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EXPERIMENTAL DETERMINATION OF BASIC PARAMETERS FOR ACTIVE VIBRATION CONTROL SYSTEM DEVELOPMENT

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Abstract. Piezoelectric actuators are widely used in structural systems for active vibration control with the aim to enhance the performance of systems. In order to improve the dynamic characteristics of active system, it is necessary to know the changes in modal parameters of systems after embedding of piezoelectric actuators. The effectiveness of chosen piezoelectric actuator on real system is a very important characteristic in order to determine capabilities of vibrations suppression. This paper presents two experimental investigations whose aim is to define the input and output parameters for development of active vibration control system. In the first experiment modal parameters of the thin rectangular plate with embedding of piezoelectric actuator is determined. The dynamic behavior of the thin rectangular plate is identified by using the strain gages (full bridge) sensor. The second experiment is performed aiming to identify the voltage limits of the controller's output for the first three natural frequencies of the rectangular plate. The determined parameters (natural frequencies and control voltage limits of piezoelectric actuator) represent boundaries which must be satisfied in the process of development of the active vibration control system.

Keywords: Active vibration control, piezoelectric actuators, strain gages sensor

1. Introduction

Recent studies of structural control systems using piezoelectric actuators have become a routine in order to increase the effectiveness in vibration suppression of structures [1,2]. Integration of actuators and sensors on the structure area has changed its modal parameters. The selection and optimization of sizing and location of actuators and sensors for active vibration control of flexible structures has proved to be one of the most important issues in the designing of active structures since these parameters have a major influence on the control system performance [3].

An active structure consists of a host structure incorporated with sensors and actuators coordinated by a controller. The integrated structure includes some vibration modes of the structure whose dynamic response must be considered. If the set of actuators and sensors is located at discrete points of the structure, they can be treated separately [4]. With the developments of sensor/actuator technologies many researchers have concentrated on active vibration control using piezoelectric materials (PZT – lead zirconium titanium, SMA – shape memory alloys) for sensors and actuators [5]. Piezoelectric materials have been applied in structural vibration control because of their fast response advantages, large force output and the fact that they generate no magnetic field during the conversion of electrical energy into mechanical motion.

Vibration control is one of the major issues that need to be considered carefully in designing a structural system exposed to external disturbances. Depending on sensors, the vibrations can be controlled by different control strategies. However, the acquaintance with system parameters and all state variables are required of controller development.

In this work a procedure for determination of the adequate reinforce of input signal from vibrating body to the controller which is based on the use of strain gages is presented. The knowledge of modal properties of the body is necessary for the input signal implementation. The first experiment defines the vibrating system natural frequencies due to the embedded piezoelectric actuator. In the second experiment, the actuator is used like a driver for all natural frequencies of the system in order to define adequate strain gages signal reinforcement as a controller input.

2. Development of the Active Vibration Control System

An active vibration control is a method for vibration reduction based on the use of an external power source. An active vibration control system working principle starts with measuring the response of the system using suitable sensors. Then the electronic circuit reads the sensors output, converts the signal appropriately and sends it to the control unit. Being on the control law and previously chosen controlling strategy, the calculated signal is sent to the actuator and the corresponding force is applied to the system. The actuator force will actually compensate the vibration force in the system.

The proposed vibration control system is developed being on feedback control strategy with Wheatstone “full” bridge stain gages sensor and PZT actuator. The scheme of proposed system is given in Fig 1.

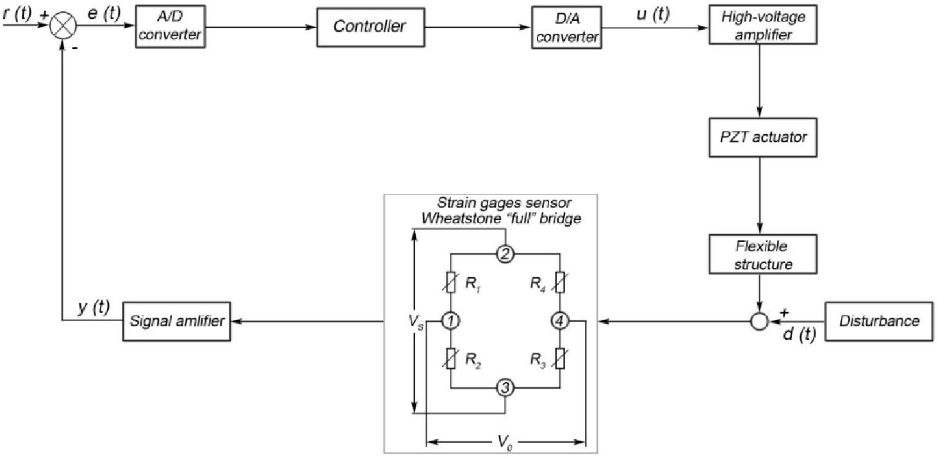

Figure 1. The scheme of proposed active control vibration system

where are: ( ) – measured signal from strain gages bridge, ( ) – reference signal (( ) = 0 in active control vibration system), ( ) – error signal (controller input) and ( ) – control signal (controller output).

2.1. Integrated structure

The aluminum plate with integrated piezoelectric actuators considered here is presented in Fig. 2. It is assumed that piezoelectric patches and strain gages sensor are perfectly bonded to the plate.

The particle swarm optimization technique is used to find optimal position of actuator in order to control first three natural modes.

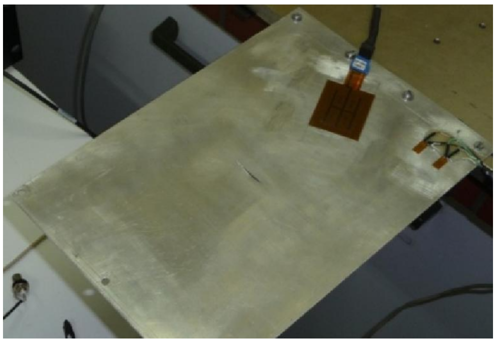

Figure 2. The plate with integrated piezoelectric actuator and strain gages.

The Wheatstone bridge is usually used to measure the deformation of mechanical system. The four arms of the bridge circuit are formed by the resistances R_1 to R_4 (Fig. 1). The corner points 2 and 3 of the bridge, designate the connections for the bridge excitation voltage (Vs); the bridge output voltage (V_0), is available on the corner points 1 and 4.

When the bridge is balanced:

$$\frac{\;}{\;} = \frac{\;}{\;} \tag{1}$$

the bridge output voltage is zero ($= 0$), but with a preset deformation, the resistance of the strain gage changes by the amount Δ . The output voltage is given by next equation:

$$= \frac{\Delta}{\Delta \qquad \Delta} + \frac{\Delta}{\Delta \qquad \Delta} \tag{2}$$

Full bridge sensor platform has the following advantages:

- With a mirror-imaged cross-section, normal strains are compensated.
- The magnitudes of changes to strain gages which are located in adjacent bridge arms in the circuit are subtracted.
- Thermal strains are compensated to a high degree.
- Interference effects through internal bridge connections are largely suppressed.
- The change in AC voltage level is very suitable for measuring the signal of vibration.

The disadvantage of this type of sensor is its low output voltage level. This type of measurement must be considered in conjunction with the signal amplifier system. The

signal amplifier's primary task is to raise the level of the bridge circuit's output signal from the millivolt to volts region [7]. In this system the signal amplifier has had a gain of 200.
Mide QP10w piezoelectric ceramic actuator is choosen for system development. It is designed to provide precise and repeatable actuation or strain induced measurement in challenging operating environments. The typical performance power characteristic of QP10w actuator is given in Fig. 3.

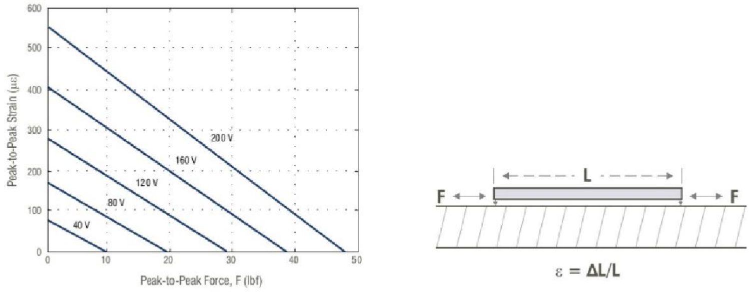

Figure 3. The typical performance power characteristic of QP10w actuator.

The actuator is driven by high voltage. The proposed controller output signal, ( ), in the best case has a value between ±5 V. For amplification of this signal to nominal actuator working voltage the special “high-voltage” amplifier is needed. Used “high-voltage” amplifier has had gain of 40.
Mechanical displacements of the plate are the highest at the natural frequencies. In proposed system the mechanical displacements correspond to strain gages output voltage. The success of the designed system will be verified in the next experiments.

3. Experimental determination of the measurement signal gain

The experiment is done in the CFFF (clamp-free-free-free) plate configuration (Fig. 2). In the first experiment the integrated plate was excited on the side opposite the clamped one. The response measurements were acquired, using the multi-channel signal analyzer NetdB 12, and its matched software dBFA Suite, with a sampling rate of 12800 Hz.
The frequencies for the first three natural frequencies of integrated structure are: 11.80 Hz, 36.71 Hz and 61.72 Hz, respectively. The transfer function of the integrated system is given in Fig. 4. The natural modes are marked in Fig. 4.

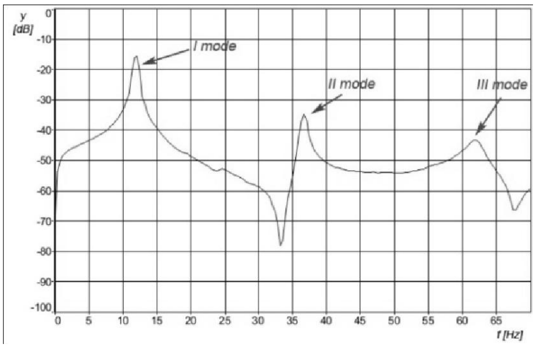

Figure 4. The frequency spectrum.

In the second experiment, the actuator was driven by signal generator in conjunction with “high-voltage amplifier. The measurement signal from “full” bridge strain gages was acquired with signal analyzer NetdB 12. The experiment set-up is given in Fig. 5.

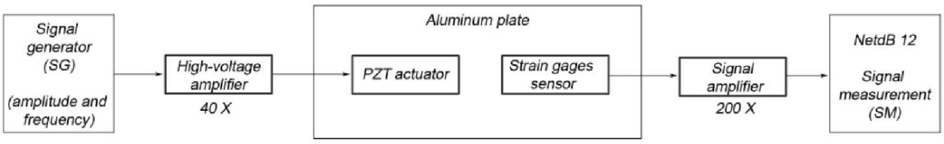

Figure 5. Experiment set-up.

For every the first three natural frequencies, the changes of excited signal were done with the aim to determine the system response for excitation set. The relationship between the excited signal from signal generator and the system response from amplified strain gage sensors is given in Table 1 and Fig 6.

Table 1. Experimental results of the first three natural frequencies for the integrated structure.

11.80 Hz (I mode)		36.71 Hz (II mode)		61.72 Hz (III mode)	
Excited signal [V pk-pk]	Response signal [V pk-pk]	Excited signal [V pk-pk]	Response signal [V pk-pk]	Excited signal [V pk-pk]	Response signal [V pk-pk]
2.0	0.226	2.0	0.023	2.0	0.018
3.0	0.390	3.0	0.041	3.0	0.036
4.0	0.590	4.0	0.062	4.0	0.049
5.0	0.794	5.0	0.082	5.0	0.057
6.0	1.078	6.0	0.094	6.0	0.065
7.0	1.410	7.0	0.114	7.0	0.085
8.0	1.678	8.0	0.136	8.0	0.096

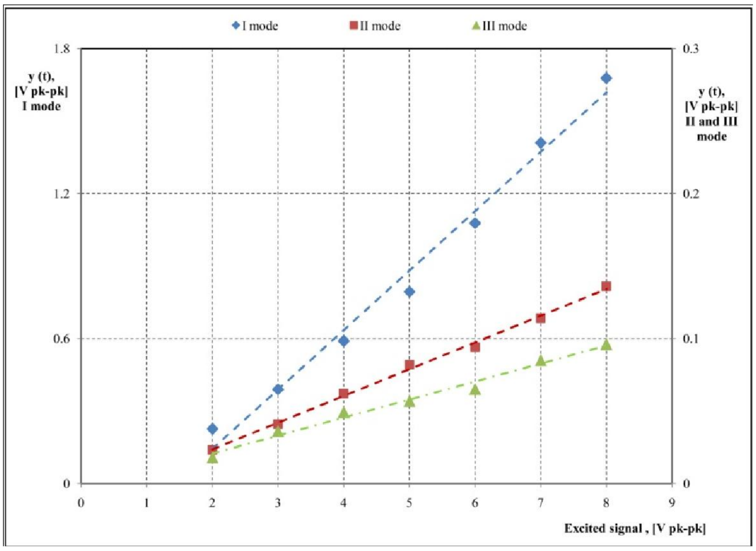

Figure 6. The relationship between excited signal and system response signal.

4. Conclusion

In this work, the basic parameters of active control vibration system are determinate performed two experiments. After analysis of experimental results proposed active vibration control system can be concluded:

- The “full” bridge strain gage is adequately sensor platform for use in active vibration control system.
- The overall system gain of integrated structure is not adequately to control whole system (aluminum plate).
- The controller input signal must be amplified minimum 4 times more for effective vibration suppression at first natural frequency.
- The effectiveness of vibration suppression for the second and third natural frequency for proposed “full” bridge strain gages configuration cannot be achieved. The change in strain gages position can provide the higher level of response signal.
- The relationship between excited signal from signal generator and system response from amplified strain gage sensor are practically linear. The linearity provides the simplification of control algorithm.

Based on present concludes the proposed active vibration control system must be modified with aim to increase the vibration suppression effectiveness.

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