Active Control of Sound Radiation Using a Foam-PVDF-Plate Passive/Active Composite Device

C. Guigou[(1)], J. Pan[(2)], C.R. Fuller[(1)] and C.A. Gentry[(1)]

[(1)] *Vibration and Acoustics Laboratories, Mechanical Engineering Department, Virginia Polytechnic and State University, Blacksburg, VA 24061-238 USA*

[(2)] *Mechanical and Materials Engineering Department, University of Western Australia, Nedlands, WA 6907 Australia*

The development of a hybrid passive/active device in the form of a foam-PVDF-plate composite transducer designed for active noise control is discussed. The composite material consists of cylindrically curved sections of PVDF piezoelectric film (active component) embedded in partially reticulated polyurethane acoustic foam covered with a light weight stiff sandwich plate (passive components). For performance testing, the foam-PVDF-plate system was mounted over the surface of an oscillating rigid piston located in a baffle in an anechoic chamber. Two types of error sensors, a far-field microphone and an accelerometer located on the plate surface, were considered and compared in terms of their efficiency to control the far-field sound radiation. A feedforward LMS controller was used to minimize the signal from the error sensor. The results are presented in terms of the far-field sound radiation and, in order to understand the control mechanism, the surface normal velocity distribution of the sandwich plate. The potential of the hybrid foam-PVDF-plate passive/active device for simultaneously reducing global sound radiation at low and high frequencies is demonstrated.

1. INTRODUCTION

In the last decade, many research studies have been dedicated to reducing interior noise of aircraft. Noise fields generated by turbofans, propellers and turbulent boundary layer for example, impinge on the exterior of the fuselage and induce large sound levels inside the cabin of aircraft. Two main active control methods have been widely studied to reduce low frequency sound transmission in aircraft [1-5]. Active Noise Control (ANC) consists of adding secondary acoustic sources (most commonly loudspeaker) inside the aircraft fuselage [6]. These secondary sources are used to minimize sound pressure levels by reducing signal from error microphones usually located close to passenger head height. Active Structural Acoustic Control (ASAC) involves secondary structural input (either mechanical shakers or piezoelectric ceramic actuators) applied directly to the aircraft fuselage [7]. In this case, the control actuators are used to decrease either microphone signals or structural information measured on the fuselage that is related to sound radiation. Although good performance is often obtained, localized sound attenuation, control spill-over and the inability to obtain high frequency sound reduction are some of the drawbacks associated with both the ANC and ASAC approaches. On the other hand, the use of passive materials such as damping visco-elastic material, added mass and porous layer can be considered for reducing sound radiation. For example, a porous layer can absorb large amount of acoustic energy if its thickness is comparable to a quarter of the wavelength of the incident sound. This implies that such a passive technique is not very efficient in the low-frequency region. Therefore, the complementary nature of passive and active noise control techniques can be used to develop a hybrid device with extended performance [8]. For such composite systems, the passive component fulfills in general the primary control function while the active element is used to overcome some limitations of the passive system and therefore enhance the control performance. Active control techniques can then be used to extend the frequency range of passive sound absorbing materials application to lower frequencies. Bolton et al.[9] presented an analytical analysis demonstrating that the low frequency performance of a finite-depth layer of elastic porous material may be enhanced by applying an appropriate force to the solid phase at the front surface of the layer. They showed that at any angle of incidence, the solid phase of the foam may be forced so as to create a perfect impedance match with the incident plane wave, thus causing the sound to be completely absorbed. However, no physical implementation of such a device was discussed. In connection with this, Fuller et al.[10] outlined a "smart foam" to be used as active-passive sound absorber can be obtained by incorporating piezoelectric materials within the foam layer. When a high AC voltage is applied to the active piezoelectric layer, expansion and contraction associated with the piezoelectric effects are induced, forcing both the solid and fluid phases of the foam. A recent study has shown that such a hybrid device is very effective in reducing sound radiation from a simple vibrating source (piston) over a large frequency range [11]. This passive-active sound control device seemed very suited for reducing interior noise of aircraft over a wide frequency band as it is light weight. However, experimental results presented by Gentry et al.[11] involved the use of a far-field microphone as error sensor which is not realistic in practice. This implies that a more compact passive/active system has to be implemented. Such a device can be achieved by either bringing the error microphone closer to the surface of the foam (using a near-field microphone [12]) or by incorporating a structural error sensor in the system. However, a structural sensor such an accelerometer cannot be mounted directly on the porous