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Rapid SEA Model Building Using Physical Measurements on Vehicles

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INTRODUCTION: The complexity of various CAE techniques for modeling NVH phenomena has long remained a difficulty for much of the Automotive Supply community. Complex details of Body Structures and Sound Packages are often not available outside of the OEM community and short program timing provides only a narrow window of opportunity to fine tune CAE models. This paper presents an efficient approach to build full vehicle Statistical Energy Analysis (SEA) models when no CAD/FEA data is available. The resulting model is then used to study the effects of changing the Transmission Loss characteristics of laminated glazing system components. Thereby providing a basis for verification of product performance within the vehicle as a whole, and as a foundation for the direction of future product development of glazing systems.

BACKGROUND: Over the last decade, Statistical Energy Analysis (SEA) has been widely accepted as an effective methodology in the automotive industry to study vehicle acoustics. One of the most prominent applications of SEA is found in the evaluation of sound packages including acoustic treatments in the vehicle interior and structural treatments on the Body-In-White (BIW). Due to the simplicity of modeling in SEA and the ability of SEA to handle noise problems over a large frequency spectrum, it is considered an effective tool in analyzing structure-borne as well as air-borne noise paths in vehicles.

Even though SEA models offer great simplicity over Finite Element (FE) models of full vehicles, the approach adopted by expert SEA users to study various noise paths inside the vehicles has led to considerable modeling complexity over the years. The comprehensive SEA models used in the auto-industry today may contain as many as 1500 subsystems capable of analyzing structure-borne and air-borne noise. As a result, the time spent on building full-vehicle SEA models has grown considerably, challenging the original notion of SEA being a quicker approach to analyze vehicle noise.

The scope of the present work is to analyze the change in acoustic response at the driver's headspace due to a change in the windshield glass properties using a full vehicle SEA model built without the help of any CAD/FEA data. To achieve this, a new approach is proposed which combines the old hand-measurement techniques with the capabilities of an advanced morphing tool, that allow the creation of a full-vehicle model in less than two weeks. Approximately 80% of time saving is achieved by the proposed process, which relies on making a few physical measurements on the targetted vehicle to capture the geometry and uses features of an existing template to create an SEA model.

Template Model: A template is a family of subsystems defined by any number of nodes with X, Y, Z coordinates. The template serves as a reference model used in this process, which includes the required features of the final SEA models (material, subsystems, junctions, sources…). The template is generated from scratch as a one-time process for each architecture of vehicle such as family car, SUV, mini-Van, etc. There is no stringent requirement that needs to be followed while creating a template, however, a general trend relating to the shape and the size of the type of vehicles to which the template belongs should be observed. Figure 1 shows the template of the 4-door sedan used during this project.

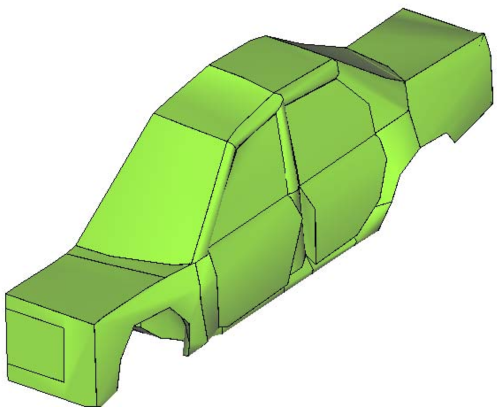

Figure 1: Template of a 4 door sedan

Measurements: Manual physical measurements on a vehicle require prior thinking to minimize the effort and improve quality of the model. However, SEA doesn't demand as much accuracy in dimensions of the model as an FE model, so tape measurements made with reasonable accuracy (within an inch of true dimensions) are considered acceptable. A global reference point is fixed and X, Y, Z coordinates of "key points" on the vehicle are measured using a measuring tape. Figure 2 shows a few key locations along the plane of symmetry of the model. Similar measurements are carried out for key locations of the interior of the car. Note that choosing key locations for measurements is more important than making a large number of measurements concentrated in one area. It is a good practice to treat point junctions in the template model as "key points" in this process. The primary focus is to make a good estimation of the size and relative positions of subsystems. Once key points are picked, the parametric nature of an SEA model built using AutoSEA2™ and the morphing tools provided by TemplateModeler™ will automatically reshape the template and calculate the surface area, perimeter, and volume of subsystems. X, Y, Z measurements were made for 90 key locations on the vehicle and approximately 15 hours was spent in the process.

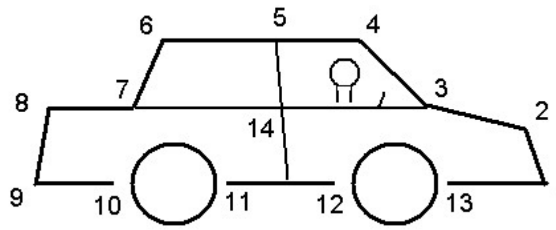

Figure 2: Typical key locations used during measurement on vehicle

Model Building: TemplateModeler™ was used to morph the template and generate the final SEA model using measured data. Symmetry was used to reduce the effort in the modeling process. The measured locations (key points) were numbered as per the relevant nodes in the template. A stick model was automatically generated from the template representing the skeleton of the model. Based upon coordinates of key points, TemplateModeler™ morphed the subsystems in the template model to fit the skeleton defined by key locations. The step-wise process used is summarized below.

1. Make measurements on the vehicle with respect to a global reference.
2. Renumber the measurement locations according to the key nodes in the template.
3. Morph the model to the new geometry.
4. Mirror the model.

Figure 3 shows the 4 door sedan SEA model generated by the described process. As a result, an SEA model of the targeted vehicle is obtained directly from the template. All the features of the template are carry over to the newly created SEA model. If any further modifications are required to the SEA model, they may be made directly to the final SEA model.

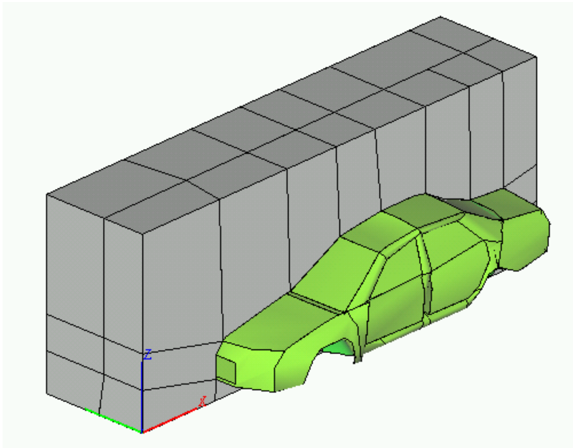

Figure 3: Final SEA Model generated from template

Results: A completed SEA model with 468 subsystems (plates, shells, and cavities) was developed using the procedure described in this paper. The goal of this project is to study the effect of different type of glass on the SPL at driver's headspace for the studied vehicle. Four types of glasses were analyzed using this model. The experimental STL curves are shown in Figure 4 for different PVB types.

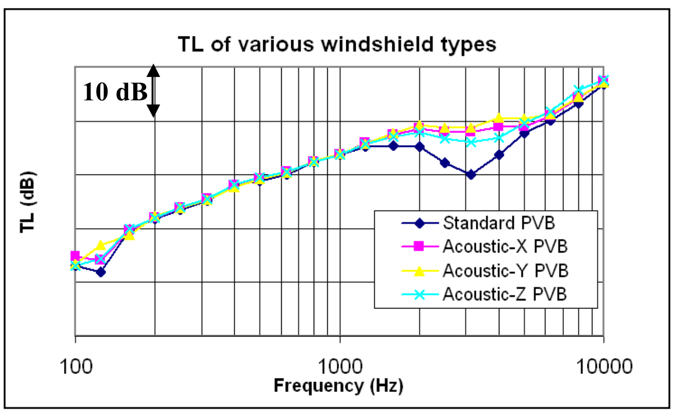

Figure 4: Comparison of STL for different glasses

A typical sound package was applied to the vehicle model as shown in Figure 5. Typical engine, tire/road and wind noise were used in the SEA model as acoustic power sources. SPLs at driver's headspace were predicted using the model. Preliminary results in predicting the acoustic effect of each windshield are presented in Figure 6.

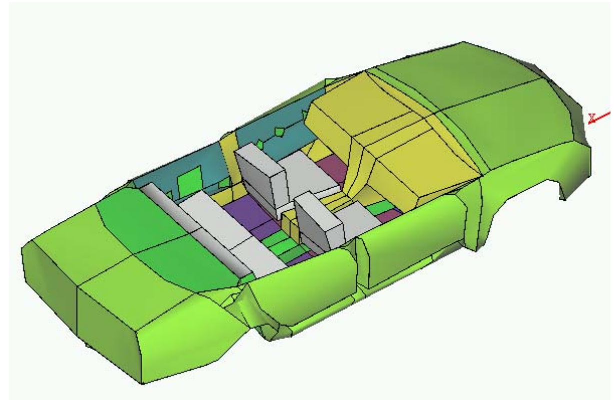

Figure 5: Acoustic package applied in the SEA model

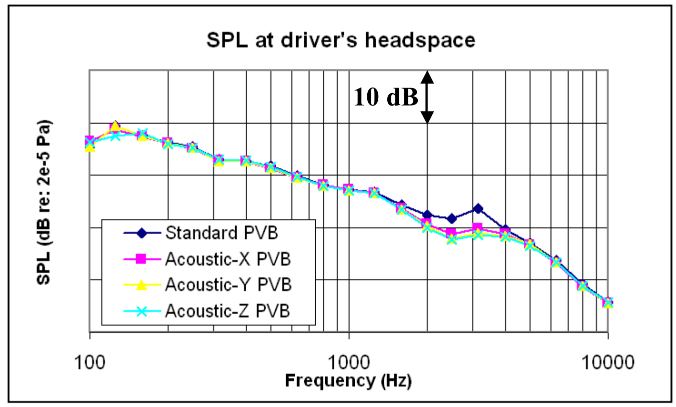

Figure 6: Response at driver's headspace

Conclusion: A full vehicle SEA model was built without the use of CAD/FEA data. This process took approximately 2 weeks to complete. Preliminary results show that the SEA model predicts reasonably well the acoustic trends of the different windshields.

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