Modeling of the Piezoelectric Elements Using «Piezo» Solver

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***Abstract* – Article is devoted to check of adequacy of the piezoelectric analysis by the finite-element method for simulation of the ultrasonic vibrating systems. We analyze the distribution of vibration amplitude of the radiating surface of the piezoelectric element. The coincidence of the modeling results to the data obtained by measuring on the stand shows the correctness of the proposed approach.**

***Index Terms* – Modal analysis, piezoelectric analysis, piezoelectric element, vibration amplitude.**

I. INTRODUCTION

AT PRESENT at the development of the ultrasonic equipment CAE systems are widely used. In particular for the calculation and the design of the piezoelectric vibrating systems the modal analysis realized by the packet Ansys Workbench is applied. In spite of all advantages of the modal analysis it has some disadvantages caused by the impossibility to take into account a number of influencing parameters and factors. Firstly the use of such parameters as Young modulus, Poisson ratio and material density of the parts of the ultrasonic vibrating system is insufficient for the calculation of proper resonance frequency and distribution of mechanical vibration amplitude. Secondly the system is intended for the calculation of standard one-packet transducers that leads to the increase of calculation errors at the modeling of multi-packet and multi-element ultrasonic vibrating systems. Thirdly the parameters of the piezoelectric elements ($[S_E]$, [d], $[\varepsilon_T/\varepsilon_0]$) are not taken into consideration. Thus, there is a need to search other set of instruments, which allows eliminate mentioned above disadvantages.

II. MAIN PART

The analysis of the possibilities of modern CAE-systems allows determine, that among the solvers of the packet Ansys Workbench there is a "piezo" module, which lets take into account the interaction of electric and mechanical fields, i.e. it is able to consider the effect of the piezoelectric properties of the materials on the parameters of the piezoelectric transducers. It lets study distribution of vibration amplitudes of various constructions of the piezoelectric systems at the application of electric voltages of certain frequency [1,2].

The adequacy of earlier used modal analysis at the modeling of the ultrasonic vibrating systems was considered in the papers [3,4]. The analysis of the systems by "piezo" module was never carried out before; its functional possibilities are unknown and require the study.

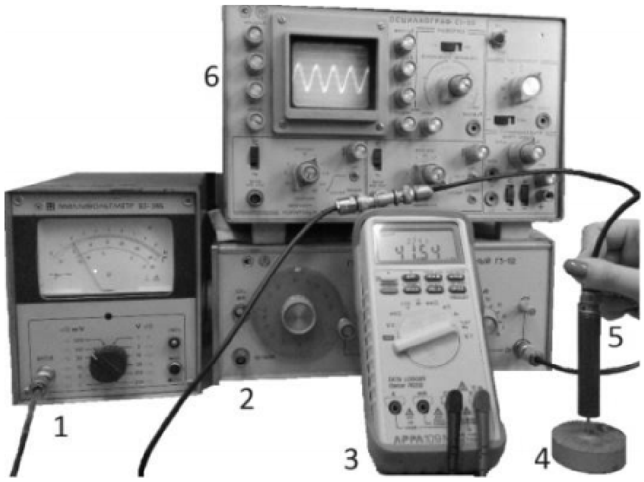
The solution of the stated task should be divided in several stages: modeling of the several piezoelectric elements; modeling of Langevin transducer consisting of some piezoelectric elements between frequency-lowering covers; modeling of the piezoelectric ultrasonic vibrating systems ready-assembled (Langevin transducer, booster, concentrator, working tool); modeling of the piezoelectric ultrasonic vibrating systems with the applied acoustic load. The article is devoted to the results of the first stage realization.

The procedure at the application of "piezo" solver of Ansys Workbench is carried out in a following way.

First of all the solid model of the piezoelectric element is designed, for instance, by CAD-system. Then developed model is exported to the solver. Further the piezoelectric matrixes describing chosen piezoelectric material and polarization direction are set. In conclusion the potentials are applied to positive and negative electrodes and the frequency of supplied voltage is specified.

The cylinder with the diameter of 50 mm and height of 15 mm made of the piezoelectric material LZT-19 is taken for the modeling. The cylinder is polarized in height.

With the help of the test bench shown in Fig. 1, several resonance frequencies of the developed piezoelectric element, which are 41410 Hz and 87590 Hz, were measured.



1 – a millivoltmeter; 2 – a generator;3 – a frequency meter; 4 –piezoceramics; 5 – a piezoelectric probe; 6 – oscillograph

Fig. 1. Measuring test bench.

Fig. 2 and Fig. 3 show the results of modeling of vibration amplitude along the Z axis of developed piezoelectric element obtained by the "piezo" solver of the packet Ansys Workbench.

The distributions of vibration amplitudes of the radiating surfaces of the piezoelectric element at specified frequencies were measured additionally by the measuring test bench shown in Fig. 1. Comparative normalized graphs are presented in Fig. 4 – Fig. 7. Dotted line shows the results obtained from the measuring test bench, and continuous line is the result of the modeling.

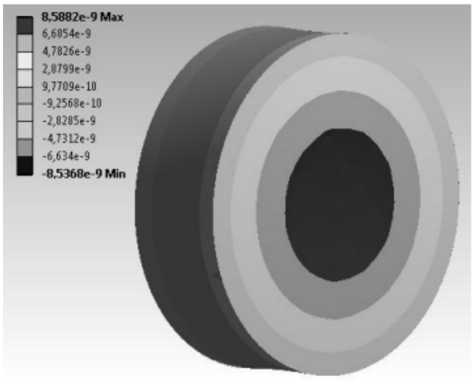


Fig. 2. Distribution on the frequency of 41410 Hz

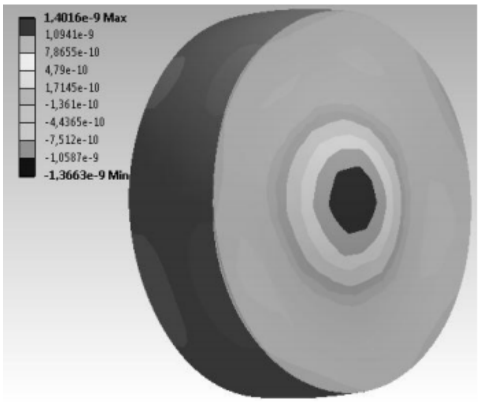


Fig. 3. Distribution on the frequency of 87590 Hz

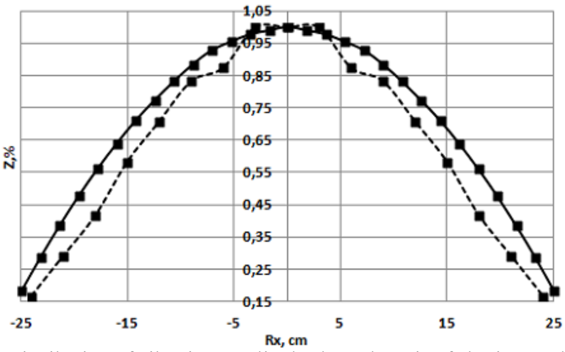


Fig. 4. Distribution of vibration amplitude along the axis of abscissa at the frequency of 41410 Hz.

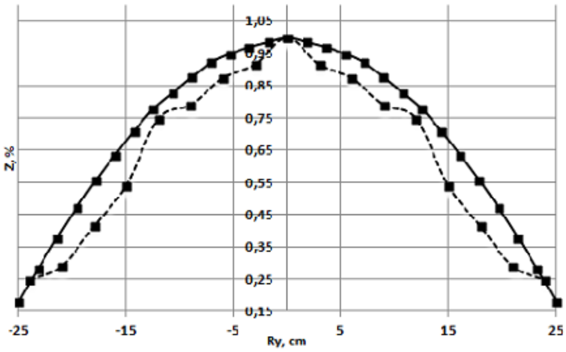


Fig. 5. Distribution of vibration amplitude along the axis of ordinates at the frequency of 41410 Hz.

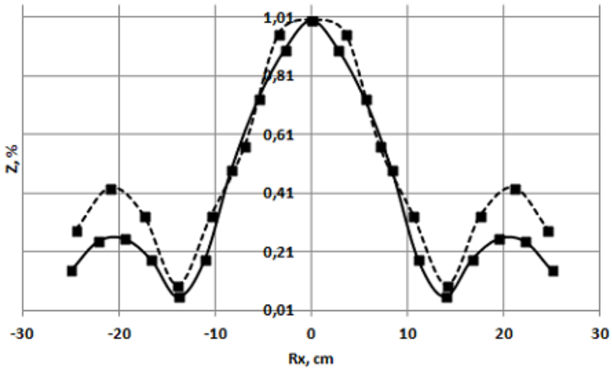


Fig. 6. Distribution of vibration amplitude along the axis of abscissa at the frequency of 87590 Hz.

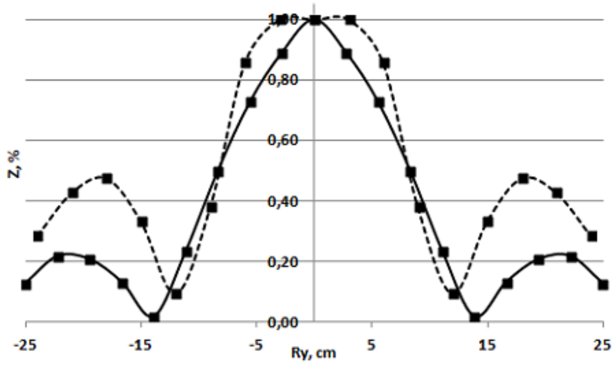


Fig. 7. Distribution of vibration amplitude along the axis of ordinates at the frequency of 85790 Hz.

At the analysis of the curves shown in graphs it can be concluded, that the results of modeling and measured data are very close.

III. CONCLUSION

At the solution of stated task the possibility of application of the “piezo” solver of the Ansys Workbench packet for the modeling of the ultrasonic vibrating system was considered. It was proved, that mentioned above solver can be used for the modeling of the distribution of piezoelectric element amplitudes at its excitation at the specified frequencies.

REFERENCES

[1] Senousy, Mohamed W., Piezoelectricity in ANSYS Mechanical, Say Goodbye to Command Snippets, accessed February 04, 2015, http://www.ansys-blog.com/piezoelectricity-ansys-mechanical-say-goodbye-command-snippets.

[2] Mityok, V.N., Fluctuations of piezoelectric bodies of final elements, V.N. Mityok, Rostov-on-Don:2009.

[3] Khmelev V.N., Levin S.V., Lebedev A.N., Tsyganok S.N. High power ultrasonic oscillatory systems В сборнике: 2007 8th Annual International Workshop and Tutorials on Electron Devices and Materials, EDM'07 - Proceedings 2007 8th Annual International Workshop and Tutorials on Electron Devices and Materials, EDM'07. sponsors: Russian Foundation of Basic Researches (RFBR). Novosibirsk, 2007. С. 293-298.

[4] Khmelev V.N., Lebedev A.N., Tchyganok S.N., Barsukov R.V. Designing and efficiency analysis of half-wave piezoelectric ultrasonic oscillatory systems // В сборнике: 6th Annual International Siberian Workshop and Tutorials on Electron Devices and Materials, EDM 2005 sponsors: Novosibirsk State Technical University, Institute of Semiconductor Physics SB RAS, Biysk Technological Institute, IEEE NSTU Student Branch, IEEE Russian Siberian Section. Erlagol, Altai, 2005. P. 82-85.

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