BIW DAMPING PACKAGE EVALUATION/OPTIMIZATION USING FEA/SEA COMBINED APPROACH

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INTRODUCTION

Following styling and surface definitions, FEA models for structural subsystems, such as floor and wheelhouse, are constructed early in the vehicle design/development process. At this early stage, there is a need to define appropriate damping treatment and their coverage for different panels in the vehicle. Computationally, it is more efficient to calculate average surface velocities from FEA models for different configurations at the subsystem level. However, comparison of these velocities would not directly yield the passenger's perception of SPLs resulting from different damping configurations. In the following, the implementation of a combined FEA/SEA method is demonstrated during the evaluation of damping treatments for an automobile.

As shown in Figure 1, the process starts by extraction of physical properties of visco-elastic material. In the next step, the classical RKU analysis is employed to calculate the equivalent properties of composite damping treated vehicle panels. Later, a subsystem FEA model with the derived damping and coverage information is used to calculate the surface averaged velocity response. Finally, the panel velocities are used in a SEA model to predict SPL at the driver's ear location.

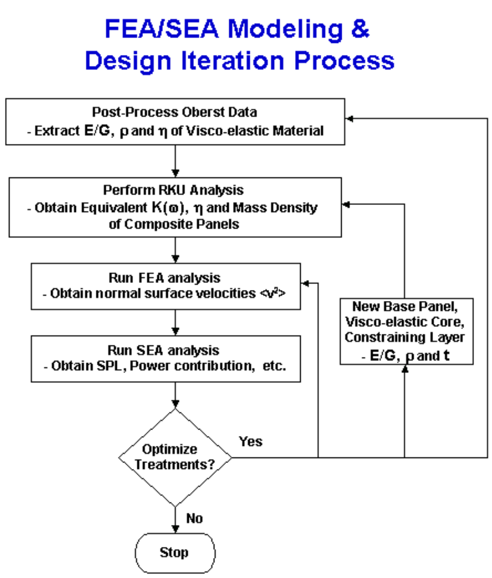

Figure 1 – FEA/SEA Modeling & Design Iteration Process.

MODELING DAMPING MATERIAL

During a typical design evaluation process, different damping treatments are considered, such as SOM (Sprayed On Mastic), BOM (Baked On Mastic), MPM (Metal Polymer Metal) and PCL (Patched-on Constrained Layer). As shown in Figure 2, these treatments are applied to floor panels, toe-board, wheelhouses and dash panels.

Different modeling approaches can be used to create an analytical representation of these damping treatments. In this study, Ross-Kerwin-Ungar (RKU) method was used. This method is based on an equivalent single layer representation of a damping treatment. Because of its accuracy, simplicity and ease of use, this is the most widely used method to represent the equivalent bending stiffness and loss factor of a panel treated with simple single or double layered damping treatments. The RKU method provides a way of calculating equivalent properties of a panel as a function of frequency. A complete description of the RKU method can be found in the reference [1].

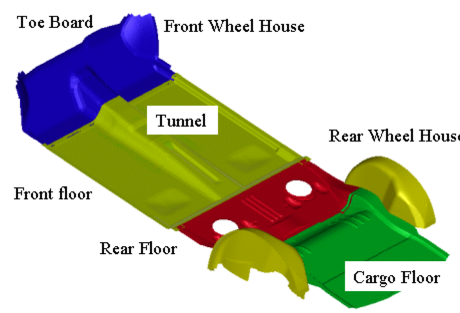

Figure 2 - Areas where damping treatments are applied.

FEA MODEL

Once the equivalent properties of damping treated panels are computed, they are applied to all corresponding elements in the FEA model. The source of excitation can be a force that is applied to the desired location(s) with defined spectrum. In return, the average squared velocities $\langle v^2 \rangle$ over treated/untreated floor areas are determined for each configuration of damping treatment. The component of velocity that is oriented normal to the surface of the panel is considered for the calculation of $\langle v^2 \rangle$. In this study, multiple unit force spectra were applied at the attachment points to excite all structure-borne paths. The lower panels of the vehicle Body-In-White (BIW) were represented in the FEA model, as shown in Figure 2. The objective was to predict the trends (ΔdB) rather than absolute response levels. Surface-averaged velocities for different damping configurations are compared in Figure 3.

These results are then used in the SEA model to predict the driver's ear SPL. During this analysis, all interior sound package components, such as seats, carpet, and headliner, are represented in the coarse SEA model. As a result, this method gives a quick and efficient way of evaluating the effects of damping treatments at the driver's ear location.

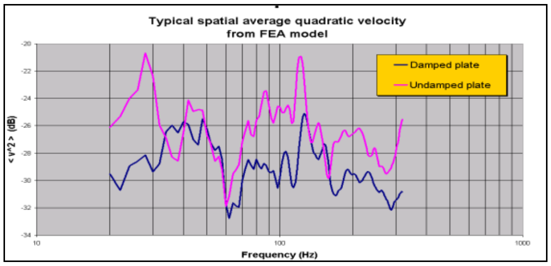

Figure 3 – Typical surface-average mean-squared velocity from FEA model.

SEA MODEL

In order to convert surface-averaged mean-squared velocity $<v^2>$ obtained from FEA model to SPL at driver's ear, a coarse SEA model is built. Diffuse field acoustic characteristics of all interior components are represented in the SEA model. The model is made up of SEA subsystems, which represents the geometry of the vehicle, SEA junctions, material database and load cases.

In the SEA model, the interior cavities were defined by subdividing the total volume into partitioned-cavities, which matched the floor partitions in the FEA model. There were less than 50 subsystems in this coarse SEA model of the automobile. Due to its coarse nature, the model was built significantly faster and was different from a fully detailed SEA model [2]. As an airborne model, no structural elements were defined, structural behavior being captured by the FEA model and accounted for in the average velocity levels. Seats were also considered since they replaced a large amount of volume that needed to be taken out from the interior space. The engine compartment, exterior and under floor acoustic spaces were not included in the model.

In this study, seven acoustic cavities were defined to describe interior air space. The sum of the volumes, areas and perimeters of these seven cavities represent the acoustic behavior of the complete interior cavity. For this reason geometric properties (perimeter and surface) of each of these cavities have to be overridden in AutoSEA2 to avoid artificial effects on mode count.

The equivalent damping loss factor resulting from the RKU representation of each treated panel is supplied to the AutoSEA2 model as a damping loss factor (DLF) spectrum. The data is brought into AutoSEA2 in a narrowband format and later converted automatically by band-averaging to 3rd-Octave frequency representation. Equivalent bending rigidity is provided as the mean value across the whole spectrum, since AutoSEA2 does not allow frequency dependent bending stiffness.

Equivalent bending stiffness and damping loss factor of the panels treated with damping material are set according to RKU results. In addition, the non-structural mass (NSM) due to the damping material is added to treated panels. This is done by computing a new equivalent density and applying it to each corresponding panel.

In the SEA model, a high damping loss factor is assigned to represent the heavy air in the seat cavities. Other interior acoustic cavities are assigned damping loss factors (DLF) based on typical experimental data (decay rate with trimmed interior) from similar vehicle constructions. Acoustic treatments relevant to the current problem were also included in the SEA model, such as the transmission loss of the floor carpet.

In the SEA model, the targeted panel velocities are constrained by using average velocity supplied from the FEA model. These constraints are based on the RMS velocities obtained from the FEA model. Since these velocities are normal to the surface of the panels, the constraints are imposed only on the flexural wave fields.

In AutoSEA2, the effect of each damping treatment can be compared to others by using either graphs or thermogram [3]. An example of thermogram for a bare, baseline and full coverage configuration is presented in **Error! Reference source not found.**. Histogram shows that adding damping treatment reduces SPL at ear level in front and cargo area of vehicle while rear section remains almost constant.

In Figure 4, a gain of 2-3 dB at driver's ear location is observed when bare panel is treated with full coverage BOM. These results are expected to still over-predict the damping effect of each configuration because no flanking paths, such as through windows, are considered. Also, since no exterior cavities were considered, the energy is transmitted and accumulated only in the interior of the vehicle. Adding exterior cavities would improve the representation of the physical vehicle configuration in the model.

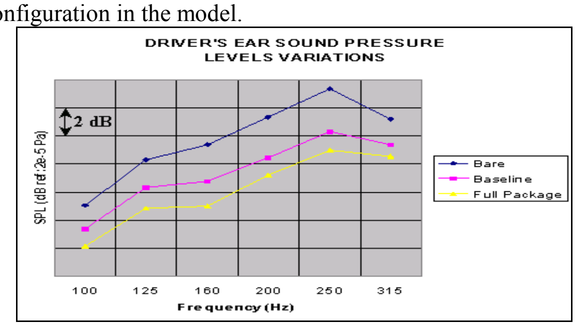

Figure 4 – Effect of each damping treatments on driver's ear SPL

CONCLUSION

The combined FEA/SEA methodology outlined in this study provides a fast and effective way of evaluating different damping treatment configurations at the early stages of design process. Since typically the performance criteria is based on the response of the system in terms of SPL at the driver's ear, this methodology gives a direct comparison between design alternatives. The efficiency of the methodology is due to employment of subsystem FEA and coarse SEA models.

REFERENCES

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