ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Sweep Sin Simulation for Exhaust System

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Abstract

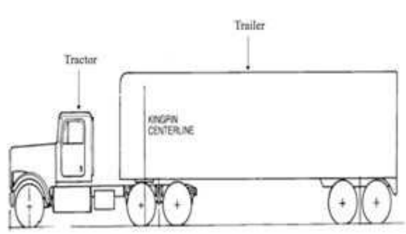
Truck chassis forms the structural backbone of a heavy commercial vehicle. When the truck travels along the road, the chassis is subjected to vibration induced by road roughness and excitation by vibrating components mounted on it. The vibration of the chassis will also cause high stress concentrations at certain locations, fatigue of the structure, loosening of mechanical joints and creation of noise and vehicle discomfort. To solve these problems, study on the truck chassis dynamic characteristics is thus essential. This thesis concentrates on analysis of vehicle using virtual proto typing approach which includes simulation of load cases for tractor-trailer combination. This helps in to determine the loads acting on various components of tractor chassis, which are used as inputs to finite element model for stress analysis. Sub system level analysis of exhaust system to compare various designs to check for modal acceptance criteria.

Keywords: Virtual proto typing, HCV, Virtual Models.

Introduction

The growing competition of automotive market makes more and more necessary the reduction of development time and cost. One of the most costly phases on the vehicle development process is the field durability test, both in function of the number of prototypes used and time needed for its execution. Also multiple cycles of designing, building and testing prototypes are no longer practical with the time and cost constraints for developing a competitive product. Today, analytical tools in the form of computer simulation, models have been developed that reliably predict performance in determining loads, durability, fatigue and many other areas. Hardware prototypes are not available early in the design process, today with the use of CAE; virtual models are useful to achieve best possible output before production.

The modeling and simulation of heavy vehicles, such as truck, tractor-trailer combination is difficult. The multi body systems programs help to model and simulate heavy vehicles to study its performance and to determine the acceleration at different points of chassis, loads acting on suspension components and chassis points which then further useful for the stress analysis and predicting durability of the critical components of vehicle structure using finite element methods.



Tractor-Trailer Combination

Objective of Present Work

Basic objective of this simulation is,

1. To compare various design of exhaust system
2. To check for modal stresses and modal acceptance criteria i.e. natural frequency of exhaust system must be more than 15 Hz
3. To find out acceleration at a point on exhaust system at the resonance condition, for calculation of modal scaling factor for modal stresses

Methodology

1. Modal analysis using MSC. Nastran to find out natural frequency and modal stresses
2. Preparation of dynamic model, using Motion

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View of Altair Hyper Works, consisting of full vehicle with exhaust system for each design iteration

3. Give excitation in the form of sweep sin function, at the bottom of front tires, with a frequency varying from 0 to 25 Hz, to determine acceleration at a particular point on exhaust system at resonance condition
4. Determination of modal scaling factor and scaled modal stresses
5. Comparison of various designs

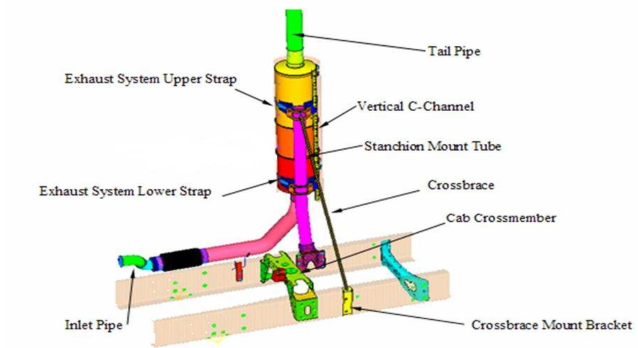
Literature Review

Thomas D. Gillespie and Michael W.Sayers [1] studied performance of truck using TruckSim software. The growing competition of automotive market makes more and more necessary the reduction of development time and cost, one of the most costly phase is durability testing because it needs more number of prototypes and time.

Cicek Karaoglu, N. Sefa Kuralay [2] presented paper on stress analysis of truck chassis with riveted joints using FEM. Three dimensional finite element model was used and solved in ANSYS. Static loads due to bending, torsion and dynamic loads on chassis with appropriate boundary conditions were considered in the analysis. Stresses at the joint location of cross members were found out and solution is given to use local plates at the joint location

Frame Mounted Vertical Exhaust System

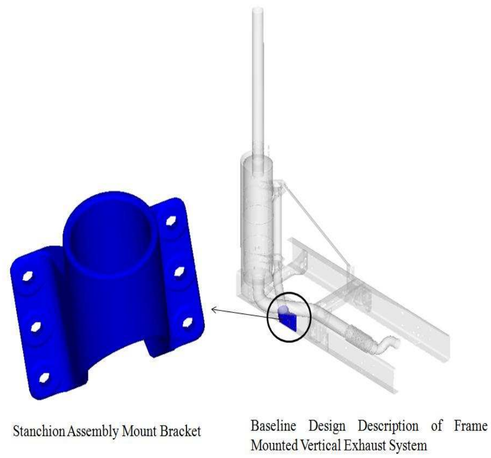
In High Commercial Vehicle (HCV), like tractor-trailer combination, frame mounted vertical exhaust system is available. It is mounted vertically upward behind the cab of tractor. It consists of main inlet pipe coming from engine, vertical 'C' channel along with tail pipe. Stanchion mount tube is upright vertical tube used for support; it is connected to the vertical 'C' channel with the help of upper and lower straps. Stanchion mount tube is connected to the stanchion mount bracket at its lower side and bracket is connected to the chassis frame. Cross brace is supporting structure connected to stanchion mount tube at its one end and to frame at other. Frame mounted vertical exhaust system with its main components is shown in fig. 6.1.



Frame Mounted Vertical Exhaust System

Baseline Design of Exhaust system

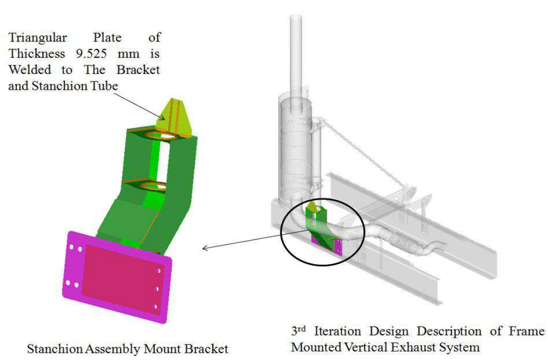
In base line design stanchion assembly mount bracket is in the form of casting as shown in fig.



Baseline Design

Design Iteration of Exhaust System

1st design iteration of exhaust system is not satisfying modal acceptance criteria, so a changes are done in previous design in order to increase the frequency of exhaust system. Triangular plate of thickness 9.525 mm is welded to the stanchion mount bracket as shown in fig. 6.33.



Design Iteration

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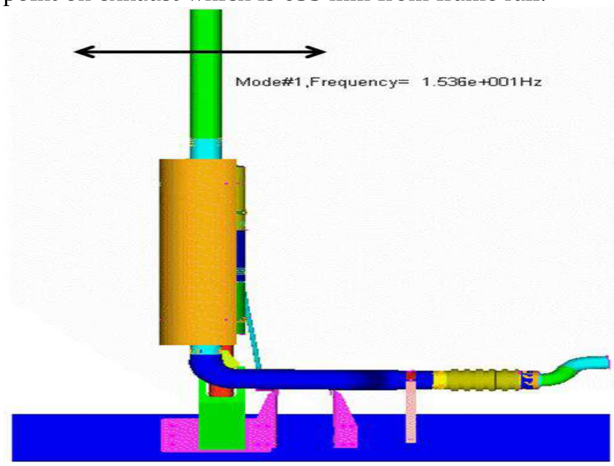
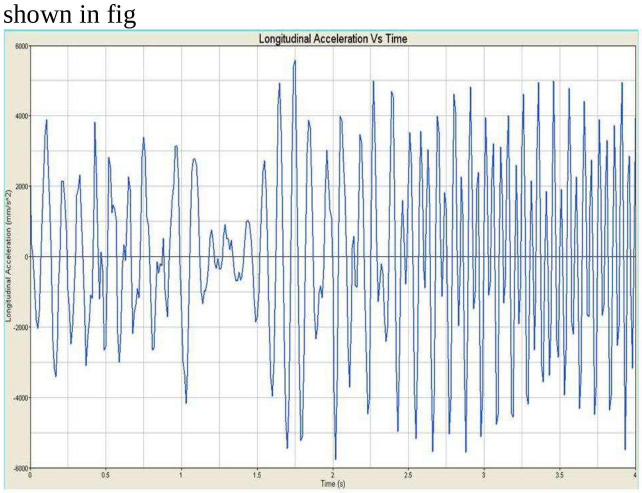
Modal Analysis for Design Iteration

Same procedure is followed as described earlier for determination of natural frequency, modal stresses and modal scaling factor. 1st mode of exhaust system for 2nd iteration has natural frequency 15.36 Hz and vibrates in longitudinal direction as shown in fig. 6.34. Displacement is also measured in same direction at a point on exhaust which is 655 mm from frame rail.

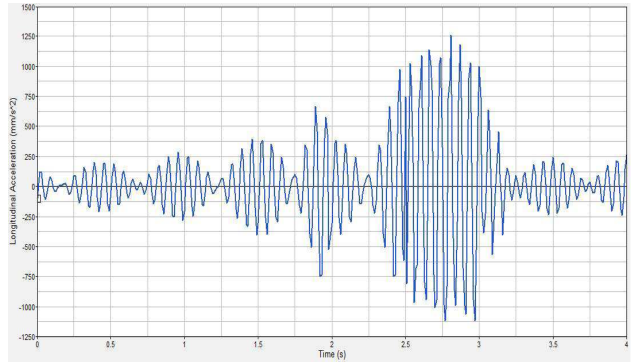


Mode of Exhaust for 3rd Design Iteration

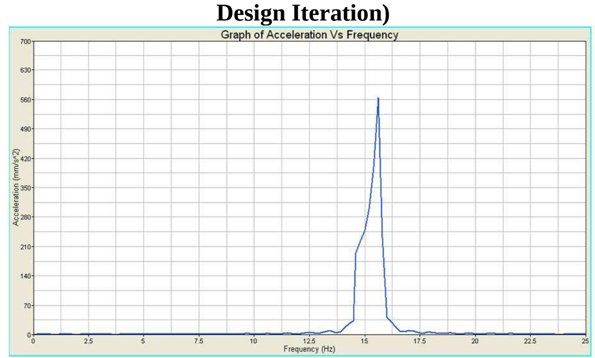
Graph of longitudinal acceleration vs. time is shown in fig. 6.36 but as it is difficult to decide which pick is to be consider because it contains response for 0 to 25 Hz frequency but interest is to find acceleration at resonance condition i.e. at natural frequency so frequency filtering is necessary, in that only frequency between 14 to 16Hz are passed, graph of longitudinal acceleration vs. time after frequency filtering is shown in fig. 6.37 and acceleration at resonance condition is 1259.69 (mm=s2). Graph of acceleration vs. frequency is shown in fig



Graph of Longitudinal Acceleration vs. Time Measured at 655 mm from Frame Rail (3rd Design Iteration)



Graph of Longitudinal Acceleration vs. Time Measured at 655 mm from Frame Rail after Frequency Filtering (3rd Design Iteration)



Graph of Longitudinal Acceleration vs. Frequency Measured at 655 mm from Frame Rail (3rd Design Iteration)

Table shows acceleration found out from Motion Solve and Modal Scaling factor.

Motion Solve Acceleration (mm=s2)	Displacement in FE Analysis (r) (mm)	Natural Fre-quency (!) (Hz)	Acceleration (r_!2) (mm=s2)	Modal Scaling Factor
1259.69	0.245	15.36	2279.648054	5.53E-01

Modal Stresses for 2nd Design Iteration

Modal stresses for important components of are shown in fig. 6.39 to 6.42.

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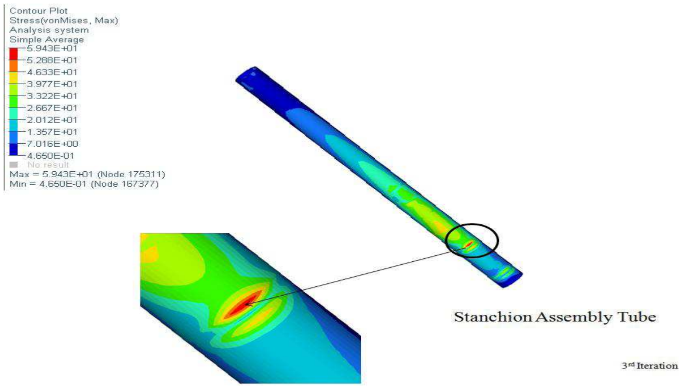


: Stress Plot for Stanchion Assembly Tube

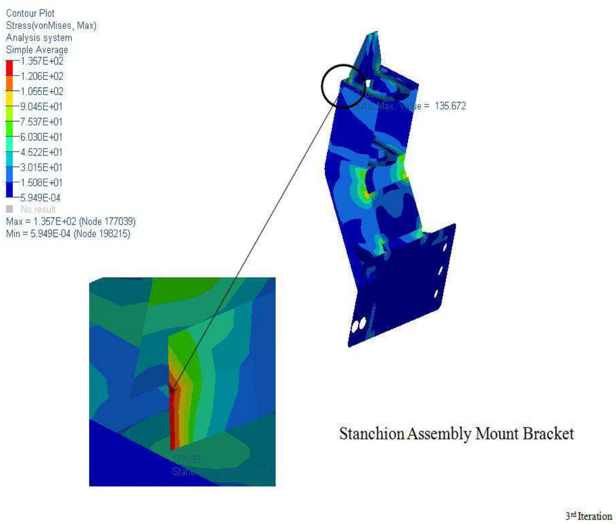


Figure 6.40: Stress Plot for Stanchion Assembly Mount Bracket

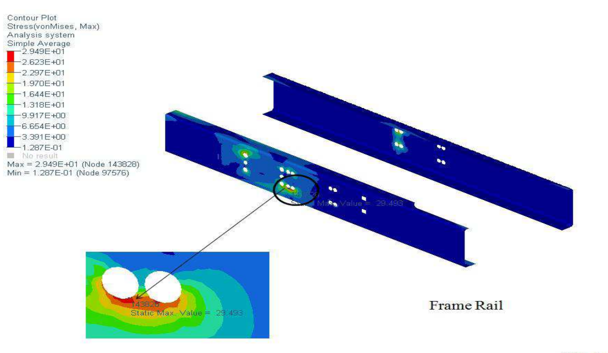


Figure 6.41: Stress Plot for Frame Rail

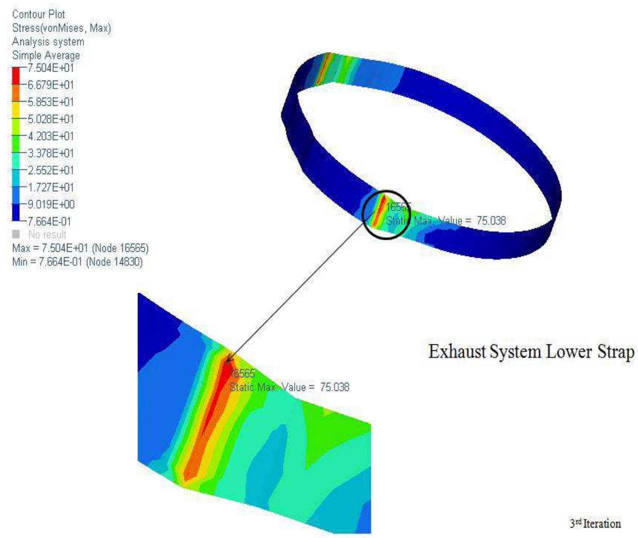
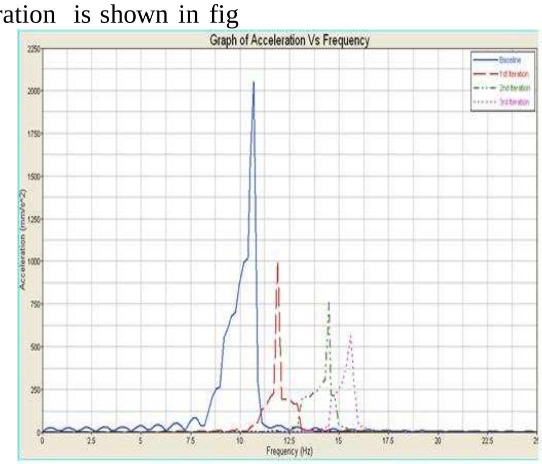


Figure 6.42: Stress Plot for Exhaust System Lower Strap

It is observed that stresses for all components are less than fatigue limit, 2nd design iteration is safe but is not satisfying modal acceptance criteria because natural frequency (14.53 Hz) is less than 15 Hz.

Graph of acceleration vs. frequency for all the design iteration is shown in fig



Frequency Shift from 10.8 to 15.4 Hz for Baseline to Design Iteration

Observations

From the graph of acceleration vs. frequency it is clearly observed that frequency of exhaust system is increased from baseline to iteration with decrease in acceleration value.

Conclusionand Future Scope

Here an attempt is made to study the dynamic behavior of a vehicle under different load cases using virtual prototyping approach.

Thesis includes, literature review that is deemed to be significant for this analysis, complete modeling of a tractor-trailer combination with modeling of leaf spring, IROS stick type suspension, flexible frame etc., simulation of fifth wheel coupling load case for determination of kingpin load and validation by using analytical method, stress analysis of chassis for coupling load case, simulation bump event and sweep sin simulation for analysis of exhaust system.

Following are the conclusions drawn from above study,

1) Comparison of dynamic coupling impact load found by analytical means and using Motion Solve shows that coupling forces obtained using Motion Solve are found to be nearly close to the analytical calculations.
2) Further these coupling loads are used in FE analysis of chassis frame, stresses are found out for each load i.e. vertical and longitudinal for important components of chassis, results shows maximum stresses are found near holes and corners but are within limits, stresses are more for longitudinal load case than vertical.
3) It is difficult to solve complicated model like truck using analytical approach, so first simple 2D 5 DoFs model is prepared to simulate bump event, tire forces are found out by analytical means and comparison is done with results obtained using Motion Solve to validate it, results obtained using Motion Solve are found to be nearly close to the analytical calculations.
4) More realistic 3D model built in Motion View is used to simulate bump event for determination of acceleration at different points of chassis, it is found that overall acceleration of chassis frame is '3g'. Further inertia loading analysis is done with load of three times acceleration due to gravity for important components of chassis, stresses are found to be within limit.
5) Finally various designs of exhaust system are compared to check for modal stresses and modal acceptance criteria. Baseline design which is initially available is not meeting the modal acceptance criteria so new design with sheet metal compo- nents is considered, and changes are made in designs to stiffen it, to increase its frequency, until it satisfies modal acceptance criteria.

In summary it can be said that this virtual prototyping approach is very useful to test vehicle under different road load events, to compare various designs of sub-systems before manufacturing and select best among them, it saves time and cost needed for testing and manufacturing of prototypes.

Future Scope

This thesis is an attempt made for modeling and simulation of high commercial vehicle using virtual prototyping approach. Model built using MotionView has some unique features but there is scope for improvement for better results. The suggested future work for extension of this study are listed as follows,

1. Simulation of more complicated events like braking, cornering using same model used in this thesis.
2. Use of actual road profiles just like various testing tracks for better results.
3. Inclusion of nonlinear stiffness characteristics for springs and bushings.

References

[1] T. D. Gillespie and M. W. Sayers, "A multibody approach with graphical user interface for simulating truck dynamics," SAE Paper No. 1999-01-3705, 1999.

[2] C. Karaoglu and N. S. Kuralay, "Stress analysis of a truck chassis with riveted joints," Journal of Finite Elements in Analysis and Design,Vol. 38, 2002, pp. 1115-1130.