ACTIVE CONTROL OF SOUND WITH FOAM-PVDF COMPOSITE MATERIAL

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1. Introduction

In this paper, the development and testing of foam-PVDF composite material designed for active noise reduction are discussed. A schematic of the composite material is shown in Figure 1 and consists of sinusoidally curved sections of the piezoelectric polymer film PVDF embedded in partially reticulated polyurethane acoustic foam. The transducer is designed to reduce sound by the action of the passive absorption of the foam (which is effective at higher frequencies) and the active input of the PVDF element driven by an oscillating electrical input (which is effective at lower frequencies).

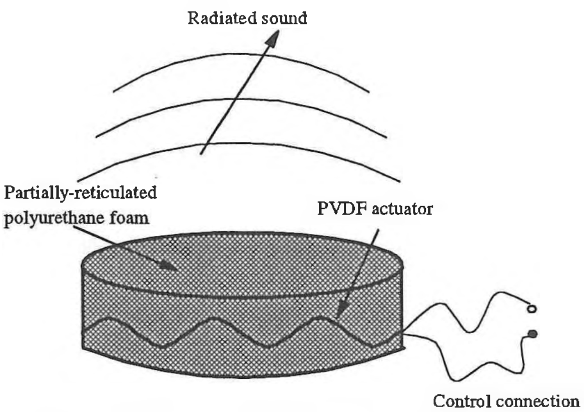

Figure 1: Schematic of the composite material.

2. Actuator Configuration

Much work has been performed to configure the active PVDF layers to behave in a linear sense as well as produce significant sound levels at low frequencies when driven by an oscillating voltage [1]. Figure 2 shows two configurations of the PVDF film presently under study. The main characteristic is that the PVDF is intentionally curved to couple the predominantly in-plane strain due to the piezoelectric effect and the vertical motion which is needed to accelerate fluid particles and hence radiate sound away from the surface of the material. The arrangement first suggested by Tibbetts [2] is shown in Figure 2. In the series-parallel configuration, the continuous PVDF film is broken up into cells in which the bottom surface electrodes are wired 180 out-of-phase into a single lead (or control channel). A slightly different configuration is the parallel arrangement in which the top and bottom electrodes are connected to their neighboring cell with a phase reversal, again into a single lead (or control channel). For these two arrangements, each cell moves in the same vertical direction under voltage activation and the sound radiation is increased. In addition, the non-linearities are canceled by the cell interaction.

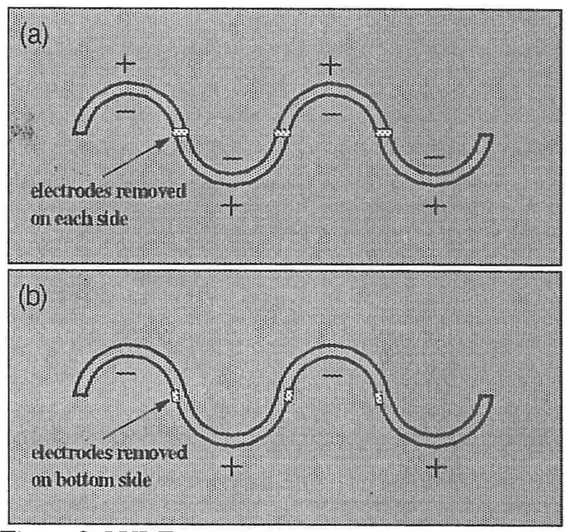

Figure 2: PVDF actuator configurations, (a) Parallel, (b) Series-parallel.

3. Radiation Control

The foam-PVDF composite active material was first mounted near the surface of an oscillating rigid piston mounted in a baffle and positioned in the VAL anechoic chamber at VPI&SU. The piston was of 15 cm diameter while the foam was 5 cm thick with a single layer of 28 μm Ag metalized PVDF. The piston was driven with band limited random noise (0-1600 Hz) and the radiated sound was measured with a polar microphone traverse of radius 2 m from the piston. An active controller based upon the Filtered-x version of the feedforward LMS algorithm [3] was used to minimize radiated sound at an error microphone located normal to the piston at 2 m (far-field error sensor) and 0.15 m (near-field error sensor) distance. Figure 3 shows the sound pressure level (SPL) attenuation averaged over the radiation angles. The attenuation is relative to the radiation from the bare piston. The "passive" case corresponds to the attenuation due to the foam-PVDF composite material installed and control not turned on, and the "passive/active" case to the attenuation due to the foam-PVDF composite material installed and the control activated. Control performance of the series-parallel and parallel configurations for the actuator was found similar. The difference between the two configurations was the voltage required for the actuator: the series-parallel requires about twice the voltage of the parallel actuator to control the same acoustic levels, but is associated with less non-linearity effects. The results obtained with the series-parallel actuator are shown in this section. In Figure 3, it is apparent that the passive foam works well above 500 Hz as attenuation of about 14 dB is obtained in average. The results also reveal that the active component provides significant additional attenuation in the 100-1100 Hz frequency range as a further sound reduction of 10 dB is observed. It can also be seen that the near-field error microphone performs as well as the far-field error microphone. Note that the active material is associated with global sound attenuation (reduction in all radiation angles). Note that above 1.1 kHz the control effect is not demonstrated mainly due to the number of coefficients in the FIR filter used to model the impulse response function of the system.

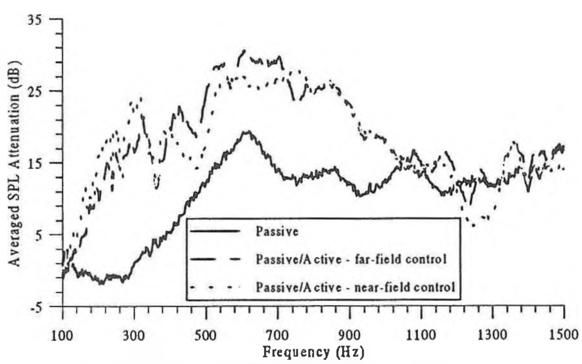

Figure 3: Sound Pressure Level Attenuation averaged over radiation angles (-90° to 90°).

4. Transmission Control

In this case, a rigid sandwich plate was added in front of the foam-PVDF composite active material. This corresponds to a simple local model for a fuselage structure with the active material mounted between the outer (excited by propellers and/or turbulent boundary layer) and inner skin (radiating inside the airplane). The piston (outer skin) was driven with band limited random noise 0-800 Hz. The sound radiation was minimized using either a microphone at 2 m distance or an accelerometer located at the center of the rigid plate.

The results corresponding to parallel configuration for the PVDF actuator are presented. Figure 4 shows the attenuation obtained due to the passive elements (composite material and sandwich plate) and due to the active control with the different error sensors investigated. It can be seen that the accelerometer performs as well as the far-field microphone, as in the low frequency region, the sandwich plate can be associated to a monopole radiator. Active control then results in an additional 10 dB global reduction in average in the frequency band 150-650 Hz.

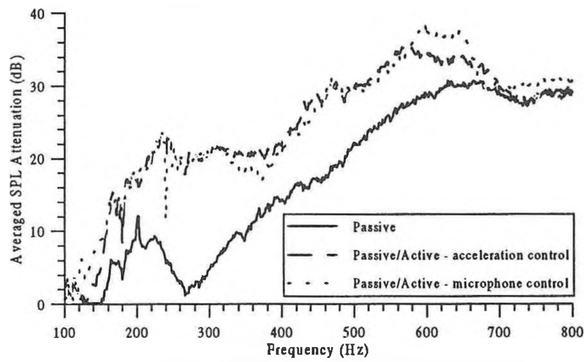

Figure 4: Sound Pressure Level Attenuation averaged over radiation angles (-90° to 90°).

5. Conclusions

The results presented demonstrate the potential of the active material composed of a foam-PVDF composite for reducing sound radiation as well as sound transmission. The device thus has the potential of simultaneously controlling low and high frequency sound in a very thin compact arrangement.

References

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