INTEGRALLY DAMPED HONEYCOMB STRUCTURAL CONCEPTS TO INCREASE NOISE TRANSMISSION LOSS

Jefferson F. Newton*
Roy Ikegami
David J. Carbery

Boeing Aerospace & Electronics
Structures Technology
Seattle, WA

ABSTRACT

This paper describes the design, analysis, fabrication, and testing of design concepts to add passive damping to honeycomb panels to enhance the noise transmission loss in honeycomb structures. The loss factors for several damping material and panel configurations were analyzed. Statistical Energy Analyses (SEA) were then performed to predict the expected benefits of the calculated panel loss factors in terms of increased acoustic transmission loss through the panels. Based on the analyses, a honeycomb panel structural design concept was developed and three 6-ft by 6-ft panels were fabricated for acoustic testing. The first was a baseline bare honeycomb panel with no passive damping treatment, the second incorporated a NITRILE rubber material, and the third incorporated a 3M ISD 113 viscoelastic material. Acoustic testing was performed in a split reverberant/anechoic chamber at the Boeing Noise Engineering Laboratory. The results of the acoustic testing verified the predicted acoustic transmission loss and performance of the damped panels. The acoustic test results for the NITRILE damped panel showed less transmission loss than predicted indicating an apparent problem with the honeycomb core cutting into the NITRILE rubber during the fabrication of the panel. This was verified by radiographic inspection and subsequent sectioning and visual inspection of the panel.

•Correspondence and comments may be addressed to:
J.F. Newton, M/S 82-97
Boeing Aerospace & Electronics
P.O. Box 3999
Seattle, WA 98124-2499

INTRODUCTION

The trend toward the development of stiff lightweight structures in the designs of spacecraft, launch vehicles, and aircraft has made the task of protecting avionics equipment, payloads, and passengers from the acoustic environment increasingly important and demanding. For example, the design of launch vehicle shrouds, which shield the payload not only from the acoustic load, but from aerodynamic forces, thermal input, rain, sleet, and lightning, must satisfy stringent and often conflicting requirements.

It was the purpose of this research to develop and investigate design concepts that would solve or ameliorate problems of noise transmission through stiff lightweight structure, while satisfying other constraints, such as structural integrity, light weight, and low cost. One such concept, utilizing integral passive viscous damping in a honeycomb panel, is described in the following sections, along with the analyses and tests used to evaluate it.

CONCEPT DEVELOPMENT

The objectives that we set out to meet were two-fold: first, to develop stiff, lightweight structural designs to provide noise attenuation in the 50 to 200 Hz range; and second, to determine the feasibility of incorporating passive damping treatments into the design of honeycomb structures to increase noise transmission loss.

In order to understand these objectives we must examine some trends, First, there is the trend toward larger engines, or clusters of engines for both launch vehicles and aircraft. This, of course, increases the total acoustic output, thus increasing the exterior acoustic environment. In addition, as total power increases, the sound frequency at which the spectral maximum occurs tends to decrease. The effect of the above two trends is to significantly increase the exterior noise in the 50-200 Hz region of the spectrum. The other trend of significance is the decreasing effectiveness of standard, or traditional noise suppression techniques at low frequency. Absorbers, such as fiberglass blankets and sound barriers such as lead-loaded vinyl, both become largely ineffective below 100 Hz. The net effect of these trends is to create a "noise window" in the 50-200 Hz spectral region, as shown in figure 1, and explains the particular interest in the low frequency end of the spectrum.

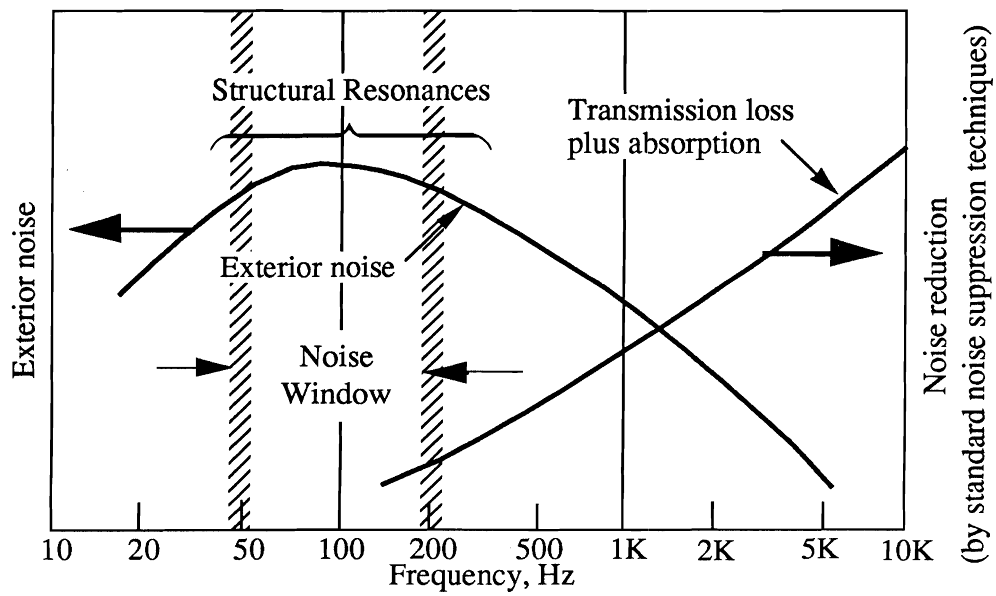

Figure 1. Launch Vehicle Noise Window

The objective of a stiff honeycomb panel is dictated by our decision to investigate integral passive viscoelastic damping. It was felt that passive damping could be integrated into a honeycomb structure with a small weight and stiffness penalty. Aluminum honeycomb was chosen for the investigation since it combines high stiffness with low weight.

Figure 2 shows the panel design corresponding to this concept. An aluminum honeycomb core is separated from the facesheet on either side by a layer of viscoelastic material (VEM). As the panel bends, due to an impressed noise field, for example, the viscoelastic layer on each side is put into shear. Damping occurs because of the strain energy converted into heat through the VEM loss factor.

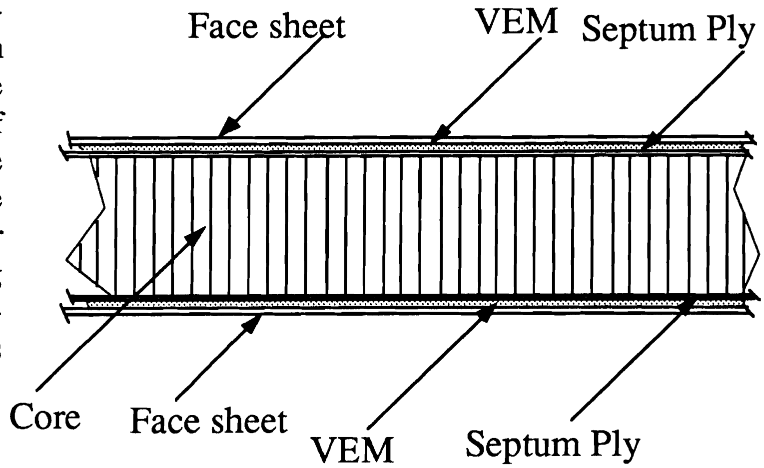

Figure 2. Damped Honeycomb Panel Design

An optional, thin epoxy fiberglass septum ply is shown in figure 2 bonded to the core and acting to transfer the shear from the core to the VEM. It can also serve to prevent the sharp edges of the core from punching through a soft viscoelastic layer.

ANALYSIS

Two analysis programs were written to act as design tools as well as to provide performance predictions for subsequent testing. The first program calculates panel loss factor as a function of frequency; the second, using loss factors obtained from the first analysis, calculates transmission loss through the panel.

DAMPING PREDICTIONS

This is programmed on SMART spreadsheet, using modal strain energy methods, for rapid parameter change and recalculation. Input parameters include: facesheet thickness, Young's modulus, and density; core thickness, shear modulus and density; VEM thickness, density, shear modulus as a function of frequency, and loss factor as a function of frequency. Loss factors can be input for the facesheets and core, as well. The program calculates strain energy for the facesheets, core and VEM, as a function frequency and deduces the composite panel loss factor. Outputs include: composite panel loss factor, stiffness, and bending wave velocity versus frequency.

TRANSMISSION LOSS PREDICTIONS

This is a simple SEA model, again programmed on SMART spreadsheet, to allow rapid change of panel input parameters and observation of their effects. The SEA model represents the test as subsequently performed in the Boeing Noise Engineering Laboratory (NEL) Anechoic/Reverberant Facility (ARF). Figure 3 shows the ARF and schematically diagrams the SEA calculation. Figures 4 and 5 are photographs of the interiors of the anechoic room and the reverberant room, respectively.

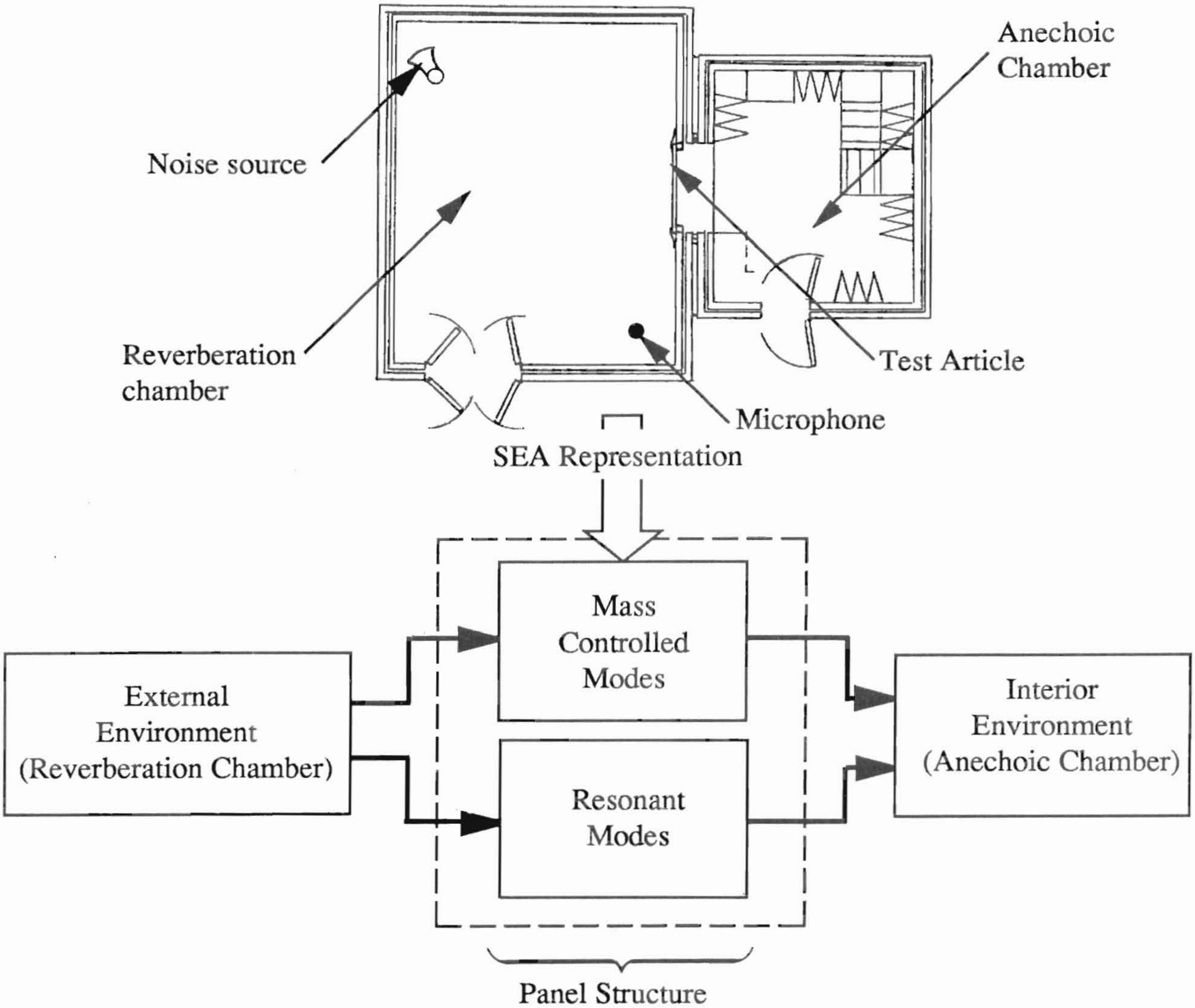

Figure 3. Anechoic/Reverb Facility With SEA Representation

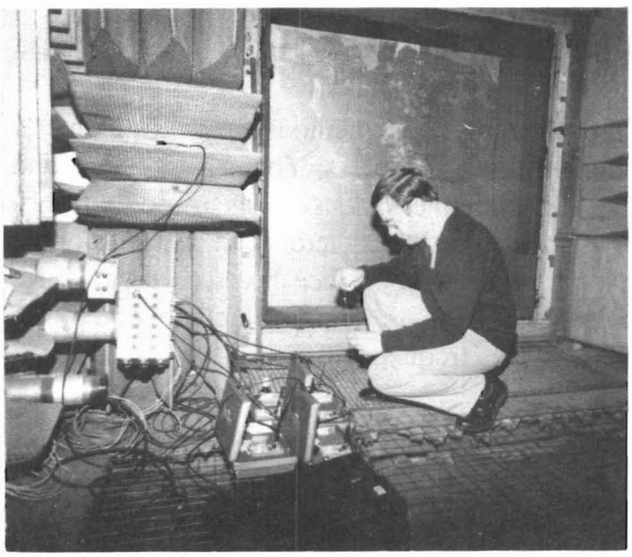

Figure 4. Anechoic Room With Mounted Panel In Background

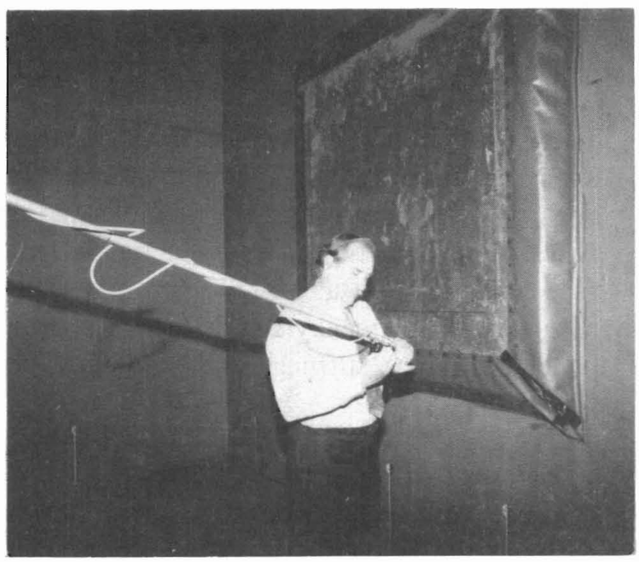

Figure 5. Reverberation Room and Rotating Microphone With Panel In Background

TEST PANELS

As a result of parametric studies done using the damping analysis and the transmission loss analysis, three test panels were designed and fabricated. All three panels were 6-ft by 6-ft in outer dimension, all had 0.050-inch aluminum facesheets, and all had identical 1.00-inch-thick aluminum honeycomb core. See figure 2. The baseline panel consisted only of the above, with the facesheets structurally bonded directly to the core. The second panel had a 1/32-inch-layer of Nitrile rubber bonded between the core and the facesheet on each side. The third panel had a 0.030-inch-thick layer of Scotchdamp ISD-113 acrylic under each facesheet. Because of the softness of the VEM, a thin septum was bonded to either side of the core, thus sandwiching the VEM between the septum and the facesheet. The septum was an 0.008-inch-thick, cured epoxy fiberglass sheet, and served to distribute the shear load from the core to the VEM, as well as preventing punch-through.

TEST PROCEDURE

Transmission loss tests were performed on all three panels using the intensity method. (Reference 1) The tests were performed at the Boeing NEL Anechoic/Reverberant Facility. The reverberant room measures 17.7-ft by 22.0-ft by 13.5-ft high and has hard, reflective walls. A speaker set acts as the noise source. Multiple reflections off the reverberation room interior surfaces ensures a diffuse sound field. A rotating boom microphone measures the spatially averaged sound pressure level (SPL). The test panel is mounted in a window separating the reverberation room from the anechoic room. Great care is taken to prevent noise leaks around the panel (flanking paths), using clay, fiberglass, and lead-loaded vinyl sheet to seal around the edge of the panel.

Noise penetrating the panel into the anechoic room (8.5-ft by 11.0-ft by 8.0-ft high, measured at the wedge tips) is measured directly, as it exits the panel, using an intensity probe. This is a relatively new procedure, made possible by the advent of the Fast Fourier Transform (FFT). It measures the sound vector intensity rather than the SPL. This method is procedurally simpler than the traditional Reverb/Reverb suite method, and is conceptually more straightforward. It has the additional advantage of allowing spatially resolved measurements over the surface of the test panel. Figure 6 shows the intensity probe being used to survey the panel. Reported transmission losses are spatial averages.

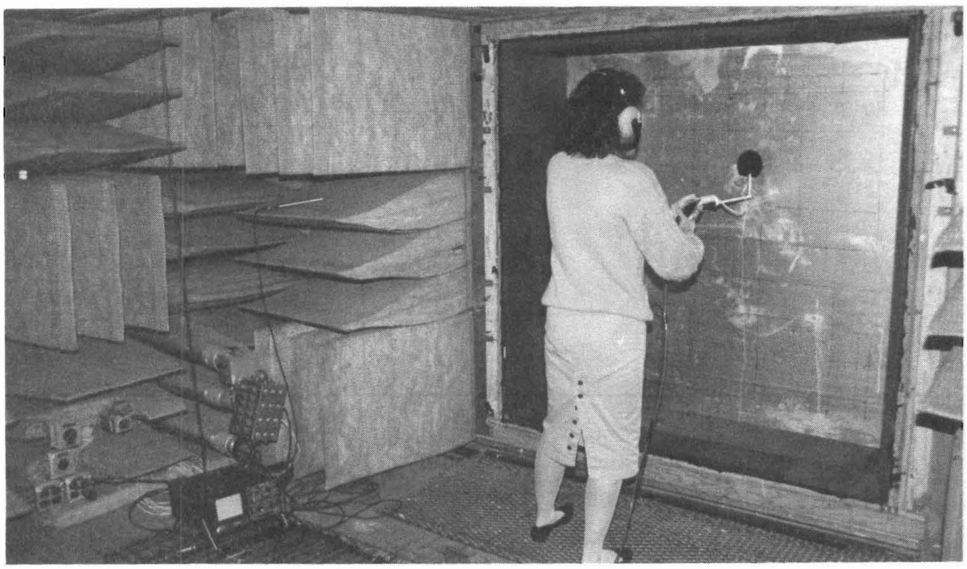

Figure 6. Intensity Probe Survey of the Test Panel Inside the Anechoic Room

Four accelerometers were mounted on the panel to assist in interpreting results. A Norwegian Electronics NE-830 analyzer was used to obtain the intensity measurements.

TEST RESULTS

The efficiency of the damping treatment is best illustrated by comparing the transmission loss of the treated panel with that of the baseline. Figure 7 shows the performance of Panel 3, the Scotchdamp ISD-113 treated panel, versus the baseline panel. Panel 2, the Nitrile panel, is not included, because examination after the test showed that the core had punched through the rubber during panel fabrication. This resulted in a transmission loss curve essentially similar to the baseline.

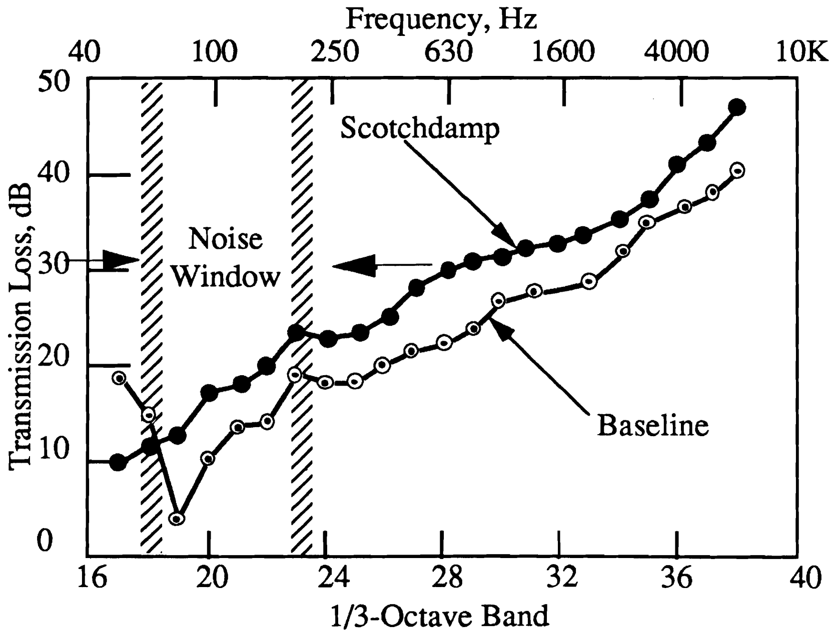

Figure 7. Noise Transmission Loss Test Results

The Scotchdamp (ISD-113) treated panel performed well, exhibiting an average improvement in transmission loss over the baseline panel of almost 6 dB (i.e. half the transmission of the baseline panel). A maximum difference of about 9 dB was obtained at 80 Hz, in substantial agreement with the pre-test predictions shown in Table 1.

- Panel transmission loss (TL) test
  Average difference between baseline panel TL and "Scotchdamp" panel TL over frequency range 100-10,000 Hz

Average Transmission Loss Difference ("Scotchdamp" minus baseline)	
Analysis	Test *
6.7 dB	5.6 dB

- Beam Test

	Beam Mode	Loss Factor: Analysis	Loss Factor: Test
"Scotchdamp" beam	1	37.7	46.2
(cut from test panel)	2	40.7	54.9

* Note:

The test results do not show the full difference predicted by analysis because the analysis neglects losses due to edge damping

Table 1. Comparison of Test Results with Analytical Predictions

At the conclusion of the transmission loss tests, the panels were cut into beam samples, approximately 6-inches wide by 60-inches long. These were tested at the Boeing Vibration Laboratory and the loss factor measured for the first two modes. The results of this test as well as those of the transmission loss test are shown in Table I along with the corresponding analytical predictions. It can be seen that agreement is good.

SUMMARY

The objectives of, first, developing a stiff, lightweight structural design providing noise attenuation in the 50 to 200 Hz range and second, determining the feasibility of incorporating passive damping treatments into the design of honeycomb structures to increase noise transmission loss were achieved.

The damping and transmission loss analysis programs were verified by test, giving us confidence in their future usefulness in design and prediction.

The effectiveness of the use of a septum ply to transfer the shear load from the honeycomb core to the VEM was demonstrated, as was the septum ply's efficiency in preventing punch through.

The capability of Boeing Noise Engineering Laboratory to provide fast, accurate measurements of transmission loss using the intensity method was verified.

REFERENCES

1. "Measurement of Transmission Loss of Panels by the Direct Determination of Transmitted Acoustic Intensity", Crocker et al, Noise Control Engineering, July/August, 1981.