International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 7, Issue 1, ISSN No. 2455-2143, Pages 324-328
Published Online May 2022 in IJEAST (http://www.ijeast.com)

DEVELOPMENT OF NEW APPROACH TO SIMULATE OILPAN LOW FREQUENCY RADIATED NOISE USING NASTRAN BASED FEM SOLVER

Mr. Pandurang M. Jadhav, Dr. KishorB Waghulde
Department of Mechanical
Dr D Y Patil Institute of Technology, Pune, Maharashtra, India.

***Abstract*—Currently to calculate radiated noise from vibrating surfaces requires two steps: First, calculation of surfaces velocity using a finite element model and second, surface velocity is used as input to calculate acoustic response in acoustic solver such as LMS. Developed new approach using Nastran is simple, low cost, less turnaround time and all calculations are done within single solver as compared to old approach. New approach is validated with sensitivity study of Oilpan noise results with different parameter variations below 2000 Hz. Finally Oilpan noise results of old approach and new approve compared and got fair correlation.**

***Keywords*—Nastran, Noise, Low Frequency, Oilpan.**

I. INTRODUCTION

Powertrain noise will have contribution from combustion noise, noise radiation by the surface vibration of engine, accessory noise and other components, which may also include aerodynamic noise and noise due to auxiliary sources. The radiating surfaces of power train consist of various components such as oil pan, gear cover, tappet cover, cylinder block, transmission housing as well as exhaust and intake manifolds.

Overall dynamic performance of power train assembly will be driven by the internal forces, speed of power transmitting components along with mass and inertia. Apart from the above factors, how the power transmitting components has been supported and internal vibrations will be transferred to the outer surfaces. A vibration of outer surfaces creates pressure pulse in the air or radiates noise.

Coupled fluid-structure method is used to transfer oilpan outer surfaces vibrations to surrounding fluid (Air) in the MSC Nastran solver. Fluid (Air) was represented with conventional solid elements (CHEXA, etc.) using acoustic property and material data. Fluid element each grid defies the pressure as its degree of freedom. The fluid is automatically connected to the structure via the ACMODL Bulk Data inputs.

Here structural and fluid part is simulated using equation of motion as follows:-

Structural Part[5] [22];

$$\mathrm{Ma} + \mathrm{Cv} + \mathrm{Kx} = \mathrm{F} + \mathrm{A^T p} \qquad (1)$$

Where, M, C, K and AT are the mass, damping, stiffness and transpose of area matrix generated from structural model / elements.

Acoustic Part[5];

$$\mathrm{Qd}^2 \frac{\mathrm{p}}{\mathrm{dt}^2} + \mathrm{D}\frac{\mathrm{dp}}{\mathrm{dt}} + \mathrm{Hp} = -\mathrm{Aa} \qquad (2)$$

Where, Q, D, H and A are the matrices generated from the acoustic model / elements.

Complete coupled structural – acoustic equation is

$$\begin{bmatrix} M & 0 \\ A & Q \end{bmatrix}\begin{pmatrix} a \\ \frac{d^2p}{dt^2} \end{pmatrix}+\begin{bmatrix} C & 0 \\ 0 & D \end{bmatrix}\begin{pmatrix} v \\ \frac{dp}{dt} \end{pmatrix}+\begin{bmatrix} K & -A^T \\ 0 & H \end{bmatrix}\begin{pmatrix} u \\ p \end{pmatrix}=\begin{pmatrix} F \\ 0 \end{pmatrix} \qquad (3)$$

Nastran solves the above equations as any structural, only model. Complication for solving this equation is that the equation is non-symmetric. Modal solution (SOL111) is typically used. First normal modes are calculated separately for the structural and acoustic models. Then the two models are coupled with the area matrix and solved.

Generally noise analysis is the later part of the design; once prototype engine or power train has been tested in test lab. If test demands for noise reduction then it is not possible to modify the internal loads / excitations without altering the performance of the engine / power train. Hence need to know noise contribution of each surface / component within the short time to make decision of design change before product launch.

Birth of this new approach happens to fulfill the above need using available low cost software (Nastran), to get results quickly with less turnaround time and simple way of calculations to perform CAE based multiple design iteration.

II. BACKGROUND AND LITERATURE REVIEW

Currently in industries MSC Nastran[11] is proven and recommended solver / algorithm has been used for dynamic analysis. Basically used to do modal analysis, FRF (Frequency

Response Function) analysis, Transient analysis and low frequency (<250 Hz) noise analysis. It requires three steps and single FE model to complete noise / acoustic calculations as shown in figure 1.
LMS Virtual tab[5] is proven and recommended solver / algorithm for acoustic calculation (noise / NTF) only. For this solver dynamic vibration / surface velocity results are required from external solvers such as Nastran, Ansys, Abaqus, etc. Use of external results means additional cost, time, complexity and additional FE Model required. It requires four steps and two FE models to complete noise / acoustic calculations.
New approach of Nastran solver has been developed to use only one FE model and eliminate use of external solver and reduce cost, turnaround time and complexity.

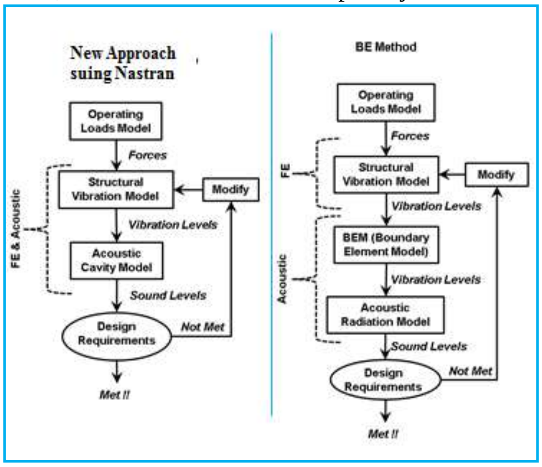

Fig. 1. Steps of Old (LMS) and New (Nastran) Approach

III. ENHANCEMENT TO EXISTING METHOD – A NEW APPROACH

This new approach provides few advantages such as quick turnaround time, less steps to calculate noise of power train. Conventional software's are available for predicting vibration and noise radiated by vibrating surfaces. These conventional softwares use the Boundary Element method (BEM) which requires input as surface velocity distribution. Surface velocity distribution needs to be obtained from the Finite Element analysis. Then need to generate BEM mesh and map surface velocities on it. The BEM is computational intensive and requires many hours of computer time to obtain a solution.
Existing FE model of engine / power train assembly is used in this new approach to do noise simulation (using Nastran Solver). Only need to add the surrounding air cavity FE model up to our response location and couple the vibrating surface with cavity region by ACMODL card within the Nastran. As shown in figure 1, this new approach uses Nastran solver for both structural as well as acoustic calculations. Hence the data transfer from FE solver to acoustic solver is not required. Executing the analysis or optimization within single software will save time.

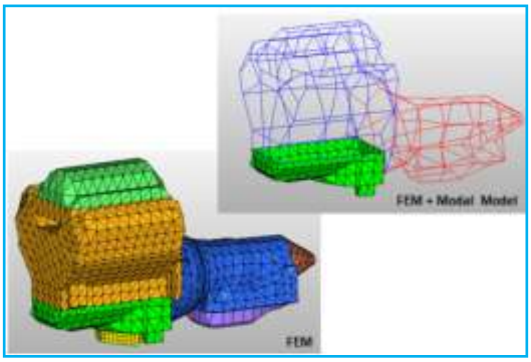

Fig. 2. Full Power train model for Oil pan noise analysis

IV. STUDY OF SENSITIVE PARAMETERS EFFECT

Six different parameters are taken to verify and validate the new approach mentioned in this paper; engine oilpan is taken as example. As shown in figure 2. Full power train and oilpan acoustic cavity model is considered to capture total dynamic behavior of power train. Power train model consists of detailed FEM of oilpan and Modal Model of rest of the power train. Surrounding cavity of the oilpan is modelled with solid elements as shown in figure 3.

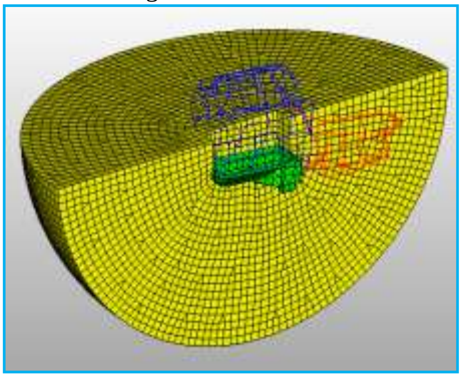

Fig. 3. Cut Section of Hexa. Element Cavity and Oilpan

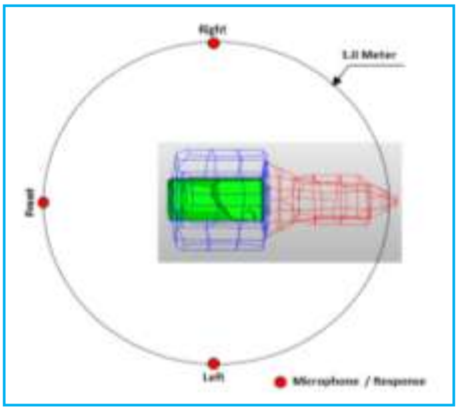

Fig. 4. Noise Response Location at 1 Meter.

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 7, Issue 1, ISSN No. 2455-2143, Pages 324-328
Published Online May 2022 in IJEAST (http://www.ijeast.com)

Engine loads are applied to the model at appropriate excitation locations and noise response has been taken at 1 meter distance from engine on front, left and right of engine as shown in figure 4.

To make sure the accuracy of results, sensitivity study has been carried out by changing parameters of vibrating surfaces and cavity. Variation of these FEM parameters will test the effect of each parameter on transfer of vibration from the structural surfaces to the response location in the cavity. We will come to know more sensitive parameter for this noise analysis. Here elements variation is considered based on the maximum frequency (~2000 Hz for solution) of interest and to keep minimum 10 elements per wave length. Elements length is calculated using following relation.

$$\text{Element length} = \frac{\lambda}{10} = \frac{1}{10} \times \frac{c}{f_{max}} \qquad (4)$$

Where, λ is wave length, **c** is speed of sound and f_{max}. is maximum frequency of interest.

Following parameters are considered for sensitivity study:-

1. Type of Elements – Hexagonal (CHEXA) and tetrahedral (CTETRA) elements used for cavity
2. Size of Elements – Hexagonal 20 mm and 30 mm element size is used for cavity.
3. Type of Couplings – Element-to-element and grid-to-grid coupling is applied between oilpan and cavity (structure-Fluid interface)
4. Shape of Cavity – Hemi-spherical and square cavity is used to represent the surrounding cavity.
5. Structure-Fluid Interface-Matching & Non-matching grids–structure-fluid interface coupling is defined between the grids of Oilpan outer surfaces and cavity inner faces.
6. Distance of NTF responses from Oilpan Outer Surface – Response is taken at 1 meter and 0.5 mm distance on front side, left side and right side of oilpan.

NTF (Noise Transfer Function) responses with variation of above parameters at 1 meter are shown in figure 5 to figure 10.

V. NTF RESULTS OF SENSITIVITY PARAMETERS

To make sure consistency and accuracy of the noise output (NTF – SPL) from Nastran solver. Key parameters noise analysis has been done within the 20 – 2000 Hz. Noise results with change of each parameter has been studied and listed the below observations.

a) NTF results (Noise) with CHEXA or CTETRA elements of acoustic cavity, are observed similar with less variation in amplitude as shown in figure 5.
b) NTF results with 30 mm or 20 mm CHEXA elements of cavity gives same results as shown in figure 6.
c) NTF results with change in coupling method (element-to-element or grid-to-grid) also gave same results as shown in figure 7.
d) NTF results with change in shape of cavity (square or hemi-spherical) gave same results as shown in figure 8.
e) NTF results with matching or non-matching of coupling grids gave same results as shown in figure 9.
f) NTF results with response points considered at 1.0 m and 0.5 m gave same pattern with constant change in amplitude across the frequency band as shown in figure 10.

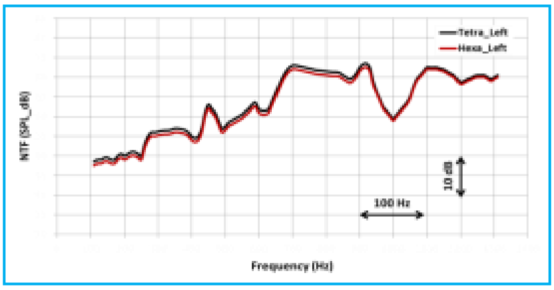

Fig. 5. NTF at 1 Meter with Tetra. and Hexa. Elements

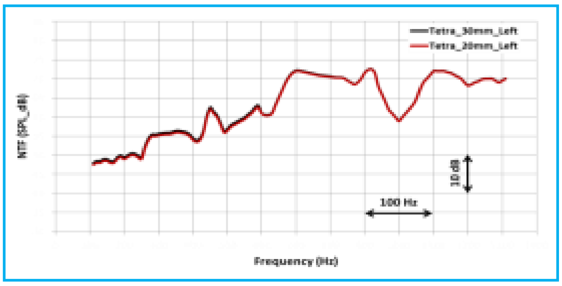

Fig. 6. NTF at 1 Meter with 30 & 20 mm Hexa. Elements

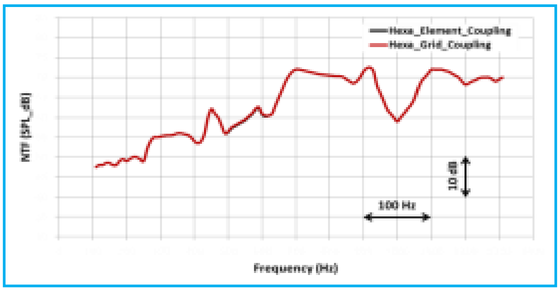

Fig. 7. NTF at 1 Meter with Grid and Elemental Coupling

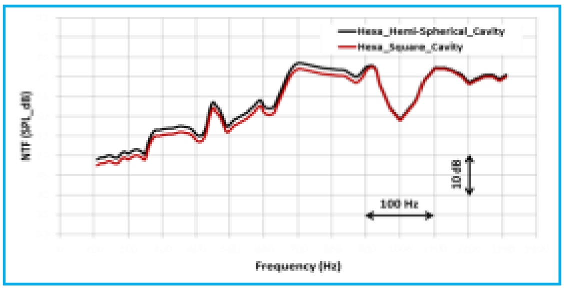

Fig. 8. NTF at 1 Meter with Hemi-Spherical and Square Cavity

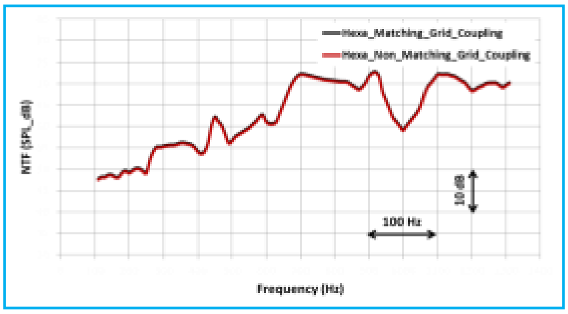

Fig. 9. NTF at 1 Meter with Matching & Non-matching Coupling Grid

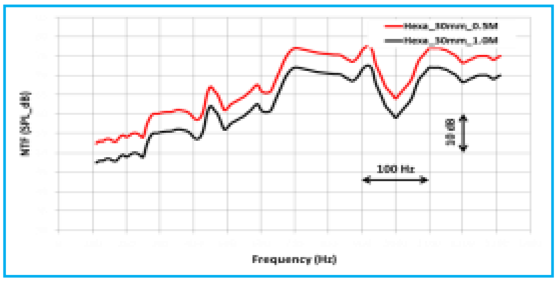

Fig. 10. NTF response correlation at 0.5 Meter and 1 Meter Distance

VI. NTF Results Comparison of LMS and Nastran New Approach

All models are solved using conventional BEM solver (LMS Virtual Lab) and new approach Nastran FEM based solver to calculate NTF responses at 0.5 meter and 1 meter distance. While doing this care had taken to retain the engine load application points and structural mesh model same as used in Nastran solver. Instead of cavity FE model, BEM mesh and field point mesh is used.

Noise response results of new approach with FEM based method using Nastran solver on Front, Left and Right of Oilpan are calculated and compared with BEM based LMS Virtual Lab results.

The NTF / SPL(dB) response between LMS Virtual Lab and Nastran solver at 1 meter are similar at all three locations (Front, Left and Right of oilpan) for low frequency range (below 2000 Hz) as shown in Figure 11.

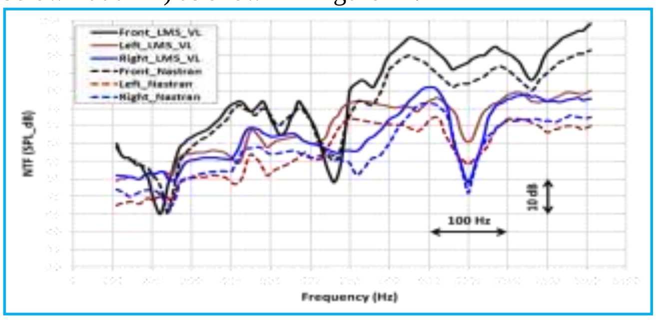

Fig. 11. NTF response at 1 Meter Distance for LMS and Nastran Solvers

VII. CONCLUSION

- NTF - SPL (dB) response correlates well between MSC Nastran solver and LMS Virtual Lab, gives a confidence to use this new approach for low frequency radiated noise analysis.
- A smaller cavity size of 0.5 m radius can be used to get quick results for iterative optimization and finally validate response with 1 m or at the required distance.
- Acoustic cavity can be modeled using CTETRA elements which are easy to model complex shape.
- Coupling can be applied between matching or non-matching grids.
- New approach is cost effective.

VIII. FUTURE SCOPE

- Validation of FE model results with physical test.

IX. Acknowledgements

The authors would like to acknowledge the Dr. D Y Patil Institute of Technology, Pimpri for providing opportunity to present this study.

Special thanks to Dr, Kishor B. Waghulde for valuable guidance and support in formulating this paper.

Nomenclature

FEM	Finite Element Model
BEM	Boundary Element Method
NTF	Noise Transfer Function
SPL	Sound Pressure Level

X. REFERENCE

[1] M Calloni, A Golota, A Mejdi, and C Musser, "A Vehicle Pass-by Noise Prediction Method Using Ray Tracing with Diffraction to Extend Simulation Capabilities to High Frequencies" SAE International, SIAT, India. 2021-26-0264.

[2] M D Kandalkar, J bari, D Mole and N H Walke, "Sound Power Assessment, Noise Source Identification and Directivity Analysis of Compaction Machines" SAE International, SIAT, India. 2021-26-0281.

[3] V Hipparge, S Bhalerao, A Chavan, V V Chaudhari, and R Suresh, "Agricultural Tractor Engine Noise Prediction and Optimization through Test and Simulation Techniques" SAE International, SIAT, India. 2021-26-0277.

[4] P Gunasekaran, A Chavan, and K Somasundaram, "Methodology Development for Open Station Tractor OEL Noise Assessment in the Virtual Environment" SAE International, SIAT, India. 2021-26-0310.

[5] J. Feng, X. Zheng, H. Wang, H. T. W. Y. Zou, Y. Liu, and Z. Yao "Low-Frequency Acoustic-Structure Analysis Using Coupled FEM-BEM Method" Hindawi

Publishing Corporation, Volume 2013, Article ID 583079.

[6] L N Patil1, H P Khairnar " Investigation of Human Safety Based on Pedestrian Perceptions Associated to Silent Nature of Electric Vehicle" EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 08, Issue 02, pp280-289, June 2021.

[7] A Jain, C S Kumar, Y Shrivastava “Fabrication and Machining of Metal Matrix Composite Using Electric Discharge Machining: A Short Review” EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 08, Issue 04, pp740-749, December 2021

[8] W Yu “Analysis and Optimization of Low-Speed Road Noise in Electric Vehicles” Volume 2021, Article ID 5537704.

[9] A K Gupta, Venkatakiran B, Rahul K, Anupam P, and Manoj J “Digital Approach for Dynamic Balancing of Three Cylinder Gasoline Engine Crank-Train” SAE International, SIAT, India. 2021-26-0265.

[10] R Kasliwal, S Saxena and S Jadhav “Design & Development of Helmholtz Resonator for Low Frequency Exhaust Noise Reduction in Commercial Vehicles” SAE International, SIAT, India. 2021-26-0279.

[11] M D Kandalkar, J bari, D Mole and N H Walke “Sound Power Assessment, Noise Source Identification and Directivity Analysis of Compaction Machines” SAE International, SIAT, India. 2021-26-0281.

[12] S Rahman, A Chavan, D M Pyla, S Deguntla, M Jayakumar, and V V Chaudhari “A Case Study of Compressor Surge Related Noise on Turbocharged 2.0-L Gasoline Engine” SAE International, SIAT, India. 2021-26-0281.

[13] Y Yeola, D Kalsule, P Sawangikar, and S Naidu, M Petale, and R Bhandari “Innovative Approach to Address BS VI Challenges of NVH Refinement and Total Cost of Ownership of Small Commercial Vehicles with Naturally Aspirated Two Cylinder Diesel Engines” SAE International, SIAT, India. 2021-26-0284.

[14] S Shenoy, M Gumma, S Gopakumar, P Durgam, and S Potarlanka, S Hegde “Virtual Validation of Electric Vehicle NVH by Architecture Changes” SAE International, SIAT, India. 2021-26-0302.

[15] Arun Kumar K, G Taware and G Kumar “Novel Technique to Address the Humming Noise with Pulley Driven Hydraulic Power Steering Pump on Light Commercial Vehicles” SAE International, SIAT, India. 2021-26-0308.

[16] P Gunasekaran, A Chavan, and Somasundaram K “Methodology Development for Open Station Tractor OEL Noise Assessment in the Virtual Environment” SAE International, SIAT, India. 2021-26-0310.

[17] L Zhang & C Sun “Simulation Analysis of Fluid-Structure Interaction of High Velocity Environment Influence on Aircraft Wing Materials under Different Mach Numbers” Sensors 2018, 18, 1248.

[18] M Ren and X Shu “A Novel Approach for the Numerical Simulation of Fluid-Structure Interaction Problems in the Presence of Debris” Fluid Dynamics & Materials Processing, fdmp.2020.09563.

[19] H Andersson, P Nordin, T Borrvall, K Simonsson, D Hilding, M Schill, P Krus, D Leidermark “A co-simulation method for system-level simulation of fluid–structure couplings in hydraulic percussion units” CrossMark, Engineering with Computers (2017) 33:317–333, s00366-016-0476-8.

[20] Jung Min Sohn, Ji Woo Kim and Sang Ho Kim “Experimental and Numerical Studies on Fluid-Structure Interaction for Underwater Drop of a Stone-Breaking Crusher” Journal of Marine Science and Engineering, 2022, jmse10010030.

[21] F-K Benra, H J Dohmen, Ji Pei, S Schuster, and Bo Wan “A Comparison of One-Way and Two-Way Coupling Methods for Numerical Analysis of Fluid-Structure Interactions” Hindawi Publishing Corporation Journal of Applied Mathematics, Volume 2011, Article ID 853560.

[22] B E Griffith, N A Patankar “Immersed Methods for Fluid–Structure Interaction” Annu Rev Fluid Mech. 2020;52:421-448, annurev-fluid-010719-060228.

[23] M T Malazi, E T Eren, J Luo, Shuo Mi 1 and Galip Temir “Three-Dimensional Fluid–Structure Interaction Case Study on Elastic Beam” Journal of Marine Science and Engg, 2020, jmse8090714.

[24] H Li, Z Lu, Y Ke, Y Tian and W Luo “A Fast Optimization Algorithm of FEM/BEM Simulation for Periodic Surface Acoustic Wave Structures” Information 2019, info10030090.