563. Development and experimental analysis of layered actuators

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Abstract. Calculations indicate that a layered actuator composed of constituent elements tied together with binding material is a system characterized by high static strength. For this reason, these actuating systems are implemented in mechanisms that operate under heavy loads and require very precise displacements. Layered actuator used in mechanisms requiring high precision displacements have demonstrated that accuracy depends on design and technological factors. Analysis of different parameters of the actuator has enabled optimization of the structures and determination of their capabilities under varying mechanical loads.

Keywords: layer actuator, holographic interferometry method, scanning vibrometer

Introduction

Theoretical investigation of piezoactuators and dynamic analysis of their components has demonstrated that increase in the loading force and initial tension reduces harmonic components of fluctuations [1, 2]. Therefore, dynamic characteristics of each individual element of compound piezostack have to be determined separately. Dynamic model of the actuator and piezoelements are excited either by harmonic (a) or pulse (b) excitation force F(t) illustrated in fig. 1.

Mechanical and electrical laws pertaining in layer piezostack are analyzed separately and their interrelation is expressed as follows:

$$\left.\begin{aligned} m_1\ddot{x}_1 + F_y(x_1 - x_2, \dot{x}_1 - \dot{x}_2) + H_1(\dot{x}_1 - \dot{x}_2) + c_1(x_1 - x_2) + H_0\dot{x}_1 + c_0x_1 = F_B(t) \\ m_2\ddot{x}_2 - F_y(x_1 - x_2, \dot{x}_1 - \dot{x}_2) + H_1(\dot{x}_2 - \dot{x}_1) + c_1(x_2 - x_1) = -F_B(t) - P_H \end{aligned}\right\} \tag{1}$$

there two masses - m_1 and m_2; the strain – *F;* parameter of intensity *c* and damping *H;* coordinates x_1 *and* x_2 *;* harmonic excitation force - $F_B(t) = A\sin\omega t$.

$$F_B(t) = \begin{cases} A, kT \le t \le kT + T/2 \\ -A, kT + T/2 \le t \le (k+1)T \end{cases} \tag{2}$$

there A - amplitude; T - period,; *k* – number of period

Solutions of system (1):

$$x_1 = a_0 + a_1 \cos \omega t + a_2 \sin \omega t$$
$$x_2 = b_0 + b_1 \cos \omega t + b_2 \sin \omega t \quad (3)$$

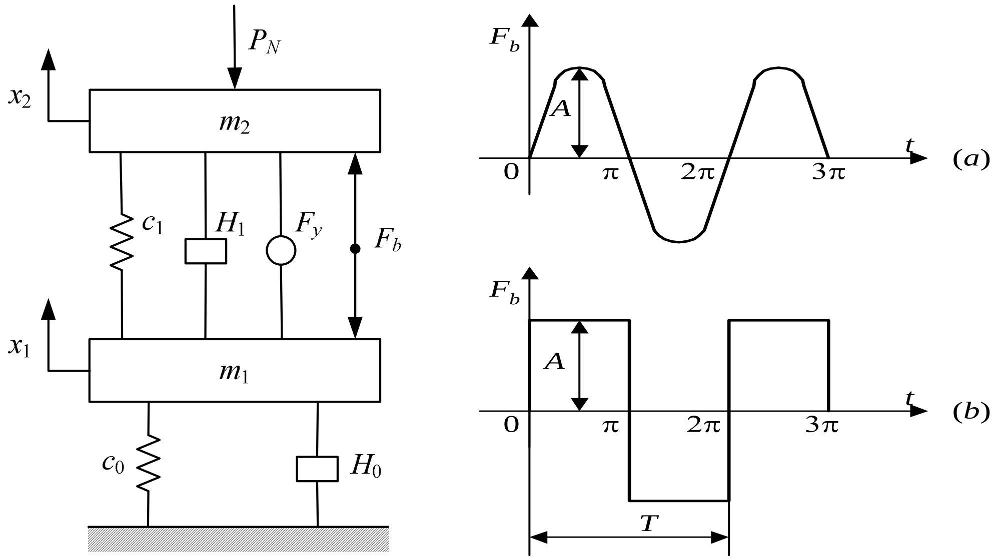


Fig. 1. Dynamic model of a layered actuators and types of the excitation force in the actuators

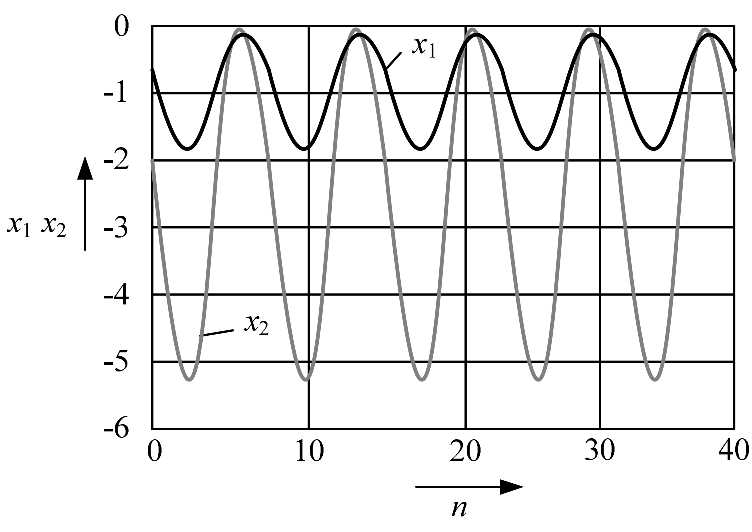


Fig. 2. The first harmonics of vibration motion of two masses m_1 and m_2 when P_N=0,9 N A_b = 2,0 N, ω =9000 rad/s

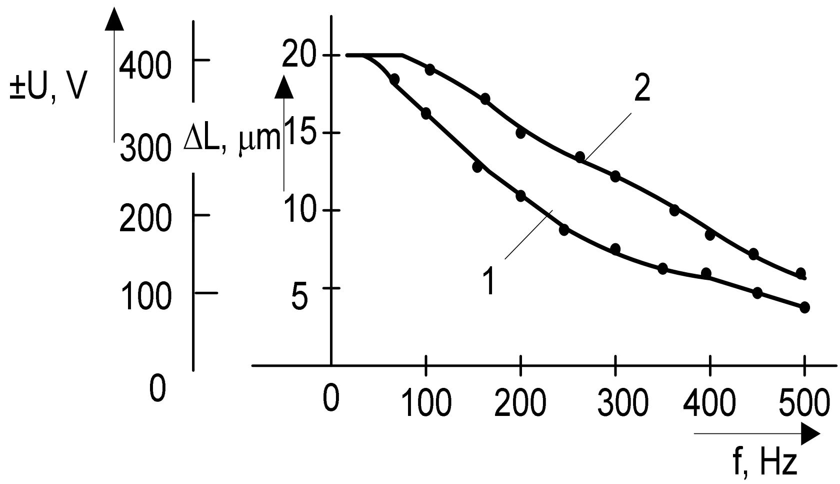


Fig. 3. The dependence of frequency curves on the quantity of the elements of a layered actuator

Theoretical calculations of the first harmonics of vibrations, in case of harmonic excitation of a layered actuator, call for a conclusion that the initial compression and the mechanical load of piezoelements increase the amplitude of vibrations.

Experimental analysis

Experimental investigation of layered actuators with combined stack has revealed the possibilities to optimize the design and materials for obtaining maximum displacements. The results of investigation enable development of modern designs of actuators with combined piezostacks for high precision [3-5]. The overall dimensions of the actuator (depending on quantity of piezoelements) are strictly defined since the device has to meet stringent requirements for achieving maximal motion amplitude. Therefore optimization of piezoelements and layered actuator design has been performed together with dimensional analysis of spring-type pressing device, which key criteria is to achieve maximal displacement amplitude of actuator output part. These mechanisms may be applied to various optical systems got calibration of active anodic and cathodic holders of lasers.

Experimental investigation of precision mechanical systems (or their separate elements) by means of holographic interferometry enables one to obtain appreciably larger amounts of information about the surface deformation in comparison to traditional methods [6, 7]. The paper deals with the consideration of methods for determination of the characteristics of surface deformation of precision mechanical systems from the holographic interferograms of linked analysis of these characteristics determined by means of numerical techniques based on the theories of mechanical systems under deformation and holographic interferometry. A multipurpose device has been developed for storing the holographic interferograms. It allows the application of various methods of holographic interferometry in order to obtain interferograms of excellent quality.

The latest experimental investigation was accomplished with Polytec scanning vibrometer PSV-400 (Fig. 4), which is based on laser Doppler vibrometer - a precision optical transducer used for determining vibration velocity and displacement at a fixed point. The technology is based on the Doppler effect, sensing the frequency shift of the back-scattered light from a moving surface. Experimental investigation of actuators with layered packets has revealed the possibilities to optimize the design and materials in order to generate maximum displacements.

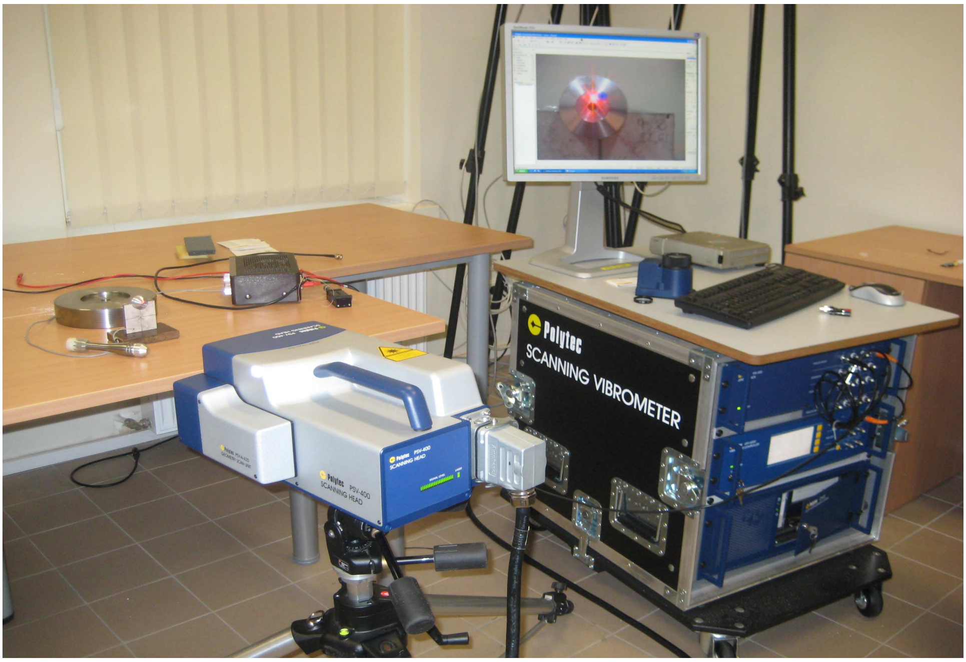


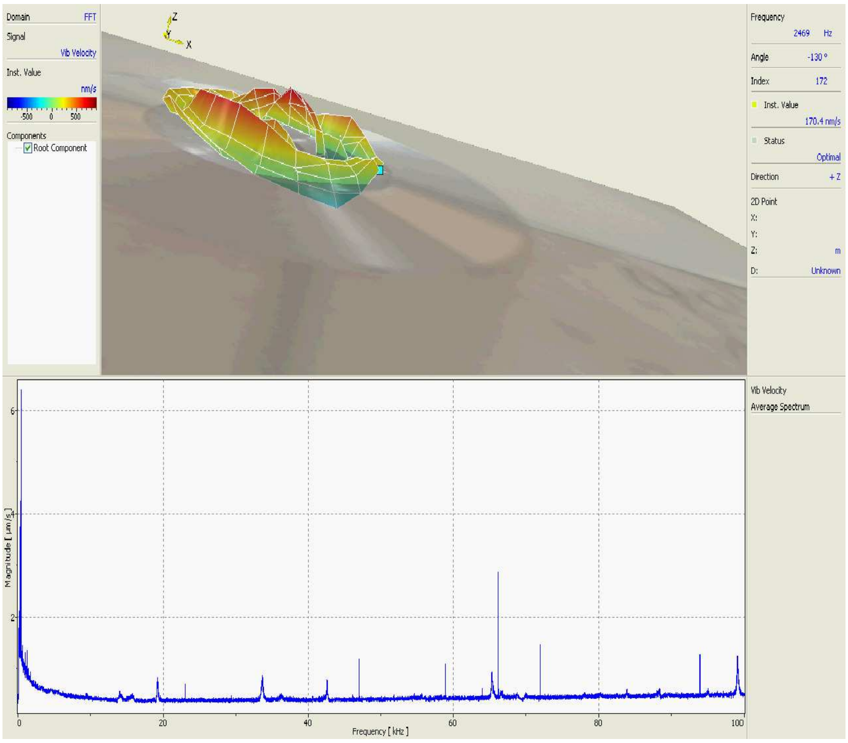
Fig. 4. Experimental setup based on Polytec scanning vibrometer PSV-400

Holographic interferometry method and Polytec scanning vibrometer PSV-400 used in the experimental work has strengthened the expressions of differential equations and were used for supporting conclusions of the investigation.

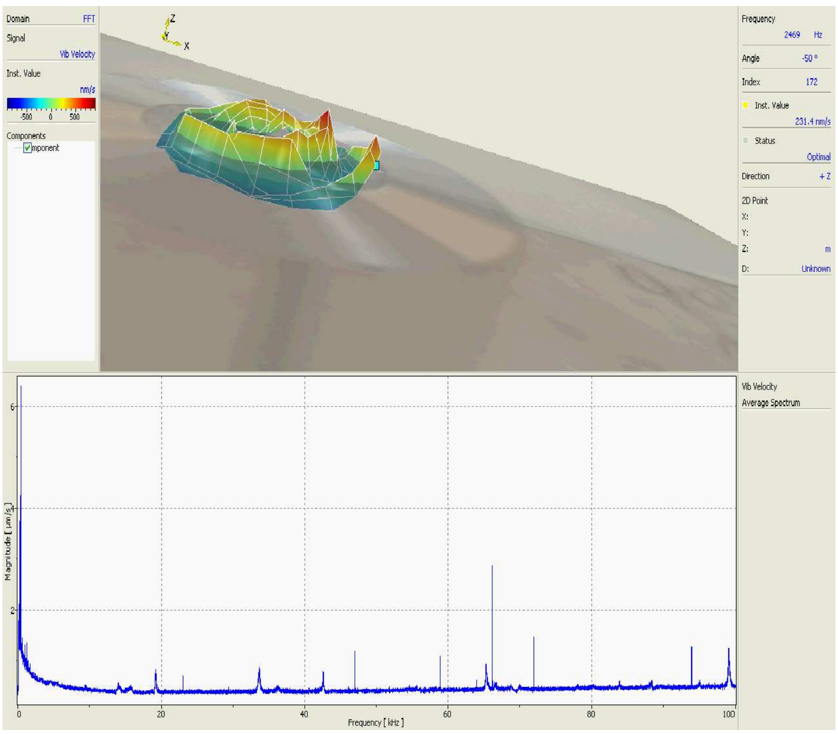
The initial measurements of mechanical vibrations in a layered actuator were performed with a purpose to define the behavior of the output part of the layered actuator excited by the electric vibrations of certain frequency. PSV-400 system includes an integrated generator, which is capable to excite vibrations in a piezo-package. This method of excitation allows simplifying the measurement of extremely low motions, since simultaneous synchronization of the generator and the measurer of vibrations allows eliminating positional changes between the measurer and the object of measurement.

The performance of several measurements of the amplitude movements on the output part of layered actuator on the same moments of a fluctuation period, and the subsequent calculation of the arithmetic mean of measures taken allows more accurate evaluation of a real value of the amplitude. The more measurements, performed on a certain moment of a discrete period, are used for the calculation of the arithmetic mean, there more exact evaluation is obtained.

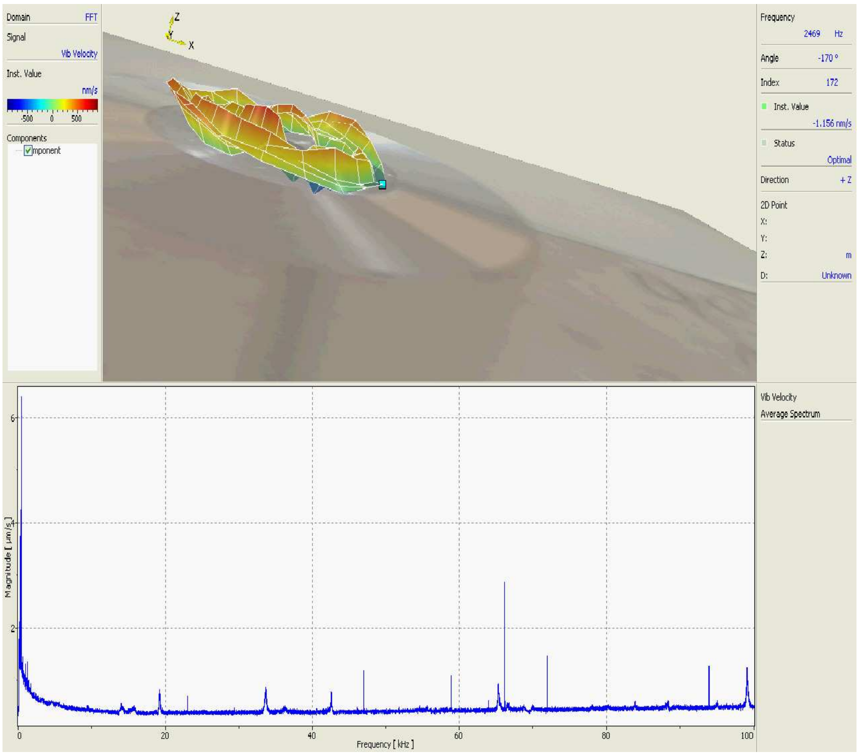
The measurements evaluate the tension of a piezo-package of a layered actuator that influences the amplitude of vibrations. Aiming to evaluate the influence of this factor on vibration amplitude of a layered actuator, persistent measurement of tension in a piezo-package of a layered actuator is necessary. Such measurement may be implemented using holographic measurements analyzed in articles [6-7].



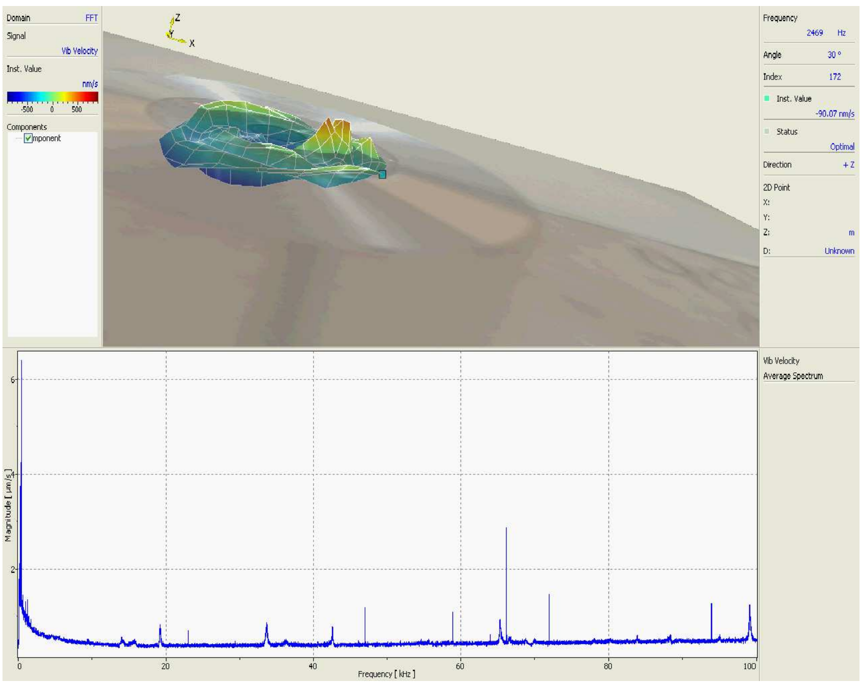
a)



b)



c)



d)

Fig. 5. Images ***a***, ***b***, ***c***, ***d*** of the sequence of measurement

Conclusion

The development and perfection of layered actuators raise many complicated problems for design of various mechanical systems. In the paper mechanical and electrical laws pertaining to the layer of piezostack are analyzed separately and their interrelation is formulated and resolved by a mathematical expression. The experimental investigation of layered actuators has revealed the possibilities to optimize the design and materials for obtaining maximum displacements. Holographic interferometry method and Polytec scanning vibrometer PSV-400 used in the experimental work has strengthened the expressions of differential equations and were used for drawing conclusions of the investigation

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