International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 02 | Feb-2016 www.irjet.net p-ISSN: 2395-0072

Virtual Durability Simulation for Chassis of Commercial vehicle

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Abstract – *In conventional virtual validation by Computer Aided Design of truck chassis was based on the static analysis based. Load cases derived was by Experience. This led to some of the critical areas being unnoticed. Hence, it was necessary to rely on physical testing for the validation of the design, which is costly and time consuming. In order to fast track the development & cut short the validation time and cost , validation of new product or design a technique is required that depends on virtual prototype testing at the design stage of development. The use of multi body dynamics and finite element method makes this task simple and accurate taking into account the road load data (RLD) stress history and multi axial stress field, thus making the durability predictions more accurate. In this paper Virtual validation Methodology using RLD approach for a typical heavy truck Chassis is presented with good correlation with Physical validation reducing overall design and development cost and time to deliver first time right product.*

***Key words*—RLDA , CAE, MBD, Rig Testing, Fatigue life, Design optimisation**

1. INTRODUCTION

In the past, the CAE validation of truck cabin and chassis was based on the conventional static analysis based on the load cases derived by experience. This led to some of the critical areas being unnoticed. Hence, it was necessary to rely on physical testing for the validation of the design.

The physical prototype testing is a time and cost consuming activity. In order to reduce the development period, development cost and number of prototypes, a technique is required that depends on virtual prototype testing at the design stage of development. Thanks to recent improvements in computer performance and the availability of the commercial finite element & fatigue softwares. Using these commercially availably codes , engineers can conduct fatigue analysis that take into account the road load data (RLD) stress history and multi axial stress field, thus making the durability predictions more accurate.

The accelerated testing is done on a multi poster test rigs on cab and chassis separately. The acceleration history to the multi-poster test rigs is derived from proving ground (torture track) history. The truck cabin is fitted on part of chassis frame along with its suspension for testing. Similarly, the chassis is suspended at its front and rear suspension area. In order to predict the durability by fatigue analysis, the multi axial stress fields are required for the entire load history. The use of multi body dynamics and finite element method makes this task simple and accurate.

The case study of a typical heavy truck (both chassis & cabin) is presented with detailed simulation procedure.

2. MULTI POSTER DURABILITY TESTING & SIMULATION

The fatigue strength of Frame is generally assessed through the proving ground (torture track) testing and accelerated tests like four-poster testing. In a four-poster test, the displacement history of the four hydraulic shakers is first determined using the frame accelerations determined from the experimental rough road driving, and input accelerations experienced by an actual vehicle in field. In multi poster test, the load history is reduced by reducing non damaging events in order to shorten the test time. This is done through the damage correlation between the rough road driving, torture track test-driving & multi poster test. The typical multi poster test setups are shown in Fig. 1 and 2

Chassis Fatigue Testing is accelerated test procedure similar to 4-poster test, which is used for chassis durability. In this testing along with Z-direction road inputs, X and Y (Longitudinal and Lateral) direction inputs, braking torque loads are considered. In case of chassis, the Longitudinal and lateral forces are significant in addition to Z forces. A 22-poster test rig used for 6 x 4 tractor – 49T Tractor

- all direction road excitations

- braking effects

- Cabin and engine excitations to Chassis.

- Fifth wheel reactions

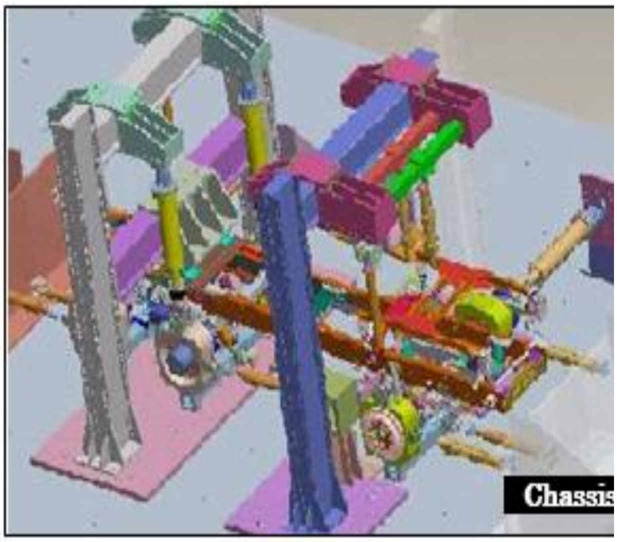


Fig 1- Typical Multi Poster set up

Fig 2- Multi Poster Test Rig for Frame

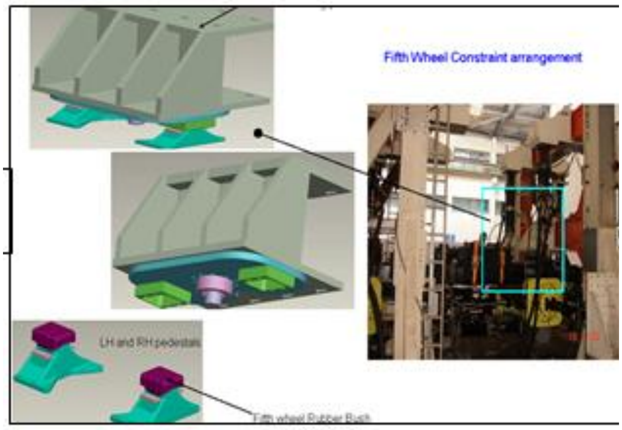


Fig 3- Fifth Wheel constraint arrangement

The cabin weight, Powertrain weight, fifth wheel loads are applied by actuators with suitable fixtures. The effect of above aggregates in vehicle running condition is simulated. Refer fig. 2 &3

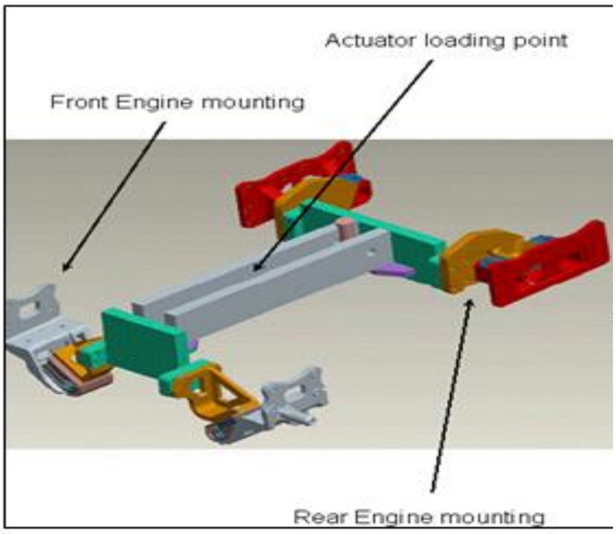


Fig 4 –Power Train arrangement

Methodology adopted

- Review present conentional system of design optimisation
- Identify the aggregates requiring optimisation
- Build initial 3 D CAD model of the vehicle aggregates in Pro-e or CATIA software
- Do initial Finite Element analysis for the built CAD model with analyiss softwares like hypermesh , NASTRAN
- Find out the critical zones or areas related to maximum stress / deflection in order to decide intrumentation points on the physical parts
- Identify the referance vehicle model for intrumentation and capturing road load data
- Identify the service routes where new model will be subjected to usage for desired target life of product
- Intrument the referance vehicle at various locations as identified in the earlier step with the help of various devices like strain gauging , LVDT, WFT, Accelerometer, RPM meter, Rosette as the requirment of capturing output like strain , displacment , Forces along XYZ, Moments about XYZ for damage analysis, damage edit and control
- Do physical running of the instrumented vehicle on identified with the desired payload and application speed , grade and acceleration
- Data acquisition by use of data acquisition system like eDAQ plus (SOMAT) which is having 64 Channel analog, 500 Hz sampling rate , GPS channels , Digital inputs
- Analysis of the measured data using analysis

- software like ICE-flo GlyphWorks, Plotting amplitude time history , rainflow analysis with respect to number of cycles and rainflow change histogram
- Development of correlation with service usage and proven ground (torture track) in order to decide number of cycles for service life usage , Signal processing and damage edit , drive file generation
- Kinematic model building in ADAMS based on drive file and extraction of forces
- Durability analysis (Virtual simulation) of the 3D CAD model Fatigue calculation software like FEMFAT, Design Optimisation using optistruck & Hyperstudy

Below are below two major steps followed

2.1 Transformation of rig test signals to load time histories at chassis attachment points through ADAMS

On- road / torture track testing of vehicle for predefined cycles is the general way to evaluate durability of frame mountings. Performing on-road testing, as number of vehicle variants increases, is time consuming and costly affair. Hence, with the objective to perform vehicle frame durability evaluation at laboratory level and to accelerate testing activity, this full Frame fatigue test evaluation has been planned. Drive files for the rig using the strain, LVDT and WFT data is collected by instrumenting reference vehicle and running on service road.

Frame Fatigue analysis test rig set up there is actuators (J1 to J19) are used for giving axle vertical motion, axle longitudinal force, axle lateral force and cab vertical force input. One end of all above-mentioned actuators is connected to rigid structure. Two rubber bush are provide between frame and fifth wheel assembly. Axles are excited through adapter assembly, which are fixed together.

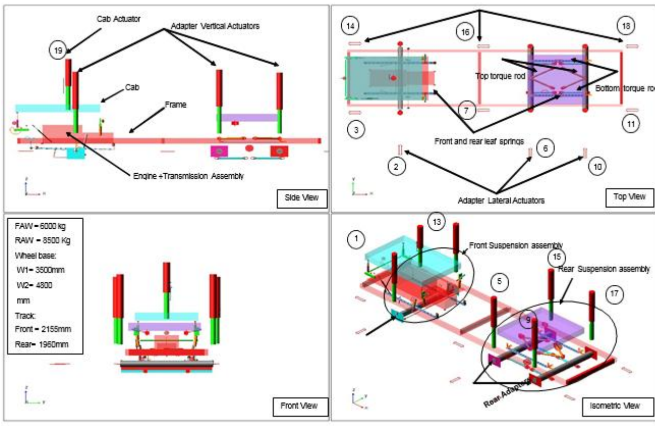


Fig 4 – Frame Fatigue test ADAMS Model

The test activity is performed in the virtual world through simulations using ADAMS and Nastran, FE fatigue. Equivalent ADAMS model is made replicates test setup. This ADAMS multi body simulation is performed giving the displacement input drive file at the four-poster leg locations. The multi body dynamic analysis output is the force history at all the mounting locations on the cab. Dynamics analysis is performed to get the load history at various front and rear suspension mount locations.

The attachment point load time histories calculated through ADAMS are then used to calculate fatigue life. These time histories is taken as input for durability simulation

2.2 Durability simulation for fatigue life simulation

Fig 5 & 6 shows the flowchart of simulation method used for the prediction of fatigue strength of frame.

This method makes use of various CAE solvers like MSC-ADAMS, MSC-NASTRAN & MSC-FATIGUE. The brief description of the process is as given below.

First, a finite element model of the Chassis is created using CAD data and then an eigen value analysis is performed using NASTRAN. The results of the eigen value analysis are then converted into an ADAMS's modal model using ADAMS/FLEX.

After this detailed modelling, ADAMS multi body simulation as per earlier process performed giving the displacement input drive file at the four-poster leg locations. The multi body dynamic analysis output is the force history at all the mounting locations on the cab. This history is then combined with the NASTRAN's static unit load inertia relief analysis results to obtain a stress history in the cabin for the entire multi poster cycle using linear superposition method.

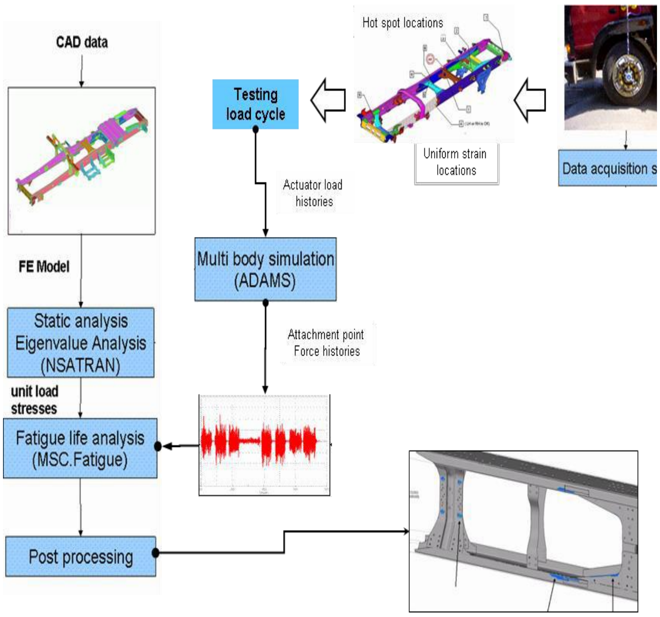


Fig 5 –Chassis Simulation process flowchart

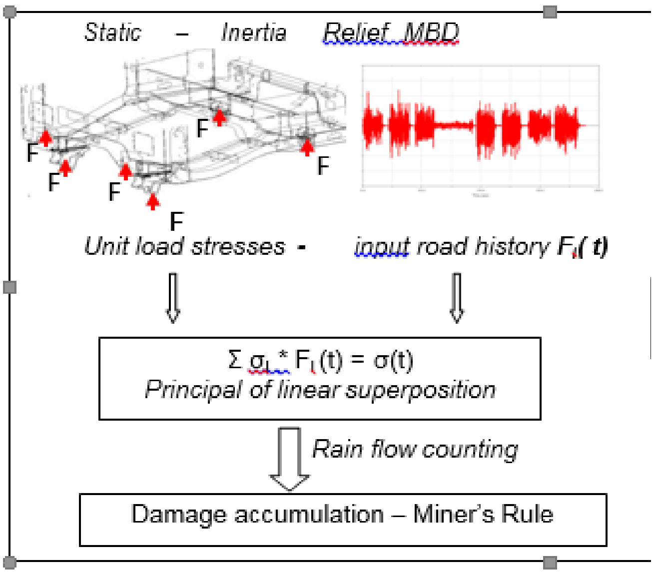


Fig 6 –Fatigue analysis process in MSc Fatigue

This process of linear superposition method followed by rain flow cycle counting & finding the cumulative damage by Miner's rule & finally arriving at fatigue life of cabin is performed in MSC-FATIGUE. Refer fig.6 for the schematic model of the analysis process.

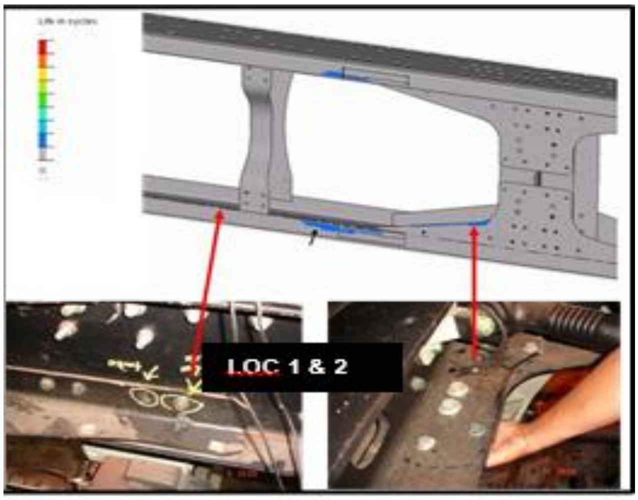


Fig 7- Rear Cross member Gusset Location

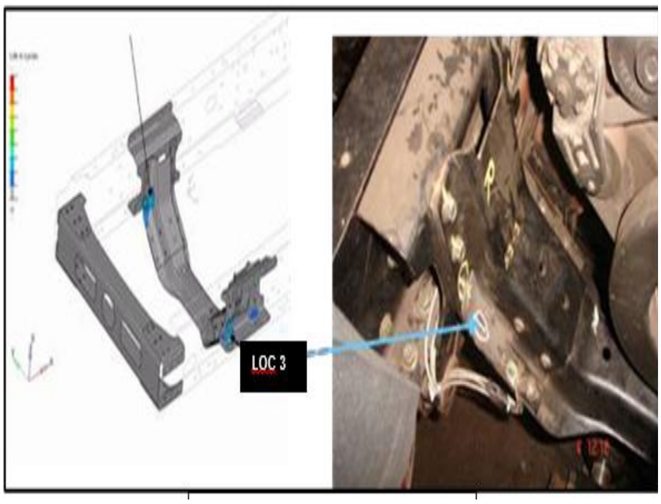


Fig 8- Engine Mounting cross member location

Table 1 shows the detailed durability simulation results for the Chassis. Based on this it's concluded that Chassis is meeting target fatigue life cycles as required

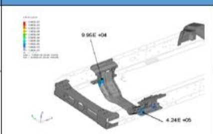
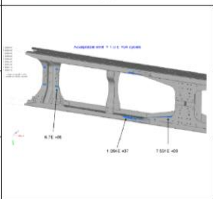
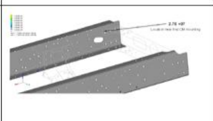
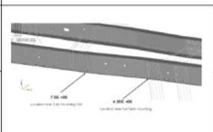
SN	Frame location	Component	Life as per Durability Simulation	CAE correlation	Target TT Cycles for Actual service life	Results
1	Cross memer location	Engine Mounting CM	9.95E +04		1.0 E+04	Meeting target life
2		Engine Mounting CM Gusset	4.24E +05		1.0 E+04	Meeting target life
3		Alligated CM - Bottom	6.7E +05		1.0 E+04	Meeting target life
4		Reinforcement LM rear bottom flange	1.064E +07		1.0 E+04	Meeting target life
5		C-C CM gusset	7.551E +06		1.0 E+04	Meeting target life
6		Rear CM gusset	5.37E +05		1.0 E+04	Meeting target life
7		Location near first CM mounting.	2.7E +07		1.0 E+04	Meeting target life
8	LM	Location near Cab mounting CM.	7.5E +06		1.0 E+04	Meeting target life
9	locations	Location near fuel tank mounting.	4.35E +06		1.0 E+04	Meeting target life

TABLE 1 (Durability Simulation Result Summary)

3 *CONCLUSION*

This virtual simulation methodology for durability life prediction can be effectively used at the design stage for evaluating the fatigue durability chassis for eliminating expensive physical prototype testing. A virtual simulation methodology was developed for finding out the vehicle durability, which has a correlation with physical testing in terms of the sequence of failure and locations, and number of cycles. This simulation methodology makes use of input test data, multi-body dynamics & finite element method. This methodology eliminates the use of static assumed service load cases, which do not represent the full duty cycle to which the vehicle will be subjected. This is very effective simulation tool which can be used during design and development of new products reducing overall development time and cost of Design iteration and physical validation.

ACKNOWLEDGMENT

I would like to express my special thanks of gratitude to my superiors who gave this golden opportunity to do this wonderful project which also helped me in doing lot of Research and I came to know about so many new things. I am really thankful to them. Secondly I would also like to thank my family and Friends who helped to complete this project in limited time period.

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BIOGRAPHIES

Mahendra A Petale is working in Leading Automotive Industry. He is leading Design and Development of future generation commercial vehicles starting from concept to launch. He has wide experience in Key aggregate designs, Product finalization and Value Engineering.