Study of Effect of Varying Engine Mount Locations and Stiffness on Vibration in Heavy Commercial Vehicles

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***Abstract*— Engine mounting plays a vital role in isolating the vibration caused by the engine firing forces and also in improving the vehicle's vibration behaviour, which the driver uses to express his comfort. This paper describes the study of vibration attributes of Heavy commercial Vehicle with respect to different engine mount positions, in terms of nodal point and stiffness for achieving the better vibration isolation performance. Output vibration levels are measured at the tactile points such as steering wheel, gear lever, pedal and seat rail. Comparative analysis of above experiments with different combinations conducted using CAE (Computer Aided Analysis) predictions to recommend a suitable engine mount combination.**

Keywords*— *Vibration Transfer function (VTF), Stiffness, CAE.

I. Introduction

In recent trends, all the automotive OEM's moving towards modular vehicle program, where position of the engine mounts in powertrain, carries major role considering space availability. In the Past decade, there has been lot of research in all aspects pertaining to selection of isolators and different design of engine mounting system to reduce vehicle vibration and increasing driver comfort, in all the aspects. Iwahara and Tsakai [1] conducted 6 DOF lumped mass engine model to find, which of the mounting layout contributing for better isolation using eigen value, the frequency response and transient response analysis and Shane et al [2] found new concept to relate percentage of decouple by focusing the excitation, acting on the powertrain mounts. Vibration plays major role against driver comfort and considered as very vital to have the preliminary analysis for the initial stage of design, where the Engine mount location (mounting pitch) and mount stiffness considered as variable in powertrain mounting system. CAE (Computer Aided Analysis) analysis, conducted for different positions of engine mounts and with same configuration of powertrain using CAE collaborative in achieving the better isolation..

II. Engine Mounting System

The primary function of engine mounting system is to support the power train unit, isolate the engine vibrations, support engine reaction torque and act as a damper during frame bending. Generally Isolation increases with decrease in stiffness of elastomer, which directly affects the life of the mount and vice versa. Selection of engine mounts also very important in order to obtain, both the fatigue life of elastomer and better isolation of vehicle. At the same time, position of engine mounts also influencing the vital role in reduction of vibration as well as improvement in bending strength by reduction in overall bending moment.

III. Methodology

Recent scenarios of all automotive OEM's are moving towards Modular Vehicle Program, where fixation of engine mount positions are such a challenging task for different power train combinations. To obtain a modular layout for the drivetrain and to locate the engine mount at a convenient position, the following methodology followed.

This paper targeted for the Engine mounting system for a new platform of vehicle, where vibration behaviour in cabin compartment studied, for different set of positions of the engine mounting system, with the same configuration of 6 cylinder inline engine and 9 speed gearbox as power train.

Primarily this paper started with basic bending moment calculations, where the existing engine mounting system studied and modified to maintain value of bending moment to zero in RFOB (Rear face of block) as new proposed position in order to achieve better structural strength of the system.

As second step, analyzed the VTF (Vibration transfer function) for both the existing and proposed engine mounting locations using CAE tool, where the unit load applied on to the crankshaft and tactile vibrations measured in the cabin compartment for improvement. Refer the below flowchart Figure 1 for methodology, which consists of the above steps explained.

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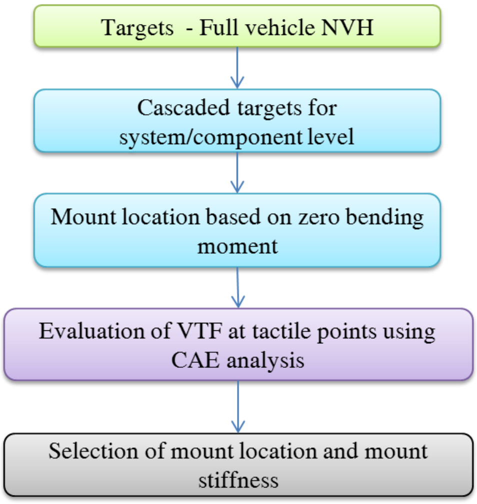

Fig 1. Methodology adopted

A. Therotical Approach

In general, engine installations must be designed to limit the vertical bending moment at rear face of the block in order to get the structural rigidity of the mounting system. Optimum engine mount location derived using theoretical calculation by considering vertical bending moment and the calculations as per Ashok Leyland Standard for Engine Mounting System (Ref [3]).

For theoretical calculation, Mass and Centre of Gravity of the Engine, gear box considered and located with respect to R1, R2 Supports in powertrain as shown in Figure 2.

As ideal case, the engine being mounted using 2 supports namely R1 and R2.With the aid of bending moment calculation R2 support relocated to the new distance in such a way that bending moment value to zero at RFOB (Rear face of block) and the same shown in Table I.

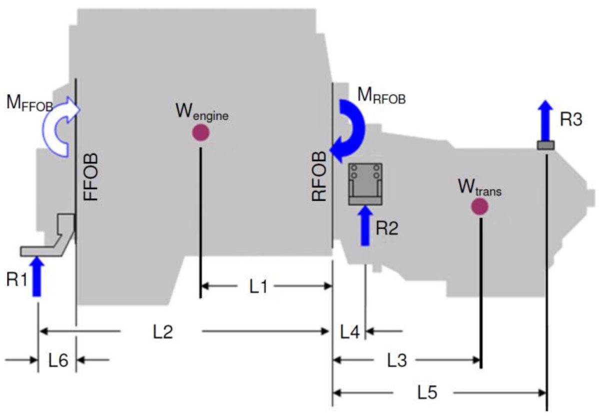

Fig 2. Bending moment calculation

Based on the calculation, the new proposed rear mount location obtained and indicated in Figure 3.

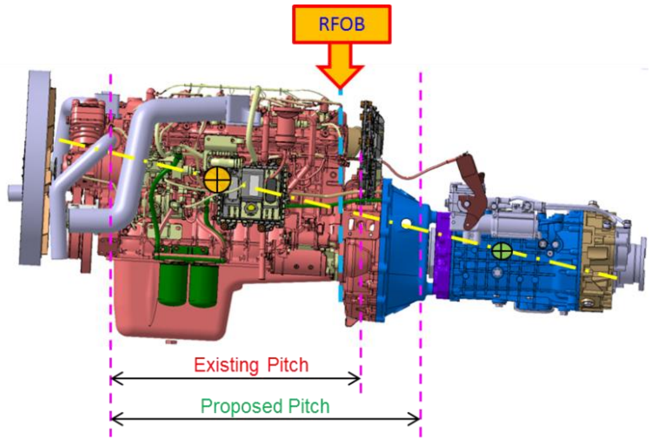

Fig 3. Picture of Engine and gear box with existing and proposed pitch

TABLE I. CALCULATED VALUES FROM THEORITICAL APPROACH

Configuration	**Mounting Pitch**	**Bending moment (kg-m)**
Existing Pitch	Old Value	>0
Proposed Pitch	New Increased	0

According to the calculation, proposed pitch selected for further study of vibration transfer function of engine mounting system using CAE (Computer aided engineering) tool.

B. CAE on Vibration transfer function

For the four proposals, including baseline computer aided analysis carried out to determine the vibration transfer function from powertrain to tactile points and based on the relative comparison of vibration transfer function (VTF) better proposal is recommended.

1) FE Model Construction: Full vehicle of the truck including the power train unit considered for the analysis. Power train unit as well as most of the cast brackets in frame/cabin structure meshed with solid elements. Panel structures in frame and cabin meshed with shell elements. Bolt connections represented with one dimensional beam elements and weld connections represented with rigid connections. Cab suspension and power train suspension represented with linear spring elements (Refer in Figures 4.1 and 4.2)

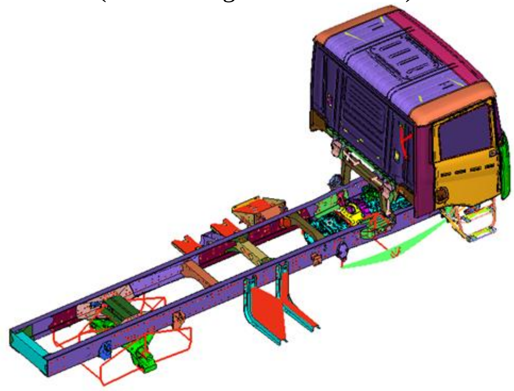

Fig 4.1. CAE Model representation

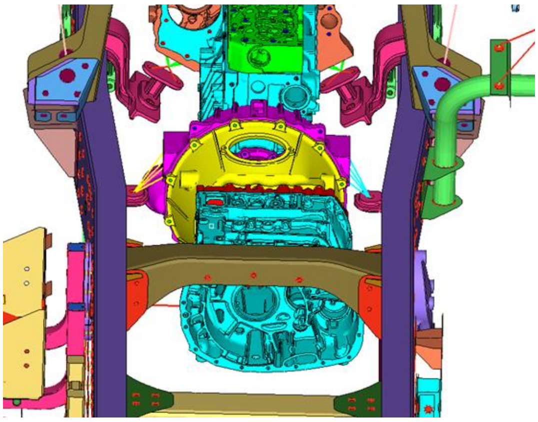

Fig 4.2. CAE Model representation

2) Vibration Transfer Function (VTF) calculation : FE model checked for its quality and connectivity.Then modal analysis carried out, extracting mode shape results at tactile points (Floor RH/LH, steering wheel, gear lever) for all the four proposals. VTF analysis carried out by applying vertical force in z-direction at the crankshaft main bearing as shown in Figure 5. Variation of main bearing forces with firing order not accounted in the analysis. Other forces, specifically piston slap force and valve impact forces assumed to be insignificant.

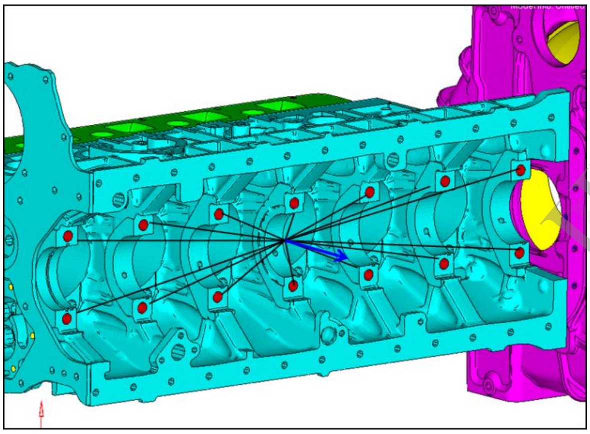

Fig 5. Input Definition

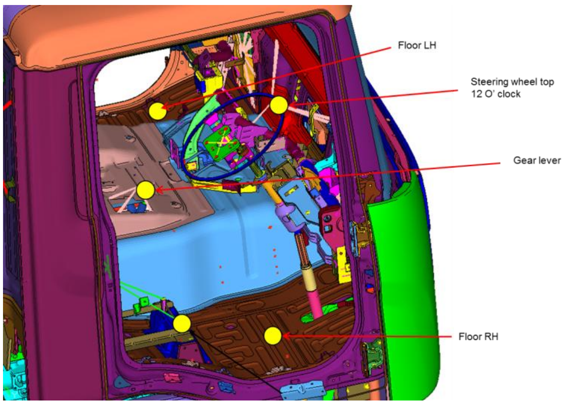

Fig 6.Tactile points in the cabin

3) Output Measurements from Tactile Vibration: Vibrations measured in the tactile points (shown in Figure 6) like Steering wheel, gear shift lever, floor and seat rail for the configurations shown in Table II. Bar chart in Figure 7 shows the VTF (Vibration transfer function) comparison at 30 Hz and Figure 8 shows the average VTF comparison between 20-100Hz.

TABLE II. CONFIGURATION FOR ANALYSIS

Configuration	Location	Stiffness
Proposal-1 (Baseline)	Existing Pitch	Existing
Proposal-2	Existing Pitch	Softer
Proposal-3	Proposed Pitch	Existing
Proposal-4	Proposed Pitch	Softer

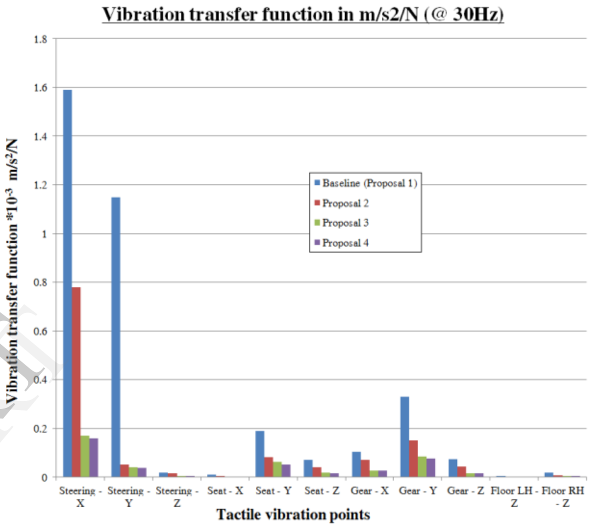

Fig 7.VTF at main engine firing frequency at idle

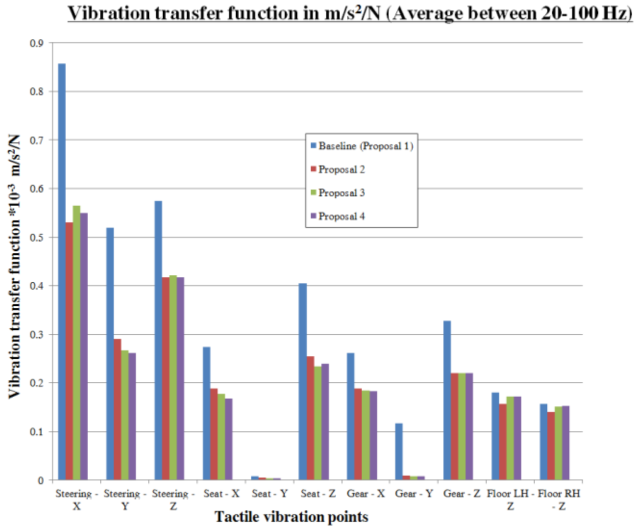

Fig 8. Average VTF between 20-100Hz

From the VTF, it is observed that proposal 2, 3 and 4 has considerably lower VTF compared to proposal1 and also they are comparable with each other.

IV. SUMMARY

Through the conceptual analysis, the following points were observed:

- New mount location has been proposed to reduce the bending moment of acting on the power train unit.
- Tactile vibration transfer function evaluated from power train to tactile points and it is observed that proposal 2, 3 and 4 is better than proposal1 and they are comparable to each other.
- Proposal No 4 is better than other proposals, which calls for increased mounting pitch with softer stiffness for improved bending moment strength, better vibration isolation performance and tactile vibration characteristics.

V. CONCLUSION

- For the six cylinder engine configuration, to reduce the bending moment as well as improve the vibration performance characteristics, a combination of new mount location and stiffness has been evaluated. .
- New mount location have been proposed to achieve improved strength by reduction in bending moment.
- With the new mount location, existing and proposed mount stiffness were evaluated and it was observed that with proposed stiffness (proposal4) the vibration isolation performance is better compared to other proposals.
- Proposal 4 has lower VTF compared to other proposals with. increased structural rigidity of power train..
- Hence proposal 4 is recommended for implementation after physical validation.
- The above study throws light on how the engine isolation can also be altered by location of the engine isolator along the longitudinal direction of the powertrain.

REFERENCES

[1] Iwahara, M. and Sakai, T., "The Optimum Layout of Engine Mounting by Dynamic Analysis," SAE Technical Paper 1999-01-3717, 1999, doi: 10.4271/1999-01-3717.

[2] Sui, J., Hoppe, C., and Hirshey, J., "Powertrain Mounting DesignPrinciples to Achieve Optimum Vibration Isolation with Demonstration Tools," SAE Technical Paper 2003-01-1476, 2003, doi:10.4271/2003-01-1476.

[3] Ashok Leyland Standard for Engine Mounting System

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