A Measurement Technique for Evaluating Insertion Loss of Cavity Fillers

Sachin K. Jain, Manasi Joshi, Paresh Shravage, N.V. Karanth

NVH Laboratory, Automotive Research Association of India, Pune-411038

Abstract

The interior noise in a vehicle is of significant importance in today's highly competitive market. A vehicle with improved sound quality certainly has a leading edge. However, the challenge is not only to reduce the interior noise of the car, but also to fine tune it, such that the perceived noise will be pleasant. One of the ways to cater this problem is use of cavity filler materials (expandable baffles) inside vehicle cavities like rails, pillars, and cavities to reduce noise propagation. Increased use of cavity filler materials on rockers, pillars, posts has resulted in the need to develop a standardized procedure for ranking of performance of these materials. This paper gives a detail insight of a measurement technique that has been used for properly evaluating the acoustical performance of expandable cavity filler materials. The test method is intended to simulate actual conditions inside vehicles so that different materials can be evaluated to achieve optimum acoustical performance within a channel representing the rails or pillars in automobiles. The paper also presents Insertion loss results measured using Reverberation chamber with anechoic chamber as a receiver room for typical cavity filler materials.

Introduction

In vehicles, the primary noise generation mechanism is located outside of the passenger cabin. The major noise sources include powertrain, tire, road and wind noise. The primary path for this noise to travel from outside to inside the car is through the body panels or channels of the car. Therefore, major emphasis has been given on developing acoustical materials and packages to reduce noise transmission through these channels [1]. A significant amount of noise is also carried through rails, posts, and pillars through hollow cavities, which are the main structural support of any car. Once the noise in the engine compartment enters the rails, it encounters a path of open communication to the pillars and to the rest of the car. Expandable sealant materials are widely used in these hallow cavities to control this noise. Noise will escape though leaks and increase the noise level at the receiver location. So it is important to fill the hollow cavity, but also to fill it properly so that there are no leaks. Otherwise leaks will control the performance [2]. Today the majority of the automotive specifications for expandable sealant materials give detail physical requirements of the material before and after baking. This approach does not allow one to understand thoroughly the potential noise control capabilities of expandable sealant materials.

Noise Control Engineering

Sound Package materials are widely used for noise control treatments in Transport industry. It is therefore required to understand behavior of acoustic materials and how their acoustic performance is evaluated.

Definitions of Acoustical Performance

The acoustical performance of a noise control treatment can be expressed in several ways. The three most common descriptors are:

- Sound transmission loss (STL)
- Noise reduction
- Insertion loss

Sound Transmission loss-It is defined as the ratio of transmitted sound energy to the incident sound energy. The SI unit of sound transmission loss is dB. It blocks the sound propagation through the material from one side to other. When a sound wave impinges on an acoustical barrier some part of the sound wave will be reflected and some part of the sound wave will pass through the acoustic material. This pass out sound is transmitted sound and it depends upon material properties. Generally thicker walls will have less transmitted sound than thinner walls. The sound transmission properties of acoustical barrier materials vary significantly with frequency.

Sound transmission loss is given as

$$\mathrm{STL} = 10\log\left(\left(\frac{1}{\tau}\right)\right) \quad \mathrm{dB}, \quad \tau = \frac{\textit{Transmitted sound energy}}{\textit{Incident sound energy}} \qquad (1)$$

Noise reduction is the difference in noise levels measured on the source side and on the receiver side. The difference in noise levels measured in the engine compartment and inside the car can provide NR performance of parts such as the dashmat. **Insertion loss** is the difference in noise levels measured at the receiver location without any treatment and with the noise control treatment in place. The difference in noise levels measured at the operator ear without and with any treatment in the hollow cavity provides IL performance of that treatment.

Measurement Test Set:

The measurement test setup is similar to Sound transmission loss measurement as per SAE J1400 [3]. The test method discussed here is based on the procedures described in an SAE J2846 [4]: Laboratory measurement of the Acoustical Performance of Body Cavity Filler Materials. The method uses a large reverberation room as a source room. In this room, noise is generated electronically using a loudspeaker to create a uniform sound field. One of the walls of this room has an opening where the test samples are mounted to evaluate the acoustical performance. On the other side of this opening is a small anechoic termination chamber which is used as the receiving room. (Anechoic means no echo) Figure 1 shows the schematic of such test facility. Expandable sealant materials were tested in a rectangular channel, where the channel represented the rails and pillars in the car. There are, however, several variables to consider in simulating the actual application and also in obtaining meaningful information from the test results. Some of the concerns in the laboratory tests are:

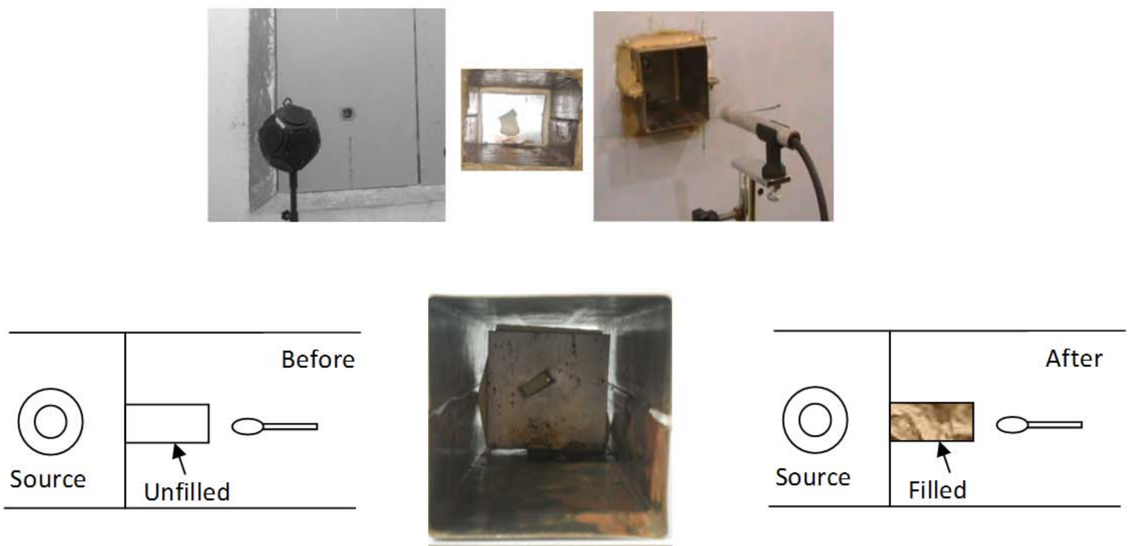

Figure 1: Test set for Insertion Loss of Cavity Filler Measurement

Size (cross-section) of the Channel:

A rectangular cross sectional channel with pinch welds is used for the testing as it provide some simulation of actual applications. Most commonly the test channel is to be used is of 75 mm X 75mm in cross section with 250 mm in length. The cut-off frequency for this channel is around 800 Hz as shown in figure 2. While for other channel of size 150 mm X 150 mm X 250 mm, cut off frequency is 400 Hz.

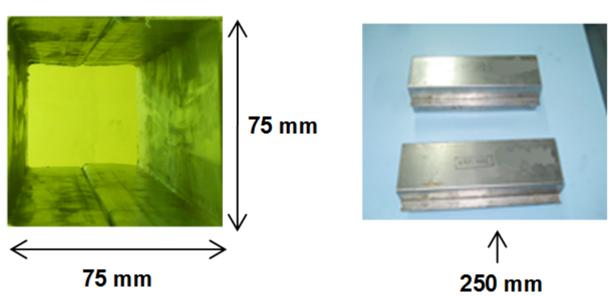

Figure 2: Cross section of channels

Measurement Position:

Sound measurements were made both in the source room and in the receiving room. The source room is a large reverberation room with a diffused sound field. Measurements were made at different locations in this room and later were averaged to obtain an average noise level in the source room. The receiving room has an anechoic environment. Measurement location selected for this test method was 100 mm from the sample because at this distance spread in the results is very low and also at this distance microphone will not be that much sensitive to the incident sound. The concept of IL measurement assumes that the sound pressure level produced by the source is the same for both the “Before” and “After” test conditions. Both unfilled and filled channels need to be tested. The IL performance of the sealant is then expressed as

$$IL = SPL_{Unfilled} - SPL_{Filled} \quad (2)$$

where, SPL= Sound pressure level in dB

Material preparation:

It is observed that chemical composition of expandable sealant materials is very critical. The performance of these types of materials depends upon expansion rate and amount, cell structure, stiffness, profile of the expandable material etc. With these variables in mind, care has been taken during baking of the samples. In this test, samples were baked at around 160^0C, so that the gap between the channel and the plate holding the sample is filled completely.

Types of Cavity Fillers: Different types of cavity baffles are available. Some of the types are as follows [5].

Race-track type expansion-These types of baffles use heat activated foam either at the edges of the baffle or sandwiched between two metal carrier plates to hold the foam. This type of material expands as much as 300 to 1500 times by volume. **Full expansion type-**these types of baffles use heat activated foam either fully covering the top or bottom portion of the plate. The expansion rate this type of baffle is same as that of race track type expansion. **Injectable type-**these types of baffles does not need heat treatment for expansion [6]. This type of baffle expands chemically when two different chemicals are injected into the cavity. Current automotive requirements for Sealant materials are in terms of

- Specific gravity
- Adhesion to automotive substances
- Thermal and environmental
- Durability

- Rate and amount of expansion
- Corrosion protection

Results and Discussions:

Two samples of expandable sealant material were tested. The test was repeated two times with and without the expanded material in place. Figure 1 shows the test set up for cavity filler mounted and sealed at the edges with putty in between reverberation chamber and anechoic termination. Figure 3 gives sound pressure levels for bare channel and channel filled with expandable material are shown. Figure 4 shows IL comparison for two types of materials. For these two materials, IL is almost same as they have same density near to 1.1 gm/cc. At high frequencies, Sample B is having low IL, because sealant in that channel was not fully expanded during sample preparation process.

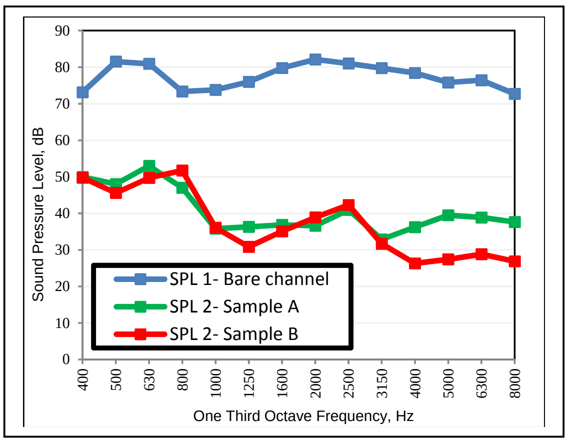

Figure 3: Sound Pressure Levels for Bare and Filled Channel

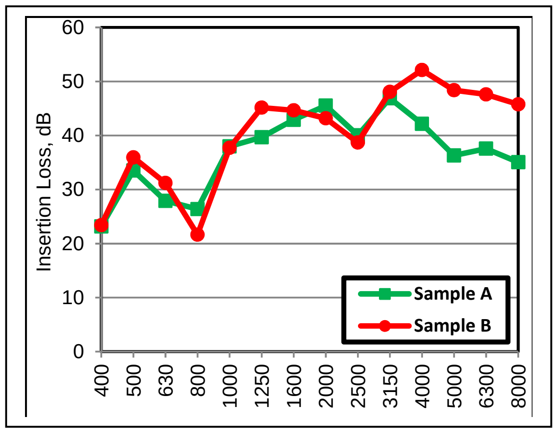

Figure 4: Comparison of Insertion Loss for expandable sealants

Depending upon size of the channel, the performance of sealants will be better at and above 1000 Hz. At frequencies lower than 1000 Hz (especially the dip observed in between 800 – 1000 Hz), the results are affected by the fundamental resonance of the channel and by the geometry of the channel including the size and length. In this frequency range, results may still be useful, but the reliability may be questionable.

Conclusions

In this paper, a method used to evaluate Insertion Loss of expandable sealant materials is discussed in details. The expandable materials play very crucial role in interior noise reduction as well as in sound quality of vehicles. This test method gives the rank ordering the performance of expandable sealant materials. The future plans for these materials are modelling these complex materials as their expansion rate is temperature dependent and hence modelling of the cavity fillers will be a challenging task Also work on cavity fillers which can expand across it periphery will be the future goal it will reduce the weight of one steel (carrier) plate.

Acknowledgements

The authors are thankful to Director, ARAI for his permission and support to complete this work. The authors are also thankful to NVH Dept. for their help during the work.

References

1. Saha, P., and Meyers, R. D., "Importance of Sealants for Interior Noise Control of Automobiles"- Paper 920412, presented at International Congress & Exposition , Detroit, Michigan, Feb. 24-28, 1992.
2. Saha, P. And Chahine, J., "Sound Package Materials in Automobiles"- Proceedings of the ASME Noise Control and Acoustics Division, NCA-Vol. 22, 1996.
3. SAE J1400- Laboratory measurement of the Air borne sound barrier of flat materials and assemblies.
4. SAE J 2846-Laboratory measurement of the acoustical performance of body cavity filler materials.
5. Gettys, G. A., "New Concepts in Acoustical Baffles"- Automotive Interior and Exterior Systems, IBEC (International Body Engineering Conference), 1993.
6. Prashanth B., Sachin Wagh, David Hudson, "Evaluation of acoustic performance of expandable foam baffles and correlation with incab noise", SAE International, 2011-01-1624.