NOISE REDUCTION OF ENGINE STRUCTURAL COMPONENTS BY FEM-BEM APPROACH

Mr. V. K. Dhummansure[1*], Dr. D. Ramesh Rao[2]

[1*]Research scholar, Bapuji Institute of Engineering and Technology, Davangere, India

[2]Professor, Mech., Presidency University, Bengaluru, India

1. vdhummansure@gmail.com, 2. rameshrao@presidencyuniversity.in

Abstract

For improvement in vibration of mechanical systems local modification in components have become very important tool in engineering design. Today's Finite element method(FEM) coupled with Boundary element method(BEM) capabilities has made it easy to study the acoustic behavior of engine components. Present work deals with finite element analysis (FEA) of structural components of four-cylinder diesel engine to reduce noise and vibration level. The simulation results of noise level of assembly are used for comparison. Components subjected to maximum noise transmission are considered for analysis. A considerable reduction in radiated noise level is observed by changing the thickness and, adding ribs to the components subjected to critical noise.

1. INTRODUCTION

The vibration analysis of an internal combustion engine assembly is highly complex phenomenon. Engine components are not only subjected to varying loads but also runs at wide range of speed. The resonant modes of the components get excited while operating at various speeds. Optimizing the noise and vibration level at these resonant modes is a difficult task for design engineer. The dynamic simulation can be used for study and optimization of noise related problems. The research work carried out in recent decades have been summarized in the following sections.

Zhang Junhong [1] used CAE and enhanced experimental investigation tools leads to rapid and problem-focused development process. The analysis mainly focuses on the application of CAE tools to simulate the dynamics of acoustically predominant components. T.Priede [2] predicted that, a considerable amount of injector noise was reduced by relevant design changes in component mounting arrangements and redesigned the engine structure. The relation between diesel engine and fuel injection equipment noise was considered over the whole range of operating conditions. Siano D et al. [3] investigated the acoustic performance of engine cover by FEM-BEM approach. Author concludes that Nylon P A 6.6 is having better acoustic properties than existing material in operating frequency range. R. Citarellaa et al. [4] predicted vibro-acoustic behavior of a car body by combined FEM-BEM methodology. Author concludes that FEM-BEM approach based on acoustic transverse vector(ATV) can be considered as valid alternative to traditional FEM-FEM or FEM-BEM approach. The methodology has following advantages

- Reduce the discretization effort as there is only boundary element used in the analysis and possible to evaluate external problems easily.
- It can easily characterize the surface acoustic behaviour by the use of impedance values as boundary conditions and, highly flexible due use of ATV approach.

The following discussion focuses on the application of FEM-BEM capabilities to identify the source of critical noise in the assembly. Further noise reduction is achieved by modifying the source component.

2. Methodology

A 2000cc inline four-cylinder prototype inline engine is selected for the study. Modeling of engine block, oil sump upper, valve cover, cylinder head and oil sump lower is completed using Pro/E. Modal analysis of assembly has been carried out to obtain natural frequencies and associated mode shapes using the FEA tools. Further, the assembly model is used to measure the noise level corresponding to natural frequencies. By studying frequency-noise curve critical noise frequency/s is identified. Component/s corresponding to critical noise are considered for modification. The selected component is modified either by addition of rib or change in thickness as per the mode shape. The methodology is presented in figure 1.

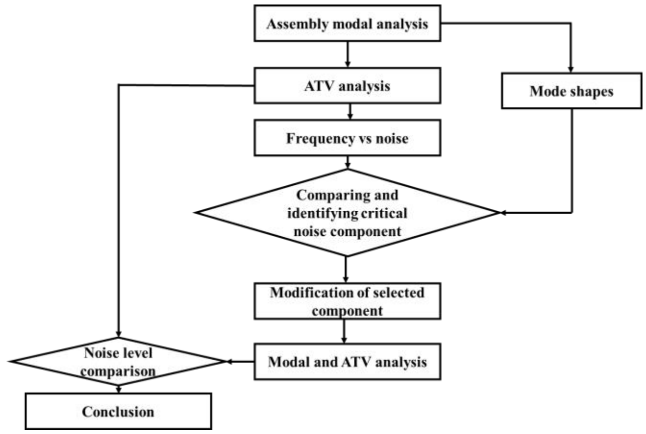

Fig1. Methodology of the research

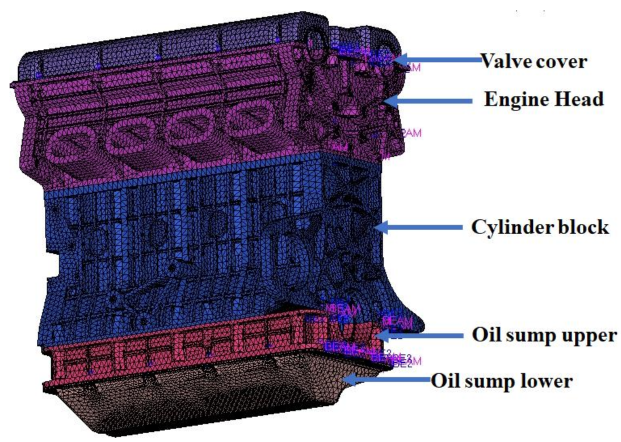

Fig2. The Finite Element models

3. Finite Element Modal Analysis

The FE model of the engine assembly consists of 412920 tetra elements as shown in figure2. 1D beam element with same diameter as actual bolts are used represent the bolts in the assembly. Rigid elements are used to connect components and bolts. Cylinder head, block and oil sump upper are made of grey cast iron (Young's modulus = 120000Mpa, Density = 7280Kg/m^3). Oil sump lower and valve cover are made of steel (Young's modulus = 200000Mpa, Density = 7800Kg/m^3). NASTRAN standard file format is generated from FE model to carry out modal analysis. A free-free modal analysis is carried out in the frequency range 0-3000Hz.

4. ATV Analysis

Results of modal analysis are imported into LMS Virtual lab and acoustic transverse vector analysis has been carried with unit load in X, Y and Z direction at main bearings. Overall sound pressure level of 116.44dB(A) is observed and maximum value is in the frequency range 2400-2700 Hz (highlighted in figure 3). Critical mode shapes are observed in oil sump lower and valve cover at 2473 Hz, 2611 Hz as shown in figure 4 and figure 5 and, they are considered for modification.

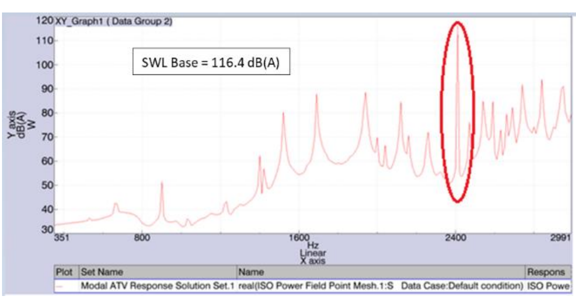

Figure 3. SWL response of base model

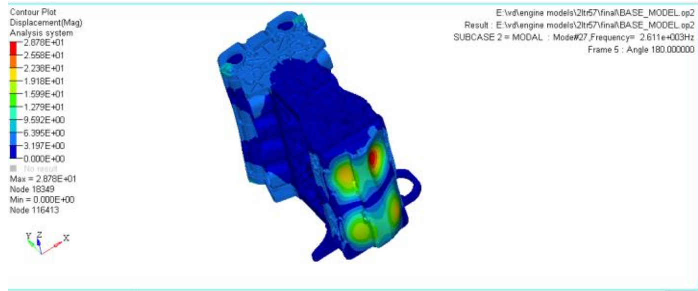

Fig 4. Mode shape of oil sump lower at 2611 Hz

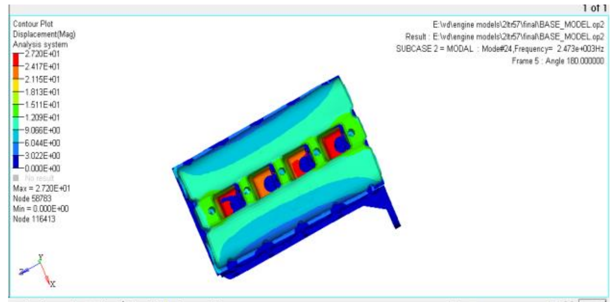

Fig 5. Mode shape of Valve cover at 2473 Hz

Modification1: Overall thickness oil sump lower and valve cover is increased by 2mm.

Modification2: Ribs are added to oil sump as shown in figure 6.

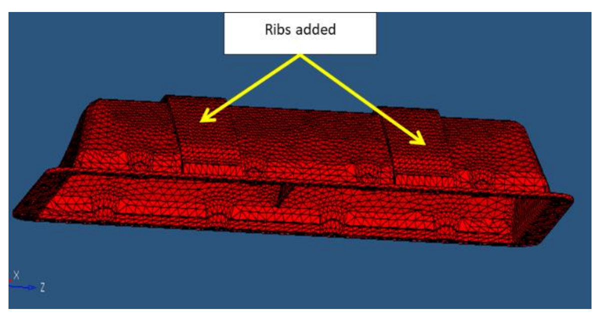

Fig6. Lower Oil sump with Ribs

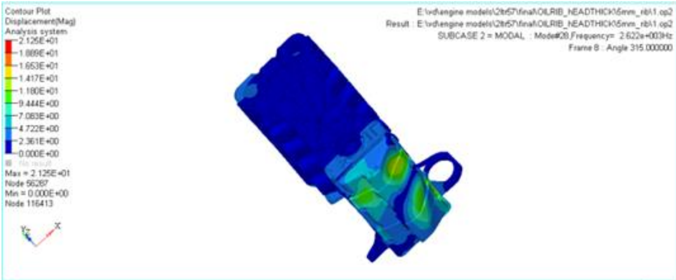

Fig 7. oil sump lower mode shape at 2622 Hz

Displacement at critical frequency is reduced as shown in figure 7. Overall sound pressure level is measured in the modified engine. The radiated noise level is reduced by 23 dB(A) with 5mm rib shown in figure 8.

Fig8. SWL for 12mm rib thickness

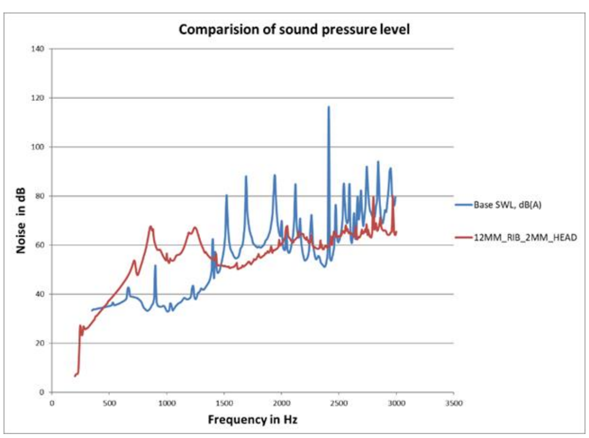

Fig9. SWL comparison

The results of analysis are compared in the figure 10. Optimized noise of 93.4 dB(A) is observed in 12mm thick rib in oil sump lower and 2mm uniform thickness in both oil sump lower and valve cover.

5. Conclusions

Considerable accurate prediction of noise and critical vibrations cab be possible by FEA simulation technique. From the acoustic analysis of the engine assembly following conclusions are obtained.

1) Critical frequencies and associated mode shapes of engine assembly were within the range of 2400-2600 Hz. 2) In a feasible design modification, it is observed that noise level was reduced by 23 dB (A). 3) In the modified assembly displacement is reduced by 7.45mm in oil sump lower and 6.92mm in valve cover

REFERENCES

[1] Zhang Junhong_, Han Jun, "CAE process to simulate and optimise engine noise and vibration", Elsevier, Mechanical Systems and Signal Processing 20 (2006) 1400–1409

[2] T.Priede, "Noise of Diesel Engine Injection Equipment", J. Sound WI. (1967) 6 (3), 443-459

[3] Siano D., M. Viscardi, Aiello R."Sensitivity analysis and correlation Experimental/Numerical FEMBEM for Noise Reduction assessment of an engine beauty cover" 69th Conference of the Italian Thermal Machines Engineering Association, ATI2014742 – 754

[4] R. Citarellaa, L. Federicoa, and A. Cicatiellob. Modal acoustic transfer vector approach in a FEM–BEM vibro-acoustic analysis. Engineering Analysis with Boundary Elements 31 (2007) 248–258