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Study of Vibrational Effects on Heavy Duty Truck Chassis with the Help of Model Analysis Using Fem Technique

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Abstract

Modern heavy duty vehicles are designed to sustain the large amount of loads and carry out best performance on that load. Due to the running condition of vehicle as well as engine, the deformation of chassis produces over the time which causes the failure and needs maintenance. Vibration is the major cause of deformation in chassis, as it always undergoes vibrations due to the shocks from road also the engine vibration. Truck chassis is the main component of vehicle over which a large load is mounted and carries away to long distance. Therefore chassis frame must be defect free. It also carries engine and body of a vehicle.

In this study the vibrations due to the loading as well as running condition is studied so as to understand a range of defect free loading for chassis. A model analysis is performed on virtual truck chassis frame and the ranges of vibrations are found for five different modes of frequencies. It can help for the analysis of frame in vibration point of view. Study explains how the vibrations are set in the chassis and in what range due to applied load and running condition with the help of FEA model bases on FEM (Finite Element Method).

1. INTRODUCTION

Truck chassis is consisting of thick sections which are connected to each other. Its thickness provides a better strength and strong resistance to shocks. Its strength and shock resistance also can be increased by adding the structural objects like beams. But due to addition of such structural objects will also increase the weight and engine will suffer for increased weight. It will also increase the cost of chassis. More than that increasing the beams or structural members may not have the good effects on increased frequency range of a chassis. So it is also important that the chassis should be sensitive to high frequency rage. Increasing the thickness of the sections will affect the frequency range.

If the cost and design optimization reduces the safety issues regarding the chassis then better solution is needed by comparing it with safety. So the detail study of vibration behaviour is required to produce reliable and cost, design optimized chassis.

To examine the chassis for vibrations model analysis is performed and five different frequency sets are obtained which itself illustrates the nature of chassis while undergoes vibrations.

Truck is mainly having body or cabin and loading trolley where load is placed to carry from one station to another. Chassis attached to the both body as well as trolley of truck. It consists of structural members connected to each other which creates truss like structure. Steel is the base material used to manufacture chassis. Also some cross members are given which provides strength to the chassis. These cross members are located in such a way that it creates box-like structure to increase rigidity, strength and stress resistance. Joint plates are given to connect cross members with side members by means of rivets. Riveted joint have given because, due to hot rivets the shape of the hole adjusted and tighten upon after cooling the chassis frame as chassis holes are smaller than the diameter of the rivet and the rivets are driven home by heating up to an incandescent red using hydraulic or air pressure. Hence the flexibility of a chassis is increased by riveting cross members with side members. Therefore, stresses developed in critical area get prevented.

Riveted joints are not so good for vibrations, because due to the vibrations the riveted joints will gate lose and it will enlarge the chassis hole and cross member hole. But up to some extend it also absorb the vibrations which produces due to the engine vibrations but its end effects are more undesirable than absorption of vibrations. Welded joints are also used to connect the members to the chassis. Side and cross members are less costly and usually open sectioned. Structural analysis of a truck chassis frame is studied by I. Kutay YILMAZCOBAN and Yasar KAHRAMAN [1]. A various loads acting on truck chassis will gives us deformation in the body. Finite Element Method is used for the calculation of deformation. Commercial packages are used to conduct the analysis and obtaining the results. For maintains of members or replacement, few members are also attached with nut and bolts which allows replacement or maintains ease. For chassis modelling various techniques are available. Stress analysis of chassis with riveted joints is also studied by Cicek Karaoglu and N. Sefa Kuralay [2]. Same with ladder chassis frame have studied by Vijaykumar V. Patel and R. I. Patel. All have tabulated their results according to load application and vibrations become unsuspected.

In Finite Element Analysis different static or dynamic testing methods are available with variety of failure criteria which are major diverging factors. With the help of FEA packages we can consider the many of working conditions and obtain the required solution. Vibration analysis is also can be carried by considering associated material properties and loading conditions. It will obtain the range of frequencies for various modes.

To perform Finite Element Analysis CAD modelling of Truck chassis is required with all members connected to each other. This model is then imported in FEA package using neutral file format like IGES (Initial Graphics Exchange Specification). Further materials properties are defined and exact loading conditions are simulated with different constraints. This will form the basic model of FEM and by solving this model by applying the model analysis conditions it will generate few sets of frequencies and also gives chassis natural frequency [3].

Some troubleshoots such as crashworthiness, structural impact of chassis frame depended much on destructive experimental tests. Some numerical approaches Such as finite element method, finite volume method or hybrid methods are proposed to carry out these problems. Model analysis gives details of the structural behaviour of the vehicle during the period of vibration and running. This task was expensive in early days. But now it becomes more economical and time saving due to high end computers and CAD software's [4].

Longitudinal stresses developed due to loading are subjected to localised cycles stresses. Hence the failure of chassis can be observed. Also cracks will grow which leads to fracture of the component [5].

Structural analysis of low loader chassis consisting of I-beams with specific material properties are examined by Mohd Azizi Muhammad Nora, Helmi Rashida, Wan Mohd Faizul Wan Mahyuddinb etc. Stress and displacement contour are obtained and the maximum stress and deflection are determined by structural analysis. Validation of analysis is done with analytical model [6].

Lightweight chassis concept is also desirable but for light weight vehicles which can safely work on the required loads. Also chassis must be able to protect the driver while crashing the vehicle. Taking steel material for chassis and performing analysis will produce required results using FEA. Results are obtained with less deflection and unknown from vibration effects [7].

2. CAD MODELLING OF TRUCK CHASSIS.

All CAD model is prepared by taking dimensions of chassis using reverse engineering method. For the modelling and analysis purpose we have chosen TATA 407 truck chassis, which is fully manufactured by TATA Motors, India LTD. Modelling, is done by using CATIA V5R17 software and it is converted into IGES format to import in FEA package. Overall chassis virtually developed using CAD software with its all members. This virtual prototype will exactly simulate the actual chassis and gives us required results.

Thickness of each member is exactly taken same so that during vibration analysis result calculation will be more reliable. Complete chassis is taken as a unique part as it is made up of different members connected to each other either by welding, riveting or by means of nut and bolt. But it will not vary result much. Each section is modelled properly so that during conversion in IGES format there should be minimum data losses.

Bellow figure 1 shows the CAD model of TATA 407 truck chassis. It is developed in CATIA V5R17 software and further converted into IGES format.

While importing CAD file from one CAD software to another CAD software, there are always data losses which must be reduced. In IGES format dimensions are kept as it is. Means dimensional losses are reduced so that we can get accurate CAD model.

STEP, Parasolide etc neutral file formats are also available for conversion of CAD file. We can use any one of them as per requirement.

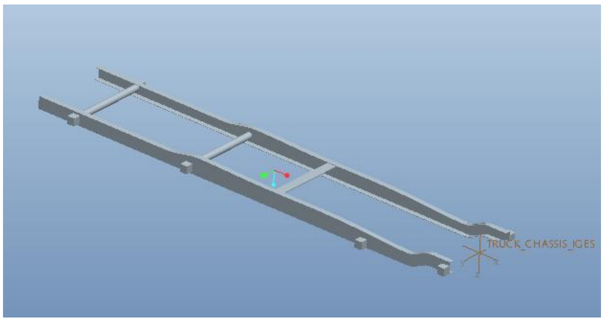

Figure 1: CAD model of truck chassis.

3. VIBRATION ANALYSIS OF TRUCK CHASSIS.

To perform Vibration/Model analysis of chassis we have first imported IGES file into the FEA package. Here ANSYS 14.0 FEA package is used to carry out Vibration Analysis.

3.1 Assigning properties of metal.

In FEA package defining material is very important which directly affect the results. For truck chassis mostly steel and its alloys are widely used and for the frame structures, wide variety of alloy materials, composite materials are used. For model analysis we are using St 52.3 steel as chassis material. Its various properties are discussed bellow in table 1.

Density	7827 kg/m3
Poisson Ratio	0.28
Symmetry	Linear isotropic
Young Modulus	200GPa

Table 1: Material properties of Chassis (St 52.3).

Above properties are used to carry out model analysis of truck chassis frame. A set of frequency range will give chassis natural frequency. More the frequency, safer will be the object.

3.2 Meshed model of truck chassis.

Fine meshing provides a better approximate solution of FE model. Meshing or discretisation of CAD model is initial step towards obtaining solution. This will form small pieces of an object called element which are connected to each other by means of points called nodes. To perform Vibration Analysis meshing of chassis is required.
CAD model is completely discretised according to area of loading and constraining. Tetragonal element is used for discritisation. While at some places where the stresses may induce, the fine meshing is applied. This will form a meshed section which is shown in bellow. It is also indicating the points where the chassis is fixed. Means its displacement at that position is restricted. Meshed model of truck chassis is given bellow in Figure 2.

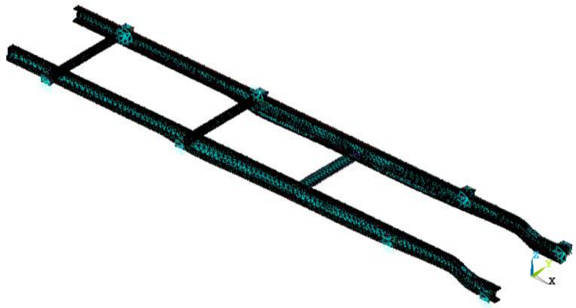

Figure 2: Meshed model of TATA 407 truck chassis.

3.3 Obtaining Solution.

In Vibration Analysis, the loads applied on chassis are not considered as we want its natural frequency so that we can understand how many vibrations it can sustain and at what frequency level chassis may bend. Applied loads do not affect the results. Therefore the solution is obtained for five different sets of frequency. Each set will give its own chassis displacement value with area of displacement. Complete result obtained using FEA package is discussed bellow.

4. RESULTS AND DISCUSSION

By obtaining analysis result we got various frequency ranges for various modes. The maximum frequency obtained is 215.15 Hz. Vibration in the truck chassis are allowed up to 215 Hz frequency level. Bellow table shows the frequency values for each mode.

SET	FREQUENCY	LOAD STEP	SUBSTEP
1	74.324 Hz	1	1
2	149.14 Hz	1	2
3	199.70 Hz	1	3
4	205.73 Hz	1	4
5	215.15 Hz	1	5

Table 2: Frequency values obtained for each set.

FIRST MODE OF VIBRATION: Vibrations in the first mode will carry the displacement in side members of chassis. This displacement is due to the vibrations of frequency level 74.32 Hz. This mode shows that the at the frequency value 74.32 Hz the chassis will have the deformation up to 6.82 mm.

Figure 3 shows the frequency value as well as the maximum deformation in the chassis.

Figure 3: First mode of vibration with maximum deformation.

SECOND MODE OF VIBRATION: At second mode the frequency value slightly increased with increasing deformation. Here deformation is in the cross member of a chassis. Due to vibrations frequency value 149.14 Hz will setup in the members of chassis and the maximum deformation is 14.71 mm. Figure 4 shows the second mode of vibration with frequency value.

Figure 4: Second mode of vibration with maximum deformation

THIRD MODE OF VIBRATION: Third mode of vibration gives frequency value 199.70 Hz with maximum deformation 15.20 mm. Figure 5 shows the third mode of vibration with frequency value 199.70 Hz and the maximum deformation is 15.20 mm.
Here the difference between second mode and third mode deformation is very less as compare to first and second mode.
But frequency value is having remarkable change from second mode to third mode. Same thing is happening with first and second mode of vibration. Further values are also important.

Figure 5: Third mode of vibration with maximum deformation.

FORTH MODE OF VIBRATION: Here maximum deformation is 15.14 mm with frequency value 205.72 Hz. Deformation is obtained at side member of chassis as shown in figure 6.

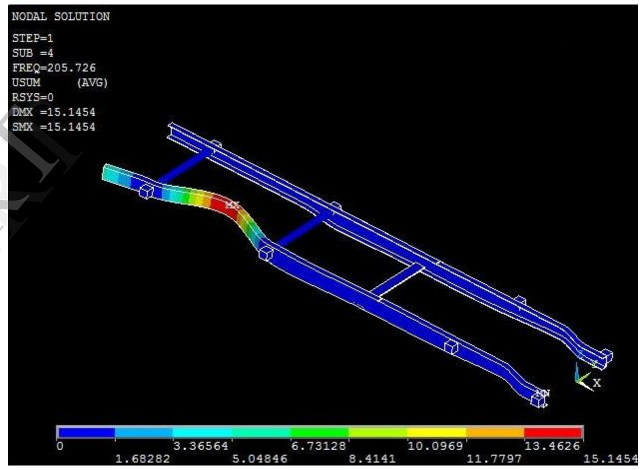

Figure 6: Forth mode of vibration with maximum deformation.

FIFTH MODE OF VIBRATION: The maximum frequency value is obtained in this last set with less deformation value. This maximum frequency value for chassis is 215.15 Hz with 7.33 mm deformation. This maximum frequency is called as natural frequency of chassis.
Now here the deformation value is very less (Approximately same as first mode deformation). But the frequency of chassis is at its height.
The details of all mode frequencies and their respective deformations are briefly discussed in table 3 given bellow.
From these results we can draw the conclusions and also with the help of such vibration analysis we can find out the natural frequency of any object.
For further analysis such as Harmonic analysis, we can use these results as input. Above natural frequency of chassis the resonance phenomenon can damage the chassis permanently.

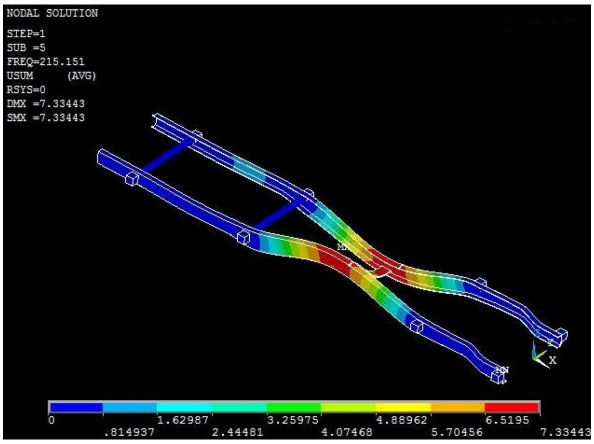

Figure 7: Fifth mode of vibration with maximum deformation.

SET	FREQUENCY	DEFORMATION
1	74.324 Hz	6.82 mm
2	149.14 Hz	14.71 mm
3	199.70 Hz	15.20 mm
4	205.73 Hz	15.14 mm
5	215.15 Hz	7.33 mm

Table 3: Frequency values and their deformation for each set.

Due to the vibrations the frequency level is induced in an object. If this value of frequency further increases then at a particular level it meet with natural frequency value of object. In this case maximum frequency value i.e. 215.15 Hz is natural frequency of chassis.

5. CONCLUSIONS

Model analysis is the optimised way to find out effect of vibration a chassis. As chassis always undergoes to continuous uniform loading, there is always need to have better chassis which must satisfy all requirements of truck chassis. Also it must have high natural frequency so that while working in vibrations it should no bend or deform permanently.

By above analysis results we can state that.

- Vibrations in chassis can cause deformation in chassis.
- Maximum frequency obtained by performing Vibration analysis is 215.15 Hz.
- Natural frequency of chassis needs to improve as more the frequency safer the object.
- Vibrations in chassis can be sustained by optimizing chassis design by means of Natural frequency.

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