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Analysis of Truck Chasis Frame Using FEM

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Abstract: An automobile is made of mainly two units' body and the chassis. A vehicle arrangement without body is called chassis. *When* a motor vehicle is rest, frame members are subjected due to vertical bending moments. When motor vehicle is in moving position the stresses are considerably increased and as a result of road shocks, bending moment reaches their maximum values. When either of the front and rear wheels pass over an obstacle, the inertia or dynamics loads are superimposed on the static loads. When one wheel passes over an obstacle at high speed, a shock with large vertical component is imparted to the adjacent corner of the frame. This causes the frame to twist generally, wheel is subjected to overloading and there is a chance of chassis failure. *In* this project, an attempt is made to find the stresses in a tipper truck frame. We are analyzing stress concentration points where the displacement and frequencies are high at the time of loading and unloading. The software used for modeling and analysis is ANSYS 10.

Key words: Truck chassis · Stress concentration · Bending moment

INTRODUCTION

An automobile is made of mainly two parts-The Body and The Chassis. A vehicle arrangement without body is called the chassis. The foundation of the automotive chassis on a different chassis units are mounted and to the axles are attached by the springs and sometimes also by other members serving to transmit or take up the axle thrust and torque. During the early years of the industry, the chassis frames were made of tubular steel, rolled steels sections, wood and "armored wood" that is wood sills reinforced with steel flitch plates. But as far as the constructions of trucks were concerned, rolled steel frames were predominantly used [1].

Development of the Chassis Frame: The conventional frame, which is made of steel members, usually of channel section, is sometimes referred to as the panel type. It consists of longitudinal and cross members and now usually also comprises an X member (called cruciform in England). Since the panel type frame is relatively flat and except where box sections-is made up of members which in themselves possess little torsional stiffness, it offers little resistance to torsion. The situation was not bad as long as engines were mounted rigidly on the frame, as then crank case with its integral or bolted-on arms formed a substantial cross member at the front end; but it deteriorated about 1930, when flexible engine mountings were introduced. Shaking or swaying of parts mounted at the front end-such as exposed radiator at high speeds, indicates torsional weakness in frames. To indicate the rigidity of the panel type frames, they formerly often were provided with tubular cross member of large diameter.

A more radical step to eliminate the evils resulting from torsional weakness consisted in the adoption of the tubular-backbone type of frame. This originated in Czechoslovakia, a rather mountainous country [2].

Vehicle Dynamics: A dynamic system undergoing a time-varying interchange or dissipation of energy among or within its elementary stage or dissipative devices is said to be in a dynamic state. All of the elements in general are called passive, i.e., they are incapable of generating net energy. A dynamic system composed of a number of storage elements is said to be lumped or discrete, while a system- containing element, which are dense in physical space, is called continuous. The analytical description of the dynamics of the discrete case is a set of ordinary differential equations, while for the continuous case it is a set of partial differential equations. The analytical formation of a

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Table 1: Vehicle Manufacturer Truck Classification

Category	Class	GVWR	Representative Vehicles
Light	1	0 - 27 kN	Pickup Trucks, Ambulance, Parcel delivery
	2	27- 45 kN	
	3	45 - 62 kN	
Medium	4	62 - 71 kN	City Cargo van, beverage delivery truck, wrecker, school bus
	5	71 - 87 kN	
	6	87- 116 kN	
	7	116-147 kN	
Heavy	8	147 and over	Truck Tractor, concrete mixer, dump truck, fire truck, city transit bus

dynamic system depends upon the kinematics or geometric constraints and the physical laws governing the behaviors of the system [3].

Experimental Setup

Truck Definition and Its Types: Generally, truck is any of various heavy motor vehicles designed for carrying or pulling loads. Other definition of the truck is an automotive vehicle suitable for hauling. Some other definition are vary depend on the type of truck, such as Dump.

Truck is a truck whose contents can be emptied without handling; the front end of the platform can be pneumatically raised so that the load is discharged by gravity. There are two classifications most applicable to Recreational Vehicle tow trucks [4]. The first one is the weight classes, as defined by the US government, ranging from Class 1 to Class 8 as listed in the below given Table-1.

The Second Is Classified into a Broader Category:

- Light Duty Truck
- Medium Duty Truck
- Heavy Duty Truck

Ansys Terminology: In ANSYS terminology, the term model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus, model generation in this discussion will mean the process of defining the geometric configuration of the model's nodes and elements. The ANSYS program offers you the following approaches to model generation:

- Creating a solid model within ANSYS.
- Using direct generation.
- Importing a model created in a Computer-Aided Design (CAD) system
- Apply operating loads or other design performance conditions.
- Study physical responses, such as stress levels, temperature distributions, or electromagnetic fields.
- Optimize a design early in the development process to reduce production costs.
- Do prototype testing in environments where it otherwise would be undesirable or impossible (for example, biomedical applications).

Pre-processing: Pre-processing involves preparation of data, such as nodal coordinates, connectivity, boundary condition, etc. processing stage involves stiffness generation, stiffness modification and solution of equations.

Post Processing: Post processing stage deals with the presentation of result like deformation configuration, mode shape, temperature and stress distribution [5].

Solving: In this stages, the pre-processing which is already meshed with a number of elements is solved for the given loads and boundary conditions.
Types of analysis done using ANSYS 10.0

- Static Analysis
- Modal Analysis
- Transient Dynamic Analysis

Static Analysis: It is used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analysis can be done. Nonlinearities can include plasticity stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces and creep.

Modal Analysis: It is used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.

Transient Dynamic Analysis: It is used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under static analysis above are allowed.

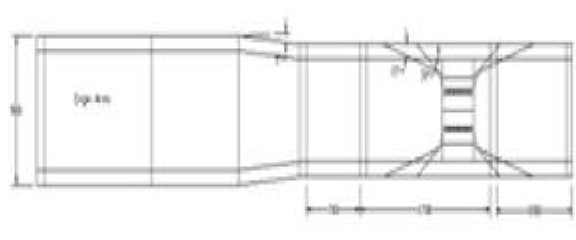
Von Misses Stress: It is a scalar stress value that can be computed from stress tensor. The von Misses stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Misses stress satisfies the property that two stress states with equal distortion energy have equal von Misses stress. Because the von Misses yield criterion is independent of the first stress invariant, I1, it is applicable for the analysis of plastic deformation for ductile materials such as metals, as the onset of yield for these materials does not depend upon the hydrostatic component of the stress tensor [6].

Model Description:

- Model: MAN TGA 33.480
- Chassis Frame: Punched frame, Channel type
- Length of Frame: 7000 mm
- Number of cross members: 5
- Cross members' position: 1000, 2700, 3400 and 7000 from the Back Axle
- Engine assembly position: From front Axle 372-1276mm
- Channel dimension: 340" × 90" × 8" mm
- Radiator assembly: 0-75 mm
- Fuel tank mounting: 3135-3863 mm
- Spare wheel carrier: 4205 mm.

Vehicle Specification:

- Engine: M.A.N. D2879LF12
- Net Power: 480 hp
- Max. Torque: 1696.4 lb ft, 2300 Nm
- Transmission Model: ZF16 S 252 Overdrive 16 speed Gearbox
- Suspension: Semi elliptic leaf spring in front and Rear axle
- Steering: Power steering
- Brakes: Dual line fuel air
- Wheel base: 3200 mm
- Overall length: 7000 mm
- Total chassis weight: 8985 kg
- Tire size: 315/80R 22.5
- Max. Speed: 100 Kmph
- Turning Radius: 7200 mm
- GVW: 16700 kg
- Pay load: up to 42 Tons



Finite Element Method: The fundamental principle of finite element method is that body or a structure may be divided into smaller elements of finite dimensions called the 'finite elements'. The original body or structure is considered as an assemblage of these finite elements connected at a finite number of joints called 'Nodes' or 'Nodal points'. The concept of Discretization used in finite difference is adopted here. The properties of the elements are combined and formulated to obtain the solution of entire body or structure [7]. For example, in the displacement formulation widely adopted in the finite element analysis, simple functions known as shape functions are chosen to approximate the variation of the displacement within an element in terms of displacement at the nodes of the element. The concept used in functional approximation method but the difference, is that the approximation to field variable is made at the element level. The strains and stresses within an element will also be in terms of nodal displacement. The principle of virtual displacement or minimum potential energy is used to derive equilibrium equations for the element and the nodal displacements will be the unknowns in the equation. The equations of equilibrium for the entire structure or body are then obtained by combining the equilibrium equations of each element such that the continuity of displacement is ensured at each node where the elements are connected. The necessary boundary conditions are imposed and the equations of equilibrium are solved for the nodal displacements. Having thus obtained the values of displacements at the nodes of each element, the strains and stresses are evaluated using the element properties [8].

Computer Implementations:

- Pre-processing (build FE model, loads and constraints)
- FEA solver (assembles and solves the system of equations)
- Post-processing (sort and display the results)

The ultimate purpose of a finite element analysis is to recreate mathematically the behavior of an actual engineering system. In other words the analysis must be an accurate mathematically model of a physical prototype. In the broadest sense, this model comprises all the nodes, elements, material properties, red constants, boundary conditions and other features that are used to represent the physical system.

- Created the Model of the Truck Chassis Frame for 8mm thickness, using ANSYS 10.0
- Meshing has been done for the Model of the Truck Chassis Frame using the Element Type Shell 181 [9].
- Created the Boundary Condition for the Finite Element Model of the Truck Chassis Frame and applying loads for statically conditions.
- Created the Mass Element for Distribution of Uniform Forces.
- Observed the Model Analysis for Natural Frequencies.
- Solved the problem by using solution.
- Interpretation of the results in the Post Processor.
- Plotted the results for Static, Model and Dynamic Analysis.
- Steps 1-8 are repeated for the Truck Chassis Frame for 6 mm thickness.
- Both the frames are compared to find out which is more optimum or better suitable for the given conditions.

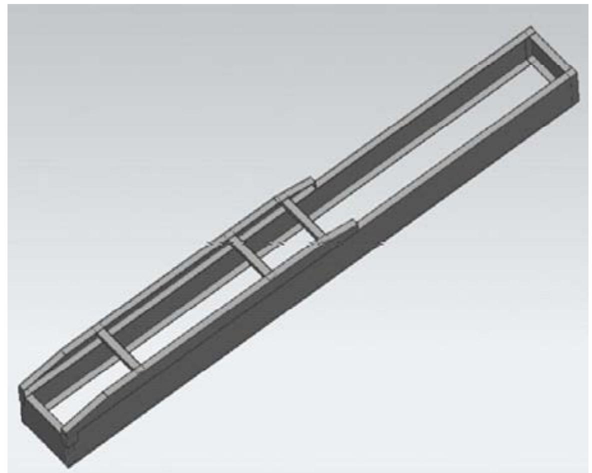
CONCLUSION

Input Specification:

- Element by: SHELL 181
- Thickness: 8 mm or 6 mm
- Density: 7800 kg/m^2
- Young's Modulus: 2.1×10^5 N/mm^2
- Stiffness k_1: 15605.8 N/mm
- Stiffness k_2: 27012 N/mm
- Poisson's ratio: 0.3
- Meshing: Mapped Meshing

RESULT AND DISCUSSION

The above Figure is the assembled model of a Tipper Truck Chassis as per the dimensions obtained and made using the Pro-E Software [10].



Model of a chassis frame t = 8 mm

The below figure shows the meshed model and the Distribution of No of Nodes and Elements. Here the no of Nodes found are 12336 and the no of Elements are 11896

No of Nodes and Elements.

Total Deformation

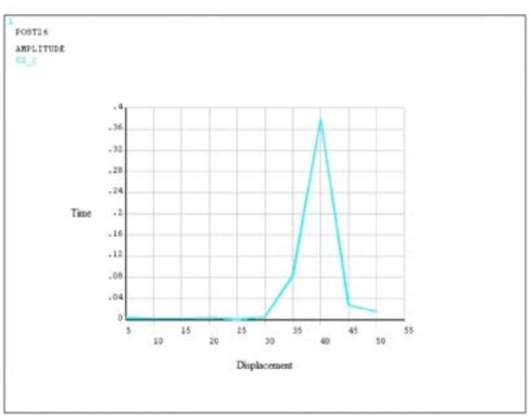
Maximum Von-Misses Stress: The above Figure shows the Deformation of the Truck Chassis It is a scalar stress value that can be computed from stress tensor. The von Misses stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Misses stress satisfies the property that two stress states with equal distortion energy have equal von Misses stress [11].

Stress in Tensile Region: The above Figures show the Tensile and Compression Regions where maximum stress in acting for the static condition, but for the unloading and loading conditions the values differs. For 8mm chassis thickness the value of Stress in Tensile region is 522 Mpa where as for the 6mm chassis thickness the value reduces to almost half and is 216 Mpa [12].

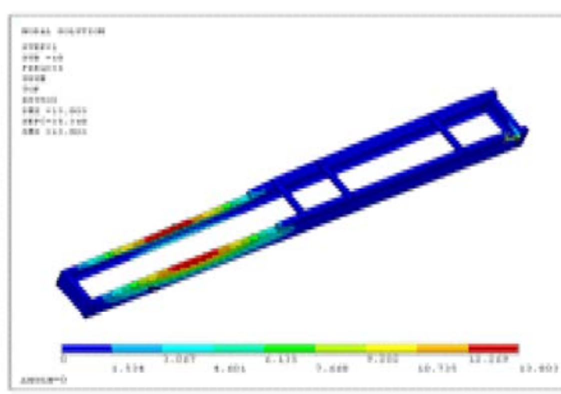
Stress in Compression Region: The above Figures shows the graphs plotted between the Time and Displacement and the other figure shows the Total Displacement. In the graph it is very clear that as the time increases there is no displacement but after 30mm it suddenly rises and with time it increases and is maximum at 40mm. whereas on the other hand the total displacement reaches up to 24mm.

Thickness of frame mm	Frequency mode	Frequency	Von misses stress Mpa	Tensile stress Mpa	Displacement mm
8	1	19.727	519	522	24
	2	27.61			
	3	34.988			
	4	39.683			
	5	50.26			
	6	62.599			
	7	72.07			
	8	74.194			
	9	86.822			
	10	98.53			
	11	94.109			
	12	111.10			
	13	118.34			
	14	124.77			
	15	125.62			
	16	131.057			
	17	134.67			
	18	139.95			
	19	145.38			
	20	147.108			
6	1	16	246	216	24
	2	25			
	3	32			
	4	36			
	5	48			
	6	59			
	7	69			
	8	71			
	9	72			
	10	84			
	11	86			
	12	95			
	13	98			
	14	112			
	15	116			
	16	22			
	17	123			
	18	125			
	19	127			
	20	130			

Time Vs Displacement



Total Displacement



CONCLUSION

The table given below shows the corresponding values for frequencies, von Misses stress, stress in compression, stress in tensile region and displacement for 8mm thickness and 6mm thickness chassis frames respectively: [13].

From the study done in this project, various features like the stresses developed, the displacements that occur, the points where these displacements occur, the natural frequencies and the corresponding characteristics, etc. have been analyzed for both the chassis frames of 8 mm thickness and 6 mm thickness respectively. According to time-displacement graph 6mm thickness frame is better than the other because of the lesser frequency. But overall, it can be concluded that in comparison to 8mm chassis thickness frame, stress is relatively less in 6mm chassis thickness frame. This is because of its own weight due to the 8 mm thickness. More the thickness, more the bending stress is concentrated.

Scope for Future Development: The analysis of the frame with the cross members positioned at various positions can be done as an extension of this project and the model can be optimized for the best positioning of the cross members. Another way of continuing on this thesis is by optimizing the weight of the model. The weight of the model can be optimized by decreasing the dimensions of any of the parts like the side rail or the cross members of the frame.

Instead of the channel section, which has been taken for study in this project, any other type of section like rolled steel frames can be taken and the model can be analyzed.

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