low frequency noise reduction from building technical equipment: a case study

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Mechanical equipment such as fans, chillers and motors often produces airborne and structure-borne noise with a significant low frequency component. In many applications in buildings, mitigation of the low frequency noise requires implementation of a conventional acoustical treatment consisting of continuous limp mass barrier elements embedded in poro-elastic materials in combination with air spaces. This treatment is often heavy, bulky and difficult to install in order to be effective. This paper presents a summary of a case study on the use of a novel, lightweight, thin acoustical material designed to mitigate low frequency noise radiating from mechanical equipment. This advanced material is based upon distributed absorber technology and was used to treat the metal housing of mechanical equipment. The novel material significantly increased the transmission loss of machine metal housing below 300 Hz. The total noise reduction was 10 to 14 dBA with 5dBA improvement over typical flexible acoustic blankets below 300Hz.

1. Introduction

It is well know that standard poro-elastic materials perform poorly at low frequencies. The standard solution to this problem is to embed a limp mass barrier into the material to increase its low frequency transmission loss. However this approach suffers from a number of disadvantages, such as increased weight and difficulty in installation. Work has been carried out at Virginia Polytechnic Institute and State University (Virginia Tech), Neva Associates and E. I. du Pont de Nemours and Company (DuPont) to develop a composite material that largely overcomes these deficiencies. Figure 1 shows a schematic arrangement of the composite material system.

Briefly, the composite material consists of a matrix of poro-elastic material(s) with embedded mass elements distributed throughout the material matrix. The embedded masses combine with natural elasticity of the material to form an array of mass-spring-damper systems with a range of tune frequencies dependent upon the stiffness of the poro-elastic material, the weight of the masses, and other tuning parameters. Thus, the composite material overcomes the limitations of the conventional tuned vibration absorber (TVA) technology, such as narrow tuning frequency, peak splitting and control only over a small area.

Figure 2 presents the results of early testing on what ultimately became DuPont™ LoWave™ technology [1]. The results are for a 4 ft by 4 ft thin aluminum panel located in a transmission loss test facility at Virginia Tech and excited by broadband random sound. The spatially averaged radiated sound intensity from the panel was measured using a scanning intensity probe located one inch from the panel surface. The “bare panel” curve is for the bare aluminum panel. The “foam” curve is when a 3-inch layer of melamine foam is attached the panel. The “2-inch” curve and “3-inch” curves are when small masses were embedded in the 2-inch and 3-inch melamine layers respectively. In both cases, the composite acoustic treatment was directly attached to the plate. The results show that the addition of the masses dramatically decreases the radiated intensity compared to the foam alone (“foam” curve) over wide bands of low frequencies from 60 to 180Hz. It is noteworthy that the attenuations occur at very low frequencies both on and off panel resonance points in contrast to damping treatments

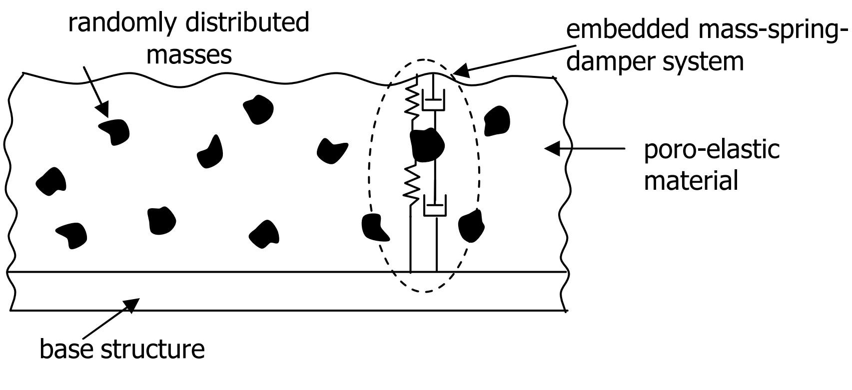

Figure 1. Schematic arrangement of composite acoustic material.

that typically only work well on resonant response with high Q's. This behavior illustrates the reactive nature of the composite material attenuation mechanism.

For the results of Figure 2, the total added weight of the embedded masses was approximately 6% of the base aluminum plate weight. As a point of comparison, the 2-inch melamine composite system (foam with masses) has a lower mass per unit area than the 3-inch melamine treatment without masses and yet provides much higher sound attenuation than this treatment.

More recent work at DuPont has concentrated on designing and constructing advanced composite material systems that are focused on applications in real building type structures and thin machine panels. A number of such LoWave^{TM} material systems were constructed and successfully tested at VAL, Virginia Tech and at a professional acoustic testing facility, Architectural Testing Inc. in York, PA. Figure 3 presents results for transmission loss testing carried out by ATI using ASTM E-90. The results are for a large (8'x8' or ~2.7m x 2.7m) aluminum panel of 0.08 inch (2 mm) thick mounted in the TL test hole. The "Al" curve is for the bare panel, the "LoWave^{TM}" curve is for the LoWave^{TM} designed blanket attached to the panel and the "Control" curve is for a control composite similar in construction to LoWave^{TM} blanket, in which the embedded masses were removed. The control test is designed to validate the effects of the embedded masses in the composite material system.

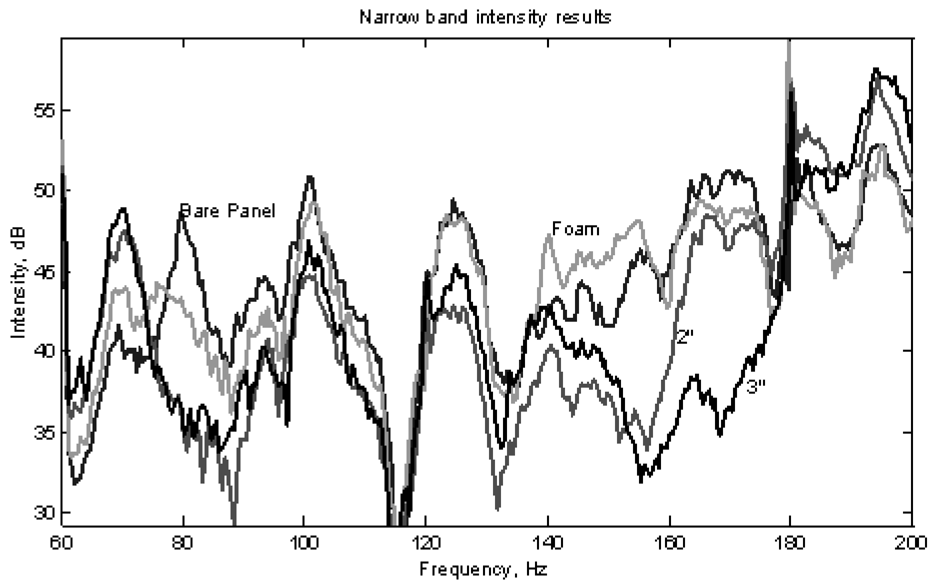

Figure 2. Attenuation of spatially averaged radiated sound intensity with composite material.

The results of Figure 3 clearly demonstrate the effect of the embedded masses at low frequency with the TL being increased by around 5dB between 120 to 250Hz. The results of Figure 3 are significant in that they are in 1/3rd octave bands which tend to average out the performance over the bandwidth. Figure 2 indicates that higher attenuations are likely obtained over narrower frequency bands particularly near the design resonant frequencies of the embedded masses.

Tests of the absorption performance of composite material have also demonstrated that the presence of the embedded masses leads to an increased absorption coefficient at low frequencies.

Figure 4 presents results of testing a composite LoWave™ material versus a control material in which the embedded masses were removed. The tests were again carried out at in a reverberation chamber at a professional acoustic test facility, ATI in York, PA under ASTM C 423, mounting method Type A under ASTM E 795. The results clearly show an increase of absorption coefficient between 400 to 1500Hz. This behavior is most likely due to the embedded masses and supporting poro-elastic matrix being excited to resonate by incident acoustic waves. The higher motion of the embedded masses on resonance likely leads to increased cyclic loss factors in the poro-elastic material and thus increases the acoustic absorption of the material.

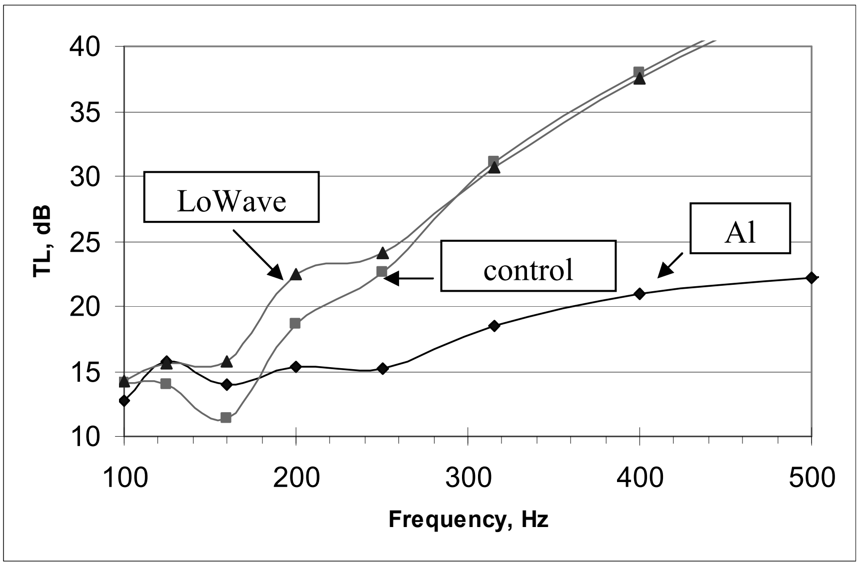

Figure 3. TL results from the ATI test.

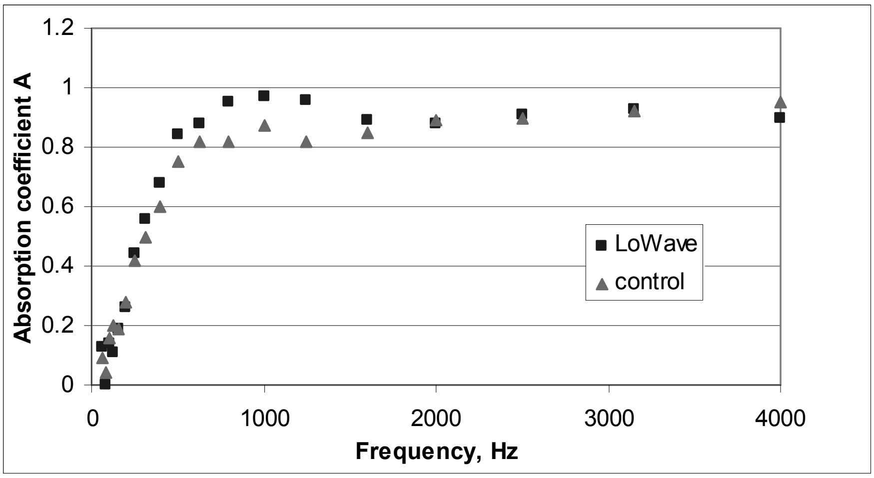

Figure 4. Absorption testing of composite LoWave™ material.

2. Application of LoWave™ to machinery noise control

Figure 5 shows an electrical motor contained within a metal housing. The noise emitted from the motor and fan assembly enclosed in a typical metal housing, was measured at 78 dBA and had significant low frequency sound levels.

The manufacturer of the equipment desired to reduce the noise level 8-10 dB and also improve the sound quality of the noise without reconfiguring the mechanical components or redesigning the metal housing. The flexible composite LoWave™ blanket system was chosen for this application. It consisted of the blanket installed around the motor and fan area, while still allowing required airflow, as shown in Figure 5. Two separate LoWave™ panels were also directly applied to the housing doors as shown in Figure 6. The system was designed to reduce both, noise transmission through the metal housing and reverberation within the enclosed space of the housing. Two materials were chosen for a performance comparison; (i) a typical commercial mineral wool-limp mass barrier composite and (ii) the LoWave™ DuPont material . The number, size and layout of the embedded masses of the LoWave™ were designed to give attenuation in the 50-200Hz bandwidth. Both blanket systems, LoWave™ and the standard commercial version, were of equal thickness and similar weight.

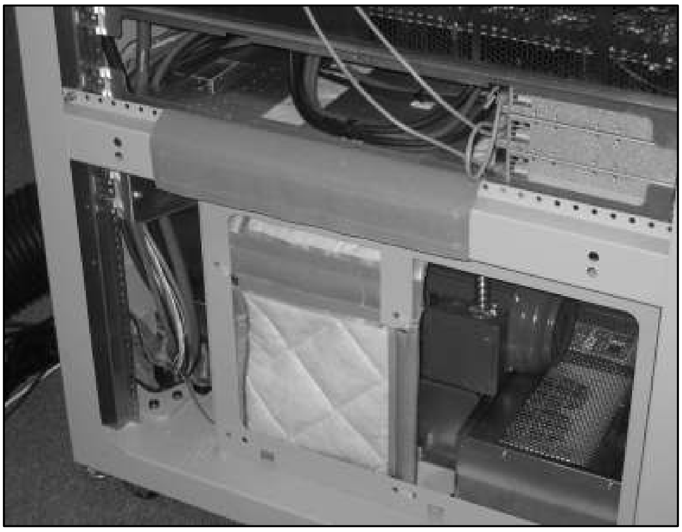

Figure 5. Electrical motor within housing and treatment.

Figure 6. DuPont™ LoWave™ treatment mounted on housing panels.

The flexible blanket systems configured for the application were applied to the same test unit in sequence, and results were compared by sound pressure (SPL) measurements and subjective sound quality evaluation. Octave band SPL measurements were taken using a Quest sound meter in the near field (at 1 inch), at 3 ft distance from the machine surface and in the far field at 50 ft. The tests were performed inside a hemi anechoic testing room. The blind subjective sound quality evaluation was conducted by a group of five engineers working in an industrial environment.

3. Results and discussion

Figure 7 shows comparison between SPL measurements taken 3 ft away from the metal housing at 40 ins height from the floor. This graph shows that below 250 Hz, a significant improvement in attenuation (3-5 dB) over the conventional, commercial blanket was achieved using DuPont™ LoWave™ material in addition to excellent performance above 250 Hz. All five engineers in the study indicated the LoWave™ material as the "quieter" acoustic treatment. The sound quality of the equipment was judged by the five engineers as more suitable to commercial environments as well as less audible.

4. Conclusions

A test of the new DuPont™ LoWave™ material with enhanced low frequency transmission loss was carried out on a real operating machine in an industrial environment. The performance was assessed by SPL measurements and also a subjective panel of technical observers/listeners. Use of the LoWave™ material led to a reduction to an acceptable sound level of 68 dBA with 7 dB improvement at 125 Hz without reconfiguring the mechanical equipment or redesigning the metal housing. DuPont™ LoWave™ material was measured to provide up to 5dBA improved low frequency performance over standard acoustic materials of the same weight. The material was also judged by the subjective listener panel to provide higher sound reductions and a better sound quality than standard materials.

5. References

[1] Fuller, C.R., Kidner, M.R.F., Li, X. and Hansen, C.H., "Active-Passive Blankets for the Control of Vibration and Sound Radiation", *Proceedings of Active 2004*, Williamsburg, Sept. 2004.

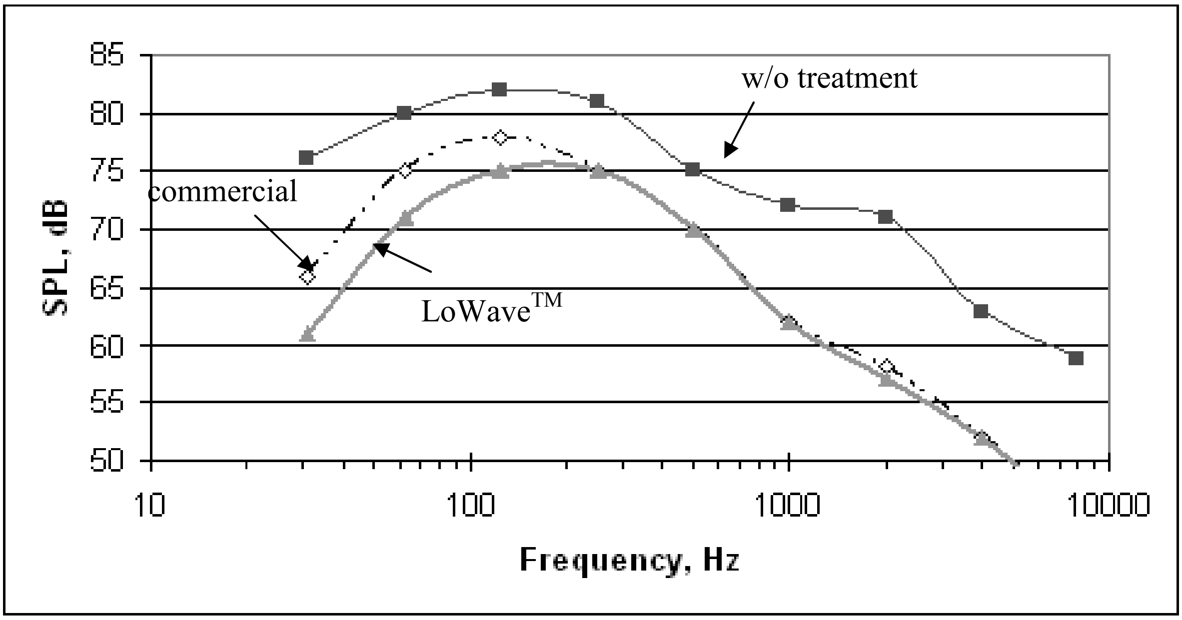

Figure 7. Test results comparing the performance of the two treatments.