APPLICATION OF SEA IN VEHICLE SOUND PACKAGE DESIGN

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INTRODUCTION

Statistical Energy Analysis (SEA) was first applied in the automotive industry to study vehicle interior noise over a decade ago [1-2] and has been developed as a tool for design and development of sound package in automobiles [3-6].

Application of SEA in a vehicle program starts in the early design stage. SEA models are used to negotiate and determine real estates (size and thickness) of sound package components such as dash insulator and carpet to ensure that vehicle acoustical performance targets are met. The SEA models are continuously updated throughout the vehicle program to reflect the latest design and are used to guide the design of sound package components. In this paper, the construction, organization and validation of a trimmed-body vehicle SEA model and component SEA models are described. Example problems are presented to illustrate the application of the SEA models.

OVERVIEW OF THE SEA MODEL

A trimmed body SEA model was built for a mid-size car using AutoSEA2. While the model contains all the major structural and acoustic components, the primary objective of the study was to handle airborne-noise problems. Thus, focus has been made on the validation for airborne noise only. With the node-based approach implemented in AutoSEA2, the structural subsystems have been defined using a finite element model of an existing vehicle.

The SEA model contains all major structural components (panels, rails, pillars and glass) as well as acoustic spaces (interior, exterior, engine compartment and trunk. The model contains almost 300 structural subsystems, 80 exterior acoustic subsystems and 30 interior cavities (including engine compartment, door and trunk cavities). The model contained enough geometric information so that the coupling loss factors (CLF) were obtained automatically using the "Autoconnect" feature of AutoSEA2. Then, the majority of CLF and modal densities were defined analytically [7]. Damping loss factors and absorption coefficients were obtained either from existing Rieter acoustical database or directly from in-situ decay-rate tests. The main components of the sound package included in the model are shown in Figure 1.

Three major components of the sound package, the dash, floor and package tray, were defined using a component-level approach. The component-level approach consisted of creating, in parallel, detailed transmission loss models of the components while keeping the level of details for these components to a minimum in the full-vehicle model. These TL models were used to evaluate the insertion loss of noise control treatments. The insertion loss results were then imported in the full-vehicle model. It is to be noted that details such as leaks, pass-thru, speaker, percentage of coverage, holes, etc. were included only in the component models, the full-vehicle model using subsystems made of bare sheet metal. The advantages of using the component-level approach are: (i) allows defining almost completely the sound package under only one AutoSEA2 database (the "User-Defined Treatment" database). Thus, quick design changes on the sound package can be made with very few manipulations of the model; (ii) since the sound package is defined using insertion loss and absorption coefficient spectra, it becomes easy to create a library or database of different sound packages; (iii) it gives the flexibility to perform both component and full-vehicle level analysis.

VALIDATION

Two load-cases have been considered for the validation of the model: 35 mph chassis roll and 3000 rpm engine noise.

During chassis-roll operation, sound pressure level (SPL) measurements have been done in different locations: wheelhouse cavities (front and rear), near the glasses (exterior, front and rear), driver's ear, rear passenger ear, leg space (front and rear), dash/toe-pan area (interior), etc. SPL's inside the wheelhouse cavities have been used as sources in the model and SEA predictions have been compared to the test results. For engine noise, SPL measurements were performed, while the engine was running at 3000 rpm, in the engine compartment and in some cavities in the interior cabin. The predicted transfer functions between the engine cavities and the interior cavities SPL were then compared to test data.

As an example, Figure 2 shows of the SEA predictions compared to the test results for the SPL at two locations for the chassis-roll load-case: exterior SPL near the front glass and interior SPL at driver's ear. For each location (cavities) the SEA predictions were compared to measurements at two different microphone locations. Good agreements are obtained for frequencies above 250 Hz. For lower frequencies it was not expected to obtain good correlation since structure-borne excitations were not included in the model. Similar type of results and accuracy has been obtained for other locations in the interior of the vehicle.

SOUND PACKAGE ANALYSIS

The model has been used extensively to perform and evaluate various design changes on the sound package of the vehicle. The objective was to reduce the contribution of the main power flow paths thus optimize and propose a better sound package. The majority of the analysis was done on the full-vehicle model to evaluate the impact and the performance of the sound package at the vehicle level. However, part of the analysis was also performed at the component-level using the component models.

As an example of design change evaluation, figure 3 presents a design alternative where the package tray absorption has been changed from the standard material to the Rieter Ultra Light (RUL) material (higher absorption). In that particular case, a relatively small improvement (up to 0.6 dB) has been predicted at driver's ear. Although it might seem to be a small improvement, it contributes to the overall performance of the vehicle when combined with other design changes.

Another use of the model was the study of percentage of coverage for acoustic treatments. AutoSEA2 include a feature that allows to easily define the percentage of coverage for an acoustic treatment on a subsystem. It automatically updates all coupling and damping loss factors as well as areas for absorption calculations. That feature has been used for several components to evaluate the effect of partial coverage in some areas of the vehicle. To illustrate the use of the feature in AutoSEA2, a simple transmission loss (TL) model has been built and predictions have been compared to tests. The tested structure was a flat 0,8 mm thick steel plate that was non-perfectly covered by a 2-layer treatment made of a 15 mm thick pad and a 3-psf barrier. SEA predictions compared to test results are presented in figure 4. It is shown that 97% of coverage correlated very well with the test data. While 3% might seem a small percentage of uncovered area, it is shown that it can have a significant impact on the transmission loss (more than 20 dB at high frequencies).

Finally, it is to be noted that the model was built based on existing vehicle geometry (production vehicle) with the intent to use it later for new design of the vehicle. The model has then been modified ("morphed") using a FE model of the new design. Sound package analysis can now be performed using the updated model.

ACKNOWLEDGMENTS

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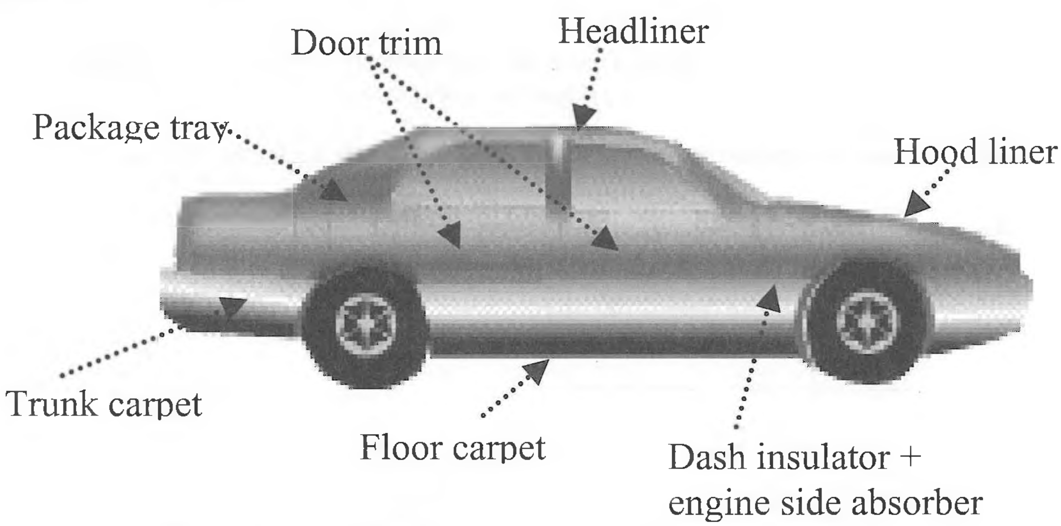

Figure 1: Major components of the sound package

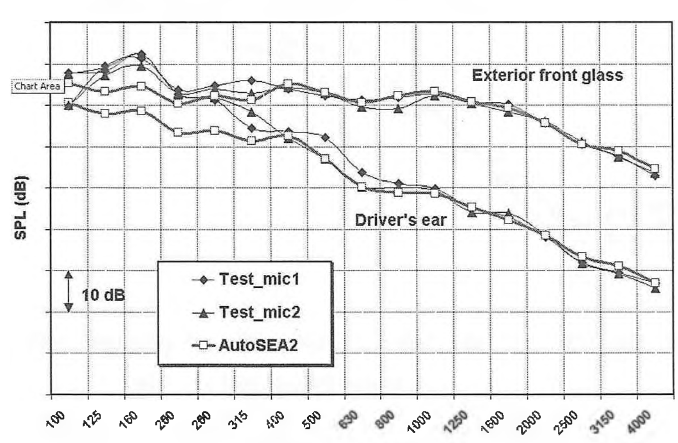

Figure 2: Chassis roll 35 mph: AutoSEA2 predictions vs test results.