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ACTIVE VIBRATION CONTROL OF RECTANGULAR PLATE WITH PIEZOCERAMIC ELEMENTS

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This paper represents the possibilities of reducing mechanical vibration of plates by active vibration control through piezoceramic elements placed on the plane. In the preliminary research a rectangular plate made of aluminium was analyzed. Sound insulation and vibrations measurement were executed on a specialized enclosure in reverberation chamber. A PZT piezoceramic was proposed to control vibrations of the plate. Piezoelements were located in four points on the plate, which have maximum amplitude for (2,2) mode. Vibrations and transmitted sound before and after control is compared using sound and vibration analyser. The results show that after control, vibrations are reduced 10 dB

Keywords: vibration, sound insulation, active damping, transmission loss, PZT, piezoelectrics, piezoceramics.

1. Introduction

In the recent times we can see a great increase in the applications of smart materials or piezoelectric materials for passive and active structural damping. With the advancement of smart material technology, smaller actuators and sensors have been created, what makes them light and easy to use. For active reduction of vibration and increase transmission loss the piezoelectric properties of PZT are used. The pre-research are the measurements of the fundamental units for the test plate. White noise sound wave incident on a simply supported thin rectangular aluminium plate to measure basic modes. In the case of a rectangular plate with simply supported edges, we can consider as if it was rectangular membrane [7, 11]. Two particular frequencies has been chosen to damp plate vibration and piezoceramics were powered at this frequency.

2. The experimental setup

Figure 1 shows the experimental setup consists of two chambers, sending and receiving chamber. The sending chamber is a semi-echo tetrahedron pyramid enclosure build inside the echo chamber in the most acute corner [3]. Dimensions of the sending chamber were designed to measure sound insulation of small elements and there are $1802 \times 1477 \times 1355$ mm so the volume is 0.47 m^3. As a matter of fact in such small volume is hard to obtain reverberant field conditions, but it has been measured acoustic field diffusivity and results are satisfactory. This is some imperfection of the experimental setup, furthermore transmission loss measurements are rough. The sending chamber enclosure is a sandwich structure made of steal and rubber with a sound insulation of $\mathrm{Rw} = 45$ dB measured when the test hole plugged with the same material as the enclosure. The test hole size is 565×460 mm. According to this the receiving chamber is total echo chamber with reverberation time in frequencies of 9.5 s (100 Hz), 11 s (200 Hz), 10 s (500 Hz) and 8 s (1 kHz) and a volume of 185.6 m^3. The test plate under study was installed in the opening between the two chambers as if it was simple-supported, the plate themselves is rectangular with size that can fix the hole.

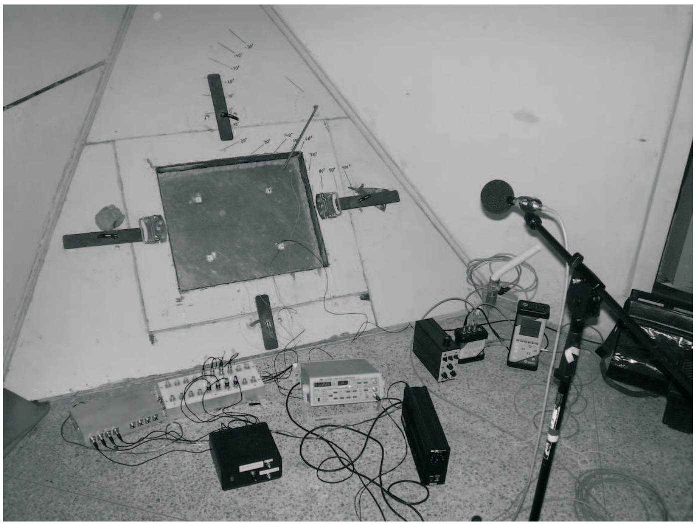

Fig. 1. View of the experimental setup.

The acive control system consist of signal generator, phase shifter and amplifier. The data acquisition and measurement system consist of accelerometer, microphones with sound and vibration analyser.

2.1. Sending chamber acoustic field diffusivity

It was examined the diffusivity of acoustic field inside the volume, to find out whether acoustic pressure affecting and exciting the test plate is spread evenly. The microphone has been moved by radius in distance of 10 cm from the plate mounted in the hole, which can be seen in Fig. 2. The obtained results of equivalent continuous sound pressure level (L_{eq}) are shown below in Table 1.

Table 1. Equivalent continuous sound pressure level in different angles.

Angle	30°	40°	50°	60°	70°
L_{eq} [dB]	104.3	104.7	105.3	105.8	105.6

The variation range of the level does not exceed 1.5 dB. Additionally taking into consideration spectrum change in different angles, the diffusivity of acoustic field inside sending chamber was positively revived.

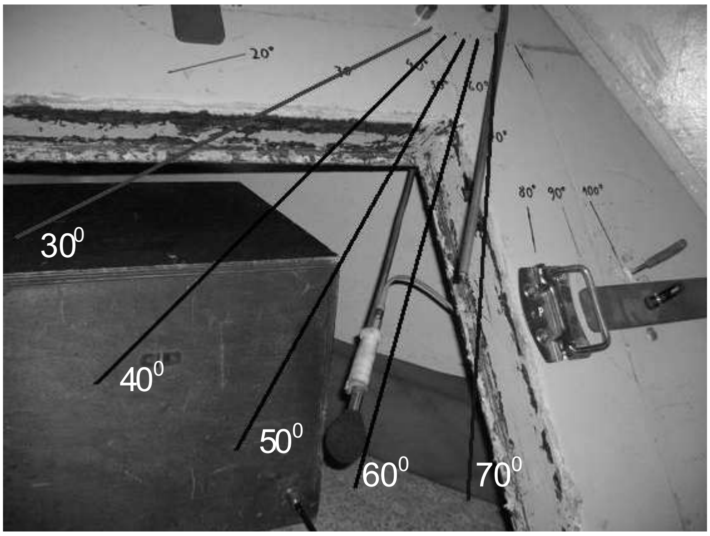

Fig. 2. View of positioning the microphone.

2.2. *Application of piezoceramic elements*

The piezoelectric effect provides the ability to use these material as both sensor and actuators. The most common material with this effect is piezoceramic consist of Lead, Zirconium and Titanium (PZT). To use the piezoefect for damping vibration two types of control are used:

- The passive control which consist almost entirely of various shunt circuit techniques, like: Inductive, Resistive, Capacitive, Switched. All of them were described in one particular study [8]. According to Lesieutre, each type of shunt circuit exhibits its own type of behavior: a resistive shunt dissipates energy through joule heating, which provides structural damping; an inductive shunt is analogous to a mechanical vibration absorber (tuned mass damper); and a capacitive shunt changes the effective stiffness of piezoelectric elements; a switched shunt offers the possibilities of controlling the energy transfer to reduce frequency dependent behavior.

- The active control via two control schemes: feed forward and feedback. Feed forward control is particularly suited to the control of tonal disturbances for which a reference signal is available. Feedback control is advantageous for the control of steady state, random and transient disturbances. Some study point out some of the disadvantages with active control. For example McGowan [10] points out that there are two important issues that need to be considered in using piezoelectrics as actuators for active control systems: they usually require large amount of power for operation, and the complexity of the hardware involved with active control.

For our application a PZT-PKT P840 was chosen. The size of PZT plate is 20 mm $\times$ 20 mm $\times$ 1 mm, material properties are summarized in Table 2. PKT is the name for piezoceramics in pressing technique.

Table 2. Technical data of the piezoceramic material.

Technical Data		PKT P840	
Curie temperature, ϑ_c		325 [°C]	
Density, ρ		7600 [kg/m^3]	
Stiffness Constant	s_{33}^E	14.7	[10^{-12}/Pa]
	s_{11}^E	12.5	
Mechanical Quality Factor, Q_m		500	
Piezoelectric Charge Constant	d_{33}	290	[10^{-12}C/N]
	d_{31}	125	
Coupling factor	k_{33}	0.72	–
	k_{31}	0.35	

where Curie temperature – value at which phase transition of the crystal structures occurs. As a rule the application temperature range of piezoceramics lies at $0.5\vartheta_c$; Stiffness constant – ratio of the relative elongation to the mechanical tension; Mechanical quality factor – the ratio of the elongations of a body, able to vibrate, in resonance and in static operation; Coupling factor – describes the ability of a material to transform electrical energy into mechanical energy and vice versa. The coupling factor allows a direct comparison of different materials: k_{33} – coupling factor of the length mode; k_{31} – coupling factor of the transverse mode; Piezoelectric charge constant – describes the ratio from relative elongation and electrical field strength at constant mechanical tension.

3. Measurements and results

The measurements were divided on two stages, frequency characteristic of vibration magnitude for the test plate and acting on the test plate by two selected particular frequencies. The piezoceramic elements were placed on the plane in symmetric way, to act on as much modes as possible. For boundary conditions like this, center of every quarter has been chosen to glue PZTs. It gives the possibility to damp maxima for modes: (1,2), (2,1), (2,2), (1,3), etc. The frequency response function of the test plate obtained by acoustic exciting with white noise indicated two particular frequencies 102 Hz and

133 Hz, both of them are the resonant frequencies. Those resonant frequencies are (3,1) and (3,2) modes. Visualization of those modes is presented in Fig. 3.

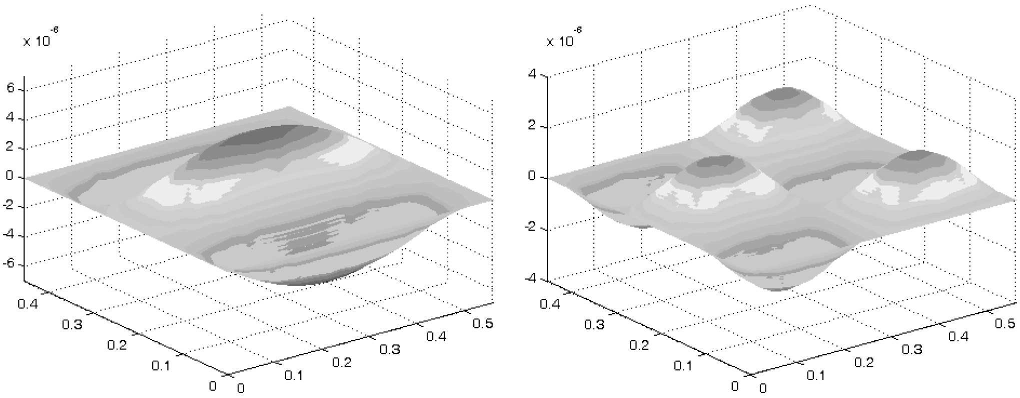

Fig. 3. Visualization for mode (3,1) and (3,2).

To measure vibration damping the test plate was actuate with harmonic signal, PZT plates were powered with the same frequencies but shifted in phase. We can see in Fig. 4 reduction for 133 Hz which is 10 dB, for 102 Hz it was 4.2 dB.

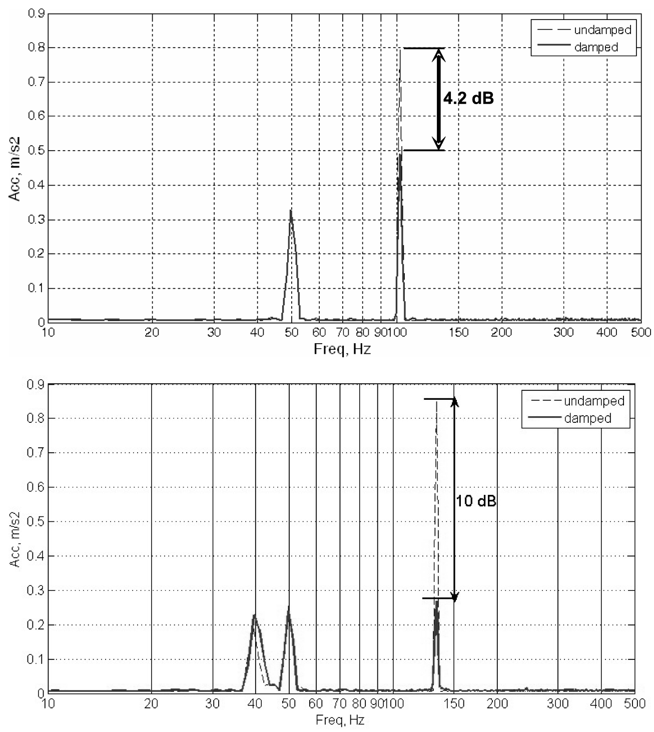

Fig. 4. Vibration damping of test plate for 102 Hz and 133 Hz.

4. Conclusions

Authors of this article presented possibilities of reducing mechanical vibration of plates by active vibration control through piezoceramic elements placed on the plane. A PZT piezoceramic was proposed to control vibrations of the plate. Piezoelements were located in four points on the plate, which have maximum amplitude for (2,2) mode. The results show that after control, vibrations are reduced 4 dB at 102 Hz and 10 dB at 133 Hz. This research is the initial step of some further, more effective control for piezoceramic elements as well as the specially vulcanized rubber for passive vibration control will be used.

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