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EXPERIMENTS ON THE ACTIVE REDUCTION OF SOUND TRANSMISSION THROUGH LIGHT-WEIGHT CONSTRUCTIONS

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ABSTRACT
Experiments have been performed to study the active reduction of sound transmission through single and double gypsum board constructions. The ElectroMechanical Film flat panel actuators were tested. The controller, based on the adaptive filtered-X LMS feedforward control algorithm was used to drive the actuators. These actuators attached to the radiating surface of the lightweight partition can significantly reduce the sound transmission. The active system achieves 4-9 dB reduction of the average sound intensity level over the controlled surface of the radiating wall for random noise excitation in the frequency range from 100 to 400 Hz.

1 - INTRODUCTION
Measured and predicted results [1], [2] indicate low transmission loss of lightweight double walls between 50 and 200 Hz due to the low surface density of the structures and due to the effect of mass-air-mass resonance. Therefore the active increase of sound transmission loss with flat actuators integrated in the partitions could be extremely useful in the construction sector. The Technical Research Centre of Finland (VTT) has developed flat actuators based on ElectroMechanical Film technology [3]. There are two operating modes for the actuators, thickness modes and membrane mode. In the thickness mode, the film itself compresses and expands according to the voltage applied and radiates sound in the air or transmits vibration to attached objects. In the membrane mode the film vibrates between the porous stators and radiates the sound. The thickness of the actuators is around 1 cm. The paper is aimed at studying the feasibility of the active reduction of sound transmission with the novel flat actuators.

2 - EXPERIMENTAL SET-UP
The test set-up consists of a single plate partition and a double wall partition, formed by two plane, parallel gypsum board plates with the mineral wool inside the cavity. The thickness of the plates is 9 mm and the cavity depth is 145 mm. These partitions are mounted in the opening of a rigidly walled enclosure, which is built in the floor of a semi-anechoic room (see Fig. 1). A loudspeaker located in the corner of this rectangular volume provides the acoustical excitation of the tested structure. Fig. 1 gives a schematic side view of the cross-section of the partitions. The EMF actuators were installed inside the cavity or were placed on the radiating surface of the gypsum plate. In both cases the actuators were directly applied to the structure in order to reduce the overall sound radiation. The microphones and the EMF panels located in the cavity or near the radiating surface of the tested structure have been used as error sensors.
The positioning of the sensors and the actuators for the single wall set-up can be seen in Fig. 2. Similar arrangement of the sensors and the actuators has been used for the double wall tests. Near-field pressure sensing strategy has been used in the tests. All control experiments have been performed using an adaptive filtered-X LMS feedforward control algorithm to drive the control actuators. The controller

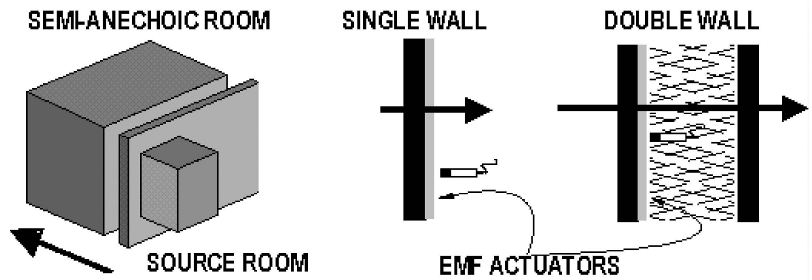

Figure 1: Experimental set-up and tested structures.

Figure 2: Location of the sensors and the actuators: a. − single sensor (microphone) and single actuator; b. − distributed sensor (EMF panel) and single actuator; c. − 4 sensors (microphones) and 4 actuators.

was implemented on a Digisonix dx-200 system. The reference signal for the feedforward algorithm is the driving signal of the loudspeaker in the enclosure below the tested panels. Broad band (100-400 Hz) random noise and harmonic excitation has been used in the experiments.

3 - RESULTS

The performance of the active reduction of the sound transmission through the partitions has been evaluated by measurements of sound pressure levels at the error sensors and by measurements of the levels of the radiated intensity scanned over the surface of the gypsum plates with and without control. For better understanding of the control strategy, several tests were carried out with harmonic excitation (171 Hz and 310 Hz) for the single wall set-up. For tonal (310 Hz) excitation the measured SPL at the microphone sensor (optimized position) in the uncontrolled and controlled cases are 74 dB and 30 dB, respectively. There is a noise reduction of about 44 dB. However for the scanned (averaged over the surface of the plate) values of the radiated intensity the reduction is about 7-9 dB. The influence of the sensor (microphone) location has been investigated. In the case of the distributed sensor the active reduction is reasonable (6-8 dB). It was confirmed in the tests that the low frequency sound radiation is directly related to the form of velocity distribution over the structure and minimizing the error signals derived from spatially weighted (distributed EMF sensor) near-field pressure signals should lead to significant reduction of the sound power [4], [5].
Fig. 3 shows sound pressure levels (broadband random noise excitation) at the microphone sensor in the uncontrolled and controlled cases respectively. There is the SPL reduction of about 10-15 dB throughout the frequency range under consideration. Overall radiated intensity (averaged over the surface of the plate) indicates the reduction in the range from 2 to 12 dB (frequency dependent).
Measured results for the double wall set-up can be seen in Fig. 4 and 5. The results presented in the narrow frequency bands at the error microphone with and without control show the complex frequency response of the coupled system. The complexity is mainly due to the coupling of the source air-volume, the gypsum plates and the cavity. As a result the modal characteristics of all sub-systems can be observed in the response. The performance of the control system and the actuators is considerable. The reduction of the SPL at the error sensors is about 10-15 dB throughout all the frequency range (100-400 Hz). The attenuation of the overall radiated intensity is around 2-9 dB. It is worth noting that the modal behavior of the source room has a great influence on the sound transmission. For instance the SPL peak at 75 Hz (Fig. 4 and 5) corresponds to the first mode of the source room. The control results indicate that the sound power of the EMF actuators should be improved in the range from 50 to 100 Hz, due to the limited active reduction (2-3 dB) of the SPL at the error sensor.

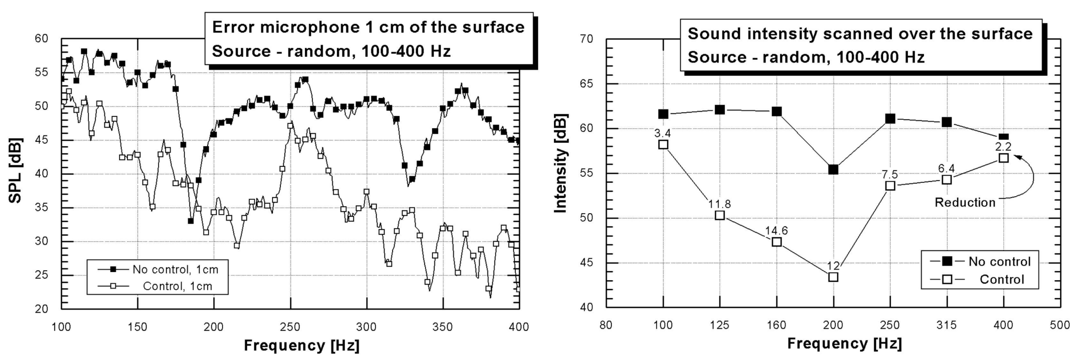

Figure 3: Single wall; results with and without control. SPL at the error microphone; intensity level scanned over the surface of the radiating plate; random noise excitation: 100-400 Hz.

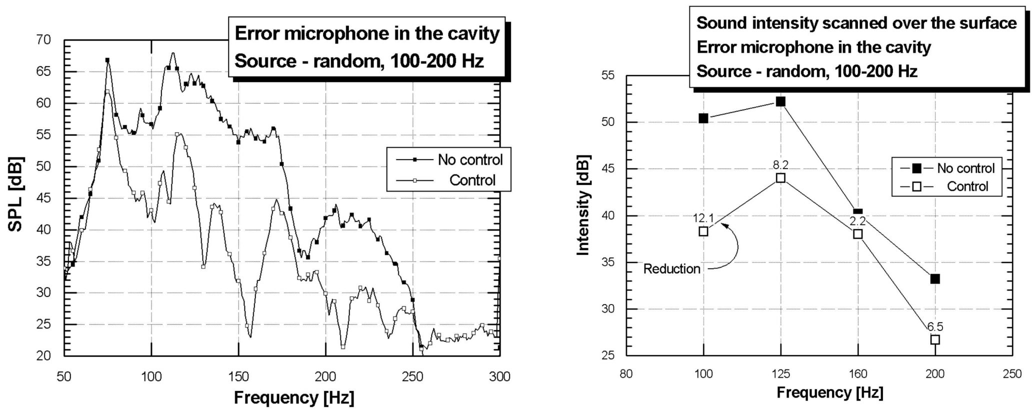

Figure 4: Double wall; results with and without control. SPL at the error microphone; intensity level scanned over the surface of the radiating plate; random noise excitation: 100-200 Hz.

4 - CONCLUSION

In this paper experiments on the application of flat EMF actuators for active reduction of the sound transmission through single and double lightweight gypsum walls have been presented.

The results showed the complex frequency response of the coupled system (source volume, plates, cavity) and their dependence upon the sensors locations and the number of actuators. In the case of the distributed sensor (EMF panel) – no optimization of the positioning is necessary. Obtained results demonstrate that the flat actuators provide very reasonable active reduction of the sound transmission. Following performance of the active control has been achieved. For the single wall set-up and harmonic excitation the SPL reduction at the error microphone is up to 45 dB and the averaged radiated intensity reduction is 8-20 dB (frequency dependent). In the case of the random noise excitation (100 – 400 Hz) the SPL reduction at the error microphone is around 10 -20 dB and the intensity decreases in the range from 2 dB to 17 dB. For the double wall set-up the SPL reduction at the error microphone is around 10 -15 dB and the reduction of the intensity levels is 2-9 dB.

Experiments with the near-field sensing and feedback control strategy (no reference signal) are in progress and initial results indicate that the performance of the control is comparable to the presented results.

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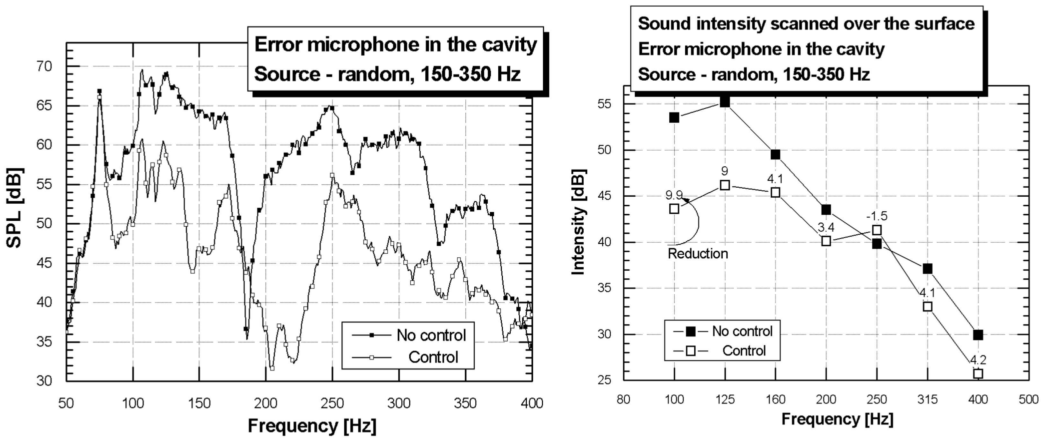

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