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ACTIVE ACOUSTIC CONTROL OF NOISE TRANSMISSION THROUGH DOUBLE WALLS: EFFECT OF MECHANICAL PATHS

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1. INTRODUCTION

Active noise control technology has recently been used to increase the sound transmission loss of double panel partitions [1–9]. Several different approaches have been suggested and investigated. One of the approaches is the so-called cavity control which attenuates noise transmission by inserting acoustic sources in the air gap (cavity) between the double panels. The previous investigations [1–4] have shown that the transmission loss of double panel partitions can indeed be increased substantially (over 10 dB) by controlling the sound field inside the cavity, provided that only acoustic transmitting paths exist in the partition. However, in many applications of double panel partitions, such as aircraft shells and partition walls, there are supporting structures connecting the two panels, thus forming structural transmitting paths in the partition. As cavity control is supposed to work on acoustic paths, the addition of structural paths will certainly affect the effectiveness of cavity control. The objective of this letter is to examine such effect through experiments.

In recent studies on cavity control [7, 8], it has been shown that two control mechanisms can be involved. One is the suppression mechanism which has been well understood previously. It suppresses the cavity pressure globally thereby reducing the vibration of the radiating panel and consequently noise transmission. This mechanism will obviously not be very effective in the case of having structural transmitting paths, as suppressing the cavity pressure cannot block the structural paths. The other mechanism is the restructuring mechanism which has often been overlooked. It restructures the cavity pressure in such a way that the resulting vibration pattern of the radiating panel is in a form of a weaker sound radiator. As this mechanism does not aim at reducing but restructuring the panel vibration, it may work well in the case of having structural paths.

2. EXPERIMENTAL RESULTS

In the experiments, a double panel partition is mounted in a common wall between an anechoic chamber (the source room) and a control chamber (the receiving room). The arrangement of the test chambers and the double panel partition is shown in Figure 1. The volume of the receiving room is 56 m^3 and its reverberation time below 200 Hz is around 1·7 s. The double panel partition consists of two identical aluminium plates of 2 mm thickness, separated by an air cavity of 275 mm depth. The other two dimensions of the air cavity are 2150 and 900 mm, respectively. The side walls of the cavity are concrete. The two panels are clamped to two steel frames, and are connected by four steel studs which form the structural transmitting path. In order to maximize the influence of the structural path, no anti-vibration measures (such as absorption and isolation) are taken. The incident panel is excited by loudspeakers in the anechoic chamber. Once excited, the incident panel radiates energy into the air cavity, thereby exciting the radiating panel, which in turn radiates energy into the receiving room.

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An adaptive feedforward controller is employed for control. The reference signal of the controller is taken from a detecting microphone located in the source room close to the partition, and the error signals are from error microphones in the receiving room. A loudspeaker in a corner of the cavity is used as the control source.

The performance of cavity control is evaluated by measuring the controlled and uncontrolled sound pressure in the receiving room. The sound pressure level (SPL) is measured at 15 selected points distributed over the receiving room and processed into two measures to provide the basis for the evaluation. One measure is the number of locations where SPL increases. This indicates whether attenuation is global. The other measure is the averaged reduction level (ARL) derived from comparison of the averaged SPL over 15 locations with and without control (i.e., $\mathrm{ARL} = 10\log_{10}(\Sigma p_u^2/N) - 10\log_{10}(\Sigma p_c^2/N)$, where p_c and p_u are sound pressures with and without control respectively and N is 15). This measure indicates the amount of global attenuation.

In order to identify the control mechanisms involved, SPL at six selected locations inside the cavity and the vibration level at six selected positions on the radiating panel are also measured.

In the experiments, two different error microphone arrangements are used. One is referred to as the internal sensing where two microphones are located inside the cavity to minimize the cavity pressure. In this arrangement only the suppression mechanism can be involved. The other is referred to as the external sensing where two microphones are located in the receiving room to minimize the room pressure. In this arrangement, both suppression and restructuring mechanisms can be involved.

To illustrate the effect of the structural path on cavity control in terms of the two control mechanisms, a tonal excitation was chosen in the experiments. The frequency of the excitation in the first set of experiments is 51 Hz at which the cavity response from both noise and control sources is dominated by the (0, 0, 0) cavity mode. The experiments are conducted in the following four conditions: internal sensing (associated with the suppression mechanism) with and without studs, and external sensing (associated with both mechanisms) with and without studs.

Table 1 summarizes the results. It can be seen that internal sensing without studs and external sensing with and without studs have very good attenuation (above 26 dB) in the

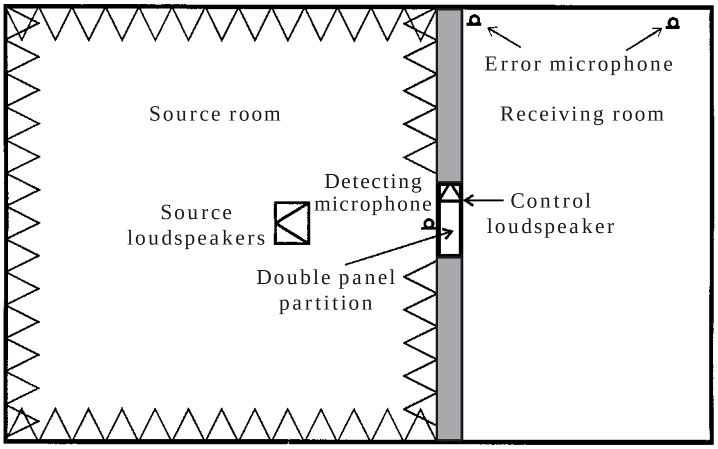

Figure 1. Schematic presentation of the experimental set-up.

Table 1

Results with a 51-Hz tonal excitation

		Room	Panel	Cavity
External sensing with studs	ARL (dB) Global	30 yes	5 no	4 yes
Internal sensing with studs	ARL (dB) Global	8 yes	2 no	7 yes
External sensing no studs	ARL (dB) Global	27 yes	10 yes	10 yes
Internal sensing no studs	ARL (dB) Global	26 yes	8 yes	8 yes

ARL: averaged reduction level

room, while internal sensing with studs only has moderate attenuation (about 8 dB). The reasons for this are given as follows.

At 51 Hz, the cavity response is dominated by the (0, 0, 0) mode. Thus, global attenuation in the cavity can be achieved with internal sensing no matter whether the studs exist (see "Cavity" column in Table 1). Without the studs, global attenuation of the cavity pressure also leads to global attenuation of the panel vibration (as the cavity pressure is the only transmitting path involved) and therefore very good global attenuation (26 dB) in the room. Whereas with the studs, global attenuation of the cavity pressure does not lead to global attenuation of the panel vibration (as vibration can now transmit through the studs). Consequently, attenuation (8 dB) in the room is not as good as that without the studs.

In the case of internal sensing, only the suppression mechanism can be involved. Since the effectiveness of the suppression mechanism relies on attenuation of the panel vibration and that cannot be effectively achieved when having the studs (as vibration can transmit through the studs), the deterioration of attenuation in the room is expected.

In the case of external sensing, two mechanisms can be involved and external sensing allows the selection of the one that yields better attenuation. As suppression of the cavity pressure is less effective, external sensing seeks the restructuring mechanism that does not aim at reducing the panel vibration. Due to the low modal overlap of the panel at 51 Hz, external sensing able to change the vibration pattern of the panel to gain very good attenuation (30 dB) in the room by restructuring the pressure distribution in the cavity.

Table 2 shows the results of external sensing with and without studs at some other frequencies. It can be seen that cavity control is still very effective in the case of having

Table 2

Results of the external sensing system with and without studs

		Frequency (Hz)					
		51	62	85	100	130	155
Studs	ARL (dB)	30	24	8	10	14	10
	NOI	0	0	0	0	0	1
No studs	ARL (dB)	27	14	5	10	4	−1
	NOI	0	0	1	1	6	8

ARL: averaged reduction level over 15 locations; NOI: number of locations where SPL increases the structural transmitting path (i.e., with the studs). In particular, the results with the studs at higher frequencies (130 and 155 Hz) are very encouraging. Global attenuation in the room of 14 and 10 dB is achieved respectively at these frequencies. Whereas without the studs no global attenuation can be achieved. The reason for better attenuation with the studs than without the studs at higher frequencies is thought to be that the stiffness of the panel is strengthened by the studs so that the pattern of panel vibration is more controllable through controlling the cavity pressure.

3. CONCLUSIONS

Regarding the effect of structural transmitting paths on cavity control, the following observations can be obtained from the experiments.

In the situations where structural transmitting paths exist, cavity control will largely rely on the restructuring mechanism which aims at restructuring rather than reducing the vibration of the radiating panel.

The internal sensing arrangement which aims at reducing the cavity pressure (i.e., the suppression mechanism) becomes less effective.

With external sensing (thus, the restructuring mechanism), cavity control can still be very effective even when structural transmitting paths exist.

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