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Analysis of Methods for Automobile Engine Vibration Control

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Abstract: *Ride comfort, driving stability and drivability are vital factors in terms of vehicle performance and the customer satisfaction. The power plant (IC engine) is the source for the vibration that reduces the vehicle performance and it need to be controlled to some extent such that the vehicle performance will be improved. The IC engine is made up of reciprocating and rotating parts and they produce unbalanced forces during their operation and produce the vibratory output at the vehicle supporting members. The vibration reduction will be possible by minimizing unbalanced forces and by providing the anti vibration mounts at the engine-vehicle interface. Many researches were made to find the causes for the vibration and to reduce the vibrations at the engine supports. But still there is a research gap on the vibration modelling and vibration isolation of the engine. In this work, an attempt is made to represent the state-of-the- art for the engine vibrations and its isolations.*

Keywords: *Vibration, engine assembly, damper, stiffness.*

I. Introduction

The internal combustion (IC) engine is the concentrated mass in vehicle and if not properly designed it will cause vibrations and transfer to the supporting structures ride comfort, driving stability and drivability are important factors for the performance of a vehicle and are affected by the engine vibrations. Because of the environmental considerations, as well as changes in consumer preferences regarding vibration induced must be reduced. Vibration behaviour of an IC engine depends on unbalanced reciprocating and rotating parts, cyclic variation in gas pressure, shaking forces due to the reciprocating parts and structural characteristics of the mounts. Engine vibrations are caused due to the reciprocating and rotating masses of the engine. The variations of inertial forces are due to the combustion and the compression differences of the piston cylinder arrangement during their operation. The engine inertial forces leads to the unbalanced forces of the engine and they are quiet varying with respect to speed, fuel supply and combustion characteristics of the fuel. To predict the vibration output of an engine and to minimize the possible durability and consumer perceived quality problems associated with engine vibration, a robust and accurate design and simulation model is needed. To reduce the engine vibration proper mounting must be provided as dampers at the interface of the engine and chassis. For vibration isolation five methods have been introduced and analysed. Modelling has been done in SOILDWORKS 10.0 and analysis has been done in ANSYS WORKBENCH 13.0. [1]Deana. M. Winton and Dowling conducted an experimental study to determine the rigid body modal content of engine block vibration on a modern heavy-duty inline six-cylinder Diesel engine. They used three engine mounts fitted with multi-axis force transducers and exploited standard modal analysis to determine rigid body modal characteristics and engine mount forces signatures of the engine vibration modes of engine block.[2]Hoffman and Dowling developed a seven degree-of-freedom model for low frequency engine vibrations that utilizes two way coupling assumption. They compared results of the two way coupling model with the one way coupling model. Also they identified that the new model properly conserves energy and account for gravitational forces. [3]Zhen-Dong Ma and Perkins developed equations of motion for major components of internal combustion engine using recursive formulation. The derivation equation of motion was automated through the computer program by the use of C and FORTRAN sub routines. The entire automated procedure forms the basis for an engine modelling template.[4]Niccole Baladazini.et.al presented an innovative approach to dynamic design that has the significant advantage of allowing dynamic requirements to be specified from the earliest design stage. They used Genetic algorithm to optimize the dynamic behaviour of engine-sub-frame system and its links to chassis. The optimization minimizes complying with the static and dynamic constraints. The GA was applied to a multi body model of Engine-mount system to derive new, improved configurations.[5]Tsuneo Tanaka and Tetsuya Sakai presented a method to effectively reduce a level of idling vibration in heavy-duty trucks. For that they developed a full vehicle vibration model using Finite element method. The flywheel velocity and fluctuation in flywheel speed were the input to this model and the output from the model is engine excitation forces.

A. ENGINE SPECIFICATIONS

The power plant (IC engine) is the source for the vibration that reduces the vehicle performance and it need to be controlled to some extent such that the vehicle performance will be improved. In this project, vibration is controlled by isolating engine assembly from chassis by different methods. The dimensions of Ashok Leyland truck engine [AL412TAC2] has been chosen for the analysis.
To reduce the complexity of the analysis, Engine assembly is considered as single engine box.

- *Ashok Leyland industrial engine AL412TAC2 specifications has been chosen for analysis which are as follows,*
- *ENGINE WEIGHT – 7450 N*
- *DIMENSIONS – 1190 x 680 x 1100 mm*
- *NO OF CYLINDERS – 6*
- *FUEL - DIESEL*
- *COMPRESSION RATIO – 17.25 : 1*
- *TORQUE – 51 Nm @ 2000 rpm*
- *RPM – 1200 to 2400*
- *BHP – 74.9 to 153.9*
- *EXCITATION FORCE – 420 N*

B. ISOLATION METHODS

Analysis is done for five different methods, which are as follows:
1. Providing springs.
2. Providing dampers.
3. Providing spring and damper.
4. Providing damper and mass
5. Providing spring, mass, damper system

II. Providing Only Spring

In this method spring has been designed based on following dimensions. There are 16 springs at the bottom and 12 springs at the top of the engine box which are connected in series.

- Mean diameter of spring - 80 mm
- Diameter of wire – 11.8 mm
- No. of turns – 6
- Stiffness of spring – 49.33 kN/m
- Free length – 180 mm
- Solid length – 70 mm
- Pitch – 30 mm

Equation of motion for this model is $F = m\ddot{x} + kx$
Where F = Excitation force in N
k = Stiffness in N/m
x = Displacement in mm.
$\ddot{x}$ = Acceleration of mass in m/s^2 .
m = Mass of engine assembly in kg

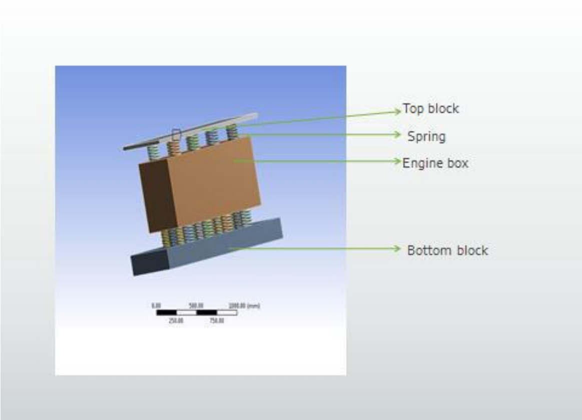

Fig 1

Maximum stress occurred in springs and minimum stress occurred in vehicle (top and bottom blocks).

III. Providing Only Damper

Viscous damper is used for damping. Value of damping coefficient of damper oil = 9.86 kNs/m. The equation of motion is $F = m\ddot{x} + c\dot{x}$. There are 16 dampers at the bottom and 12 dampers at the top of the engine box which are connected in series.
c- Damping coefficient of oil in Ns/m.
$\ddot{x}$-Velocity of mass in m/s .
Maximum stress occurred in damper and minimum in vehicle. But wearing of damper is less than spring.

IV. Providing Spring and Damper

The equation of motion is $F= m\ddot{x}+c\dot{x} + kx$. Maximum stress occurred in damper and minimum in vehicle. But wearing of damper is less than spring.This method is less efficient than method 2 and more efficient than method 1

V. Providing Damper and Mass

This method is similar to a vibration absorber. A small mass of 0.5 kg is provided with the damper. Maximum stress occurred in damper and minimum in vehicle. This method is more efficient than above other three methods. Nine small masses attached at the bottom of the engine assembly

VI. Providing Spring, Mass and Damper

A small mass of 0.5 kg is provided with the damper .Maximum stress occurred in damper and minimum in vehicle .This method is not more efficient than methods 4and 2 but it is less efficient than methods 1 and 3.

VII. Conclusion

From five different methods, damper with mass is more efficient than all. Model which has only spring is less efficient. All the methods isolate vibration from the engine.In present days active vibration control is been used,but in this project ,passive vibration control has been analysed. Passive vibration control is cost effective than active vibration control.

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