Application of LS-DYNA® to NVH Solutions in the Automotive Industry

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Abstract

There are a number of powertrain applications in the Automotive Industry made of short glass fiber reinforced thermoplastics (Polyamide 6 or 66). Examples of these are Air Intake Manifolds, Cylinder Head Covers (CHC's), Oil Pans etc. Assessment of NVH (Noise, Vibration & Harshness) characteristics using simulation tools is a critical requirement for such applications. Modal analysis, steady state dynamic analysis and acoustic analysis are some of the CAE (Computer Aided Engineering) analyses that are required. LSTC has developed a range of tools within LS-DYNA to carry out such analyses. In this paper, these capabilities are explored for various NVH analyses of automotive components. Examples of modal analysis and steady state dynamic response using the finite element method (FEM) are given and compared with other standard software. Boundary element methods (BEM) are well suited for doing acoustic analyses because of its requirement for modeling only the boundary of a vibrating body. Both the direct and the indirect boundary element methods are implemented in LS-DYNA. Examples using both methods are shown. Various options existing within these methods are also discussed. Post processing of acoustic quantities are demonstrated.

Introduction

LS-DYNA [1] is used extensively in the automotive industry for solving highly transient problems such as crash and impact. However its capabilities for solving NVH problems are not quite well known. Some of these capabilities in LS-DYNA such as modal, steady state dynamics and acoustic analysis are explored in this paper. The solution for modal and frequency response analysis are compared with other standard software. LS-DYNA has also implemented the boundary element method (BEM) [2] for doing acoustic analysis. This method is particularly amenable for carrying out acoustic radiation from vibrating bodies. Unlike the finite element method (FEM), only the boundary of the vibrating body needs to be modeled. The boundary at infinity need not be modeled since the formulation satisfies the Sommerfeld radiation condition [3]. This simplifies the modeling substantially. Both the direct BEM and the indirect BEM are implemented in LS-DYNA. In the direct method, the boundary variables are directly in terms of physical quantities such as the acoustic pressure and velocities. It is suitable for solving problems with either interior or exterior acoustic domains. The direct boundary element method when applied to exterior acoustic domains suffers from fictitious eigenfrequency problem at certain frequencies associated with the interior domain where the solution is non-unique. The Burton-Miller formulation [4] is implemented in LS-DYNA to take care of this issue. In the indirect method, the boundary variables are in terms of single layer and double layer potentials [5], [6] which are related to the difference in acoustic pressures and velocities across the boundary. Hence, this method is suitable for solving problems involving thin vibrating structures where the interior as well as the exterior acoustic solutions are obtained simultaneously. Structures with openings and/or ribbing can be handled easily. An example of a plastic oil pan is considered for carrying out the various NVH analyses. In some cases, the solution is compared with that from Abaqus [7]. For LS-DYNA, the three steps involving modal analysis, steady state dynamics and acoustic analysis are embedded in one code and can be carried out seamlessly in just one run.

Example of an Oil Pan

Plastic oil pans are of recent origin and slowly gaining acceptance in the Automotive Industry. Since they are attached to the engine and are subject to high vibration loads, it is critical to do an NVH evaluation. The types of analyses that are typically done are modal, steady state response, and acoustic analysis. A plastic oil pan as shown in Figure 1 was used for the evaluation. A steady state response analysis was carried out for unit (1G) excitation in all three directions. The modal superposition method was used for the analysis. The modal frequencies and mode shapes from LS-DYNA and Abaqus are compared in Figures 2-5 and show a good match. The velocity contour at three different frequencies is compared in Figure 6 and shows a high degree of correlation. In Figures 7 and 8, the maximum response for velocity and acceleration across the whole frequency range is compared.

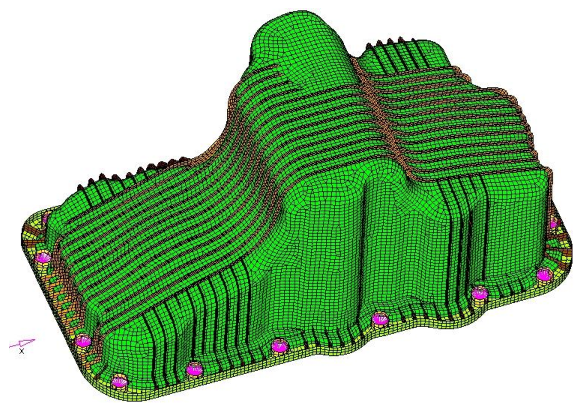

Figure 1 Plastic Oil Pan made of Ultramid® A3WG7 (Glass Reinforced Polyamide 66)

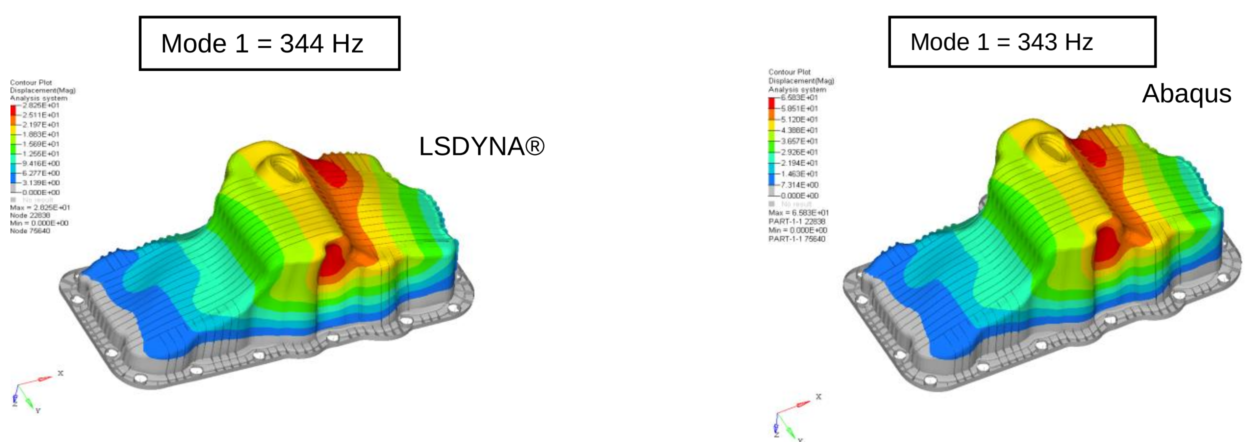

Figure 2 Mode Shape & Frequency for Mode 1

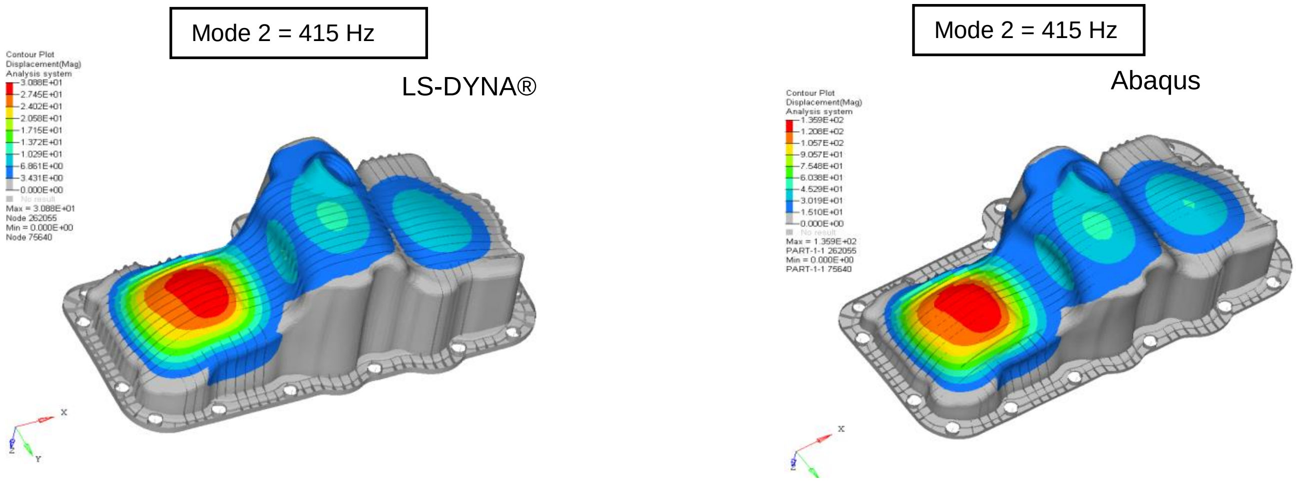

Figure 3 Mode Shape & Frequency for Mode 2

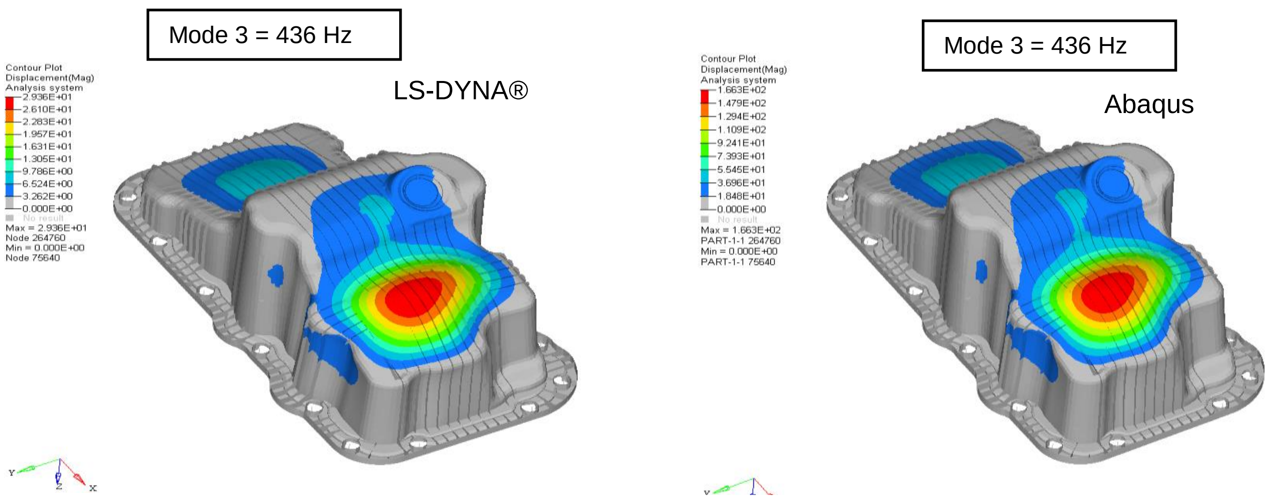

Figure 4 Mode Shape & Frequency for Mode 3

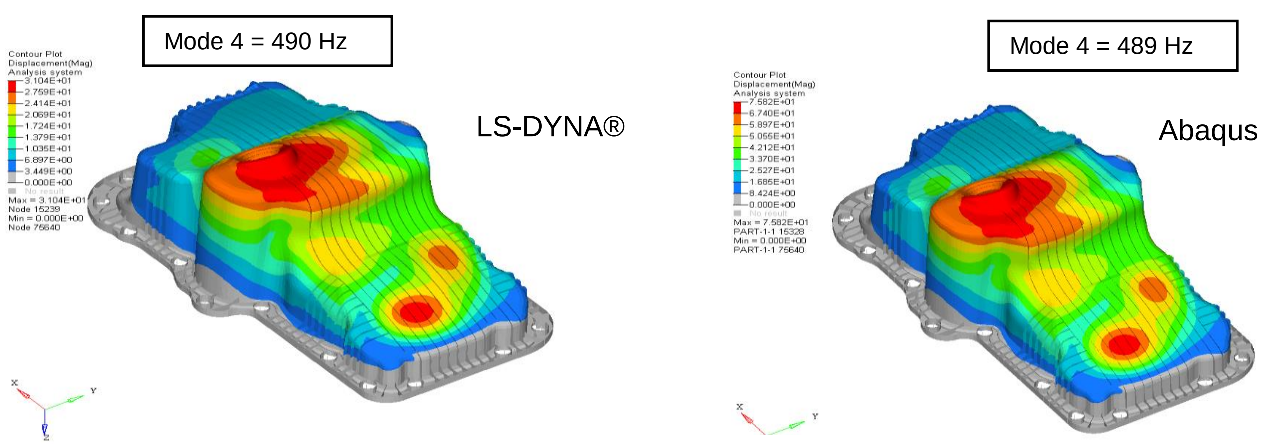

Figure 5 Mode Shape & Frequency for Mode 4

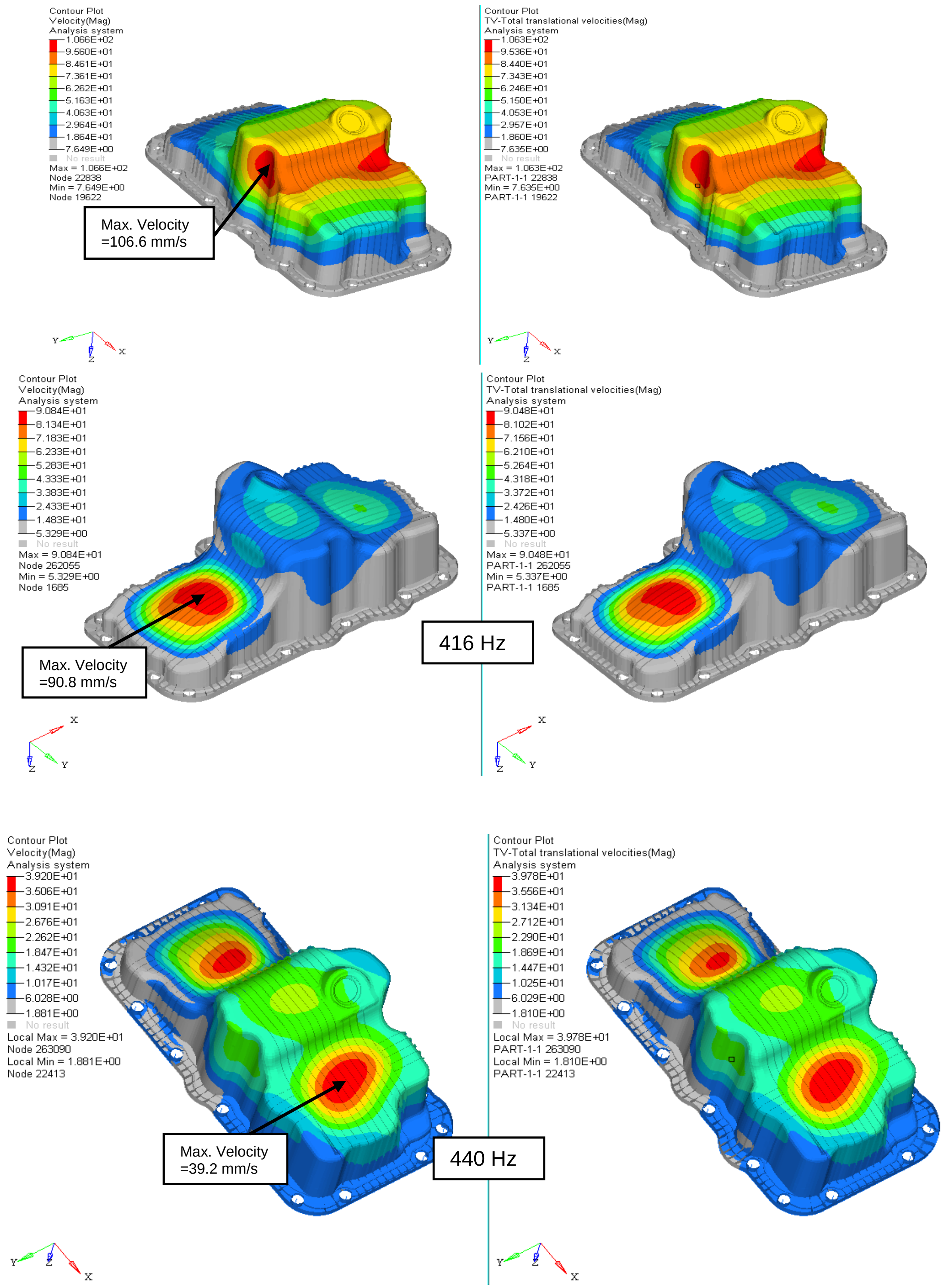

Figure 6 Comparison of velocity contour at different frequencies

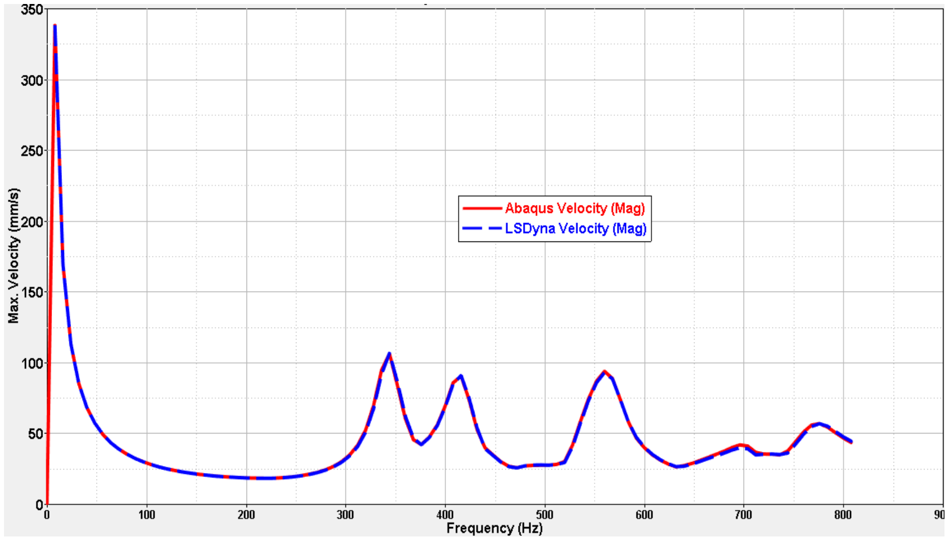

Figure 7 Comparison of Max. Velocity (amplitude) across the frequency range

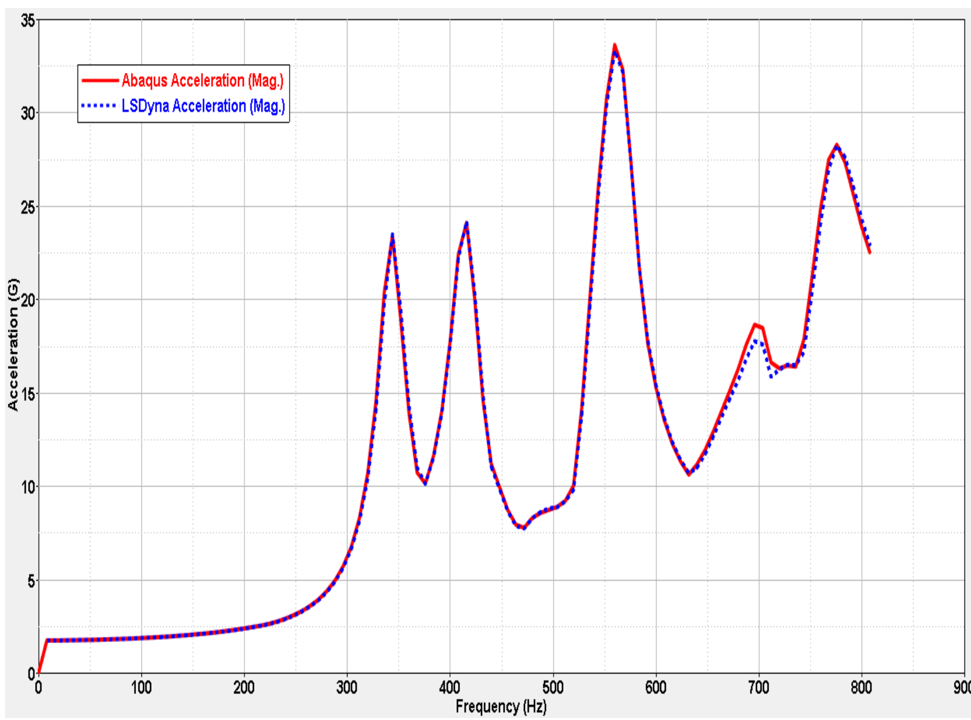

Figure 8 Comparison of Max. Acceleration (amplitude) across the frequency range

For carrying out the acoustic analysis, a boundary element model (Figure 9) was created. This captures the surface of the acoustic domain. The normal velocities are mapped from the structural model to the boundary element model. The bottom surface is assumed rigid. An exterior problem is specified and an acoustic solution is obtained using both direct and indirect BEM approaches.

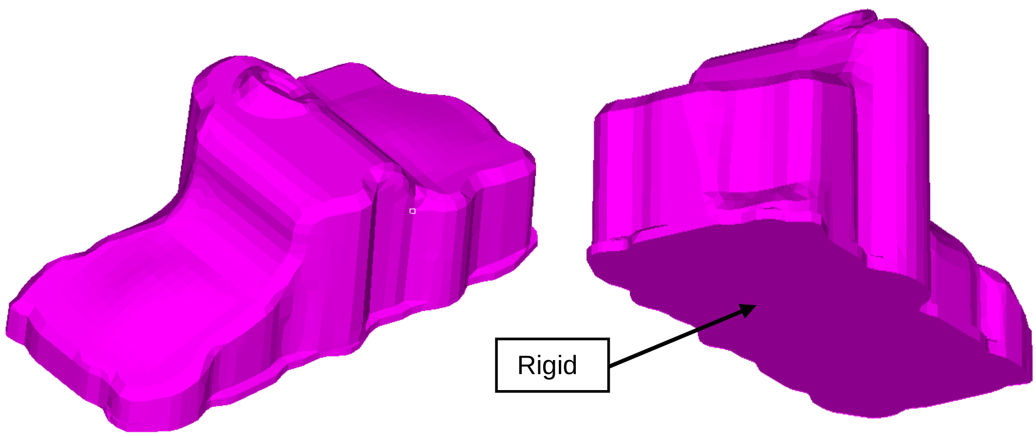

Figure 9 Boundary element model of oil pan

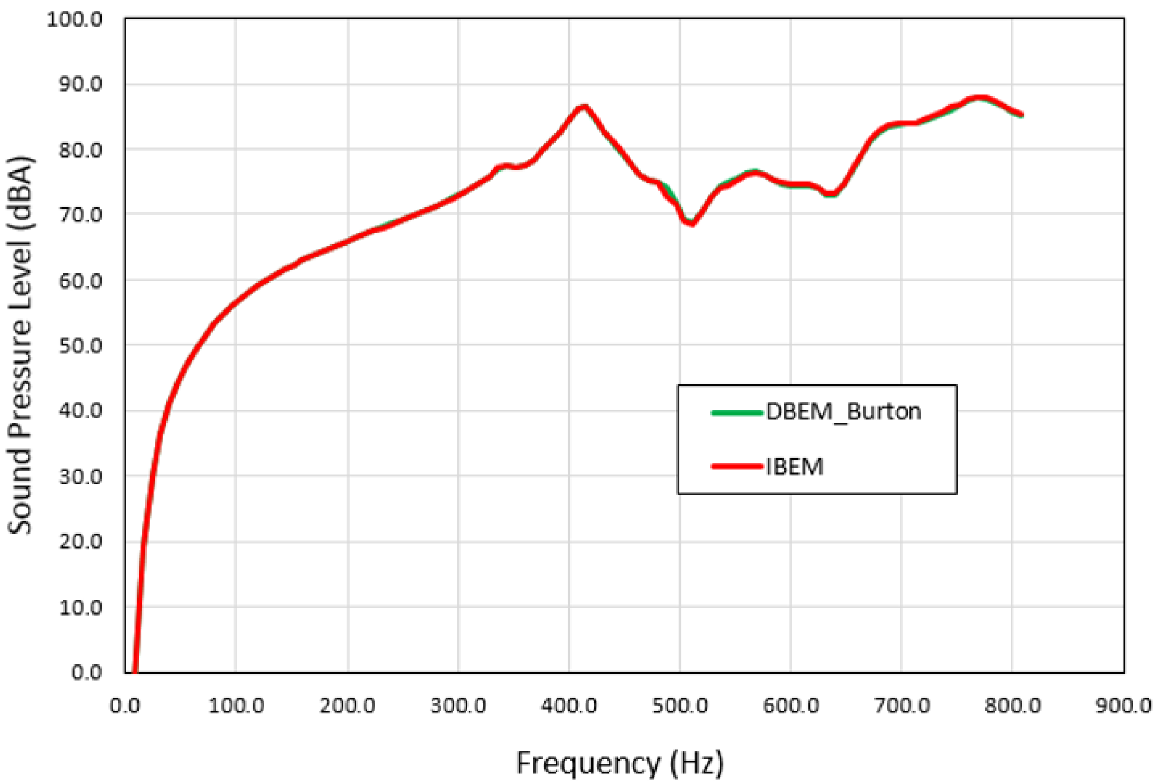

Figure 10 Sound Pressure Level (dBA) at 1/2 meter above Oil Pan

The Sound Pressure Level (SPL) at ½ meter above the oil pan is plotted from both methods in Figure 10 and shows good correlation. The SPL contour on a spherical surface of about 1 m diameter and surrounding the oil pan at three different frequencies and from both methods are shown in Figure 11. The contours show similar patterns

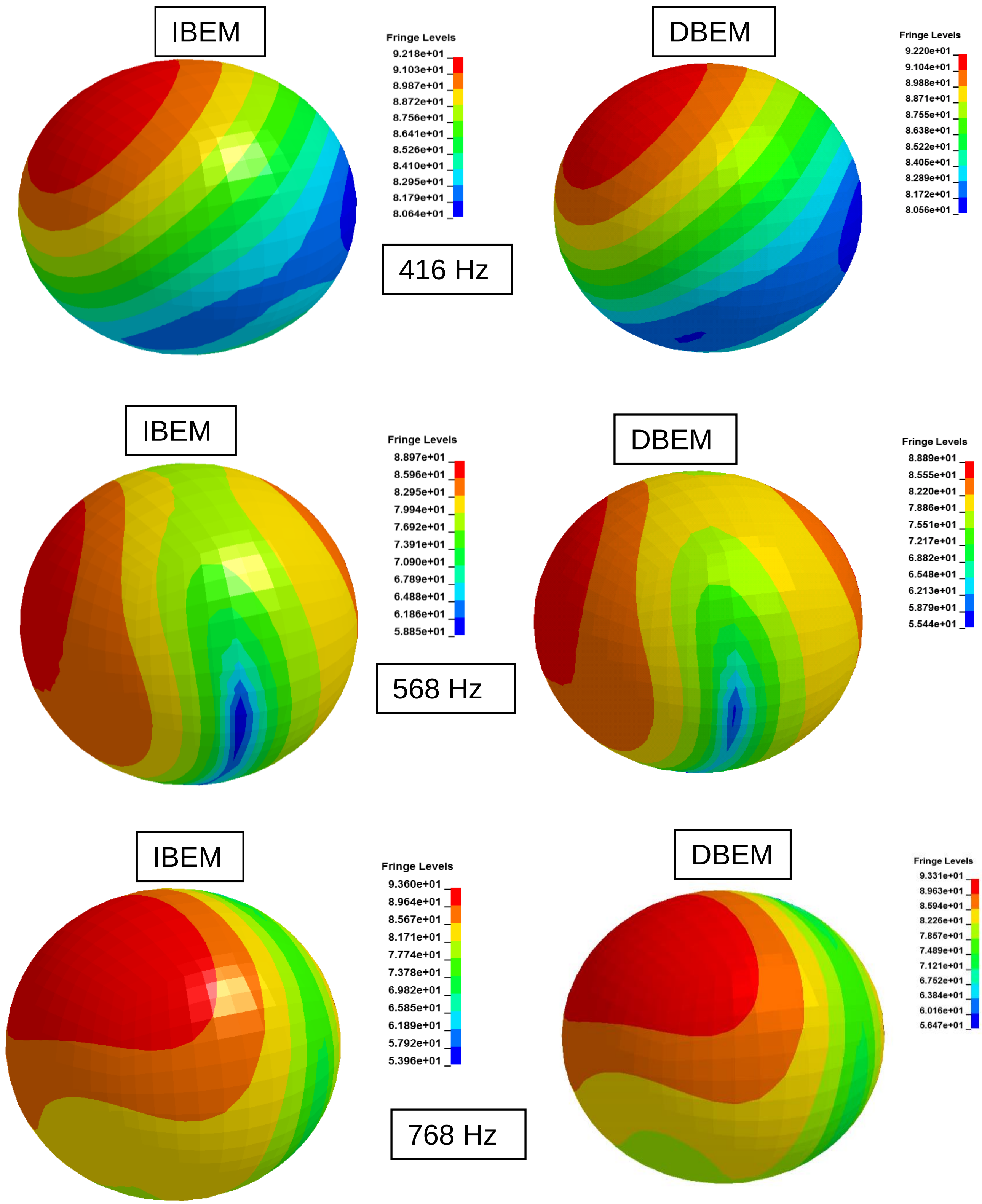

Figure 11 SPL contour on a spherical surface at different frequencies

Conclusions

The NVH capability of LS-DYNA is demonstrated in this paper. An example of a plastic oil pan was considered for verifying the various capabilities available in LS-DYNA. Modal and steady state response analysis was carried out for unit (1G) excitation and solution compared with those using Abaqus. One of the other main features in LS-DYNA is the implementation of the direct and indirect boundary element method for carrying out acoustic analysis. The implementation in LS-DYNA is such that the structural (FEM) and acoustic solutions (BEM) are obtained in one run seamlessly Burton-Miller formulation is implemented in LS-DYNA to take care of fictitious eigenfrequencies when solving exterior problems using the direct BEM. Acoustic solutions using both methods are compared and show good correlation.

References

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