Modeling of Piezoelectric Transducers Made of PZT-based for Energy Harvesting

Jacek Golebiowski, Przemysław Bakolik
Technical University of Lodz, Department of Semiconductor and Optoelectronics Devices
211/215 Wolczanska Street , 90-924 Lodz, Poland

Introduction: The analysis consists of usefulness of commercial ceramic PZT transducers to power electronic systems. Systems, which recover electrical energy for example from mechanical energy vibrations are increasingly applied to power sensors and measurement setups[1]. The simple and cheap construction of transducers based on ceramics PZT can be effectively used to recover energy from mechanical vibrations[2, 3]. This work shows the applicability of Comsol Mutliphysics environment to model and simulate transducers in various operating conditions. Fig. 1 shows the construction of the station with piezoelectric transducer and electromagnetic coil used to force vibrations . The result of modeling deflection surface shown in figure 2.

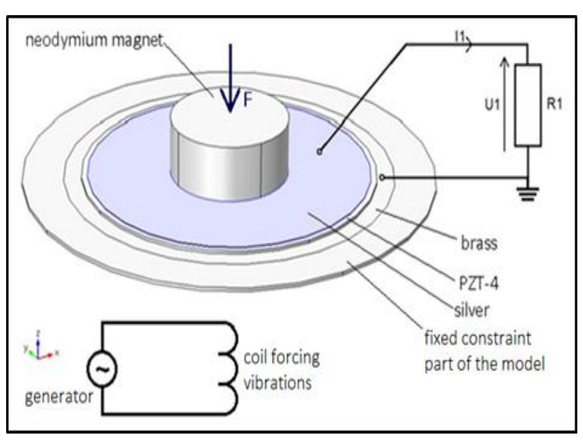

Figure 1. Schematic of the construction with PZT transducer

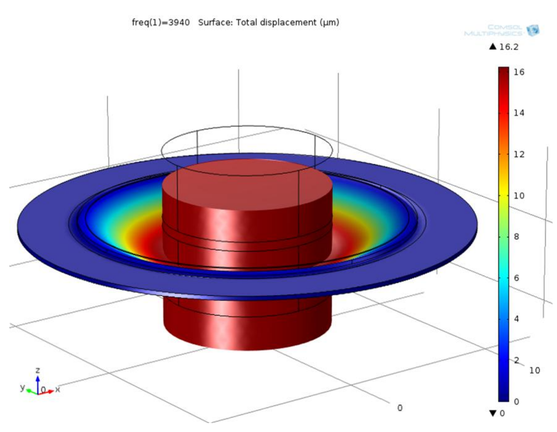

Figure 2. Surface deformations for transducer BZ 23 and force *F* = 1 N

Computational Methods: The electromechanical relations describing the piezoelectric effect can be represented in form of equations:

$$\mathbf{T}=c^{E}:\mathbf{S}-e^{T}\mathbf{E} \quad (1)$$

$$\mathbf{D}=e:\mathbf{S}+\varepsilon^{S}\mathbf{E} \quad (2)$$

where: **T** – stress components, **S** – strain components,
E – electric field components, ε – electric permittivity,
c^E – stiffness coefficients, e – piezoelectric coupling coefficients, **D** – electric displacement components

The material parameters of PZT-4 were taken into account from the COMSOL material library. Parameters of other materials were taken from the website matweb.com. , transmitter dimensions are given in Table 1.

Type of transducer PZT 4	Diameter/ thickness of brass membrane/ [mm]	Diameter/ thickness of PZT [mm]	Diameter/thickness of silver [mm]	Diameter/thickness of neodymium magnet [mm]
BZ 23	27/ 0.25	20/ 0.22	19/ 0.05	10/ 4
BUZZ 35P	31/ 0.25	20/ 0.22	19/ 0.05	10/ 4
BUZZ 35	35/0.25 aluminium	25/ 0.22	19/ 0.05	10/ 4

Table 1. Dimensions layers transducers

Results: As a result of modeling and simulations characteristics of output power have been received for commercial PZT-4 transducer working in resonance conditions (fig2) . The results of the simulation output for different excitations (forces) and various loads are shown in the fig 4,5. Boundary conditions to model the mechanical, rigid fixation on the edge of the membrane (clamping diameters respectively 20, 24, 28 mm for different transducers) and rigid fixation on the surface of the magnet.

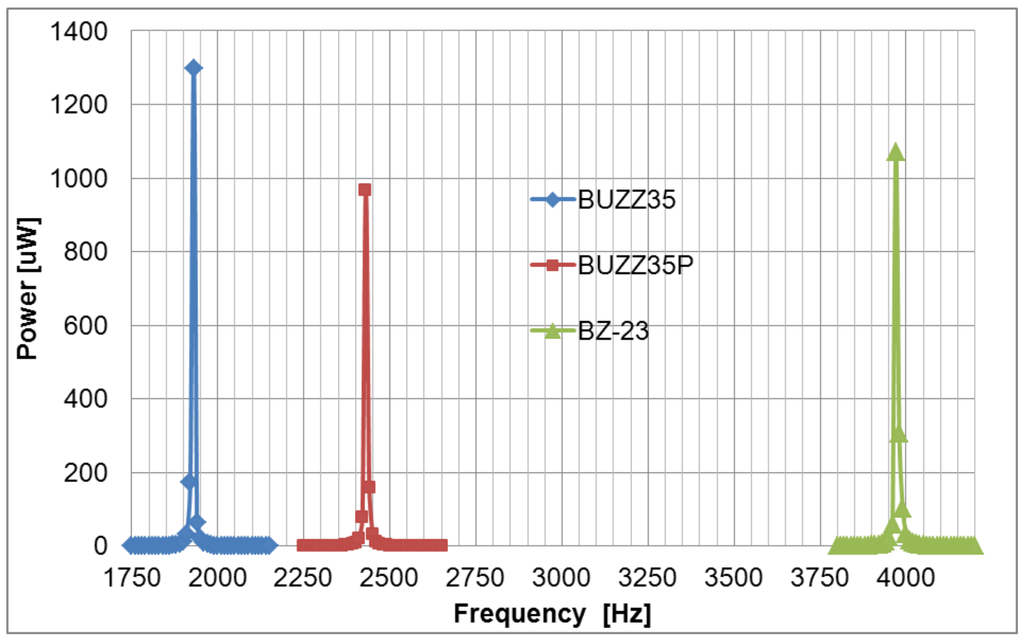

Figure 3. Characteristics of the output power depending on the frequency

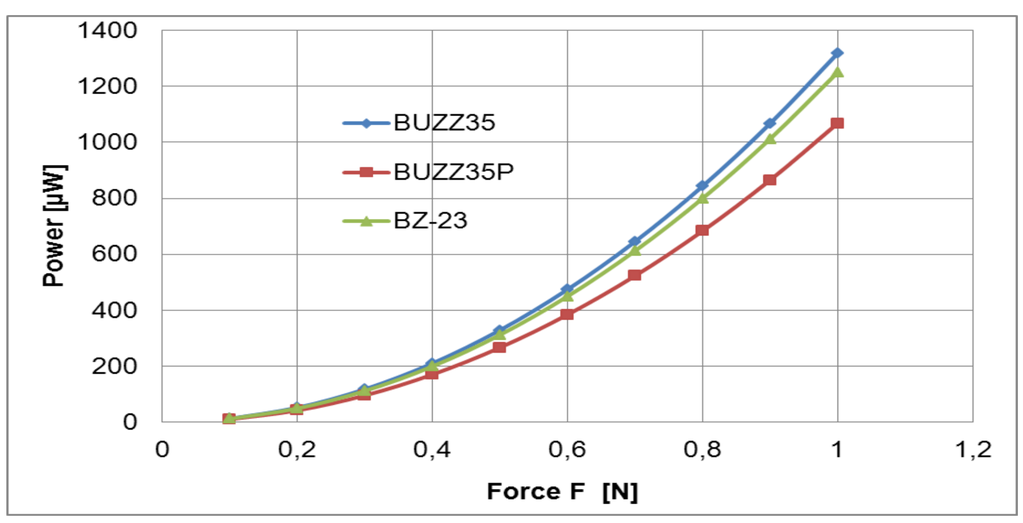

Figure 4. Characteristics of the output power depending on the forces at a constant load conditions resonance

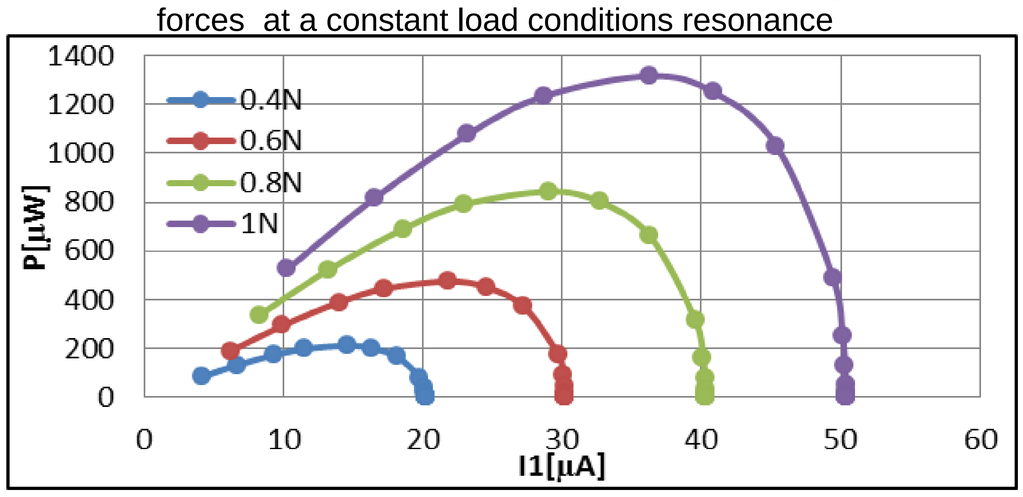

Figure 5. Characteristics of the output power depending on the load current for different *F* forces (BUZZ35)

Conclusions: The results of modeling shows, that it is possible to use cheap commercial transducers based on PZT to power electronic systems, for example measurement ones. Maximum values of the power were reached in resonance conditions (basic mode). The values of the power depend on constraint conditions. Maximum power rises with the increase of the vibration frequency and the mass of piezoelectric. Experimental results vary from the results of modeling, which is caused by the inaccuracy of parameters given by producer (the tolerance is about 20%) and troubles in fulfillment of boundary conditions during the experiment.

References:

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[2] S.P. Beeby, M.J. Tudor, N.M. White, Energy harvesting vibration sources for microsystems applications, Meas. Sci. Technol., Vol.17, pp 175-195, 2006
[3] A. Khaligh, P. Zeng, C. Zheng, Kinetic energy harvesting using piezoelectric and electromagnetic technologies-State of the art, IEEE Transactions On Industrial Electronics, Vol.57, pp 850-860, 2010