COMPARISON OF DIFFERENT METHODS TO MEASURE STRUCTURAL DAMPING

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1. INTRODUCTION

Structural damping indicates the energy loss in materials and systems respectively. Hereby, different loss mechanisms must be distinguished: namely internal losses or material damping due to conversion of kinetic energy into heat and coupling losses due to transmission of energy to adjoining systems, e.g. by structural transmission at connection points or even sound radiation from a structure into a room. Having the ability to reliably measure the damping loss factor should enhance the capability of predicting the transmission loss in wall or floor assemblies.

In the following, three different methods to obtain the damping loss factor are discussed and compared.

All methods are presented on a (2.41 m x 1.22 m x 0.012 m) Plexiglas plate to verify the methods and are further used to compare the loss factors of two wood framed walls – one with an applied constraint layer damper (CLD) and one without, both described in detail in a parallel paper [1].

2. METHODS

2.1 Reverberation Time Method

The first method, called Reverberation Time Method, uses as its name suggests the structural reverberation time, T, (time in which the energy of the system decays by 60 dB) to calculate the total loss factor η of the system.

The dependency of the loss factor on the reverberation time is $\eta \approx \frac{2.2}{f * T}$ with f being the frequency.

The reverberation time was obtained by exciting the specimen with a small force hammer at three positions using three repeats and measuring the acceleration at eight points distributed over the specimen. Schroeder Plots [2] of the responses were calculated using the Schroeder backwards integration as noted in Equation (1) and evaluated according to ISO 3382 to obtain the single reverberation times at each third octave band. The overall third octave band reverberation times are the average of all single measurements.

$$d(t) = \int_{\tau}^{\infty} f(x)^2 \, dx \qquad (1)$$

2.2 Power Injection Method

The second method, called the Power Injection Method [3], uses the relation between the power injected into a system, P_{in}, and the resulting space averaged vibration power, P_v, to obtain the total loss factor of the system

$$\eta = \frac{P_{in}}{P_v}, \text{with}$$

$$P_{in} = \frac{1}{\omega} Im\{G_{FA}\} \text{ and } P_v = \omega \, m \, v^2,$$

where G_{FA} is the cross spectrum density of the force and acceleration at the drive point. This model assumes steady state excitation and a diffuse field in the system achieved through high modal density.

In the experiment the specimen is excited by a Wilcoxon F3 shaker using white noise while measuring the velocity at the same eight points as for the first method averaged for 30 seconds. The drive point force and acceleration were measured using an impedance head that was integrated into the shaker.

2.3 Drawaway Method

For the third method, the Drawaway Method, the decay of a propagating bending wave is evaluated to estimate the loss factor on the plate η_p (not the total loss factor of the system). A very simplistic approach is used assuming a circular bending wave front around a point source on an isotropic infinite plate in the far field. This means reflections from the edges and near field terms are neglected leading to a wave power decay proportional to

$$P_p \sim v^2 \sim \left(\frac{1}{\sqrt{x}} e^{-k' \frac{\eta_p}{4} x}\right)^2$$

with v as the velocity on the plate, r distance from excitation point, and k' as the real part of the wavenumber. The loss factor can be estimated by measuring the unknowns (v^2 and k'), rearranging the logarithm of Equation (2), and performing a linear regression to obtain the slope dependent on η_p.

$$\ln(v^2) + \ln(x) \sim -k' \frac{\eta_p}{2} x$$

Because of the neglected reflected wave, this loss factor is expected to underestimate the loss factor.

A method to obtain the real part of the wavenumber from drawaway measurements is described in detail in a paper by Nightingale et al. [4]. The velocity was measured while exiting the specimen with a shaker at 24 points, 5cm apart, on a straight line.

3. RESULTS

Comparing the methods on a Plexiglas plate shows that the results from the Reverberation Time and the Power

Injection method are reasonably similar. The Drawaway method only gives sensible results above 3000 Hz (see Figure 1)

The low agreement of the drawaway method is explained by the multiple simplifications made by the model. Even in the midrange frequency bands, reflections make detecting a clear decay impossible. At low frequencies the near field additionally distort the vibration pattern especially closer to the excitation point.

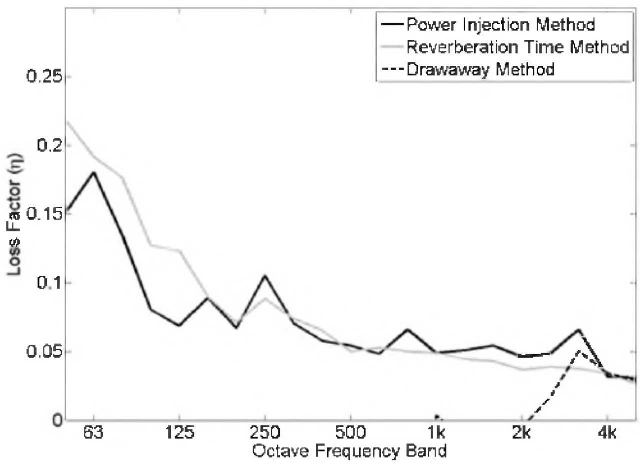

Figure 1. Three Methods on a Plexiglas plate

Because of the similarity between the power injection and the reverberation method, only the reverberation method is evaluated on the wall assemblies.

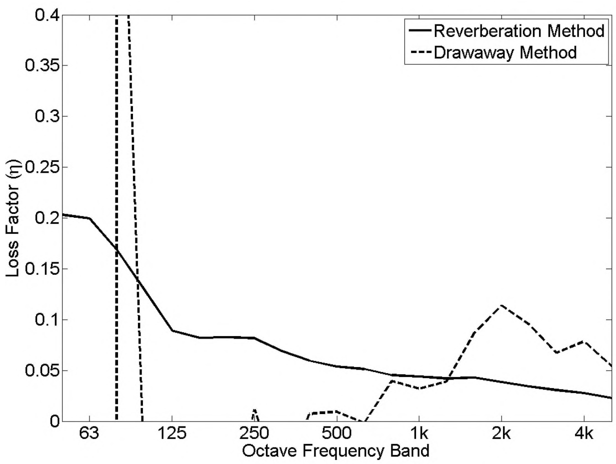

Figure 2. Loss factor before adhesive is applied

Figures 2 and 3 show the results of the measurements on the wall assembly before and after applying the viscoelastic material. It can be observed, that with the higher damping provided by the material, the drawaway method gives a more reasonable result in a larger frequency range, however by a factor of approximately 2 larger than with other methods. An additional error might stem from the inhomogeneous stiffening from fastening the plates to the studs.

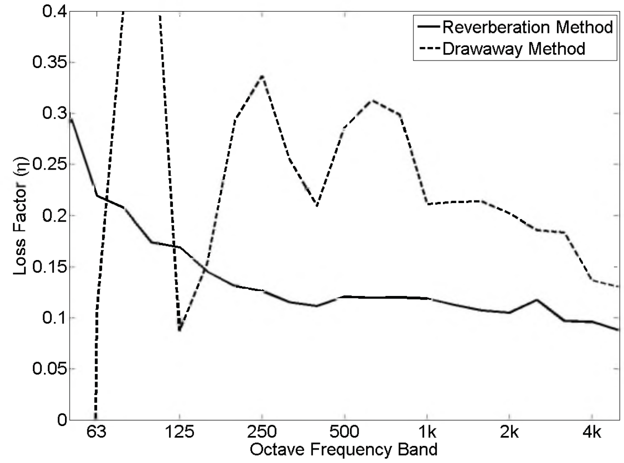

Figure 3. Loss factor after adhesive is applied

4. DISCUSSION AND CONCLUSIONS

The Reverberation Time Method is a good way to measure the total loss factor of a specimen. Although it is the most time consuming method, both in measuring and in the analysis, the results seem to be the most consistent. The power injected method gives similarly good results but will have limitations on smaller samples as the field will not be as diffuse.

The assumptions made for the drawaway method turned out to be too general. Further refinement is needed to include reflections, the near field and a none-circular expansion of the wave.

The effect of the improved damping on the airborne transmission loss according to ASTM E90 is described in a follow up paper by I. Sabourin. [3]

REFERENCES

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