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Strength Analysis on Automobile Chassis

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Abstract: ***The word automobile has been very much sought after since the very past. They are used in various modes of transport. The load that should be carried by it depends upon the type of vehicle into which it is classified, and this classification is done depending on the load it has to carry. The load carrying structure is the chassis. All the components of the automobile are mounted over it. So the chassis has to be so designed that it has to withstand the loads that are coming over it. This paper aims at analyzing an automobile chassis for a 10 tonne vehicle. The modeling is done using Pro-E, and analysis is done using Ansys. The overhangs of the chassis are calculated for the stresses and deflections analytically and are compared with the results obtained with the analysis software. Modal Analysis is also done to find the natural frequency of the chassis and seen that it is above than its excitation frequency.***

Keywords: ***Automobile, Chassis, load, stress, deflections, Strength Analysis.***

Introduction:

A motor car is designed to carry passengers in the sitting position facing the direction of motion and to accommodate their luggage. Additional space must be provided for the engine which produces the propelling force, for the transmission system which conveys the power from the engine to the driving road wheels, for the steering which enables the vehicle to be maneuvered, for the suspension layout which partially isolates the body from road wheel impact shocks, and for the braking system which enables the moving vehicle to be slowed down or brought to rest. While all these functions must be satisfied, consideration must also be given to the styling of the body to suit various aesthetic tastes and application requirements.

A Commercial vehicle is constructed with a cab and a load carrying compartment attached to a separate chassis. The chassis resembles a ladder, having two side members made from C- channel section high-tensile steel with pressed steel cross members riveted, bolted or welded to them. Mostly the side members are straight parallel constant depth sections, but they may sometimes be upswept at the rear to form a wheel arch to accommodate the axle movement relative to the chassis and they may be in swept at the front to provide adequate wheel turning clearance when the vehicle is being steered. In addition, the depth of the channeling may be reduced towards each end to reduce the weight. For heavy duty applications, certain sections of the side-members may be reinforced with flitch double channel sections.

Chassis Construction

To appreciate the design and construction of a vehicle's chassis an understanding of the operational environment is necessary. Once the operating conditions are known, a comparison of the different available chassis-member cross-section shapes can be made. The completion of chassis design then involves the reinforcement of the chassis side and cross member joints, and the various methods of fastening them together. The flowing sections examine and illustrate the basic requirements of the chassis.

Chassis Operting Conditions

To appreciate the design of a vehicle's chassis, it is first necessary to examine the kind of conditions it is likely to meet on the road. There are four major loading situations which the chassis will experience, as follows.

i) Vertical bending
ii) Loading torsion
iii) Lateral bending
iv) Horizontal lozenge

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Vertical Bending

If a chassis frame is supported at its ends (such as by the wheel axles) and a weight equivalent to the vehicle's equipment, passenger, and luggage is concentrated across the middle of its wheelbase, the side-members will be subjected to vertical bending making them sag in the centre region.

Longitudinal torsion

When front and rear diagonally opposite road wheels roll over bumps simultaneously the two ends of the chassis will be twisted in opposite directions. Both the side and the cross members will thus be subjected to longitudinal torsion which distorts the chassis.

Lateral bending

Under certain conditions the chassis may be exposed to lateral (side) forces-due possibly to the camber of the road, side wind, centrifugal force as when turning a corner, or collision with some object. The adhesion reaction of the road wheel tyres will oppose these lateral forces, with the net result that the chassis side-members will be subjected to a bending moment which tends to bow the chassis in the direction of the force.

Horizontal Lozenging

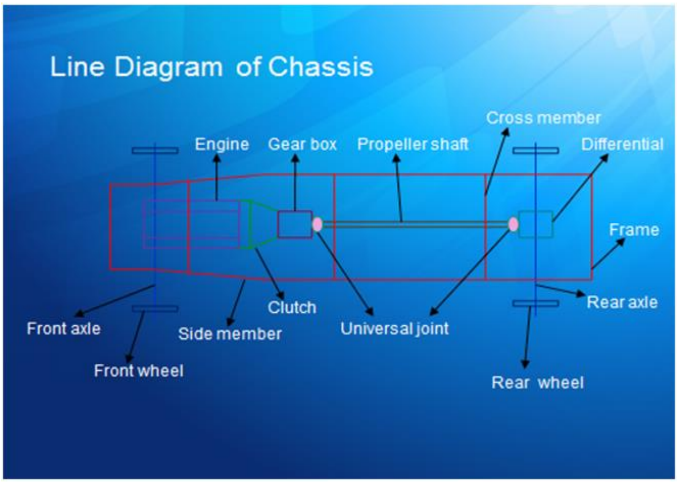
A chassis frame driven forward or backwards will continuously be exposed to wheel impact with road obstacles such as pot0holes, road joints, surface humps and cubs while other wheels will be providing the propelling thrust. Under such conditions the rectangular chassis will distort to a parallelogram shape. This is known as lozenging.

Chassis Sections

A chassis frame supporting the body and the wheel axles when traveling over normal road surfaces will be subjected to both bending and torsional distortion. The various chassis member cross-section shapes which have application are as follows

a) Solid round or rectangular cross-sections
b) Enclosed thin-wall hollow round or rectangular box-sections
c) Open thin wall rectangular channeling such as "C", "I" or "top hat" sections.

The different sections ability to resist bending and twisting will now be examined.



Line diagram of chassis

This section will briefly explain the functions of the following essential vehicle components:

a) engine
b) gearbox
c) clutch
d) propeller shaft and universal joints
e) drive shafts
f) final drive
g) steering
h) Brakes.

Engine power unit:

The engine is a machine which takes in a combustion mixture of air and fuel, burns it, and converts the released heat energy into mechanical energy which is then harnessed to a rotating crankshaft. The output power developed may be described as the rate of doing useful rotational work – that is, the product of the crankshaft rotational speed and its turning effort.

Gearbox:

This is a machine which takes in the engine powers from the crankshaft and, through a relay of gearwheels, alerts the output turning-effort and speed to suit the vehicle's propelling-force and road speed requirements. A number of different gear-ratios can be selected to cover the speed range and accelerating conditions expected from the vehicle.

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Clutch:
This is a device which is designed to separate the engine's power unit, when running, from the final drive .It thus enables the vehicle to be brought to a standstill without stalling the engine. It provides smooth engagement of the engine's power to the drive wheels from rest and enables different gear-ratios to be selected and engaged when the vehicle is in motion.

Propeller shaft and universal joints:
The propeller shaft is a hallow shaft whose purpose is to join the gearbox output drive to the final drive. Propeller shafts operate in conjunction with couplings known as universal joints whose function is to accommodate any angular misalignment which may occur between the gearbox and the final drive under operating conditions.

Drive shafts:
These are usually solid shafts which join the final drive to the road-wheel live stub-axles through the medium of universal or constant velocity joints.

Final drive:
This consists of two dissimilar sized meshing gears which change the direction of the drive through a right angle and provide a permanent gear-reduction. As a result, the connecting shafts going to the road-wheels will be slowed down, and the turning-effort (usually referred to as torque) is multiplied to match the road condition requirements.

Steering:
The steering provides the means for the driver to alter the vehicle's direction when it is moving. The steering system is designed to convert rotary movement of the driver's steering –wheel to a linear to-and-fro transverse movement of the steering link-rods. This movement is changed back to an angular movement of the stub-axles about their swivel pins, thus turning and pointing the front wheels along the path the vehicle is expected to follow.

Suspension:
The road-wheels are attached indirectly to the vehicle chassis or body structure through a sprung and hinged linkage arrangement known as the suspension. This method of mounting and supporting the body prevents bumps caused by road-surface irregularities being transferred in the form of noise and vibrations of the body or chassis, passengers, and may goods being transported.

Brakes:
The braking system is designed to slow down or bring to a standstill a moving vehicle either progressively or rapidly. A brake-drum and shoes or a brake-disc and pads are attached to each road-wheel and, when the foot-brake or hand-brake is applied, friction will be generated between the drum and the shoes or the disc and the pads. The friction produced converts the vehicle's kinetic energy of motion into mechanical and heat energy, resulting in a reduction in vehicle speed.

Related Work:
M.S.M.Sani, M.M. Rahman,(1)in their technical paper discussed about theinvestigates the dynamic characteristics of car chassisstructure by using experimental modal analysis (EMA) method and modal testing. Dynamic characteristics are divided into three parameters include natural frequency, damping factor and mode shape. In this study, modal testing was performed on the car chassis including the impact hammer and shaker test. Data analyzer was used to convert the response signal from the sensor, which was in the time domain to frequency domain.

D.V. Bhope (2) in their technical paper discussed about Tractor Trailers is very popular and cheaper mode of goods transport in rural as well as urban area. Butthese trailers are manufactured in small scale to moderate scale industry; due to which design of chassis is atprimary level. In Present work finite element method has been implemented to modify existing chassis of tractortrailer which ultimately results in reduction of weight and manufacturing cost.

Juvvi Siva Nagaraju1, U. Hari(3) In the case of vehicles, the term chassis means the frame plus the

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"running gear" like engine, transmission, driveshaft,differential, and suspension. A body, which is usually not necessary for integrity of the structure, is built on the chassis to complete the vehicle. For commercial vehicles chassis consists of an assembly of all the essential parts of a truck (without the body) to be ready for operation on the road

S. Popprath, C. Benatzky(4)-This contribution deals with the investigation of an approximately 1/10-scaled model of a metro vehicle car body concerning the low structural eigen modes. The model has been developedby means of finite element calculations in such a way that the eigen frequencies of the model lie close together. An experimental modal analysis has been carried out to determine the structural dynamics behavior of the realized model.

N. V. Dhandapani(5)-The main objective of this work is to study about the main frame linear static Analysis by the approach of localized system. The frame is having 60 ton load carrying Capacity dump truck. Method of analysis by using Finite Element Analysis. To determine the various stress distribution on the main frame by using Finite Element Method software and also, determine the various stress on the main frame structure by the method of testing. Totally 350 strain gauges used for testing. From this analysis the maximum stress distribution areas of the main frame structure has been investigated.

Materials

Cold rolled steels provide excellent press formability, surface finish, and thickness and flatness tolerances. Steel companies manufacture three groups of low- or ultra-low-carbon grades to meet a variety of customer formability requirements: CS Type B, DS Type B, EDDS, and EDDS+. They also produce HSLA steels and structural steel grades for those applications that require specified strength levels. Cold rolled steels provide excellent press formability, surface finish, and thickness and flatness tolerances. Steel companies manufacture three groups of low- or ultra-low-carbon grades to meet a variety of customer formability requirements: CS Type B, DS Type B, EDDS, and EDDS+. They also produce HSLA steels and structural steel grades for those applications that require specified strength levels. Cold rolled steels can also be specified as dent resistant or bake hardenable for applications that require dent resistance after forming and painting. Each grade can be processed with several surface finishes depending on customer requirements. Lubricants can be applied to enhance formability and to avoid at-press lubrication.

Design Process:

The process to build a Pro-E part is same for all as described below.

- Layout the part
- Creating the base feature
- Creating the remaining part features
- Modify the features as necessary

Extrusion, Revolution, Sweep or Loft can use one of the feature creation commands to convert the Auto Cad 2D sketch into Pro-E feature. When there are more number of features in the model, the same process may be repeated to make each additional sketch. The sketches can be created on parametric locations called work planes. The drawing layout can be created at any point. The drawing views are to be identified and the Pro-Esoftware automatically removes the hidden lines and also places the dimensions on the drawing. Changes made to the part update the drawing also. A sketch plane is a planar surface or workplace on the active part, in a 3D space. New features are sketched on this plane. All the profiles must lie on the active sketch plane.

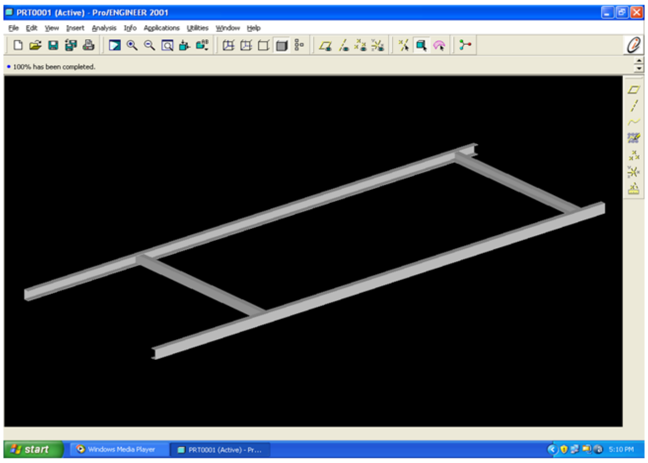

Fig: Modelling of Automobile chassis

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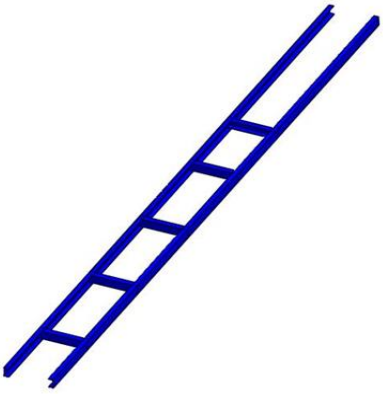

Fig: Solid Model Of Automobile Chassis

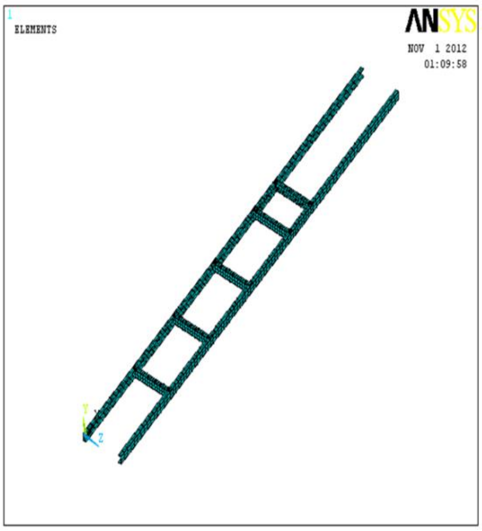

Fig: FE Model Of Automobile Chassis

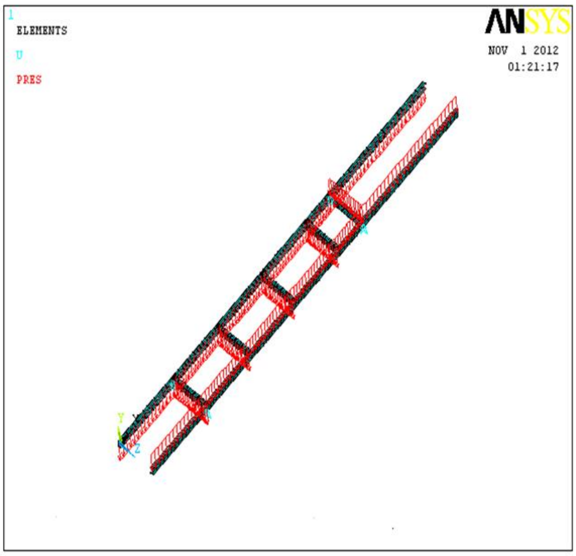

Fig: Finite Element Model Of Chassis With Boundary Conditions Applied

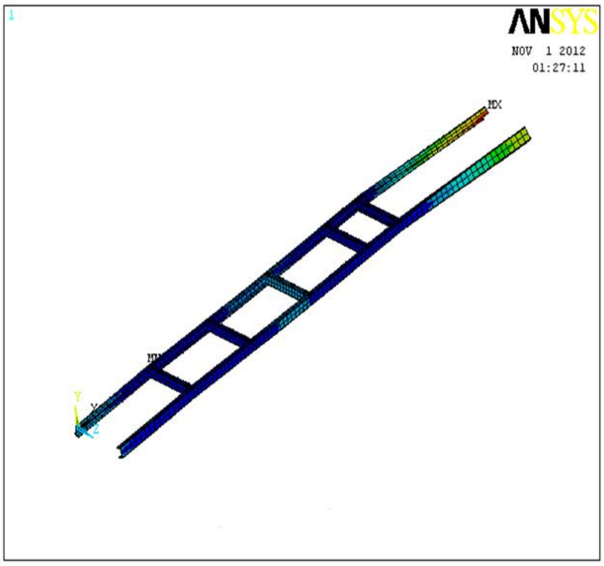

Fig: Displacement Plot Of Automobile Chassis

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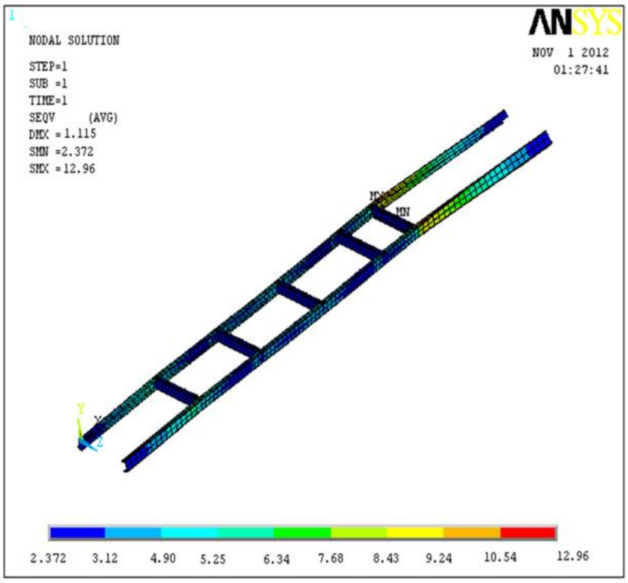

Fig: Von-Mises Stress Of Automobile Chassis

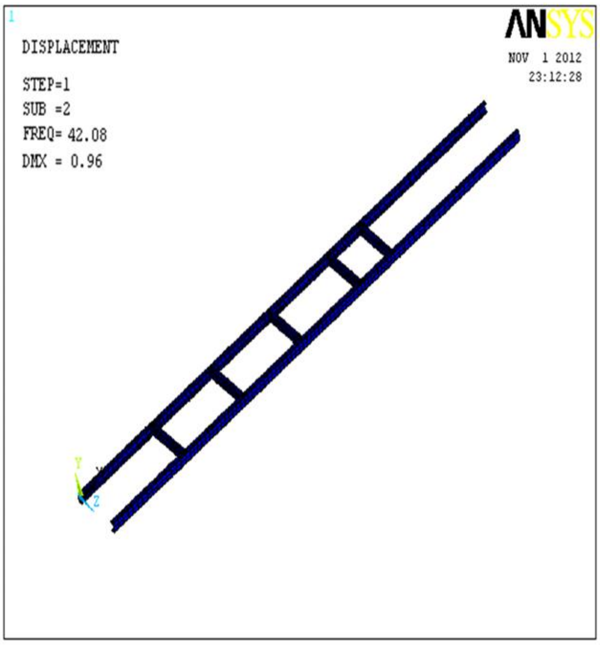

Fig: Mode Shape Of Automobile Chassis

Modal Analysis

Types Of Frequency Analysis

Linear dynamic analysis involves the computation of responses of a linear system subjected to time dependent loads. Depending on the assumptions made for the characteristics of the stiffness, mass and damping matrices and the load vector, different analysis are obtained.

Eq: $M\ddot{u} + C\acute{u} + Ku = P(t)$

Where M,C,K are respectively the global mass , damping and stiffness matrices(made up by a proper assembly of the element matrices), p(t) is the time-dependent applied force vector, and u'', u' and u are the nodal acceleration, nodal velocity, and nodal displacement vectors, respectively.

When inertia effects are not significant and when damping is zero, the responses are pseudo-static and can be obtained by STATIC analysis. When inertia forces are appreciable, the responses can be obtained by the different dynamic analysis types available in ANSYS as follows:

1. Modal or Eigen value Analysis
2. Transient dynamic analysis
3. Random vibration analysis
4. Frequency response analysis.
5. Shock spectrum analysis.

In this paper, **Eigen value analysis** is considered as chassis is tested for frequency response.

Mass formulation

In ANSYS, the inertial properties of a given system can be modeled using point mass elements and/or by specifying a nonzero material density. The latter results in the automatic computation of element mass matrices. In ANSYS, this can be done by using either a consistent or a lumped mass formulation.

Modal Analysis Or Eigen Value Analysis

Eigen value analysis deals with undamped free vibrations of a structure. Eigen value analysis does not involve the computation of response due to any loading, but yields the natural frequencies (Eigen values) and the corresponding mode shapes (Eigen vectors) of the structure when there is no dissipation of energy due to damping. A structure with a non zero initial conditions (initial displacement or velocity) corresponding to any of the mode shapes will exhibit simple harmonic motion at the corresponding natural

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frequency. The amplitudes of the free vibrations will depend on the initial conditions, and in the absence of damping will continue without any decay.

Though the above description reflects the true nature of eigen value analysis, more often than not this analysis is carried out to get the dynamic characteristics of a structure in terms of its natural frequencies and mode shapes, which may later be used for the computation of the response in the presence of dynamic loads and damping in modal dynamic analysis (also known as norm Regarding the output, the output from the eigen value analysis consists of :

1. Natural frequencies and the computational tolerances on Eigen values.
2. Printout of the selected Eigen vectors (mode shapes) which are normalized with respect to the mass matrix. The print out may be requested for a subset of the nodal points.
3. Printout of the modal participation factors, modal masses, and cumulative modal masses under a ground directions (three translations and three rotations).
4. Selective computation/printout of the element modal forces, element modal strain energies, percentage strain energies and strain energy densities.
5. Selective computation of modal reaction coefficients and printout of modal reactions.
6. Selective computation/printout of element modal stresses and averaged nodal stresses.

Fig Section of Automobile chassis

Fig Prototype model of Automobile chassis

Fig Prototype model of Automobilechassis

RESULTS

THEORITICAL CALCULATIONS

Deflection: 0.326

Stress : 12.15N/mm^2

ANALYSIS RESULT

Deflection : 0.96

Stress : 12.96 N/mm^2

MODAL ANALYSIS RESULTS

Mode No.	******FREQUENCY ******* (Rad/Sec)	(CYCLES / SEC)	Period (SEC)	Tolerance
1	2.916510E+02	4.641769E+01	2.154351E-02	1.246867E-07
2.	3.205340E+02	5.101456E+01	1.960225E-02	1.814129E-07
3.	4.920641E+02	7.831443E+01	1.276904E-02	3.663180E-07
4.	5.254386E+02	8.362615E+01	1.195798E-02	3.108020E-06
5	7.358925E+02	1.171209E+02	8.538184E-03	3.983627E-06
6.	1.104239E+03	1.757450E+02	5.690061E-03	5.785478E-07
7.	1.117632E+03	**1.778767E+02**	5.621872E-03	2.391162E-08
8.	1.166557E+03	1.856634E+03	5.386092E-03	9.256462E-08
9	1.196497E+03	1.904284+02	5.251318E-03	2.608768E-06
10.	1.291501E+03	2.055488E+02	4.865026E-03	1.131031E-06

Conclusion

The Theoretical calculations and FE analysis results are compared and it is observed that they are within the material properties. This frequency is more than 4 times the highest frequency of the excitation (i.e. 33 Hz) hence the chassis can faithfully transmit the input excitation to the vehicle bodywithout any amplification. Thus the design of automobile chassis is safe. The error is due to the approximation of the Finite element solution.

Future Scope

By starting this project based only on the objective is not recommended as is too Large or too wide to cover, and it is important to create a scope of this project. Scope of Computational Stress and Modal Analysis of Chassis are:-

a) Design - create the 3D modeling of vehicle chassis using CAD.

b) Analysis

I. Linear material stress analysis of chassis to find the stress vonmisses distribution.

II. Linear natural frequency (modal analysis) of chassis to find out the mode shape and natural frequency of the vehicle chassis.

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