Research of Acoustic Parts in Vehicle Sound Transmission Loss Test Method

Xiufeng Wang and Jie Shi

Abstract The sound transmission loss (STL) of the acoustic parts in the vehicle was proposed to be computed using the Sound Pressure Level measured at the several locations inside the vehicle and the transmitted Sound Intensity Level on the vehicle's exterior panel, which the acoustic treated vehicle passenger compartment is assumed as a small reverberation room. The necessary parts retrofits and acoustic treatments for Sound transmission loss tests of the acoustic parts in the vehicle were listed. The values of the appropriate number and positions of the loud speakers, microphones and sound intensity probes for Sound transmission loss of the acoustic parts in the vehicle were recommended. The in vehicle sound transmission loss tests of the acoustic parts such as the doors, carpets, wheel house etc. were achieved in the semi-anechoic room. Based on the door system, the correlation work has been done among the methods of the proposed in vehicle STL test, the reverberation—semi-anechoic chamber buck STL test and SEA analysis.

Keywords Acoustic parts · Sound transmission loss test · In vehicle · Door · Semi-anechoic chamber · Reverberation chamber

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1 Introduction

Customer's awareness regarding NVH comfort and new stringent legislative requirements are posing new challenges for vehicle manufactures. With increased engine power to weight ratio, there is pressure to reduce overall vehicle weight and cost. This impose constraints to NVH engineer in designing the body structure and sound package to reduce the effect of powertrain noise, road noise and wind noise on passenger compartment.

The sound transmission loss (STL) is a key specification to measure the acoustic performance of the body structure and sound package. According to the different incident sound types, the sound transmission loss test can be divided into the normal incidence method and random incidence method [1, 2]. The normal incidence sound transmission loss test method can be measured using four microphone tube as per standard ASTM E2611 [3], which is a rapid method and require only a small size sample of the material and more suitable for the material acoustic test.

The random incidence sound transmission loss test method [1] normally includes three ways: the standard reference sample test method per SAE J1400 [4], the reverberation -reverberation chamber test method per the ASTM E 90-09 [5] and the reverberation -anechoic chamber using sound intensity test method per the ASTM E 2249-02 [6].

For the accurate, simple and convenient in implementation, the reverberation chamber—anechoic chamber using sound intensity test method is the most commonly used sound transmission loss test method in the automotive industry. While the reverberation -anechoic chamber using sound intensity test method requires body structure destructive cut and the special buck fixtures that will take a lot of time (usually a few weeks) and cost for the test preparation and system setup.

In this paper, the sound transmission loss of the acoustic parts in the vehicle was proposed to be computed using the Sound Pressure Level measured at the several locations inside the vehicle and the transmitted Sound Intensity Level on the vehicle's exterior panel, which the acoustic treated vehicle passenger compartment is assumed as a small reverberation room. The necessary parts retrofits and acoustic treatments for Sound transmission loss tests of the acoustic parts in the vehicle were listed. The values of the appropriate number and positions of the loud speakers, microphones and sound intensity probes for Sound transmission loss of the acoustic parts in the vehicle were recommended. The in vehicle sound transmission loss tests of the acoustic parts such as the doors, carpets, wheel house etc. were achieved in the semi-anechoic room. Based on the door system, the correlation work has been done among the methods of the proposed in vehicle STL test, the reverberation - semi-anechoic chamber buck STL test and SEA analysis.

2 Acoustic Parts in Vehicle Sound Transmission Loss Test Method

The sound transmission loss is defined as the ratio of the incident sound power W_{in} and the transmitted sound power W_{out},

$$STL = 10\lg\frac{W_{in}}{W_{out}} \tag{1}$$

The incident sound power W_{in} of the acoustic parts in vehicle sound transmission loss test method is calculated from the sound pressure level measured at the several locations in the passenger compartment, that the retrofired and acoustic treated vehicle passenger compartment is assumed as a small reverberation room(as shown in Fig. 1), i.e.

$$W_{in} = \frac{P_{in}^2}{4\rho c}S \tag{2}$$

Where P_{in}^2 is the passenger compartment multi-point sound pressure mean square value; S is the test sample area, m^2; ρc is the characteristic impedance of air and is 400 N s/m^3 under the normal temperature and atmosphere pressure.

The semi-anechoic chamber, where the test vehicle is parked, is used to receive the transmitted sound, and the transmitted sound power W_{out} can be calculated from the vehicle's exterior panel Sound Intensity, i.e.

$$W_{out} = I_{out}S \tag{3}$$

Where I_{out} is the semi-anechoic chamber side panel surface average sound intensity;

Put Eqs. (2 and 3) into Eq. (1), then derive Eq. (4) for the in vehicle sound transmission loss test,

$$STL = SPL_{in} - SIL_{out} - 6 \tag{4}$$

Where $SPL_{in} = 20\lg(P_{in}/P_0)$ is the average sound pressure level of the passenger compartment, P_0 is the reference sound pressure and 2×10^{-5}Pa in the air; $SIL_{out} = 10\lg(I_{out}/I_0)$ is the sample surface average sound intensity level of the semi-anechoic chamber side, I_0 is the reference sound intensity and is $1\times10^{-10}W/m^2$ in the air.

Fig. 1 Vehicle test setup (setup for the *right* front door window)

3 Acoustic Parts Sound Transmission Loss in Vehicle Test

3.1 Acoustic Parts Sound Transmission Loss in Vehicle Test Preparation

In order to achieve the in vehicle sound transmission loss tests of the acoustic parts, it is necessary and very important for retrofits and acoustic treatments to the related parts of the vehicle, especially the passenger compartment. First, remove the powertrain, front and rear suspension s (including tire assemblies) from the vehicle; Secondly, make the passager compartment a more reverberant space. All of the windows, sunroof, and sunshade must be closed. Remove all free standing seats from the vehicle. For built in seats, such as the rear bench seat of a sedan, cover with sound barrier to achieve a more reflective surface. In order to create a more reverberant space, turn the floor mats upside down and cover any absorptive surfaces with acoustically reflective material, i.e. rubber, sound barrier, plywood, etc. Finally, treat all vehicle panels, other than the test panel, with sound barrier assembly material to eliminate any flanking paths, this includes hanging sound barrier assembly material from the vehicle's rockers to the floor of the car test room. Figure 1 shows a vehicle schematic of the retrofit and acoustic treatment.

3.2 Acoustic Parts in Vehicle Sound Transmission Loss Test

The acoustic parts in vehicle sound transmission loss test were implemented in the semi-anechoic chamber. Place the speakers in the 4 corners of the vehicle angled to face the center of the passenger compartment. For each vehicle panel tested the speakers may need to be moved to insure that sound is evenly distributed in the vehicle and to each of the microphones. Ensure that the speakers are at least 1.0 m from any potential microphone location. At no time should the speakers be pointed directly into any microphone, and avoid having a speaker in the near field of the

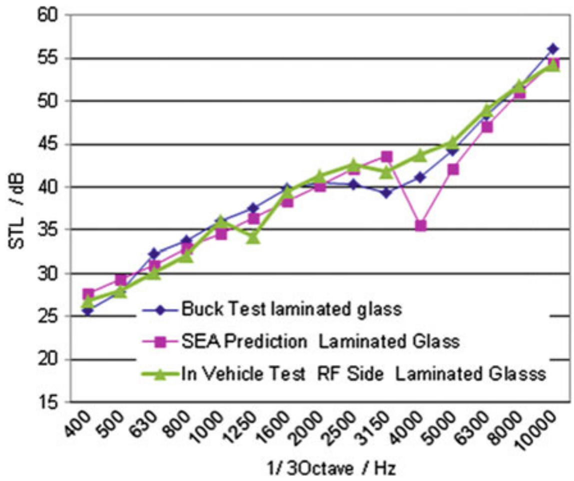

Fig. 2 *Right* front door glass sound transmission loss test results

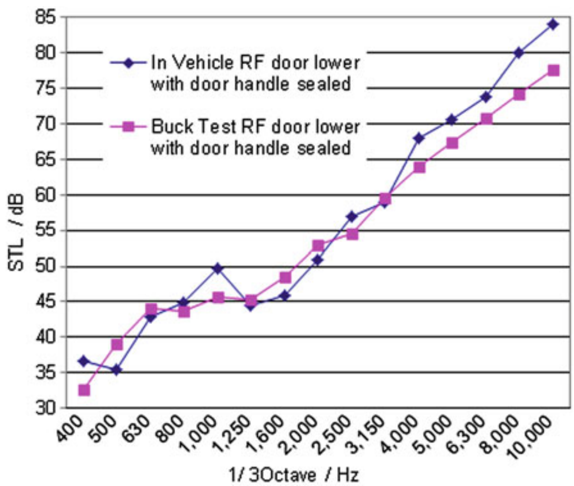

Fig. 3 *Right* front door lower sound transmission loss test results

vehicle panel being measured. Four or six microphones are used for this test. They should be randomly distributed inside the vehicle over the area of the vehicle panel being tested, approximately 15 $\sim$ 20 cm off the surface of the panel. Acquire the transmitted intensity level SIL_{out} in the semi-anechoic chamber with a scanning method, that scanning speed is 0.1 $\sim$ 0.3 m/s, sound intensity probe is 0.1 $\sim$ 0.3 m away from the test surface, the scan mode is grid-style intertwined. Finally, with the SPLin and SILout obtained, according to the Eq. (4), the sound transmission loss STL. can be calculated.

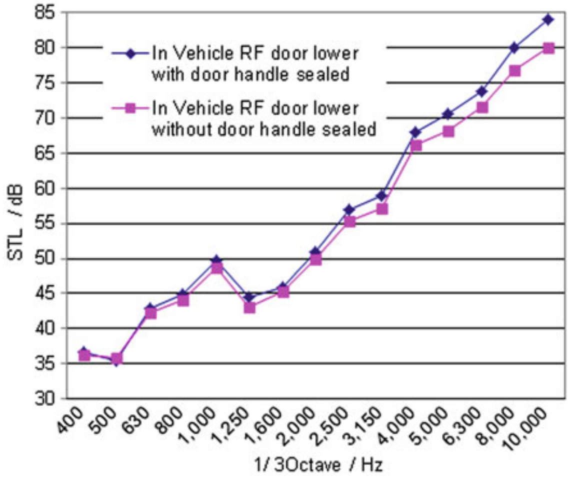

Fig. 4 *Right* front door *lowe*r door handle influence

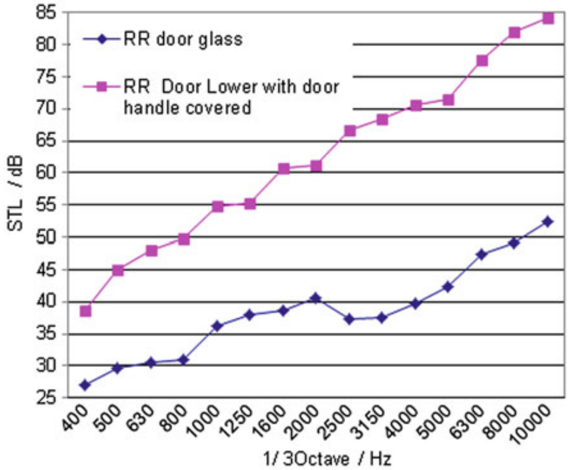

Fig. 5 *Right* rear door lower sound transmission loss test results

3.3 Acoustic Parts in Vehicle Sound Transmission Loss Test Results

In this section,acoustic parts in vehicle sound transmission loss test method was applied to vehicle as shown in Fig. 1. Figure 2 shows comparison experimental and simulated results for the left front door 5 mm acoustic laminated glass. The in vehicle sound transmission loss test results, and that of the reverberation chamber—anechoic chamber method and the analysis STL results using statistical energy analysis have a good consistency except at 4,000 Hz where the testing test results is significantly higher than the analysis results. It is because the seal treatment on the window glass run channel with tape and damping that improves

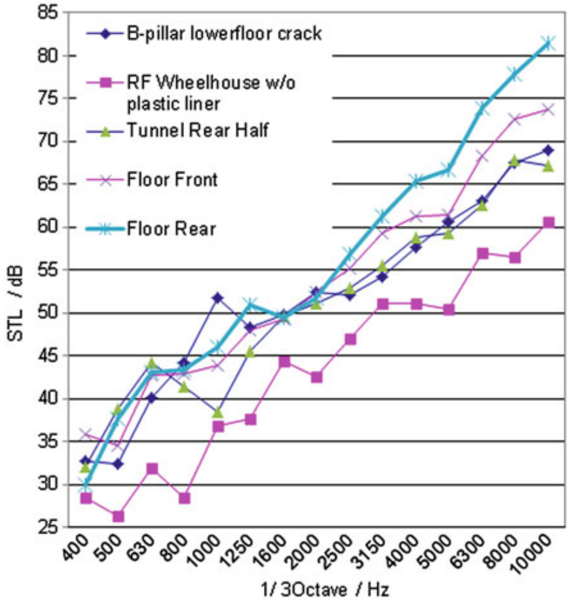

Fig. 6 Floor area sound transmission loss test results

the damping characteristics of the glass and improves the STL performance correspondingly. The in vehicle and reverberation—anechoic chamber method sound transmission loss test results of the left front door body region are depicted in Fig. 3, that also shows a good correlation. Figure 4 shows the in vehicle sound transmission loss test results of the door lower region of the left front door with and without the door handles seal, that shows the in vehicle STL test method can effectively identify STL improvement of the acoustic parts. Figures 5 and 6 list the in vehicle sound transmission loss results of the left rear door, floor region and wheel house region, that can be used to evaluate sound transmission loss performance of the above-mentioned regions in the real vehicle status and support statistical energy analysis vehicle modeling and correlation with effective data.

4 Conclusion

The body structure and the related acoustic parts are main sound insulation package of the vehicle, which can effectively block the road noise and powertrain noise and wind noise to enter the passenger compartment. A fast, accurate and relatively low cost acoustic parts sound transmission loss test method has important practical significance and engineering value. In comparison with the traditional reverberation- anechoic chamber method, acoustic parts in vehicle sound transmission loss test is a more simple, fast and convenient and vehicle based non-destructive test method that can significantly save the cost and time (buck test takes several weeks, while in vehicle only 1–2 days), and can achieve the vehicle level acoustic parts sound insulation performance assessment and identification and effectively support the vehicle statistical energy analysis modeling and correlation. It is particularly suitable for the benchmark test and analysis for competitor vehicles.

References

1. Pang J (2006) Automotive noise and vibration—principle and application. Beijing Institute of Technology Press, Beijing
2. Zhang Z (2008) Fundamentals of automotive interior design. China Communications press, Beijing
3. ASTM (2009) E2611—09 Standard test method for measurement of normal incidence sound transmission of acoustical materials based on the transfer matrix method
4. SAE (2010) J1400-laboratory measurement of the airborne sound barrier performance of flat materials and assemblies. SAE standards
5. ASTM E (2009) 90—09 Standard test method for laboratory measurement of airborne sound transmission loss of building partitions and elements ASTM
6. ASTM E (2003) 2249-02 Standard test method for laboratory measurement of airborne transmission loss of building partitions and elements using sound intensity

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