ACTIVE CONTROL OF PLATE VOLUME DISPLACEMENT: SIMULATION AND EXPERIMENTAL RESULTS

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1. INTRODUCTION

The two main strategies for actively controlling sound fields are the Active Noise Control (ANC) and the Active Structural Acoustic Control (ASAC), first proposed by [Fuller 1990]. The ANC approach is based on controlling the acoustic field itself by using loudspeakers as secondary sources, while the ASAC approach directly modifies the response of the radiating structure by using structural transducers as secondary sources. In general, the ASAC approach has been proved to require a smaller number of secondary sources for a global control of the acoustic field. Recently, piezoceramic actuators embedded in or bonded to the structure have been successfully used as structural secondary sources for active noise applications, see [Fuller *et al.* 1989], [Clark *et al.* 1992] and [Crawley *et al.* 1987]. These distributed actuators overcome many of the disadvantages of shakers.

In ASAC, the other component of prime importance is the error sensor, which defines the type of information to be minimized by the controller. Polyvinylidene fluoride (PVDF) materials have been suggested as error sensors in the active control of structural vibration [Lee *et al.* 1990], [Gu *et al.* 1992], and more recently in the active control of sound radiation [Clark *et al.* 1992a,1993], [Guigou *et al.* 1994] and [Snyder *et al.* 1993], as an alternative to discrete microphones located in the acoustic field. [Guigou *et al.* 1994] developped a volume displacement sensor for beam using a single shaped PVDF strip. With this sensor, they have successfully implemented an active control of volume displacement for flexural beams and observed significant attenuation of the radiated sound field when active control was implemented. A similar approach was used by [Charette *et al.* 1995] to developed volume displacement sensor for 2D structure, i.e. rectangular plates. This plate volume displacement sensor is made of several shaped strips of PVDF film. This paper presents experimental results of an active control of volume displacement for a clamped plate using this PVDF volume displacement sensor as the error sensor.

2. ACTIVE CONTROL SIMULATION OF A PLATE VOLUME DISPLACEMENT

Active control simulation, for the clamped plate and actuators described in Tables 1 and 2, is performed to verify the efficiency of the proposed strategy (i.e. the minimization of the volume displacement) in reducing the sound radiation. To this end, the far-field radiated power and radiation efficiency are shown before and after control in Figure 1.

TABLE 1: Clamped plate characteristics

Length	50.0 cm
Width	39.8 cm
Thickness	3.15 mm
Young mod. (E)	6.5×10^{10} Pa
Density (ρ)	2800 Kg/m^3

It can be observed that below 220Hz, the radiation efficiency before control follows that of a monopole (about 6dB/oct.). Under control, in that frequency region, the radiation efficiency is changed to that of a dipole (about 12dB/oct.). The control of the plate volume displacement gives the largest sound power reduction in the frequency range where the radiation efficiency is reduced, since it decreases the plate capacity to induce sound in the acoustic medium.

TABLE 2: Ceramic piezo characteristics

	Primary	Secondary
Length	3.81 cm	3.81 cm
Width	3.18 cm	3.18 cm
Thickness	0.19 mm	0.19 mm
Pos. along the x axis	16.0 cm	19.0 cm
Pos. along y axis	30.0 cm	15.0 cm
Young mod. (E)	6.3×10^{10} Pa	6.3×10^{10} Pa
Density (ρ)	7750 Kg/m^3	7750 Kg/m^3

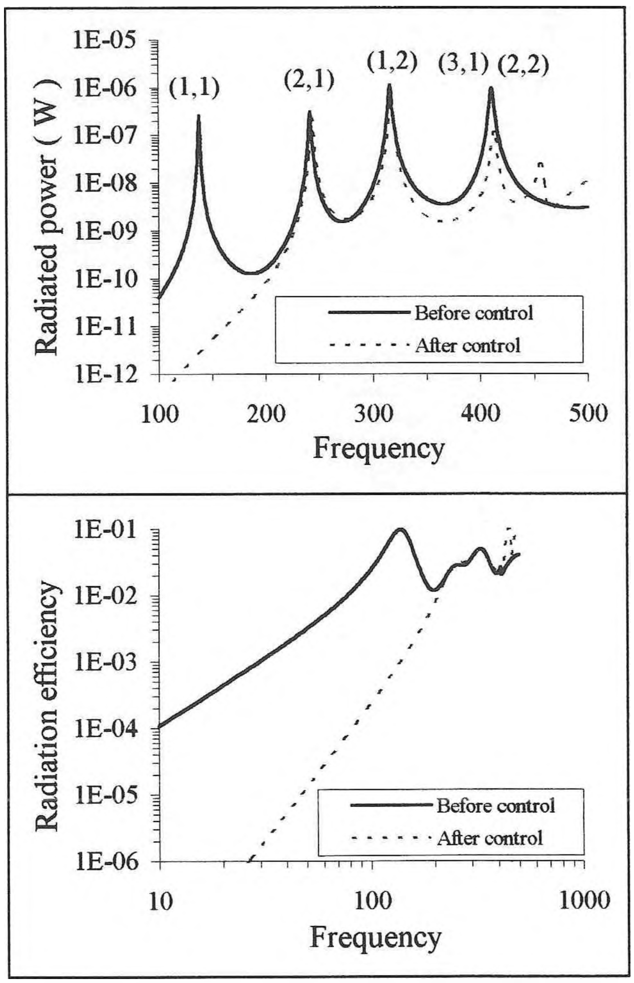

Figure 1: Theoretical simulation of the active control of volume displacement.

Over 220Hz, the radiation efficiency is approximately the same before and after control. In this frequency range, the control mechanism becomes mostly an attenuation of the plate vibration. The control efficiency near a mode depends mainly on the volume displacement of that mode. The (3,3) mode (413Hz) is thus controlled, while the (2,1) (243Hz), the (1,2) (319Hz) and the (2,2) (415Hz) which have low volume displacement are practically not controlled.

It can be noted, that a peak appears at 460Hz after control. This is caused by the control actuator which as a low authority near this frequency. Due to his dimensions and position, near 460Hz the control actuator as difficulty to generate volume displacement. This implies a high voltage is needed to control and associated with this high voltage is a global increase in the vibration level which in turn yields the regeneration of radiated power. An optimization of the control actuator characteristics should allow to prevent such regeneration of the radiated power.

3. EXPERIMENTAL RESULTS

An experimental implementation using the plate of the previous section was done. Eigth different frequencies were actively controlled using a LMS feedforward algorithm. Due to lack of space, only the results for the mode (1,1) at 140Hz are presented.

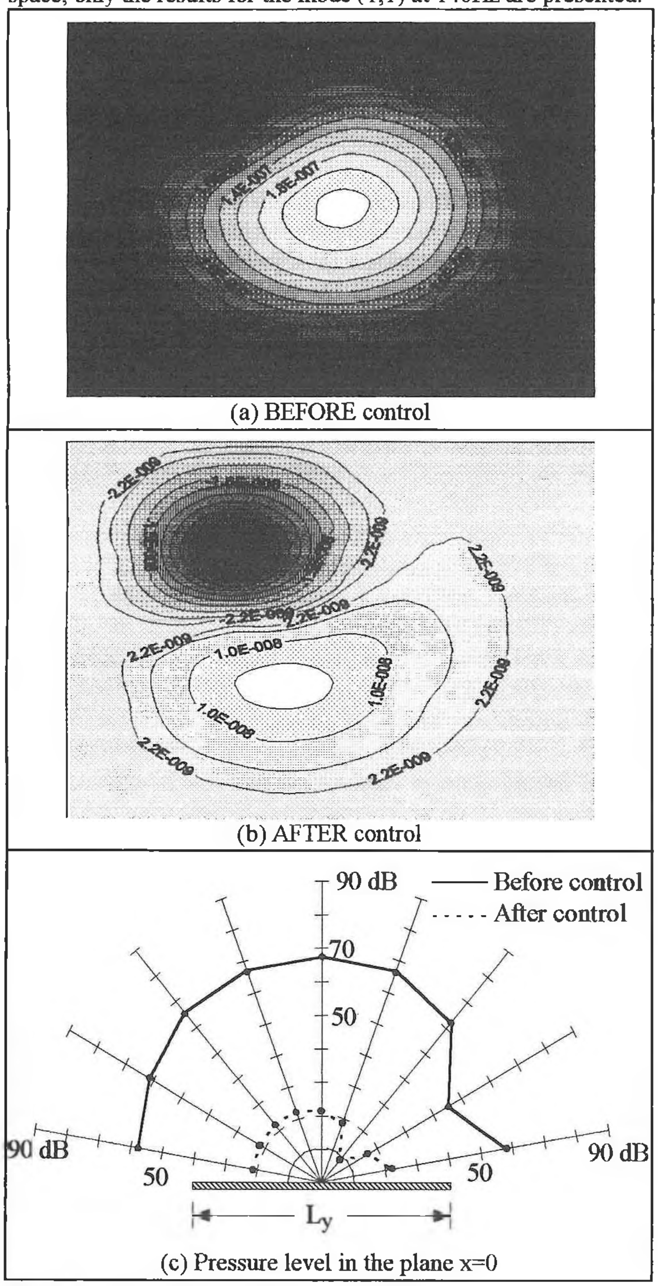

Figure 2: Experimental results at 140Hz.

Figure 2(a) and 2(b) shows the plate transversal displacement before and after control respectively. Those two plot demonstrate that the plate displacement go from a monopole type radiator to a dipole one. This confirm that the PVDF volume displacement sensor works properly. Figure 2(c) presents pressure level measurements made in the plane x=0. This plot shows a significant attenuation (between 40 and 50dB) in the pressure level at this frequenecy. Such attenuation is possible because at this frequency the control of the volume displacement minimizes the radiation efficiency and the vibration level simultaneously.

CONCLUSIONS

At low frequencies, passive control methods are generally inefficient for reducing the sound power radiated by a structure. However, the results presented in this paper clearly shows that the active control of volume displacement provides significant attenuation of sound radiation at those frequencies.

For the clamped plate considered here, the results indicates that below 220Hz the active control of volume displacement reduces the plate radiation efficiency and vibration level simultaneously. While over 220Hz, the control of volume displacement corresponds mainly to a reduction of the vibration level.

Using extended transducers, such as PVDF film, allows to have a single error channel to reduce the sound power radiated. This greatly simplifies the implementation of an active control system in the real world.

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