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Elastomer layer impact on plate radiation and transmission loss.

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ABSTRACT

The paper is an experimental study of elastomer layer impact on rectangular, steel plate radiation and transmission loss. Two plates are examined; steel plate with bonded PZTs and second with additional porous elastomer layer. The experimental set-up consist of two chambers with the test opening in between. Sending chamber has reverberant field conditions and receiving chamber is semi-anechoic. Measurements of plate vibration and sound radiation under stepped harmonic force by piezoceramics and sound wave by speaker are performed. The aim of the paper is to illustrate how additional damping in the form of rubber layer induce on active control of plate vibrations. By changing the stiffness of test plate and characteristic of its sound radiation, transmission loss increases. Measurements for the research are carried out using two methods of excitation, mechanical (PZT) and acoustic (loudspeaker). A microphone inside semi-anechoic chamber is used to measure sound radiation changes after active control of the test plate via piezoelements. Active control of test plate vibration is performed using Labview environment and data acquisition system with voltage amplifier. Results show sound radiation reduction for particular frequencies from 10 dB to 28 dB for particular frequencies and about 10 dB for whole spectrum.

INTRODUCTION

Transmission loss is a function of various different parameters for example: thickness, density, Young's modulus, Poisson's ratio, void ratio and many more. The mass law of sound insulation tells us that doubling mass we increase sound insulation 6dB and is expressed by the formula:

$$R = 10\log\left|1 + j\frac{\omega m}{2\rho c}\right|^2 \cong 20\log\left(\frac{\pi f m}{\rho c}\right) \quad (1)$$

where m is unit weight of the panel or wall. It can be a good rough approach to calculate sound insulation up to coincidence frequency.

These conventional technique of additional mass tend to be ineffective at low frequencies and can be difficult to predict their precise effect.

When we have defined the density of our material we can add void ratio in terms of porous materials. The air molecules in the interstices of the porous material oscillate with the frequency of the exciting sound wave, this oscillation results in frictional losses. Changes in flow direction and expansions and contractions of the flow throughout irregular pores result in a loss of momentum in the direction of wave propagation. These two phenomena account for most of the energy losses in the high-frequency range. However, a porous layer can absorb a large amount of acoustic energy only if its thickness is comparable to the wavelength of the incident sound.

Considering a incident sound of around 200Hz when the wavelength of sound in air is around 1,715m a porous material need to be of a 0,43m thick. This is due to the theory that it should be of a thickness around 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.

In general there are two types of active passive noise control. The adaptive passive techniques use devices whose static properties are changed. The hybrid techniques use active and passive elements in parallel. Active components are used to enhance the performance of the passive device which usually carries the primary vibration attenuation characteristic.

In this paper not only additional mass is considered to increase sound insulation but also PZT as active methods. Especially additional elastomer layer influence on radiation and transmission loss of rectangular plate is measured.

TEST PLATE AND EXPERIMENTAL SETUP

Test plate

Two different test plates are used to examine the elastomer layer effect on plate radiation and transmission loss. First is steel plate with bonded PZTs, second with additional porous 2,5mm thick elastomer layer. Both have nine piezoceramik patches placed on the plane. Eight PZTs are distributed symmetrically in the middle of each quarter. The remaining PZT, mostly used as a mechanical force excites the test plate to vibrate is located near the centre. The elastomer layer is vulcanized on the sending chamber side of the plate. The layer is porous with the void ratio of 0,5 and thickness of 2,5mm. Boundary conditions of the test plate are clamped, rigidly around the edges.

Experimental setup

The test specimen is placed in the opening between coupled reverberant chambers for sound insulation measurements. Receiving chamber is modified and a sound-absorbing enclosure is build to obtain semi-anechoic conditions illustrated in Fig. 1.

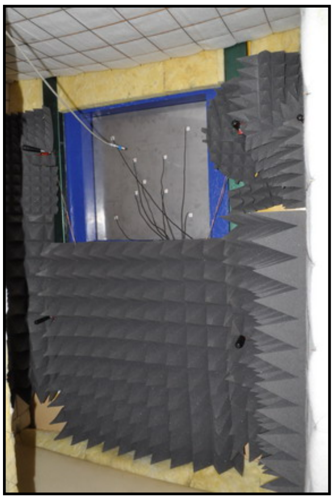

Figure 1. Receiving chamber with the test specimen.

The acoustical conditions created by sound absorbing panels allow to measure near field sound radiation. Homogenous acoustic field of white noise is created in sending chamber to measure transmission loss. For active methods efficiency measurements single frequencies as pure tone sound wave is used to excite the test plate.

Signal acquisition and control of PZT tiles is realized via multifunction data acquisition card and LabView environment.

MEASUREMENTS AND COMPARISON

Sound insulation measurements

The first measurements are performed to observe the passive technique effect of elastomer layer on transmission loss. Using white noise sound in the sending chamber sound transmitted to the receiving semi-anechoic chamber is measured. The resulting transmission loss levels in frequency domain are presented in Fig. 2. It can be seen that at frequencies below 100Hz the influence of additional mass is negligible or even negative at resonant frequencies. Above 400Hz transmission loss is increasing steadily but resulting only R = 1dB of sound reduction index in whole spectrum.

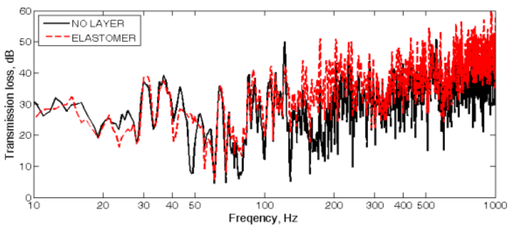

Figure 2. Transmission loss of both test plates

Sound insulation measurements confirm the theory explained in introduction. Small increase of mass of about 15% and thin porous layer slightly affected on transmission loss.

Active structural acoustic control

This part of experiment shows additional layer influence on active structural acoustic control. Active structural acoustic control refers to the process of reducing sound power transmission or radiation from a structure using actuators integrated with the structure itself. In our case PZT tiles serve as actuators to change the vibration distribution of the structure such that the overall sound radiation is reduced.

Selection of frequencies to change the vibration distributions is done after numerical computations and FEM simulations of plate resonant frequencies.

Acoustic signal at one particular frequency is generated in the sending chamber by a loudspeaker. Than the PZT tiles are actuated to vibrate by applying voltage at specific amplitude and phase.

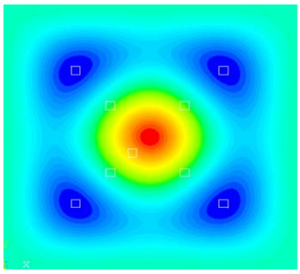

Figure 3. Mode shape of test plate at 54Hz

The first frequency to active structural acoustic control is 54Hz. This frequency correspond to 5th mode shape of square clamped at the edge plate. Figure 3 illustrates the mode shape and location of PZT tiles which exactly match the maximum vibration amplitude on the test plate. This location allowed almost totally to cut off the sound radiation at this frequency as shown in Fig. 6 and equalization to the noise level. It can be seen in figures 4 to 6 that for plate with elastomer layer the level of sound pressure and vibration is higher than for no layer plate, regardless of whether the active control is turned off or on. Not only confirms this that passive technique is inefficient at low frequencies but even make worse active methods.

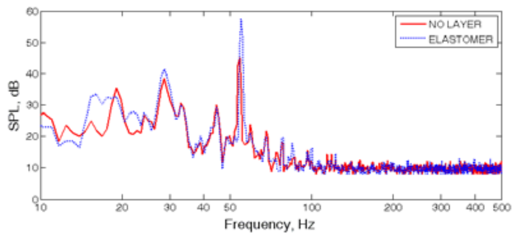

Figure 4. Soud radiation, active control turned off at 54Hz

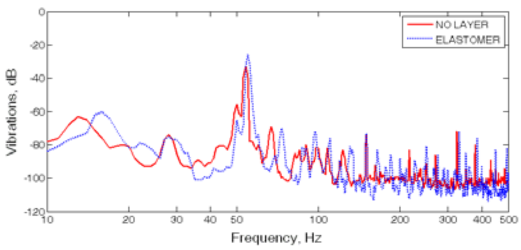

Figure 5. Vibration, active control turned off at 54Hz

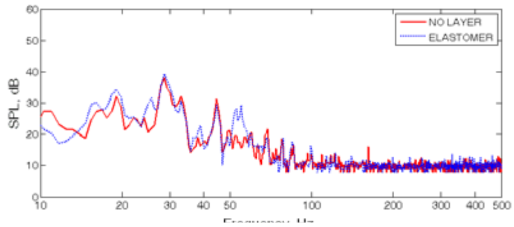

Figure 6. Sound radiation, active control turned on at 54Hz

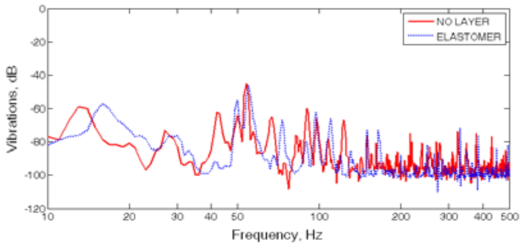

Figure 7. Vibration, active control turned on at 54Hz

Second frequency chosen to operate on was 246Hz. It is illustrated in Fig. 8 that the maximum amplitude of mode shapes at this frequency do not occur in places were PZT are stuck. Despite the fact, PZT tiles induce vibrating energy which changes mechanical impedance and in consequence reduce acoustic radiation.

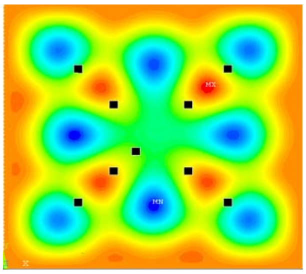

Figure 8. Mode shape of test plate at 246Hz

Figures 9 to 12 illustrate sound radiation and plate vibration with active control turned on and off. In this case the elastomer layer impact on plate radiation is slightly different. First, the vibrations measured for this particular frequency are still higher (4dB) when no active control is applied but at the same time sound radiation is in the same level.

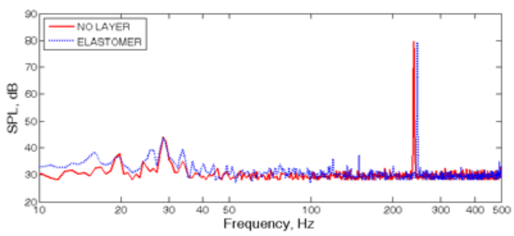

Figure 9. Soud radiation, active control turned off at 246Hz

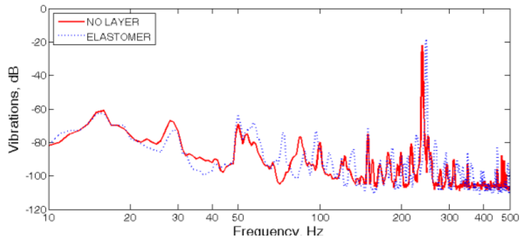

Figure 10. Vibration, active control turned off at 246Hz

In contrary to the first frequency (54Hz), when the active control is turned on the sound radiation efficiency decrease more than 3dB for the test plate with elastomer layer. Vibration level is also slightly lower (2dB) for the situation when PZTs apply bending moment to the test plate and increase its mechanical impedance.

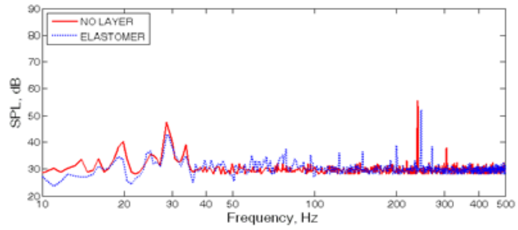

Figure 11. Soud radiation, active control turned on at 246Hz

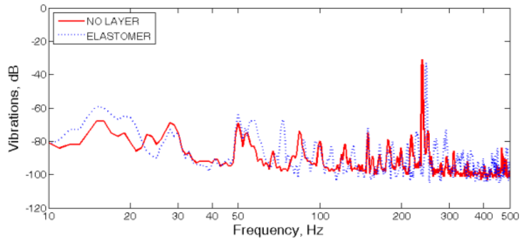

Figure 12. Vibration, active control turned on at 246Hz

In the table below (Tab.1) it is summarized the SPL measured form plate radiation in two configurations, compare active and passive method of control.

Table 1. SPL with active control turned off and on.

	Elastomer layer		No layer	
	55Hz	246Hz	54Hz	239Hz
AC on	29,5dB	52,1dB	17,6dB	55,4dB
AC off	57,5dB	79,5dB	45,2dB	79,6dB
Efficiency	28dB	27,4dB	27,6dB	24,2dB

It can be seen that for all frequencies sound radiation reduction succeeded similarly.

CONCLUSIONS

The influence on sound radiation and active structural acoustic control of elastomer layer was examined. Two plates were studied; steel plate with bonded PZTs and second with additional porous 2,5mm thick elastomer layer. Measurements of plate vibration and sound radiation under white noise and stepped harmonic sound wave were performed.

The resulting frequency characteristic of sound radiation and vibration levels illustrated in figures show different behaviour for the two configurations of test plates.

Generally at low band frequencies the influence of elastomer layer is negligible or even affect negative on sound radiation. Transmission loss measurements show some increase in insulation above 400Hz but in total it is 1dB(A).

The effect on active methods efficiency at resonant frequencies when applying elastomer layer differs slightly and depend maybe more on frequency shift.

To make significant change it should be applied porous layer of unless 50 to 100mm thick. However, a large advantage of this layer is achieved when putting it on the side where PZTs are glued to the test plate. The layer prevent fragile piezoceramik and especially wiring connections from damage.

ACKNOWLEDGMENTS

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