Combined force-moment actuator for ASAC

Ondrej JIRICEK[1]; Vojtech JANDAK[2]; Marek BROTHANEK[3]

Czech Technical University in Prague, FEE, Dept. of Physics, Technicka 2, 166 27 Prague, Czech Republic

ABSTRACT

This paper deals with a recently developed actuator based on piezoelectric bimorphs which are useful for ASAC applications. The actuator takes the form of two channels with pairs of bimorphs. Each of the bimorph transducers in the couple is connected separately so that the actuator can act in both moment and force configurations simultaneously. The control algorithm allows the ratio between the moment and force excitation to be adapted according to the desired mechanical output. The ASAC system using this actuator was tested on a simple structure in the form of a fixed beam. Configurations with maximum attenuation were selected and discussed.

Keywords: Moment actuator, ASAC, Piezoelectric bimorph
I-INCE Classification of Subjects Number(s): 38.3, 48

1. INTRODUCTION

In many practical noise control applications, it is useful to suppress the sound radiated from a thin vibrating plate that can be excited by a structure-borne noise or by incidenting sound waves. The latter case can be considered as an improvement of transmission loss. This can be realized by various passive treatments or by application of active structural acoustics control (ASAC), which has better efficiency particularly at low frequencies. A basic description of ASAC can be found in (1) and its application to light-weight structures has been presented in many publications (see e.g. (2, 3, 4)).

Actuators used for ASAC can be generally divided into two categories of force and moment actuators, according to the mechanism of actuation. The force actuators are more common thanks to their easier realization and lesser sensitivity to the actuator placing. However, the moment actuators have a wide field of application as well. Some of the actuators can be designed to operate in both force or moment mode, depending on the control strategy or physical requirements.

This paper deals with the experimental verification of the possibilities of the force-moment actuator designed at CTU. The actuator is based on couple(s) of piezoelectric bimorphs fixed in a light-weight mounting. This type of actuator was originally developed for moment actuation only (5, 6), but depending on the phase shift between the opposite bimorphs, it can operate in both force and moment configuration.

2. DESCRIPTION OF FORCE-MOMENT ACTUATOR

The original moment actuator described and tested within our previous work (5) was based on two or four couples of bimorphs driven in the opposite phase. Later, we tested the same transducer with bimorphs driven in the same phase creating a force actuator. The transducer presented in this paper was designed and realized as universal, enabling an arbitrary phase shift between the left and right bimorph in the couple. It enables a change in the behavior of the actuator from moment to force. The actuator is designed as two-channel, so each side is driven separately. Its construction is schematically illustrated in Figure 1. Both the phase and amplitude of the left and right side of the actuator can be changed during the runtime of the adaptation process.

3. EXPERIMENT WITH FORCE-MOMENT ACTUATOR

This paper presents introductory tests of the combined actuator in two basic configurations – force with same phase and the same amplitude of the feeding signal of both sides of the actuator and moment with same amplitude but opposite phase. The actuator was placed on a testing structure constructed as a baffled sheet metal strip fixed in a chipboard baffle as shown in Figure 2. The metal sheet with free dimensions of

[1] jiricek@fel.cvut.cz
[2] jandav1@fel.cvut.cz
[3] brothan@fel.cvut.cz

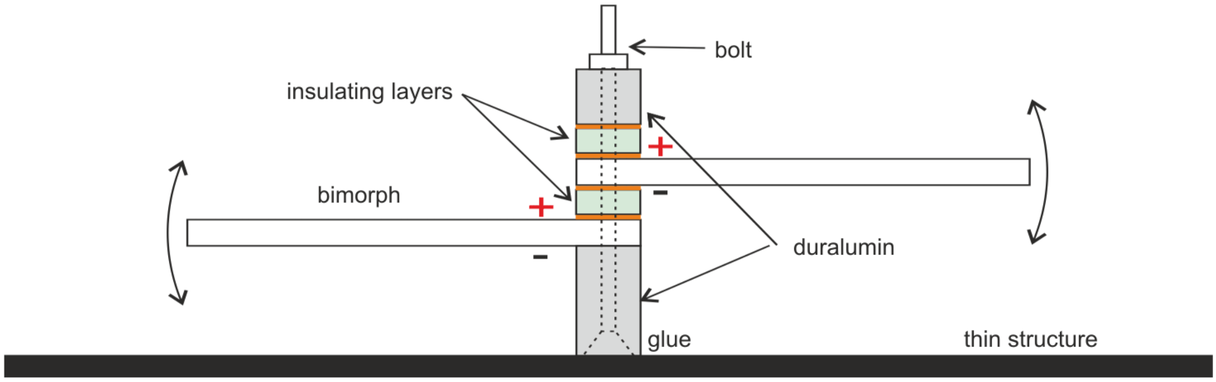

Figure 1 – Construction of the force-moment actuator.

$300 \times 60 \times 0.4$ mm was fixed on the shorter sides and excited by a shaker attached in the center of the sheet creating a point force.

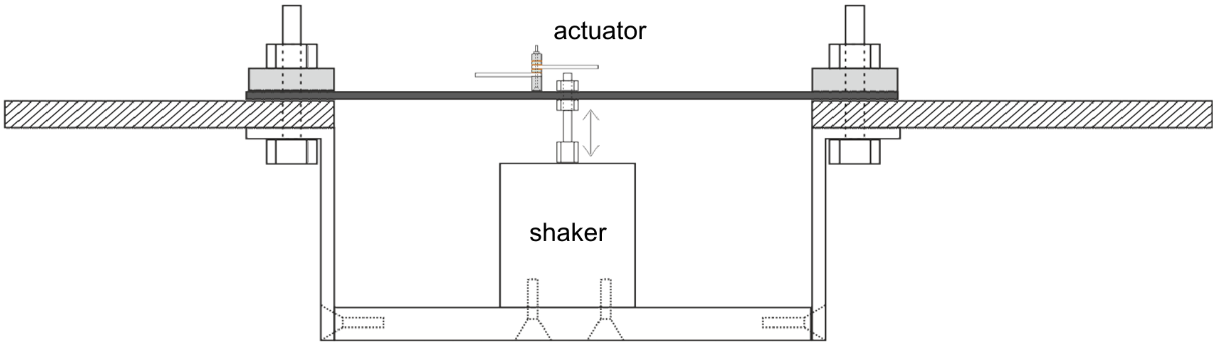

Figure 2 – Experimental setup.

For the purpose of this study, we used tonal excitation at a frequency of 128 Hz, which corresponds to the most significant mode of the primary structure (without the actuator) excited by the shaker. At this frequency, three antinodes and four nodes (including fixed ends) can be found. As the actuator is approximately of the same mass as the strip, the final distribution of the modes will be different.

The aim of this study was to find the maximum attenuation achievable with the force-moment actuator in both configurations. For this purpose, two three-channel signals in wav format were generated. The first signal was used for finding the optimal phase shift between the primary excitation signal (shaker) and the signals for the actuator. The channel for the shaker was a pure tone of 128 Hz and at the channels for the actuator (identical) the phase was smoothly shifted by 360° in 60 s. An error microphone monitoring the resulting sound pressure level was placed 0.5 m above the center of the strip.

The second signal served for finding the optimal power input of the actuator. The channels for the actuator were identical pure tones with fixed amplitude, whereas the primary signal for the shaker with the optimal phase shift found in the previous test had smoothly changed amplitude in the expected range of maximum attenuation of the active system. Changing of the amplitude of the primary excitation was selected to operate the actuator under optimal conditions.

In the presented experiment, two positions of the actuator were selected, corresponding to the one position of the node for moment actuation and one position of the antinode for force actuation found for the stripe without actuator and shaker.

The dependency of the attenuation with the actuator in the antinode position on the shaker excitation level is shown in Figure 4. The level of 0 dB corresponds to the maximum attenuation in the force configuration (blue curve). To achieve comparable results for moment configuration (red curve), the excitation level of the primary signal had to be decreased by 10 dB corresponding to 10 dB increase of bimorph signal assuming a linear system.

When the actuator is placed in node position, the excitation level of the primary signal had to be decreased by 1 dB in moment configuration to achieve the same efficiency of the active system.

Distributions of the vibrational velocity measured by laser vibrometer for the optimal phase and amplitude settings for force excitation are presented in Figure 5. Measurement was performed for the center line only as

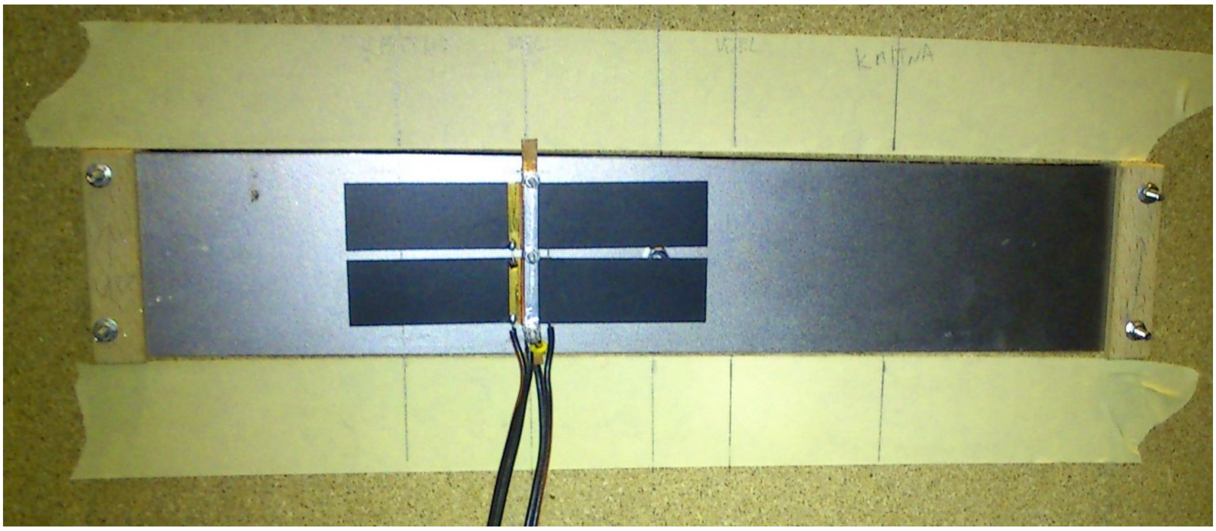

Figure 3 – Photo of experimental setup with actuator in moment position.

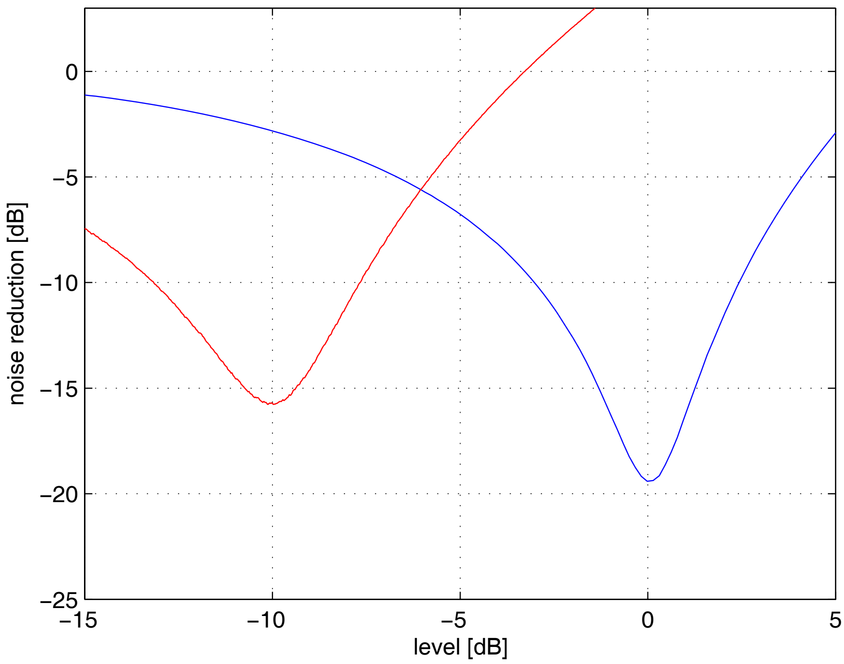

Figure 4 – Attenuation of the system with respect to the excitation level, blue – force excitation, red – moment excitation.

simple one-dimensional bending waves are assumed. This also enables measurement of vibrations in the gap between the bimorphs. From Figure 5 it is possible to see a difference between moment actuation (upper part) and force actuation (lower part).

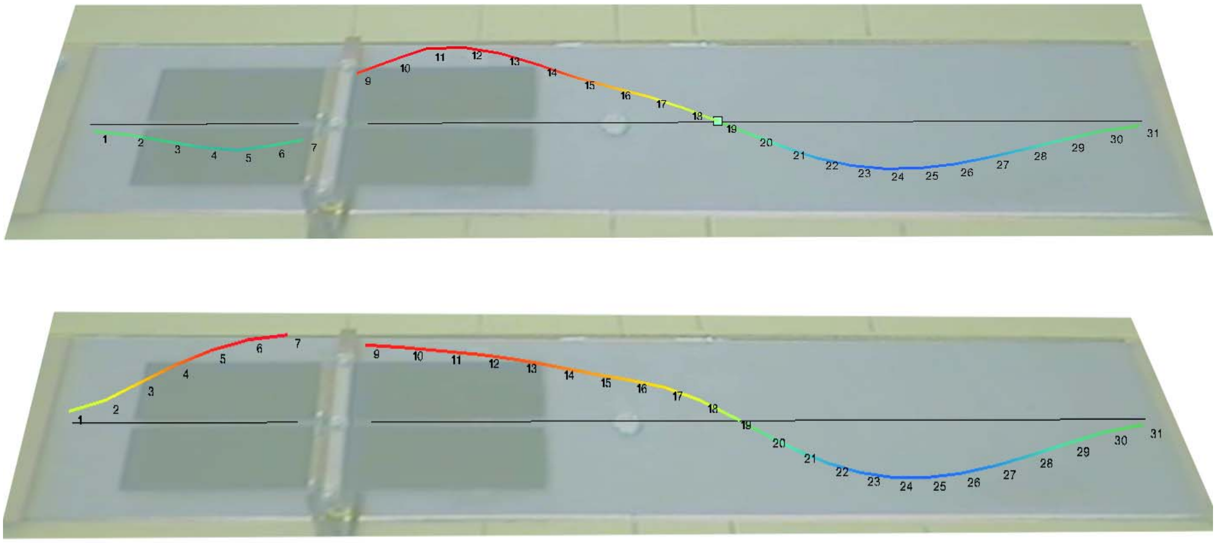

Figure 5 – Measured shape of surface velocity, actuator fixed in position optimal for force excitation.

4. CONCLUSION

The paper describes selected experiments with the new combined force-moment actuator designed in the Acoustic Laboratory at CTU. The actuator enables switching from force to moment actuation within the runtime of the active system. The better results were found in the force configuration, as this is not so sensitive to the placement of the sensor. From vibrational measurement by a laser-scanning vibrometer, it can be seen that the actuator operates as a force and moment driver respectively.

Within the following research, we would like to study the possibility of attenuation of more modes using a combination of force-moment configurations of the transducer. The efficiency of the given configuration should be a part of extensive research as well.

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