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Design, static and dynamic analysis of automobile chassis

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Abstract

In the present scenario, the automotive industry has been one of the rapid growing industries and is facing heavy competition from the competitors. This necessitates the need to work on various functional aspects of the automobile, starting from chassis design to aesthetic design. As a part of this, the present work aims to study the static characteristics of automobile chassis.

The chassis acts as a skeleton on which, the engine, wheels, axle assemblies, brakes, suspensions etc. are mounted. The chassis receives the reaction forces of the wheels during acceleration and braking and also absorbs aerodynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance.

All real physical structures, when subjected to loads or displacements, behave dynamically. The additional inertia forces, according to Newton's second law, are equal to the mass times the acceleration. If the loads or displacements are applied very slowly, then the inertia forces can be neglected and a static load analysis can be justified, but in reality the loads are dynamic in nature. Hence, in this work, an effort is made to investigate the static and dynamic response of truck chassis due to road undulations.

The geometric modeling of the various components of the chassis is carried out in part mode as 3D models using Pro/ENGINEER 2001 software. The section properties, viz, cross-sectional area details of the 3D modeled parts are estimated using the modeling software. The above properties have been used as input while performing the finite element analysis using ANSYS7.1 software.

The finite element model of the chassis is created using ANSYS 7.1 package. Static analysis is done for vehicle on a plain road and bump conditions. The model is subjected to static analysis for all the conditions specified. The stress and deflection plots are determined.

Keywords: Modelling, Static analysis, Dynamic analysis, Chassis

1. Introduction

In this type of chassis construction the frame is the basic unit to which various components are attached and body is bolted onto the frame later on.

Functions of the frame:

1. To support the chassis components and the body.
2. To withstand static and dynamic loads without undue deflection of distortion

Loads on the frame

1. Weight of the vehicle and the passengers, which causes vertical bending of the side members
2. Vertical loads when the vehicle comes across a bump or hollow, which results in longitudinal torsion due to one wheel lifted (or lowered) with other wheels at the usual road level.
3. Loads due to road camber, side wind, cornering force while taking a turn, which result in lateral bending side members.
4. Load due to wheel impact with road obstacles may cause that particular wheel to remain obstructed while the other wheels tend to move forward, distorting the frame to parallelogram shape.
5. Engine torque and braking torque tending to bend the side members in the vertical plane.
6. Sudden impact loads during a collision, which may result in a general collapse.

Frame construction

The chassis consists of longitudinal members and the cross members. The frame is upswept at the rear and front to accommodate the movement of the axles due to springing. It also keeps the chassis height low. The frame is narrowed down at the front either to have a better steering lock, which gives a smaller turning circle. C are the brackets supporting the body. Dumb irons to act as bearings for spring shackles. They also take the bumper brackets. Brackets are meant for mounting the springs. The extension of the chassis frame ahead of the front axle is called front overhang, whereas its extension beyond the rear axle is called rear overhang.

Since the commercial vehicles have to carry large loads, framed construction is invariably used for these. Because in these. Because in these vehicles, ground clearance is larger and sufficient space is otherwise available for steering the vehicles, the frames for these have only straight members without taper towards the front or upsweep at the front or rear.

The engine clutch and the transmission are all together to form one rigid assembly, which is mounted usually on the front end of the frame. It is supported on the frame at three places by means of rubber blocks. This helps to isolate the engine from road shocks and the body from the engine vibrations. Moreover, this method accommodates any misalignment between the engine or the transmission relative to the frame or the body.

Various cross sections used for the side members of the chassis frame. It is seen that the channel section and square box section have bending stiffness as compare to a solid square with equal cross section area whose stiffness is taken as due to this reason, both these sections are used extensively for side members. Sometimes the box section is formed by welding a plate to a channel section or by welding two-channel section. That section is sometimes used along with channel section, for cross members. For heavy-duty applications, side members may be formed by placing two channel sections back to back. The side and the cross members are usually joined by riveting. However, the sub sections are usually joined by lap welding.

Sub frames

Normally the various components are bolted directly to the main frame. However, many a time, these components are mounted on a separate frame called sub frame. The main frame at three points further supports this sub frame. In this way the components are

Isolated from the effects of twisting and flexing of the main frame. The advantages of sub frames are:

The mass of the sub frames alone helps to damp vibrations.

The provision of sub frame simplifies production on the assembly line and facilitates subsequent overhaul or repair.

1.1 Role of Chassis in Automotives

Every vehicle body consists of two parts; chassis and bodywork or superstructure. The chassis is the framework of any vehicle. Its principal function is to safely carry the maximum load for all designed operating conditions. It must also absorb engine and driveline torque, endure shock loading and accommodate twisting on uneven road surfaces. The chassis receives the reaction forces of the wheels during acceleration and braking and also absorbs aerodynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance. To achieve a satisfactory performance, the construction of a heavy vehicle chassis is the result of careful design and rigorous testing.

It should be noted that this 'ladder' type of frame construction is designed to offer good downward support for the body and payload and at the same time provide torsional flexibility, mainly in the region between the gearbox cross member and the cross member ahead of the rear suspension. This chassis flexing is necessary because a rigid frame is more likely to fail than a flexible one that can 'weave' when the vehicle is exposed to arduous conditions. A torsionally flexible frame also has the advantage of decreasing the suspension loading when the vehicle is on uneven surfaces.

The chassis which is made of pressed steel members can be considered structurally as grillages. It acts as a skeleton on which, the engine, wheels, axle assemblies, brakes, suspensions etc. are mounted. The frame and cross members form an important part of the chassis. The frame supports the cab, engine transmission, axles and various other components. Cross members are also used for vehicle component mounting, and protecting the wires and tubing that are routed from one side of the vehicle to the other. The cross members control axial rotation and longitudinal motion of the main frame, and reduce torsion stress transmitted from one rail to the other.

2. Modeling of Chassis

2.1 Geometric Model of Chassis

Geometric modeling of the various components of chassis has been carried out in part mode as 3-D models using Pro/ENGINEER 2001. The properties, viz., cross-sectional area, beam height and area moment of inertia of these 3-D modeled parts are estimated in Pro/ENGINEER 2001. These properties have been used as input while performing the finite element analysis using ANSYS 7.1 software.

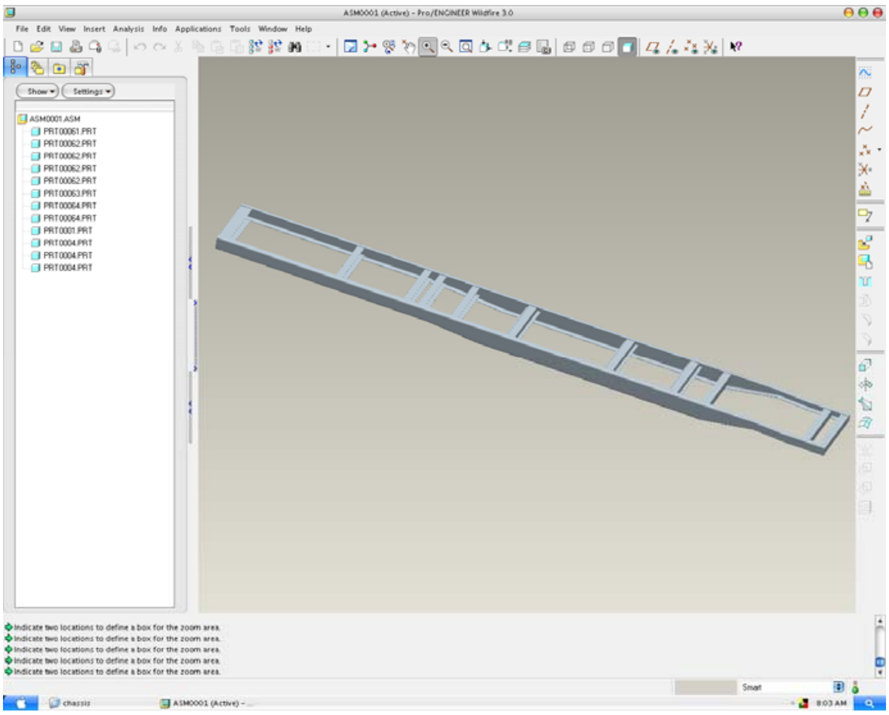

Fig 1: Model of chassis assembled in PRO-Engineering

2.2 Material

Alloy steel material is generally used for the manufacture of the chassis and the properties of the material are shown in Table 1

Heavy-duty chassis are usually manufactured with either frame rails of steel or aluminum alloy. Each material must be handled in a specific manner to assure maximum service life. Many heavy-duty trucks are presently manufactured with frame rails of mild steel high-strength low-alloy steel or heat treated steel. Material thickness increases, as the truck's intended duty becomes more severe. The depth of the rail also increases with duty severity. The on-road tractor rails will usually be less, than the damper rails.

Table 1: Properties of alloy steel

Sl.no.	Properties	Value
1	Modulus of rigidity	210 GPa
2	Poisson's ratio	0.3
3	Mass density	7800 kg / m^3
4	Yield strength	500 MPa
5	Element type	BEAM188

3. Static Analysis

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)
- Fluences (for nuclear swelling)

The deflection and stress pattern in the model of the chassis is obtained by performing static analysis. The results of model are shown in Tables.2 and 3 and the general pattern of deflection, stress and strain are shown in Fig. 2, Fig. 3 and Fig. 4 respectively. The design stress for the alloy steel material of which the chassis is made is 500 MPa. Based on this, the factor of safety is estimated as shown in Table 2.

Table 2: Static deflections in chassis

Condition\Model	Maximum Deflection (mm)
Vehicle On Plain Road	0.23
Front Wheels On Bump	4.15
Back Wheels On Bump	4.1
Side Wheels On Bump	1.53
Diagonal Wheels On Bump	1.1

Table 3: Static stresses in chassis

Condition\Model	Maximum bending stress (MPa)
Vehicle On Plain Road	6.53
Front Wheels On Bump	16.6
Back Wheels On Bump	15.4
Side Wheels On Bump	10
Diagonal Wheels On Bump	9
Factor of safety	30.12

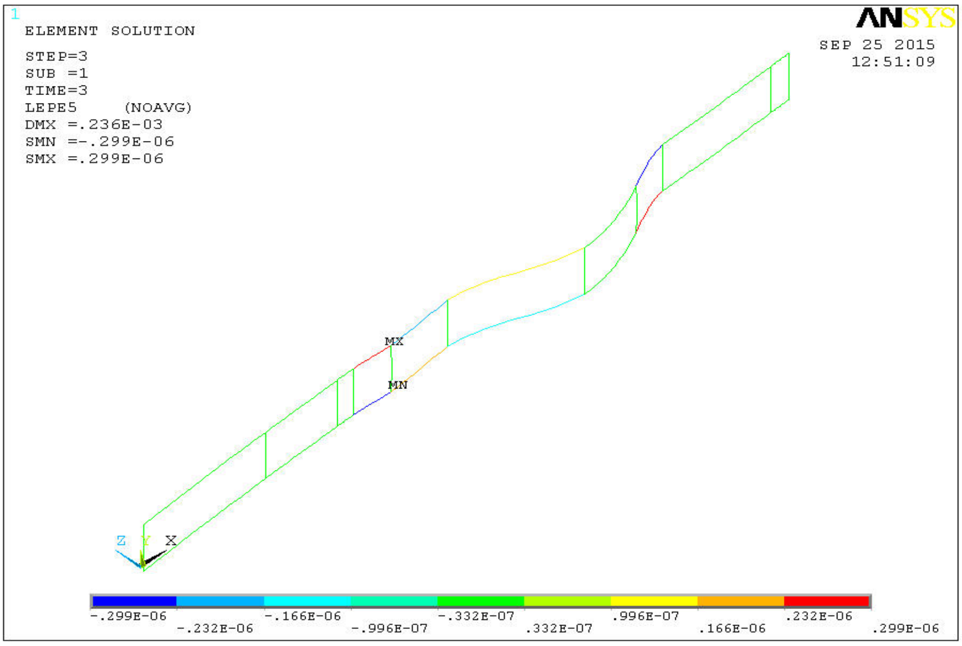

Fig 2: Maximum strain developed on chassis

Table 4: Results

Maximum Deflection	0.236MM
Maximum Stress	16.6MPa
Maximum Strain	0.22E-6
Factor Of Safety	30.12

4. Dynamic Analysis

4.1 Modal Analysis

Modal analysis is performed on the chassis and the natural frequencies have been found out, the first five natural frequencies are listed in Table 5

Table 5: Natural Frequencies

Set	Natural Frequencies (Hz)
1	52.264
2	68.680
3	125.96
4	151.88
5	213.67

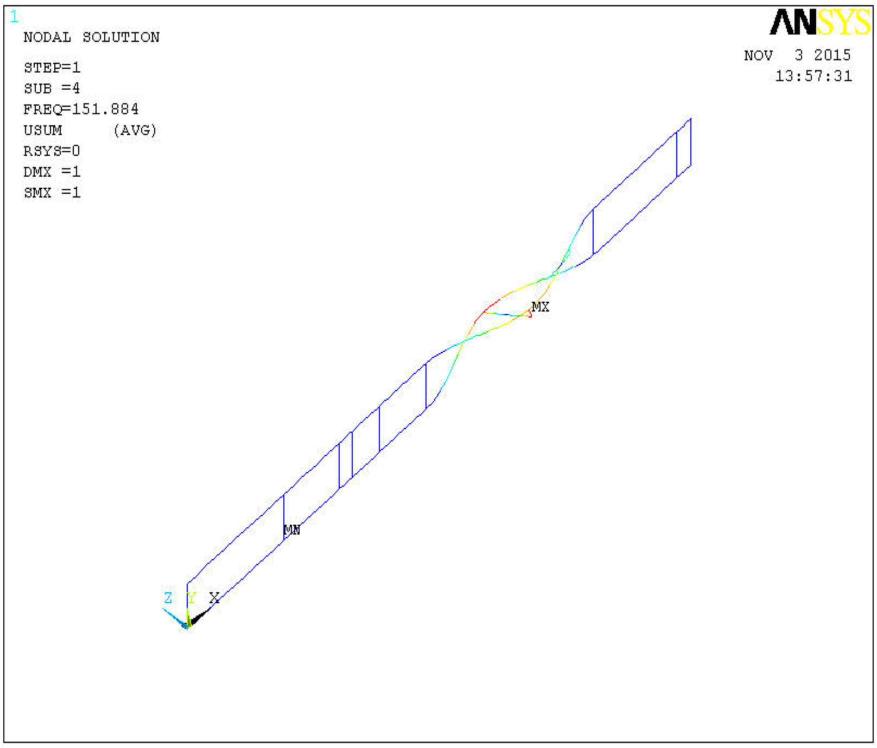

Fig 5: Fourth Mode Shape

The natural frequencies for model range from 52Hz to 213Hz. Table 5 indicates that the highest forcing frequency is in the range 30-40 Hz, whereas the fundamental natural frequency for models 52 Hz. Hence the fundamental natural frequency is well above the forcing frequency range, which shows that the chassis is safe from resonance point of view.

5. Conclusion

- Modelling has been done in solid mode and the section properties of different models are estimated using Pro/ENGINEER 2001.
- The deflection and stress pattern in the model of the chassis is obtained by performing static analysis. However, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads are also included that are approximated as static equivalent loads.
- Maximum Deflection of chassis was found to be .2mm and maximum stress was found to be 16.6MPa.
- The design stress for the alloy steel material of which the chassis is made is 500 MPa. Based on this, the factor of safety is estimated as 30.12.
- We can do case studies by changing the cross section types of both longitudinal and cross beams of the chassis.
- By altering the locations of the cross members, we can do a number of case studies.
- Material of chassis can be altered
  - Alloys of steel for Heavy duty chassis.
  - Alloys of Aluminum for light weight chassis.

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