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The Influence of Test Fixture Damping on the Measurement of Sound Transmission Loss

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ABSTRACT

The Sound Transmission Loss (STL) provided by a material depends on factors such as its mass, damping and stiffness. In the lab, the damping and stiffness of a panel is influenced by the test fixture. While some aspects of the sample mounting are well defined in the standards¹⁻², specific details regarding how the sample is sealed is left to the user. As the size of the sample decreases, the edge damping from clamping and/or sealing the sample can add significant damping to a panel. Too much damping can cause a significant overstatement of the sample STL. This paper examines the influence of edge damping due to sealing clay on the STL of steel and aluminum panels.

1. INTRODUCTION

Motivation for the paper came through laboratory comparisons of the sound transmission loss, measured according to SAE J1400, of 610 mm x 610 mm x 2.5 mm thick aluminum samples as shown in Figure 1. Although the samples are nominally identical, various samples, test fixtures, source and receiving chambers were used for the tests. In addition to high frequency differences, which may be due to damping, there are also differences at other frequencies possibly due to the test fixture influencing the stiffness of the sample and flanking sound paths.

A similar comparison made with 610 mm x 610 mm x 1.6 mm thick steel (Figure 2) shows the lab to lab variation is not as prevalent as with the aluminum sample. The improvement in consistency may be due to the higher inherent damping and lower stiffness in the steel.

Over the years, Blachford has utilized different laboratories for STL testing. This includes various in-house and contract laboratories as well as different sample fixtures, sizes and mounting systems. There is the desire to compare all historical data, not only to rank order materials but also to determine compliance with older specifications. In some markets it is not unusual for specifications to remain unchanged for 30 or more years. There is also the desire to provide the best possible data (within reason) as data generated from one laboratory may be compared to data from another laboratory for purchasing decisions.



Figure 1. Laboratory Comparisons of 610 mm x 610 mm x 2.5 mm Thick Aluminum



Figure 2. Laboratory Comparisons of 610 mm x 610 mm x 1.6 mm Thick Steel

In this study, we examined the differences in the STL of 1.6 mm thick 610 mm x 610 mm and 1220 mm x 1220 mm steel and 2.5 mm thick aluminum samples when sealed in a test fixture using a bead of 25 mm or 75 mm clay.

2. TEST METHOD AND RESULTS

The sound transmission loss was measured according to SAE J1400 (10)¹, "Laboratory Measurement of the Airborne Sound Barrier Performance of Automotive Materials and Assemblies". With the SAE standard, a reverberant source room is required, but a special receiving chamber is not. In many cases the receiving chamber is anechoic or highly absorptive, but it could also be reverberant like specified in ASTM E90 "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements". One of the unique features of SAE J1400 is the use of a correlation sample. This is a material with a known sound transmission loss value, such as a limp mass. The noise reduction of this material is measured (MNR) and a correlation factor (CF) determined through equation 1:

$$CF = MNR - STL_{known \, sample} \tag{1}$$

The STL of the unknown samples are then calculated using equation 2:

$$STL_{unknown\,sample} = MNR - CF \tag{2}$$

In the Blachford Acoustics Laboratory, two stationary microphones are used in the receiving room, shown in Figure 3, and a rotating microphone is used to obtain a spatial and time average level in the source room. Broadband sound encompassing the 100 through 8000 Hz one-third octave bands is produced in the source room and the resulting sound pressure levels are measured in the source and receiving chamber. The noise reduction is calculated by subtracting the average sound level in the receiving room from the average sound pressure level in the source room over a 32 second average. A total of 10 sets of measurements are performed and the final NR determined through averaging the data set values.



Figure 3. Blachford Acoustics Laboratory

Although also termed STL, the values obtained using the ASTM E-90 test procedure should not be compared to those provided by the SAE J-1400 procedure. The STL in the middle frequency range is often similar, however, the SAE procedure provides lower low frequency values and higher high frequency values than the ASTM procedure.

It is common in STL measurements to see a high frequency dip in the transmission loss curve. The frequency where this dip occurs is referred to as the coincidence frequency, and is the frequency where the speed of the bending wave in the panel equals the speed of sound in the medium surrounding the panel (air, in this case)³. It is calculated using equation 3:

$$f_c = \frac{c^2}{2\pi} \sqrt{\frac{m}{B}},\tag{3}$$

where c is the speed of sound in air, m is the surface density of the panel, and B is the bending stiffness of the panel material. The STL near and above the coincidence frequency depends on the damping in the test specimen.

In-situ damping loss factor of the panels were measured using a decay technique⁴. A small modal accelerometer was placed at 6 random locations on the panel. At each accelerometer location the panel was impacted using a modal hammer at a random location and the vibration decay times (T_{20}) measured. The damping loss factor(η) was then calculated by using equation 4 and averaged.

$$\eta = \frac{2.20}{T_{60}f}$$
(4)

Here, T_{60} is the 60 dB vibration decay time and f the one-third octave band center frequency.

A. Steel

Cold rolled steel samples measuring 610 mm x 610 mm and 1220 mm x 1220 mm by 1.6 mm thick were mounted in a vertical test opening and sealed using a bead of 25 mm or 75 mm of clay on the source room side and about 25 mm on the receiving room side. The STL and damping loss factors were measured for each configuration. Measured STL values are provided in Figure 4.

There is a relatively small variation in the STL between the four samples. Except for the 610 mm x 610 mm sample with 75 mm sealing clay, the variation over most of the frequency range is less than 1 dB, which is what we would expect for test to test variation. In the 500 to 2,000 Hz one-third octave bands, the 610 mm x 610 mm sample with 75 mm of sealing clay has slightly higher STL. We would expect higher STL values for the smaller samples size throughout the frequency range. Differences in STL due to sample size will be addressed in a future paper. A more noticeable difference is found in the 8000 Hz one-third octave band, corresponding to the coincidence frequency for the steel samples. This is likely due to the increased damping due to the clay.



The in-situ damping loss factor versus frequency is provided in Figure 5. Since the clay is not viscoelastic, we expected the damping to be independent of frequency. However, the data shows strong frequency dependence. This could be due to the small test specimen sizes and fast decay times. Some authors recommend use of T_{10} or T_{15} or another type of measurement instead of the T_{20} to quantify the damping⁵. Although a more accurate method for measuring the decay rate and characterizing the damping in the specimen is being studied, the general trend of the data indicates that the smaller samples tend to have higher damping.

B. Aluminum

In a similar manner, 6061 Aluminum specimens measuring 610 mm x 610 mm and 1220 mm x 1220 mm by 2.5 mm thick were mounted and tested in a similar manner. Measured STL values are provided in Figure 6. The greatest difference in STL is in the 5000 Hz one-third octave band (coincidence frequency) where the largest sample with the least amount of clay provides the lowest STL and the smallest sample with the most amount of clay provides the highest STL.

Corresponding damping loss factor measured data is provided in Figure 7. The loss factors at low frequencies follow the trends in the STL data; however, at higher frequencies all of the test specimens seem to provide similar values.



Figure 5. Damping Loss Factor Measured in Steel Test Samples



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Figure 7. Aluminum Damping Loss Factor Comparison

3. DISCUSSION

To verify that the differences in the measured STL are due to damping, aluminum panels with different amounts of damping were modeled using WinFlag⁶ and are shown in Figure 8 for 610 mm x 610 mm samples and Figure 9 for 1220 mm x 1220 mm samples. The modeling parameters were: thickness 2.5 mm, density 2700 kg/m³, Young's Modulus 69 GPa, Poissons number 0.3, and damping loss factor 0.05-0.4.

Similar to measured data, the predicted levels show that increased damping provides increased STL near and above the coincidence frequency. Hence, the amount of clay used to seal the samples in the test fixture can significantly influence the measured STL in this same frequency range.



Figure 8. Predicted STL for 0.6m x 0.6m x 2.5mm Aluminum



Figure 9. Predicted STL for 1.2m x 1.2m x 2.5 mm Aluminum

4. CONCLUSIONS

Concern about the amount of damping or the edge damping provided by the test fixture is not a new issue. There are a large number of papers discussing this topic relating to window and glazing applications of which a few are referenced in this paper⁷⁻¹⁰. We anticipate this topic to grow in importance with the increased use of aluminum in the automotive and heavy truck industry¹¹ and the sensitivity of the measured STL due to test fixture damping.

Many have heard anecdotal accounts of some laboratories using large amounts of clay around the perimeter of sample to achieve higher measured STL values. To provide improved repeatability and reproducibility, it is recommended that details regarding the sealing of the sample into the test fixture be provided in the laboratory report. In addition, bare panel (substrate) data should also be presented with the panel plus treatment results for proper analysis.

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