Study on the Effect of Glass FRPC and Aramid FRPC Structural Covering on IC Engine for Minimizing Vibrations

Neeraj Kurahatti [1], Dr. Vinay Kuppast [2]

[1]PG studies, Department of Mechanical Engineering, Basaveshwar Engineering College,Bagalkot,India.
[2]Associate Professor, Department of Mechanical Engineering, Basaveshwar Engineering College, Bagalkot, India.

---***---

Abstract - IC engine noise and vibration has been a concern for automobile as well as power generation manufacturers. Noise and vibration statutory norms laid down by the government administrations are becoming stringent in the design and manufacturing of IC Engines and other dynamic machineries. Hence it is apparent that the investigations and studies focusing on the new methods and theories which would help the designers to cater the need for the development of the quieter machines. First step is to identify noise and vibration source and the effect of it on the system. The noise and vibration studies would also necessary to decide upon the behavior of the material which would suggest some better design alternatives for the reduction of noise and vibration. Topological and geometric optimization, noise attenuation material design, noise cancellation techniques e.t.c. are the few approved procedures in the reduction of the noise and vibration levels. In this paper studies on noise and vibrations of IC engine and its reduction carried out by various researchers, have been considered. FEA (Finite Element Analysis) using ANSYS commercial software is applied to IC engine vibrations are presented. IC Engine borne noise and vibration is simulated considering Structural Steel and Aluminium Alloy with Glass FRPC and Aramid FRPC coverings over the engine. The different combinations of the thickness i.e., 5, 10, and 15 mm, of these materials showed a significant reduction in the frequency of vibrations of the coverings. Combination of Structural Steel with Glass FRPC and Structural Steel with Aramid FRPC, Aluminium Alloy with Glass FRPC and Aluminium Alloy with Aramid FRPC both of thickness 5 mm demonstrated the best combination compared with the other combination of 10 mm and 15 mm thickness for the reduction of vibrations of the engine. Further Glass FRPC is recommended for the minimized vibrations applicable to the engine covering. These studies using vibro-acoustic principles in the design of the noise attenuation techniques help in the development of the materials and methods for noise attenuation in the design phase itself.

***Key Words*: *Noise, Vibration, Attenuation*.**

1. INTRODUCTION

Automobile industries are growing rapidly with emphasis on development of less noisy engines to reduce noise and vibration, so by improving performance contribution can be done to reduce pollution. Engine vibration and noise has given rise to wider scope for predicting and controlling its noise and vibration.

1.1 Source of noise and vibration

The noise and vibration in IC engine is mainly due to combustion and movement of various parts. The Combustion noise is mainly due to rapid pressure fluctuations in the combustion area. The mechanical noise is due to primary and secondary motion of moving parts. Primary motion is because of combustion pressure which makes piston to reciprocate from TDC to BDC, this motion is linear in nature and it is desired to transfer motion. It does not produce much vibration and noise when compared to secondary motion. Secondary motion is due to impact load of combustion and it induces transverse motion in engine when piston moves from TDC to BDC. Transverse motion is not desired because it produces piston slap and twisting movement.

1.2 Modal Analysis

Modal Analysis is the study of dynamic properties of the system in the frequency domain. It provides an overview of the limits of response of the system.The designer can understand the natural vibration frequencies to make sure that they are not the same as operating or excitation frequencies.

1.3 Harmonic Analysis

Cyclic load will generate a cyclic response in a system. Harmonic response analysis predicts the dynamic performance of structures. Response of steady state linear structure subjected to loads that vary sinusoidally (harmonically) are found by Harmonic Analysis . The aim is to calculate structure response at certain frequency range and obtain a graph of some response quantities (like displacements) versus frequency. Peak responces are then identified from the graph.

2. OBJECTIVES

The simulation of the IC engine to reduce the vibrations using ANSYS software is proposed. The proposed study includes covering the IC engine with different vibration absorbing materials and finding out vibration amplitude with different material and thickness combinations.

1 To Model the lumped mass Structure as applied to IC engine
2 To investigate the vibration characteristics of the engine using modal and then harmonic analysis (Amplitude v/s frequency).
3 To propose the best suitable material and thickness combination for outer covering of engine for low vibration levels.

3. METHODOLOGY

The present work has the following steps:

- Modeling of the lumped mass as applied to IC engine in modeling Software NX 9.0
- Update the material library
- Calculation of the force acting on the piston
- To carry out Modal Analysis to get the natural frequencies
- To carry out Harmonic analysis and to know total deformation and amplitude of vibration vs. frequency plot
- Comparison of the best material and thickness combinations which gives low vibration level

3.1 Specimen modeling

Table -1: Dimensions of Lumped mass as applied to IC Engine

Model	Square Dimensions in mm	Height in mm
Lumped Mass as applied to IC Engine	250X250	300

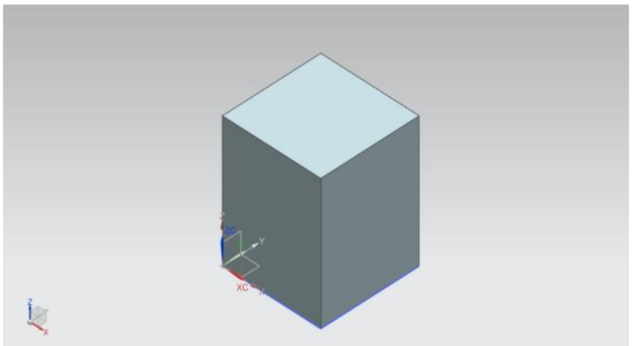

Fig -1: IC engine as lumped mass

3.2 Input force

Parameters of CRDI Engine are taken for calculating the force. It has a maximum torque of 190Nm at 2000rpm, crank radius of 41 mm.

The force is calculated using the formulae.

$$T=F\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)r$$

The maximum force acting on the piston is 6551 N at 45° crank angle, which is applied on the top face of lumped mass of IC Engine in Harmonic analysis.

3.3 Material and thickness combinations

Table -2: Material and thickness combinations

Engine Material	Engine outer covering Material	Thickness of outer covering considered in mm
Structural Steel	Glass FRPC	5,10,15
	Aramid FRPC	5,10,15
Aluminium Alloy	Glass FRPC	5,10,15
	Aramid FRPC	5,10,15

3.4 Modal analysis

Modal Analysis is carried out to find the natural frequency of the IC engine for the given boundary conditions.

Table -3: Natural frequencies of IC Engine

Mode No.	Natural Frequencies in (Hz) when engine material is Aluminium Alloy	Natural Frequencies in (Hz) when engine material is Structural Steel
1	1642.2	1637
2	1642.2	1637
3	2407.3	2426.7
4	4298.9	4270.9
5	4725.9	4739.6
6	4725.9	4739.6

Firing frequency of the Engine is calculated by the general formulae.

$$\text{Firing frequency of Engine} = \frac{2\pi n}{60 * 2}, \quad n = \text{rpm}$$

At 2000 rpm the firing frequency is 104.7 Hz, at 12000 rpm it is 628.3 Hz .The fundamental frequency of engine considering both the material are 1642.2 Hz and 1637 Hz which are well above the firing frequency. Hence resonance does not occur.

2.5 Harmonic analysis

First and Sixth mode from Modal Analysis are taken as the maximum and minimum values for Harmonic analysis.

Table -4: Frequency range for Harmonic Analysis

Minimum Frequency	1500 Hz
Maximum Frequency	5000 Hz
Damping ratio	0.01

Graph of Amplitude of vibration in 'm' v/s frequency range is obtained from ANSYS Workbench after carrying out the Harmonic analysis.

4. RESULTS AND DISCUSSIONS

Amplitude of vibration is observed by plotting the graph of Amplitude in 'm' against frequency in 'Hz'.

4.1 Engine material is Structural steel and outer covering is Glass FRPC and Aramid FRPC

The observations for the amplitude of vibrations for 5 mm, 10 mm and 15 mm thickness of combinations (Structural steel + Glass FRPC and Structural Steel + Aramid FRPC) are made and compared for the lowest vibration amplitude. These data are tabulated in Table 5 and plotted as shown in Fig -2

Table 5 Amplitude of vibration for different thickness combination

Material Combination	Thickness in mm		
	5 mm	10 mm	15 mm
Structural steel + Glass FRPC	1.08 E-08 m	4.05 E-07 m	2.40E-07 m
Structural steel + Aramid FRPC	1.33 E-08 m	6.20 E-07 m	3.80 E-07 m

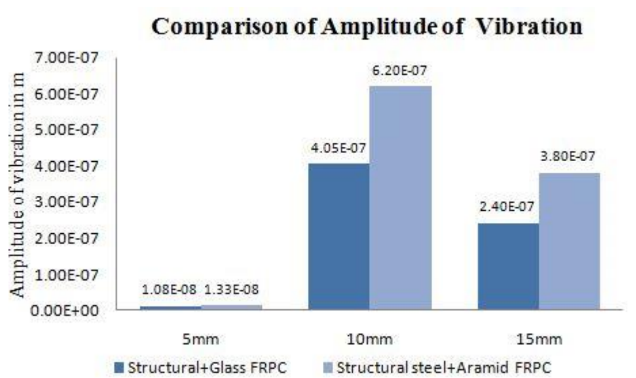

Fig -2: Comparison of amplitude of vibration for different thickness combinations

It is observed from Fig-2 that the lowest amplitude of vibration is 1.08E-08 m for Structural Steel + Glass FRPC of 5 mm thickness, when compared to other materials combination with 10 mm and 15 mm thickness.

4.2 Engine material is Aluminium Alloy and outer covering is Glass FRPC and Aramid FRPC

The observations for the amplitude of vibrations for 5 mm, 10 mm and 5 mm thickness of combinations (Aluminium Alloy + Glass FRPC and Aluminium Alloy + Aramid FRPC) are made and compared for the lowest vibration amplitude. These data are tabulated in Table 6 and plotted as shown in Fig -3.

Table 6 Amplitude of vibration for different thickness combination

Material combination	Thickness in mm		
	5 mm	10 mm	15 mm
Aluminium Alloy + Glass FRPC	2.28 E-08	5.10 E-07	5.50 E-07
Aluminium Alloy + Aramid FRPC	3.72 E-08	1.01 E-06	8.70 E-07

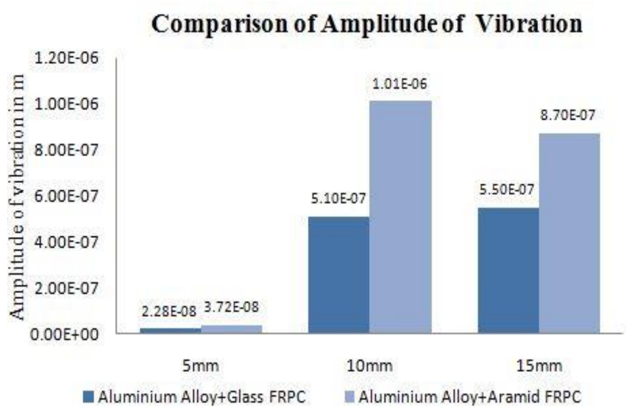

Fig -3: Comparison of amplitude of vibration for different thickness combinations

It is observed from Fig -3 that the lowest amplitude of vibration is 2.28E-08 m for Aluminium Alloy + Glass FRPC of 5 mm thickness, when compared to other materials combination with 10 mm and 15 mm thickness.

5. CONCLUSIONS

Combination of Structural Steel with Glass FRPC and Structural Steel with Aramid FRPC, Aluminium Alloy with Glass FRPC and Aluminium Alloy with Aramid FRPC both of thickness 5 mm demonstrated the best combination compared with the other combination of 10 mm and 15 mm thickness for the reduction of vibrations of the engine. However the lowest amplitude of vibration is observed for Glass FRPC with 5 mm thickness for both the combinations of the engine materials, Structural Steel and Aluminium Alloy when compared with that of Aramid FRPC.
Increase in the thickness of the combinations of materials with increased mass will help in propagation of vibrations.

Hence the optimized thickness of the combination is found to be 5 mm with Structural Steel material for engine and Glass FRPC material for acoustic covering for effective reduction of vibrations. This would help reduction of engine noise significantly.

REFERENCES:

[1] Jordan Cheer et al. "Active noise control of a diesel generator in a luxury yacht" . Institute of sound and vibration research, University of Southampton.

[2] Amar Singh et al. "Analysis of various NVH sources of a combustion engine". ISSN 1848-5588

[3] Hamit Solmaz et al. "A mathematical model to investigate the effects of misfire and cyclic variations on crankshaft speed fluctuations in internal combustion engines". Journal of Mechanical Science and Technology 29 (4) (2015) 1493~1500

[4] Anyu Chen et al. "Internal combustion engine vibration analysis with short-term fourier-transform". 2010 3rd International congress on image and signal processing (CISP2010).

[5] Namdev A. Patil et al. "vibration analysis of CI engine using FFT analyzer". IJRET:International Journal of Research in Engineering and Technology

[6] D.I. Farrant et al. "Geometrically qualified ESPI vibration analysis of an engine" . Optics and Lasers in Engineering 41 (2004) 659-671

[7] Cha-Yi Liao and Chien-ching Mac. "Vibration characteristics of rectangular plate in compressible inviscid fluid" . Journal of sound and vibration 362 (2016) 228-251

[8] Tommy luft et al. "Noise reduction potential of an engine oil pan". T. Luft, university of Magdeburg, Germany.

[9] Jung-Sun Choi et al. "Structural optimization of an automobile transmission case to minimize radiation noise using the model reduction technique". Journal of Mechanical science and Technology 25 (5) (2011) 1247~1255

[10] Yogesh V Morankar et al. "Noise reduction of a Diesel Engine A review". International journal of Engineering Research and Technology

[11] D Lavazec et al. "Attenuation of noise and vibration at low frequencies using a nonlinear microstructured material". https://hal-upec-upem.archives-ouvertes.fr/hal-01370625

[12] Mizuho Inagaki et al. "Prediction of structural and kinematic coupled vibration on international combustion Engine" . R&D Review of Toyota CRDL Vol. 37 No.2

[13] A. A. Nuraini et al. "Vibro-acoustic analysis of free piston engine structure using finite element and boundary element methods". Journal of Mechanical science and Technology 26 (8) (2012) 2405~2411

[14] Soohong Jeon et al. "Acoustic performance of industrial mufflers with CAE modeling and simulation". Int. J. Nav. Archit. Ocean Eng. (2014) 6:935~946

[15] Dinesh kumar et al. "Vibration analysis of the camshaft using finite element method". International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064

[16] K.D.Wang et al. "Noise and vibration analysis by finite element". July 2001