassis design has two aims.

- Support the components' load (weight).
- When moving condition, to assemble the suspension components in a rigid manner

The first item is a simple design solution that also served as inspiration for the first chassis designs, which were based on horse-drawn carriages. An I-Beam, a box tube, or a C-Beam is one of the most efficient shapes for following point loads fixed at two ends. A floor can be added with one beam on each side, and even the least I or C beams can carry a lot of weight.

Key Points of Chassis Design

- Shift the mass away from the neutral axis.
- In general, the thin-walled tube is the safest.
- Wall buckling is a problem that needs to be addressed.
- An issue with doors and windows.

Consider the vehicle's suspension points before worrying about the frame. Designing an optimal suspension for the appliance after the frame has been built can make construction impractical or impossible to fulfil the specifications. Suspension and all chassis requirements would necessitate a significant amount of compromise. We'll just look at the "Double Wishbone" suspension in this article

The chassis of a truck is the vehicle's foundation, containing the majority of component systems such as axles, suspension, gearing, cab and trailer, and is normally subjected to the cabin's load, as well as inertia forces caused by rough road surfaces, among other items (i.e. static, dynamic and cyclic loading).

In fatigue research and component life prediction, strain analysis is critical for determining the best stress point, also known as the juncture that leads to likely failure. One of the causes that contributes to fatigue loss is this juncture.

The magnitude of the strain are often wont to predict the lifetime of the chassis. The location of the critical stress point is critical in order to assess and optimize the mounting of components such as the engine, suspension, transmission, and others..

2. Lemans Testing

In LeMans research, a 75kg dummy was loaded to the category's prescribed weight with an additional 150kg and an impression velocity of 14 m/s. The maximum deceleration during the test should be no more than 25g. The survival cell should be unharmed structurally. It also specifies the dissipation of impact energy for LMP1 (102.9kJ) and LMP2 (95.55kJ). This knowledge is frequently used to assess whether the attenuator is strong enough to withstand other types of testing.

3. Static Tests

Formula One Testing

Formula One technical regulations stipulate that the specified load must be applied in less than 3 minutes and kept for 30 seconds. The load is released, and any failure is described as a permanent deflection of more than 1.00mm, which is the failure scenario in most cases.

Roll Structure Testing

All cars must have two roll structures, according to Article 15.2 of the F1 Technical Regulations, titled "Roll structures". The rear must be at least 94cm above ground level and 3cm behind the cockpit opening, while the front cannot be more than 25cm ahead of the steering wheel. The steering wheel must be below 5cm and the driver's helmet must be 7cm perpendicular to the line that connects these two lines. The main roll structure is subjected to a 50000N lateral, 60000N longitudinal, and 90000N vertical downward load on a 20cm diameter pad perpendicular to the loaded axis.

Survival Cell Side Tests

There are three different tests to take. In the first test, a 10cm x 30cm (W x H) pad conforms to the outline of the survival cell. When a 25000N force is applied laterally to squeeze the structure, it should be placed on a vertical plane that passes across the fuel tank's center line, with the bottom at the survival cell's lower edge in the other side, an equivalent pad can be used as a fixed support.

Fuel tank Floor Test

During the fuel tank floor inspection, a 20cm pad is mounted in the center of the fuel tank and a 12500N force is applied. There are no clear supports mentioned, so this is presumed to be at the tester's discretion. Failure is described as a permanent deformation of more than 1.00mm. This is a useful test for determining the protection of a fuel tank, and it's simple to duplicate. It might need to be tweaked to simulate particular chassis types.

Cockpit Rim Test

A 15000N force was applied to two 10cm diameter pads mounted 25cm forward of the cockpit's rear edge. Failure is described as a deflection of 20mm during loading or a permanent deflection of 1.00mm. This is also a successful

measure for evaluating the safety of the occupants. Also in a completely triangulated frame, this will place challenging bending loads on the safety framework that a chassis will struggle to handle. If the cockpit entry area differs substantially from that of a Formula One cockpit, the test may need to be changed.

Nose Push off Test

The survival cell is protected in such a way that the nose's strength is not harmed. On the impact attenuator, 55cm forward of the front wheel axis, a 40000N load is applied to a 10cm x 30cm (W x H) pad. Failure is described as any structural deformation greater than 1mm after the force has been released.

Side Intrusion Test

In the side intrusion test, a 50cm x 50cm At a pace of 2mm per second, the test panel is truncated with a cone until it has displaced 15cm.

The load should be greater than 250000N and the energy consumed should be greater than 6000 joules within the first 10cm. To pass this test, there should be no structural defect at the fixture edges. This is a good test for intrusion resistance, but it's difficult to replicate, and even then, accurate wall design skills are needed.

Rear Impact Structure Push off Test

The rear drivetrain, including the gearbox and engine, is connected to the survival cell and kept in place so that the cell's strength is not increased.

A 40000N force was applied to a 10cm x 30cm pad 40cm behind the axle to the rear impact structure, with identical failure conditions of 1.00mm of permanent deflection after forces were released, as was the case within the nose push off test.

Side Impact Structure Push off Test

As 20000N horizontal loads are added to a ball jointed pad measuring 55cm x 10cm (h x w) 60cm from the car's centerline line, the survival cell must be fixed to a flat plate.

The pad center should be 30cm above the ground as the reference plane. Forward and backward force must be applied. 60cm from the car's centerline and 500mm forward of the cockpit entrance, through a pad measuring 40cm x 10cm (L x W).

4. Types of Frame Structures

Ladder Frame

Two long beams that run the length of the vehicle and were originally designed to carry a carriage. This type of chassis could be exemplified by body on frame architecture.

Space Frame

A nodal triangulated truss network that distributes all loads axially to ensure that no part of the frame experiences greater bending forces. The Countess, like most Formula SAE chassis, is a good example of this type of chassis.

Audi Aluminum Space Frame

A technique that blends mass-produced monocoque design with wide-section aluminum members. The Audi R8 or the Lamborghini Gallardo may be an exemplar of this sort of chassis.

Skinned Space Frame

Instead of triangulating all participants, a sheet of metal is welded or riveted to the earth. Inside the tensile directions, this functions as a multi directional axial member. Because of its easy buckling, it offers little compressive resistance, but due to the nature of the space frame construction, one primary direction is normally in stress.

5. Ladder Frame

Ladder Frame Design: An Overview

The easiest and oldest frame in modern vehicle construction is the ladder frame. It was originally modified from "horse and buggy" type carriages because it had enough strength to support the components' weight. Larger beams could be used if a higher weight holding capacity was needed. It was made up of two long beams that run the length of the truck.

Ladder Frame torsional rigidity

The frame rails of a ladder are held together by a series of cross-linked members. A simple design of two rails connected by an easy distance, simulated, demonstrates how a ladder frame can aid in performance auto design. Using Aluminum, in order that a basis of comparison are often made to other chassis during this book.

X bracing

Braces were used between the edges of several cars at the time. Is there a significant increase in the ladder chassis' power as a result of this? Actually, it does, but first let's have a look at what's going on. As torque is applied to a ladder chassis, each beam is deflected separately.

6. Space Frame

Introduction to Space Frame Design

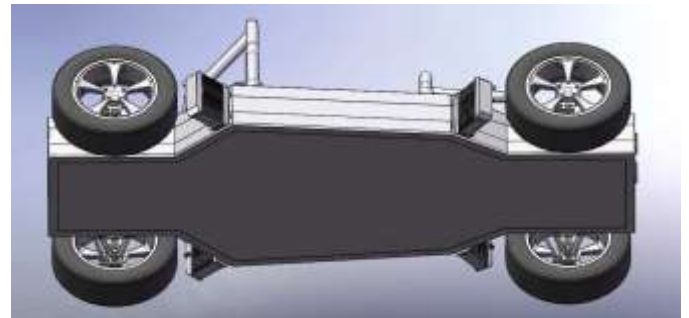
Considered to be one among the simplest chassis methods which will yield excellent results for torsional rigidity, weight holding, and impact protection it's also simple to style and only moderate in difficulty to create. This makes it ideal for a variety of uses, including Formula SAE racing, project cars, and even low-volume sports cars.

Audi Aluminum Space Frame

Audi's Aluminum space frames, shown in Figure 6.2, fall somewhere between a monologue and an area frame. It does not have to adhere to the same guidelines as the majority of space frames, such as absolute triangulation and no bending moments on any beams. In reality, if you look at the Audi R8 chassis, you'll find that the suspension points are subjected to a lot of bending forces.

Skinned Space Frame

Skinned space frame may be a technique that's wont to transition from space frame to monologue. It's exactly because it sounds. The sheet skin is welded or riveted on top of the tubular space frame. This makes it very simple to incorporate content far away from the neutral axis. At the cost of weight, advancements in torsional stiffness are frequently made.



7. Literature Survey

S. Prabakaran and K. Gunasekar [1]; has investigated the EICHER E2 (or 11.10) Chassis Frame's structural analysis for the current C-section. They first determined Using SOLID WORKS and ANSYS Software, we calculated the assembly weight, maximum shear stress, maximum equal stress, and displacement for the prevailing C-section of chassis, and then adjusted the prevailing C-section in three separate cases to decide the parameters for all cases.

B. RamanaNaik and C. Shashikanth [2]; have objective to analyse an automobile chassis for a ten tonne vehicle. The modelling is completed using Pro-E, and analysis is completed using ANSYS. The stresses and deflections of the chassis overhangs are calculated analytically and compared to measurement tool results.

Kamlesh Y. Patil and Eknath R. Deore [3]; has investigated the TATA 912 Diesel Bus Ladder Chassis frame, and as a result, a model of the chassis was developed in Pro-E and analyzed with ANSYS for various cross sections under the same load conditions.

Sharma et al [4]; have investigated the frame of a significant vehicle, the TATA LPS 2515 EX, with three

different alloys subjected to steel chassis conditions. Grey forged iron, AISI4130 steel, and ASTM A710 STEEL GRADE A are the three materials used for the chassis. Three separate cross-sections are used to model the three different vehicle chassis. Cross parts of the C, I, and Box types, to be specific. The CAE programed CATIA V5 parametric included a 3 dimensional solid model, so the analysis was omitted.

Lenin et al [5]; modelled a chassis utilized in a TATA ACE using CATIA. Structural and modal analyses are done on chassis using ANSYS. The analysis is completed using three materials forged iron, Aluminum and E-GLASS EPOXY. The strain values for Glass Epoxy and E –Glass Epoxy are just their respective permissible stress values, as determined by structural analysis results. As a result, using composites for chassis is risk-free.

**1. Geometric Model
 Dimensions of the Model**

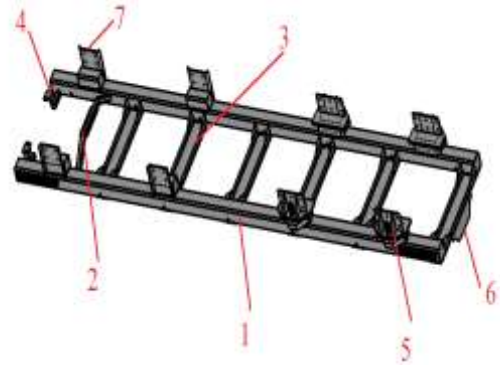


Fig 4: Major Parts Numbering

II. STEPS OF ALGORITHM TO WORK

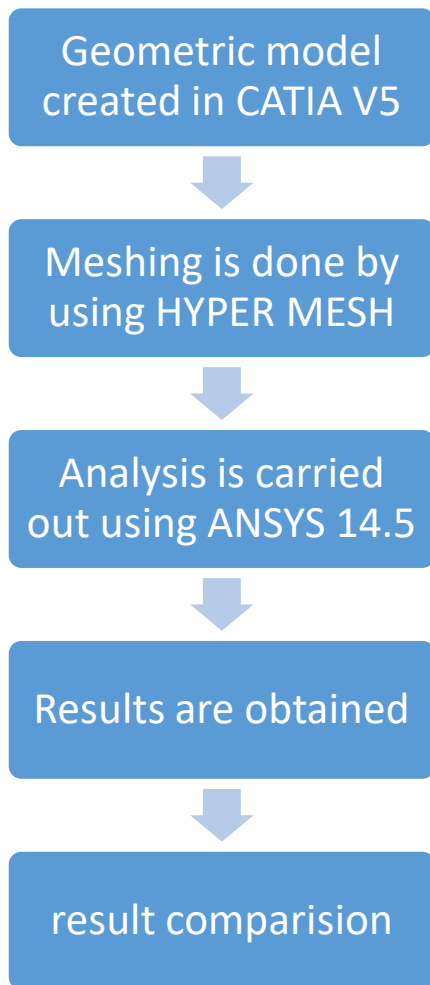


Fig 3: Flow chart of methodology

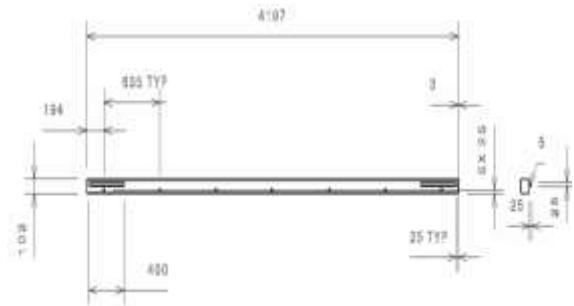


Fig 5: Dimensional details of Part 1

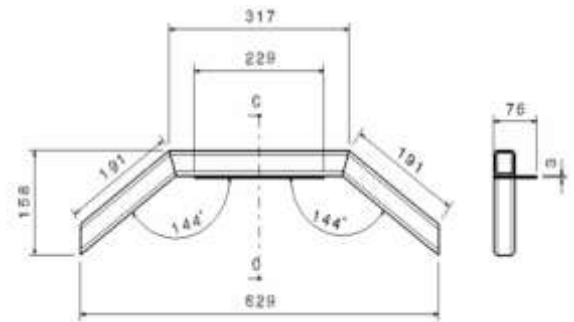


Fig 6: Part2 Dimensions

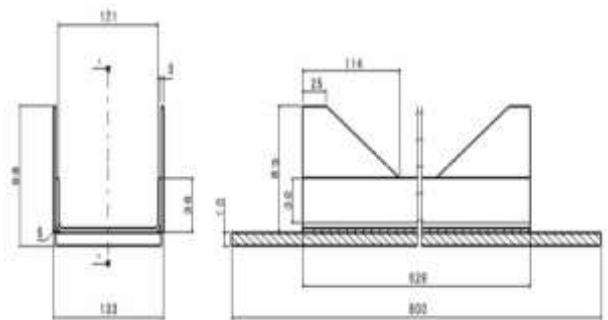


Fig 7: Part 3 Dimensions

III. RESULT AND DISCUSSION

1. Structural Analysis

Trucks are the most common type of goods transportation. Due to heavy load on the structure, speed limits are applied on the trucks during road curvatures. The trucks are subjected to heavy bending loads and torsion loads during turnings. The trucks are subjected to various types of loads depending on road conditions. Humps create an impact on the chassis structure. So proper design all possible load conditions should be considered for chassis design. The following loading conditions are considered for the structural analysis using Ansys.

Case 1: Self Weight analysis

Case 2: Normal running condition (Bending Case)

Case 3: One wheel of rear axle on hump and other on ground. (Bending and Torsion)

Self Weight Analysis

Self-weight analysis is carried out to check the structural strength under normal conditions. The geometry is modelled in meters to get correct results for self-weight. Density and acceleration due to gravity is applied on the structure for self-weight results. The results are as follows.

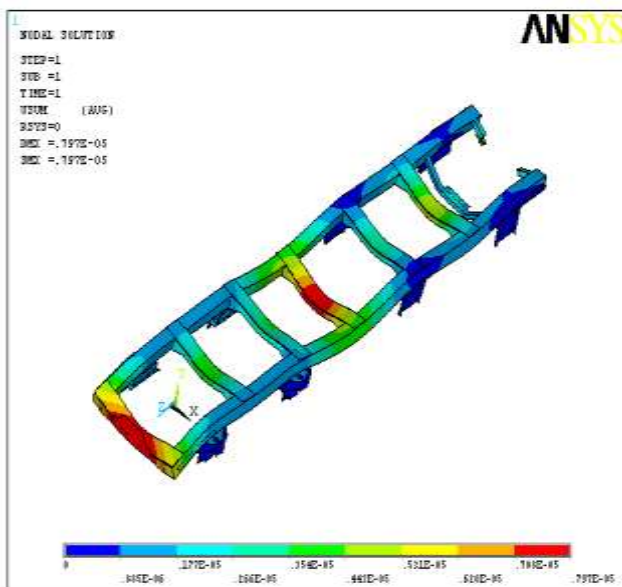


Fig 14: Deflection takes under self-weight

The deflection results shows deflection value of 7.97microns under self-weight. Maximum deflection is observed at the end geometry and at the center of central connection plate. The various colors shows displacement pattern in the structure.

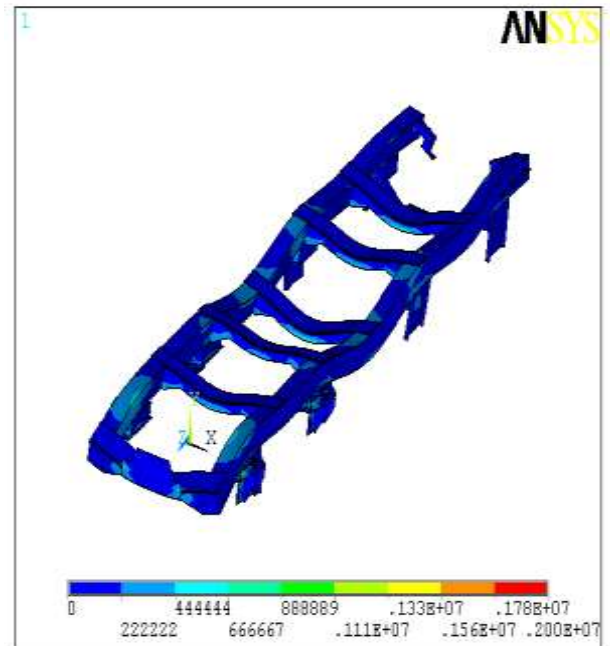


Fig 15: von-misses Stress plot

The figure3.2 shows von-misses stress development in the structure due to self-weight. The results shows maximum stress development of 2Mpa as shown in the status bar below the plot. The red color shows the maximum stress location. These stress values are much below the allowable stress of the structure. So self-weight deflection and stresses are both in the negligible conditions. So the chassis structure need to be checked for original stress conditions arising at the time of operation.

Normal Running Conditions

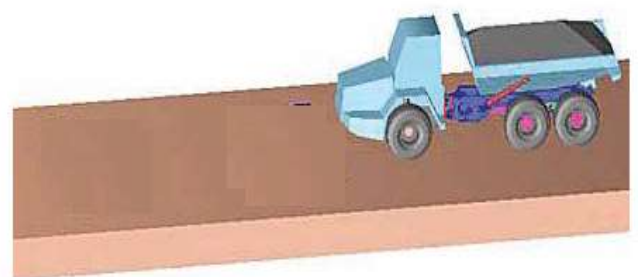


Fig 16: Normal Running Condition

The chassis structure is checked for 15 tons load during the operational conditions along with the self-weight of the member. The load is applied as uniformly distributed load on the longitudinal beams. The results are as follows.

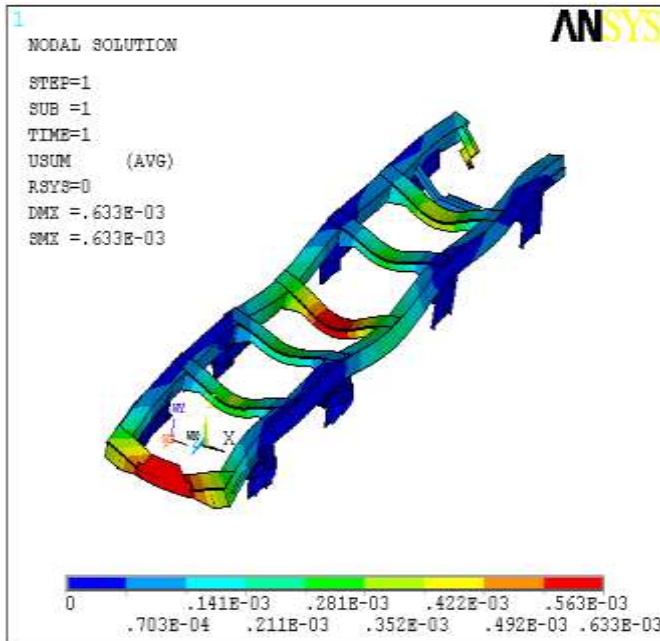


Fig 17: Deflection plot

The figure 3.4 shows developed deflection in the structure. Maximum deflection is 0.633e-3m or 0.633mm as shown by red color region. At the support regions displacements are zero and away from support regions, higher displacement can be observed. Cantilever and simply supported conditions can be inter-predated for the regions of higher displacements.

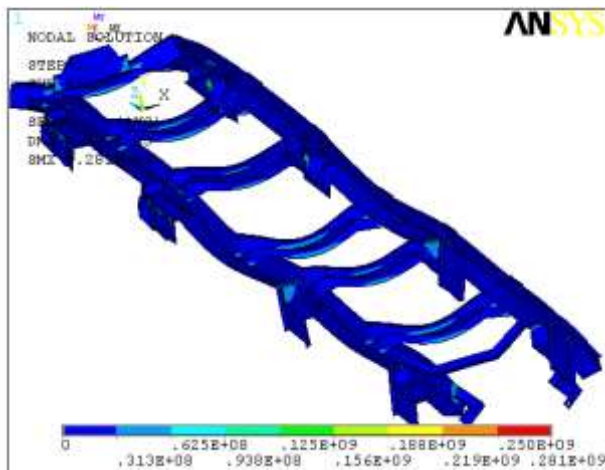


Fig 18: Von-misses stress conditions during fully loaded condition

The figure3.5 shows von-misses stress in the structure during fully loaded condition. Maximum stress development is around 281Mpa.This stress is a smaller amount than the allowable stress of the chassis material. So structure is safe for the normal running conditions.

.Back side left side wheel on hump

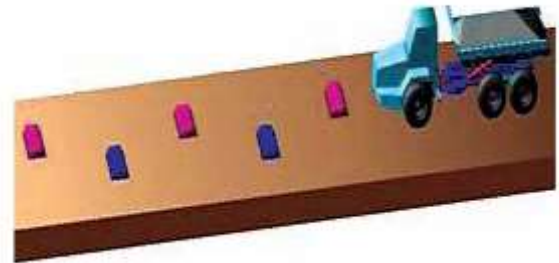


Fig 19: One Wheel on hump

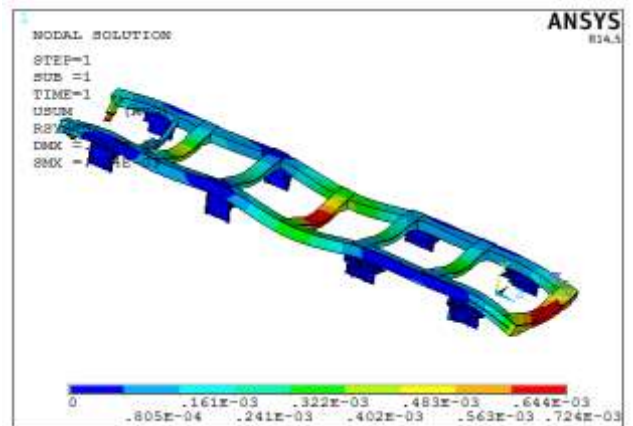


Fig: 20: Overall displacement plot (Maximum displacement: 0.724mm)

The figure 3.17 Overall Displacement Plot on the one wheel on hump. The maximum displacement is .724E-03 or 0.724mm as showing red in color. At the support region displacement are zero and other end displacement is high.

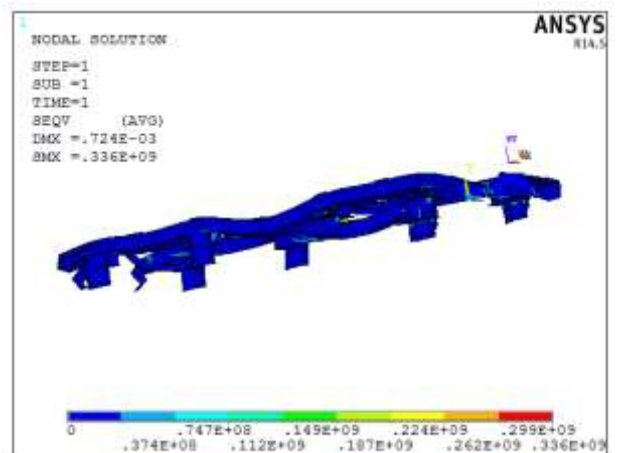


Fig: 21: Overall Stress in the structure (Maximum stress: 336Mpa)

The figure 3.8 Overall Stress in the structure of the one wheel on hump. The maximum stress is .336E+09 or 336Mpa as showing red in color.

2. Graphical Representation of the Structural Analysis

Deflection v/s self-weight, normal running condition, one wheel of rear axle on hump and other on ground.

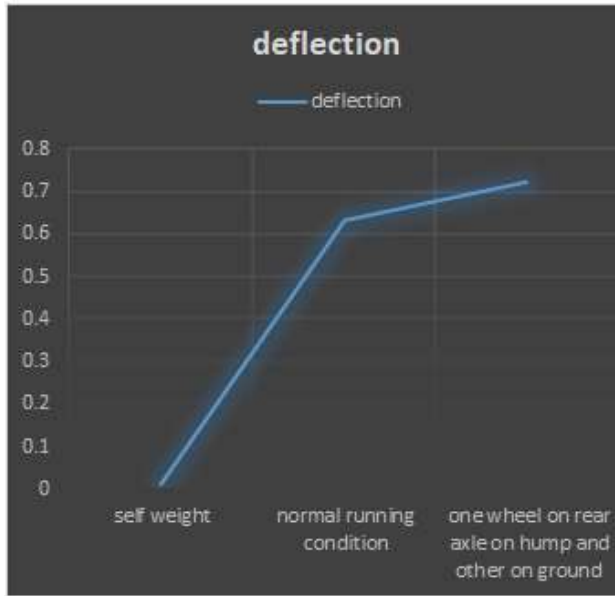


Fig 22: Deflection v/s cases of structural analysis

Von misses stress v/s self-weight, normal running condition, one wheel of rear axle on hump and other on ground.



Fig 23: Von misses stress v/s cases of structural analysis

3. LS-Dyna Simulation Results

LS-Dyna simulation is used to find the structural behavior of the members.

A free analysis is carried out to find the modal nature of the problem. The modal frequencies and corresponding mode shapes are as follows. The modal analysis is carried out to check the resonance condition of the problem. This gives prior estimates of resonant modes of the structure. Resonance is the most undesirable feature in the machine structures.

Mode 1

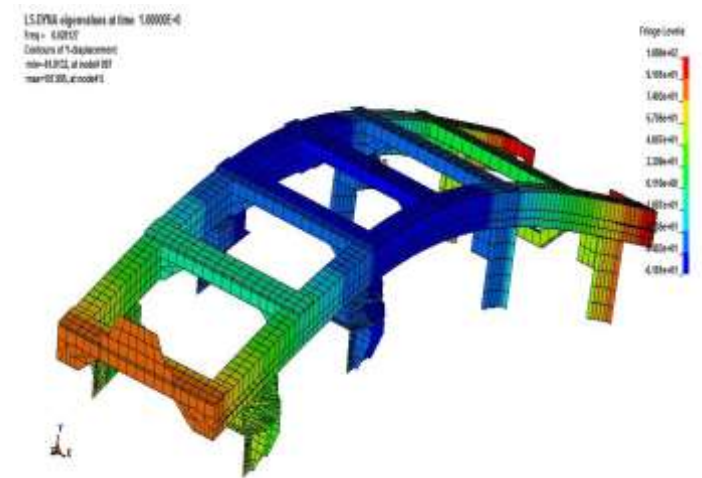


Fig 24: Mode Shape for Frequency (0.028127Hz)

Figure shows the Mode shape of truck chassis having natural frequency 0.028127Hz. The maximum deformation is 107.995mm, showing red in colour and minimum deformation is -61.8132mm.

Mode 2

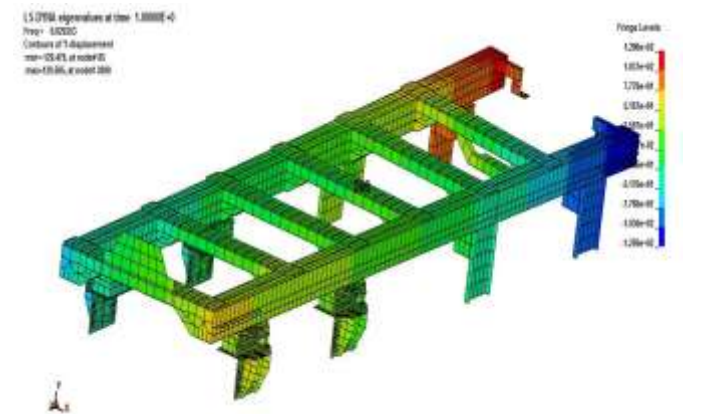


Fig 25: Mode Shape for Frequency (0.029253Hz)

Figure shows the Mode shape of truck chassis having natural frequency 0.029253Hz. The maximum deformation is 129.595mm, showing red in color and minimum deformation is -129.479mm.

Mode 3

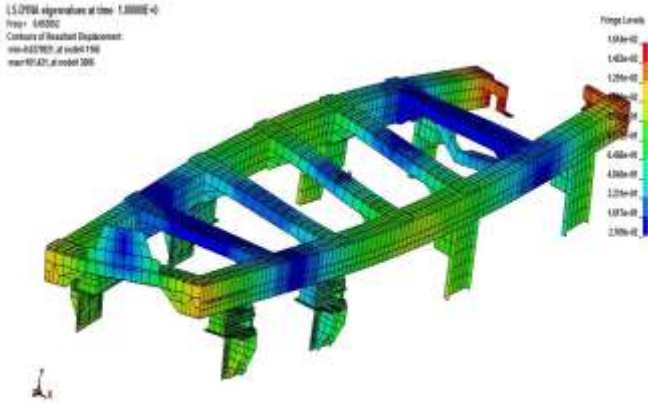


Fig 26: Mode Shape for Frequency (0.053852Hz)

Figure shows the Mode shape of truck chassis having natural frequency 0.053852Hz. The maximum deformation is 161.421mm, showing red in colour and minimum deformation is 0.0270921mm.

Mode 4

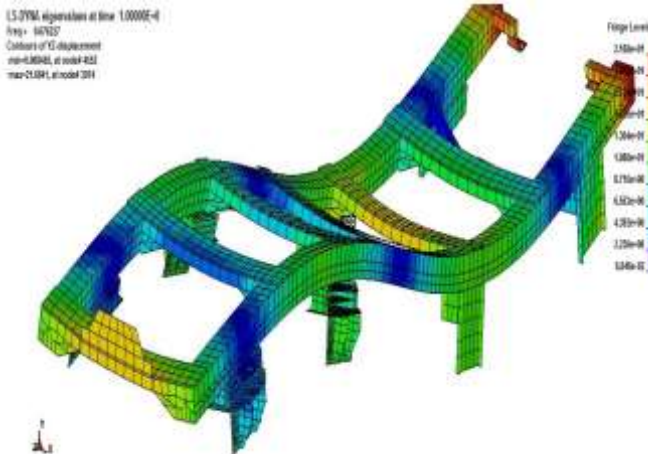


Fig 27: Mode Shape for Frequency (0.076227Hz)

Figure shows the Mode shape of truck chassis having natural frequency 0.076227Hz.

The maximum deformation due to vibration of the truck chassis is 21.6841mm, showing red in color and minimum deformation due to vibration of the truck chassis is 0.068455mm.

Mode 5

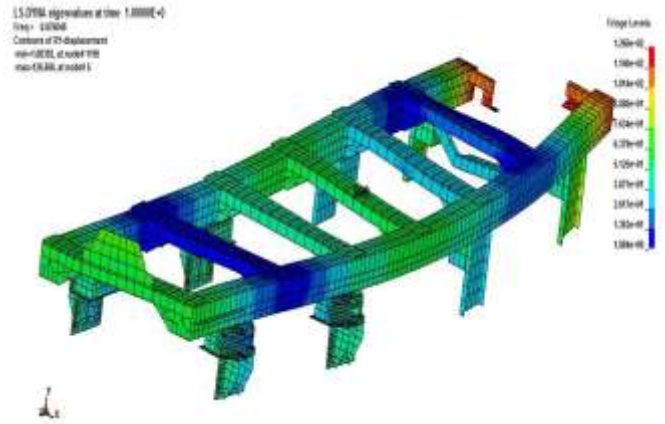


Fig 28: Mode Shape for Frequency (0.076848Hz)

Figure shows the Mode shape of truck chassis having natural frequency 0.076848Hz. The maximum deformation is 126.506mm, showing red in color and minimum deformation is 1.08392mm.

Mode 6

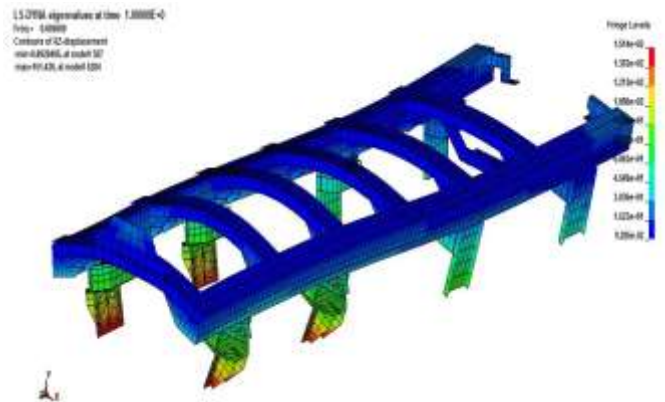


Fig 29: Mode Shape for Frequency (0.085089Hz)

Figure shows the Mode shape of truck chassis having natural frequency 0.085089Hz. The maximum deformation is 151.426mm, showing red in color and minimum deformation is 0.0928495mm.

IV. CONCLUSIONS & FURTHER SCOPE

The chassis is an important component in the construction of a car. It provides assistance to all of the participants. During operating and stationary environments, the engineered structure should be able to withstand all types of loads. Using implicit ansys and explicit Ls-Dyna solver, an analysis was performed to verify the critical regions of the chassis structure. The following is a rundown of the main points.

The modelled object is imported to hyper mesh in 'Step' file format for quality meshing. Due to extensive execution times with the Ls-Dyna solver, mesh limitations are carried out to execute in Dyna solver. Different quality checks like Aspect ratio, war page, skew angle, Min and Maximum angle quad and Jacobin is checked for better converged results in the nonlinear regions.

Initially the chassis is checked for structural conditions. It has been tested for static or self-weight condition. Later the chassis is checked for normal running condition. The results shows complete safety of the problem for the given loads. Both the deformation and stresses are within the allowable limits of the material.

So a design optimization is carried out after segregating the results on individual components. Wheel brackets shows higher stresses which needs attention. So wheel bracket is incremented with thickness till 25mm. The results shows structural safety of the members under given torsional loading conditions. The iterative design optimization shows increased weight with increased wheel bracket thickness. Along with increase in weight of the structure, the von-misses stresses are reducing proportionately. Further Ls-Dyna simulation is carried out to check the impact strength conditions.

REFERENCES

1. Patel Vijay kumar V, Prof. R. I. Patel "Structural Analysis of Automotive Chassis Frame and Design Modification for Weight Reduction" International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 1 Issue 3, May – 2012.
2. Beam formula with shear and moment diagram, American forest and paper association, Inc, American Wood Council, 1111 19th St., NW. Suite 800, Washington. DC 20036, 202 – 463 – 4713.
3. I. KutayYilmazcoban, YaşarKahraman "Truck chassis structural thickness optimization with the help of finite element technique" TOJSAT the Online Journal of Science and Technology - Volume 1, Issue 3, July 2011.
4. JadavChetan S., PanchalKhushbu C., Patel Fajalhusen "A Review of the Fatigue Analysis of an Automobile Frames" International Journal of Advanced Computer Research, Volume-2 Number-4 Issue-6 December-2012, (ISSN (print): 2249-7277 ISSN (online): 2277-7970).
5. N.K.Ingole, D.V. Bhope "Stress analysis of tractor trailer chassis for self-weight reduction" International Journal of Engineering Science and Technology (IJEST), ISSN: 0975-5462 Vol. 3 No. 9 September 2011.