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INVESTIGATION OF STL MEASUREMENT METHOD AT THE VEHICLE COMPONENT LEVEL AND CORRELATION BETWEEN MEASUREMENT AND PREDICTION

Ri Guang Nan*[1], Yong Jai Park[1], Yeon June Kang[1],
Chul Min Park[2] and Ki Sang Chae[2]

[1]Advanced Automotive Research Center, School of Mechanical and Aerospace Engineering
Seoul National University, Seoul 151-744, Korea
[2]Research & Development Division, Hyundai & Kia motor Co., Korea
yeonjune@snu.ac.kr

Abstract

The measurement method and the prediction of Sound Transmission Loss (STL) at the vehicle component level are presented. The sound intensity method was used to measure the STL, and Statistical Energy Analysis models were used to predict the acoustic performance of the system. Since the dash panel and the floor system mainly affect the NVH performance in the car compartment, the analysis process requires detailed SEA modeling and accurate measurement in these parts, which are made of many different kinds of acoustical materials. The measured data was in good agreement with the predicted data obtained by using the SEA model, and the results were helpful in determining the reliability.

1. INTRODUCTION

Reduction of vehicle interior noise has always been a matter of grave concern as vehicle passengers expect a quiet interior. Many related works have been carried out on acoustic performances, such as Sound Transmission Loss (STL) and Absorption Coefficient, and also, Statistical Energy Analysis (SEA) has been widely accepted for the study of acoustic performances in the vehicle compartment. T. Connelly and James D. Knittel presented in-vehicle testing to measure the transmission loss of dash, floor and door subsystems as an alternative to buck testing sheet metal sections of the vehicle [1]. M. Huang presented a new solution technique for the calculation of acoustic performance of automotive sound packages [2, 3]. J.A. Steel studied the methods of predicting sound transmission using SEA, but he only considered the structural vibration transmission [4]. J.E. Manning described SEA modeling approaches for structure-borne noise and presented methods to improve the accuracy of prediction in the lower frequency range [5].

Since trimmed panels can be designed to reduce the transmission of noise into the interior cabin significantly, we utilized the dash panel to measure the STL in this research. Comparison between the measured results and the predicted results from use of the SEA model is discussed.

The new measurement method, as well as the accuracy of the SEA model of subsystem, was verified for the semi-anechoic chamber.

2. MEASUREMENT

There are many different test configurations for a vehicle component. The first one is in-vehicle testing in the reverberation chamber. The car is fully clad with a heavy layer of EVA barrier and absorbing materials, except for the area to be measured. Since the exterior of the car is diffuse-filed, STL can be easily measured from inside the car. The second method is buck testing, in which a full vehicle is cut into subsystems (roof, door, etc.), and each of them is placed at the opening of the reverberation chamber to measure the STL. However, this method is limited by the availability of bodies to be cut and the availability of a transmission loss suite with a suitably large opening [1]. The third method is somewhat similar to the first method, except that the testing is done in a semi-anechoic room. In this method, the car compartment is treated as a diffuse-field. To do this, all of the sound absorbing materials, such as the floor carpet and the headliner, must be removed, and the interior surface of the car is clad with heavy layers of EVA barrier and absorbing materials. Because of the imperfect reverberating effect, some microphones are used to average the sound pressure and to calculate the intensity in the compartment.

The intensity method was used through the entire measurement process. B&K Type 3595 intensity probe with Type 4197 microphones and 50 mm spacer was used for the low frequency range (100 Hz ~ 1000 Hz), and an 8.5 mm spacer for the high frequency range (1250 Hz ~ 6300 Hz). The measured intensity was averaged before the sound transmission loss was calculated.

2.1 Measurement method in the reverberation room

In this method, the sound source was placed in the reverberation chamber, and the sound intensity transmitted through the dash panel in the car compartment was measured by using the sound intensity probe. Before measuring the STL, the gap between the dash panel and the opening in the reverberation wall must be covered completely. Steel plates and heavy layer and some clay were used for the covering job, and Figure 1 shows the vehicle with the gap and with the covered gap.

Figure 1. Vehicle with the gap and after the gap was covered

The other side of the window was also covered with the multi layers of heavy absorbing materials. Since there are many leakages in the dash panel, such as the brake booster, HVAC, steering column etc., the sound from the reverberation chamber can pass through these leakages to the car compartment directly. The passing of the sound can adversely affect the result of the measured data. These holes should be fully closed from both sides of the dash panel to obtain more reliable results from the test. Figure 2 shows the dash panel covered with heavy layers of absorbing materials.

Figure 2. Leakages in dash panel covered with the heavy layer and absorbing materials

2.2 Measurement method in the semi-anechoic chamber

Again, the intensity method is used to measure the STL in the semi-anechoic chamber. However, the positions of the sound source and the receiving point are located totally opposite to those of the first method. After all of the sound absorbing materials such as the floor carpet and the headliner were removed, the interior surface of the vehicle was clad with a heavy layer to make a diffuse-field. However, this cladding was still not enough to make a perfect diffuse field, so several Type 4942 microphones from B&K were used to average the sound pressure, as shown in Figure 3.

Figure 3. Microphones used to average the sound pressure

In the above method, Type 2692 rotating boom microphone was used to receive the incident sound at the centre of the reverberation chamber. In contrast, in the semi-anechoic room method, microphones at the receiving points should be located such that they avoid the modes which occur due to the shape of the interior cabin. Figure 4 shows the omni-power speaker at the centre of the back seat and another speaker at the bottom of the front seat for high and low frequency ranges, respectively.

Figure 4. Position of sound source for low and high frequency range

2.3 The result of the Measurement

Figure 5 shows the comparison of the result of the reverberation room method and the semi-anechoic room method. The two results show a similar level of agreement except in the low frequency range below 315 Hz due to the interior cabin of the vehicle no being as large as the reverberation chamber. It cannot be analyzed with a long wavelength, especially in the low frequency range below the 400 Hz because it is small. Accordingly, the result of STL in this low frequency range is not acceptable.

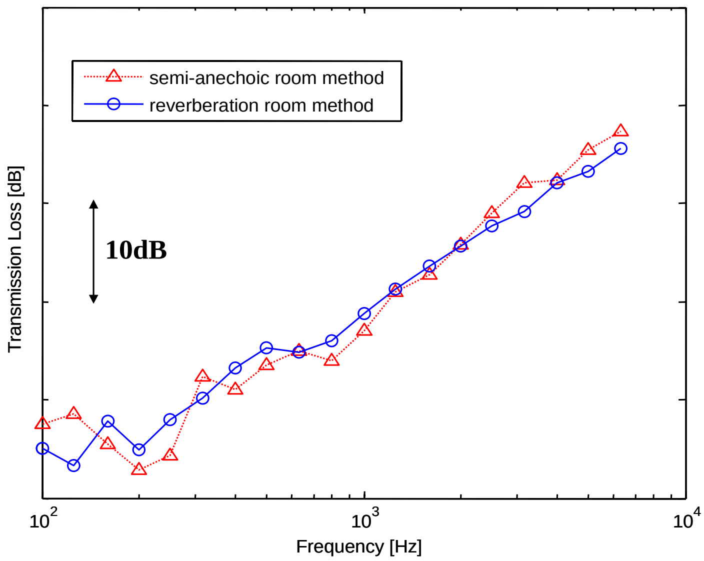

Figure 5. Comparison between the measured in reverberation room and semi-anechoic room

3. PREDICTION

Since the effects of the dash panel mainly reduce the noise in the car compartment as well as many acoustical materials are used in this part, we predicted the acoustic performance in the dash panel using SEA model. If the prediction in this part is highly accurate, then the SEA model would be acceptable for use in the other parts, as well.

3.1 The modeling of dash panel

To obtain more accurate analysis results, an almost real dash model is required, and the properties of the acoustical materials which were used in a real car must be applied to the SEA model to predict the result of STL.

Since a change in how to create an SEA model changes considerably the analysis results, the analysis model was assumed to be almost the same as that of a real situation. In the real test, both the sound source and the head of the car were placed in the reverberation chamber, and the dash insulator was the incident surface. All of these details must be considered in the analysis model to fit the result of real test. In the model of the receiving room, we applied the absorption coefficient, which was calculated by equation (1). Figure 6 shows the analysis model of the dash panel and the cavity.

$$\text{Average Absorption} = \frac{\text{Area of Panel}}{\text{Area of Receiving Room}} \tag{1}$$

Another consideration here is the application of the measured properties of acoustical materials into the analysis model. The material properties were obtained from in-house software, HONUS2005. The properties of acoustical materials can be estimated and material performances such as sound transmission loss and absorption coefficient can be predicted from HONUS2005. For instance, from the G/Wool, which has a constant surface density, the predicted properties of 'constant surface density' materials vary with the thickness. In contrast, the property of the PU foam, which has a constant bulk density, has almost no connection with the changes in thickness.

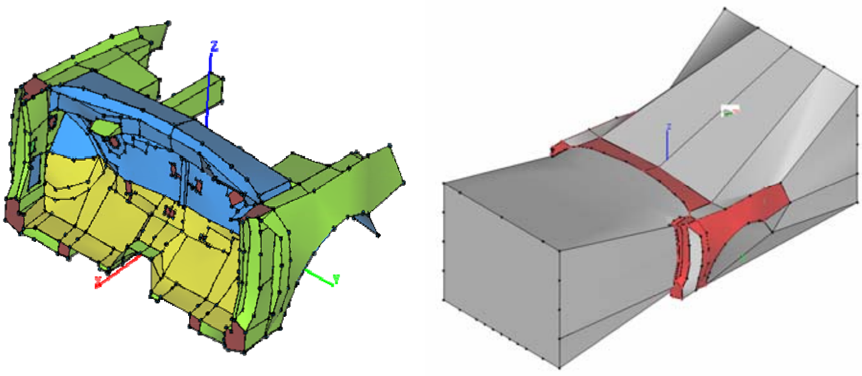

Figure 6. Analysis model of dash panel and the cavity

3.2 The result of the prediction

In practice, since the AutoSEA2 predicts the STL from the energy loss, the primary factor affecting the prediction of sound transmission loss is 'how to create the cavity and how the energy is transmitted between two cavities'. Nevertheless, if the whole surface of the analysis model is attached to the cavity and is made up of acoustical materials with a constant surface density, the variations in properties still need to be considered with the changes in thickness.

Figure 7 shows the comparison between the predicted and the measured result in a semi-anechoic chamber for the dash panel. It is almost the same in the overall range except the low frequency range below 400 Hz. This result has proved that the semi-anechoic room method is also appropriate to measure the Sound Transmission Loss of the vehicle component even if there is no reverberation room.

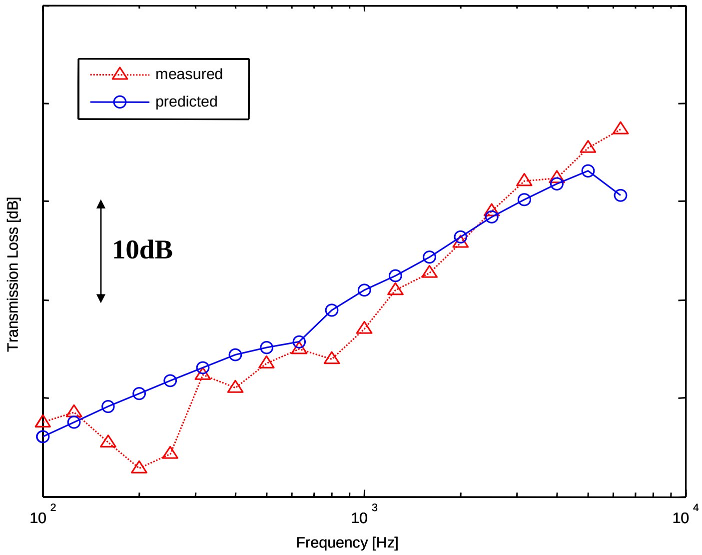

Figure 7. Comparison between results of measured and predicted

4. CONCLUSIONS

In this research, we verified the reverberation room method and the semi-anechoic room method by comparing the two results with each other and with the predicted result. The heavy layer absorbing materials are useful to shut off the sound in the mid-high frequency range, but not in the low frequency range. In addition, during the measurement of STL of the dash panel, even though it was attempted to block the leakages completely, some areas were still unable to be physically covered. The direct sound radiation from these unknown areas brought about errors in the test result. A completely covered analysis model yields higher values of the predicted STL result than those of the measured result.

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