Spherical Piezoelectric Drive

kaunas university of technology
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Introduction

Piezoelectric drives are well-known and wide-spread devices, used for various applications. These drives consists of piezoelectric actuator which converts electric into mechanical movement and mechanical part, which transfers mechanical movement to other elements. A piezoelectric actuator converts an electrical signal into a precisely controlled physical displacement. The precise movement control afforded by piezoelectric actuators is used to finely adjust machining tools, lenses, mirrors, or other equipment, act as a small-volume pump or special-purpose motor.

The idea and aim of spherical piezoelectric drive is develop a mechanism which could combine simple mechanical setup with minimum quantity of necessary components. This drive could be used in various applications, where small and precise control is needed, i.e. space industry, laser and beam control mechanisms, orientating an position control.

Mechanical Setup

Mechanical part of this drive is described further: sphere-shaped rotor inserted between two piezoelectric actuators (Fig.1). These ring-shaped piezoelectric actuators have polarization in axial direction and one of the electrodes is divided into three equal sectors. Each segmented electrode is excited by separate harmonic signal. All three electrodes can be excited independently i.e. three channels generator is used to drive actuator. Amplitude and duration of the applied signal depends on rotation velocity and motion trajectory of the sphere. The out-of-plane bending and radial vibrations of the piezoelectric rings are excited to obtain elliptical motion of the contacting points and to rotate sphere in desired direction. In addition, it must be mentioned that actuator can be driven by burst type signal in order to achieve positioning of the sphere with very high resolution.

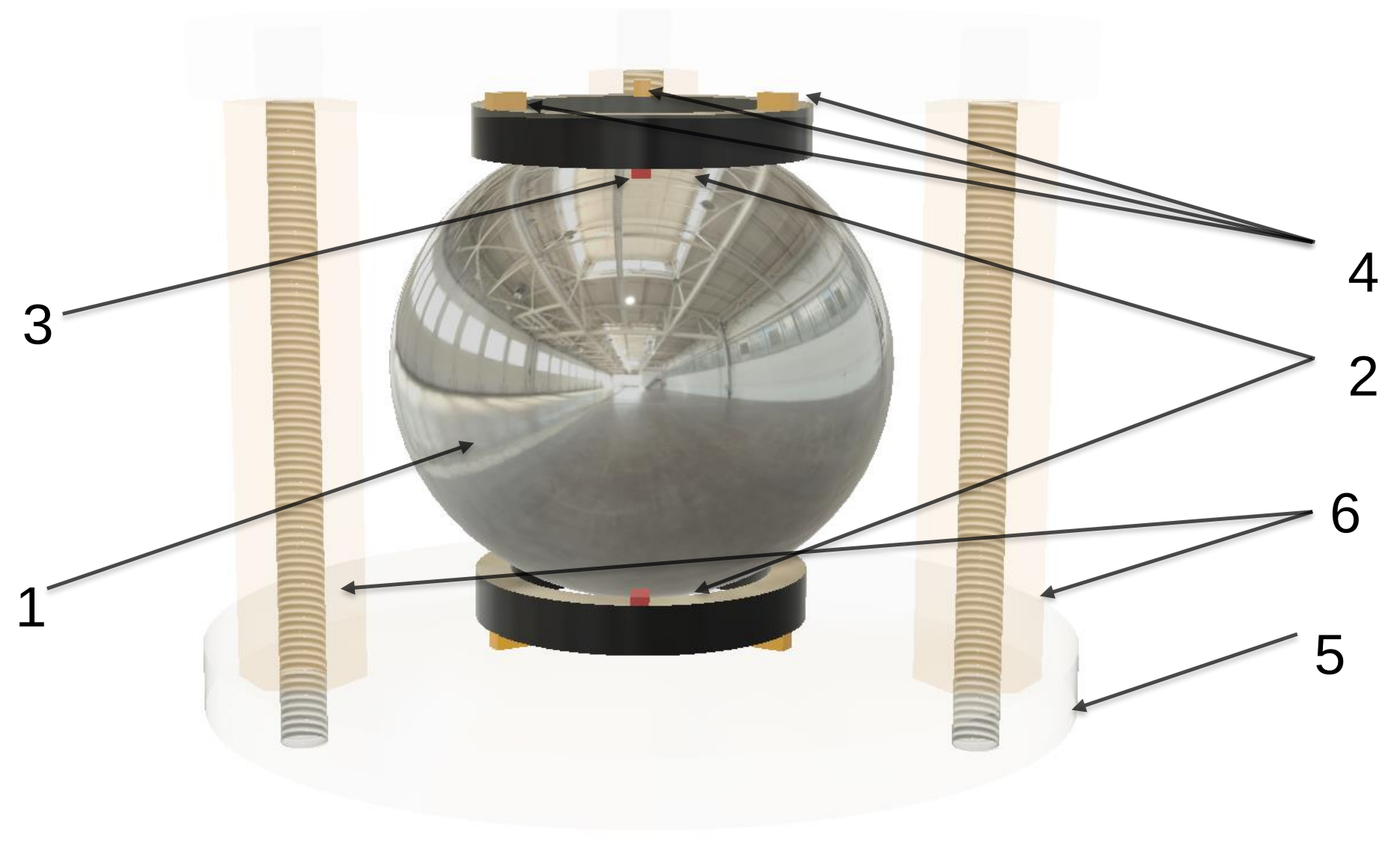

Fig. 1. 1- sphere-shaped rotor; 2 – piezoelectric actuators; 3- contact elements; 4-elastic spacers; 5 – flanges. 6 –clamping bolts

Material properties

For modelling, simulation and real experiments PZT-4 piezoceramics was chosen. The dimensions of piezoelectric actuator are OD - 20 *mm;* ID – 15 *mm;* H – *3 mm.* Properties for this material are represented in table below:

Material Property	Piezoceramics PZT-4
Young Modulus M/m^2	7.8
Poisson coefficient	0.31
Density kg/m^3	7500
Dielectric permittivity x10^3 F/m	ε_{11} = 1.48, ε_{22} = 1.48, ε_{33} = 1.3
Piezoelectric coupling matrix 10^{-12} C/N	d_{31} = -123, d_{32} = -123, d_{33} = 289, d_{24} = 496, d_{15} = 496
Compliance matrix, 10^{-12} m^2 /N	c_{11}= 12.3, c_{21} = -4.05, c_{31} = -5.31, c_{22} = 12.3, c_{32} = -5.31, c_{33} = 15.5, c_{44} = 39, c_{55} = 39, c_{66} = 32.7

Numerical Simulations and Experiments

Some numerical simulations and real life experiments were executed. The aim of these simulations and experiments was to determinate the resonance modes and deformation shapes in which piezoelectric actuator vibrates when electric signal is applied. Real life experiments were executed in laboratory using scanning laser vibrometer.

Numerical Simulations

Modal and harmonic response studies were executed. Harmonic response studies analyze how piezoelectric actuator behaves when one segment is exited by harmonic signal. Full range scanning was executed and the results shown two peak ranges a~ 68 kHz and 92 *kHz,* where the actuator behaves and deforms in necessary (rectangular or triangle) 3D shapes. Sample of deformations is shown in Fig. 2.

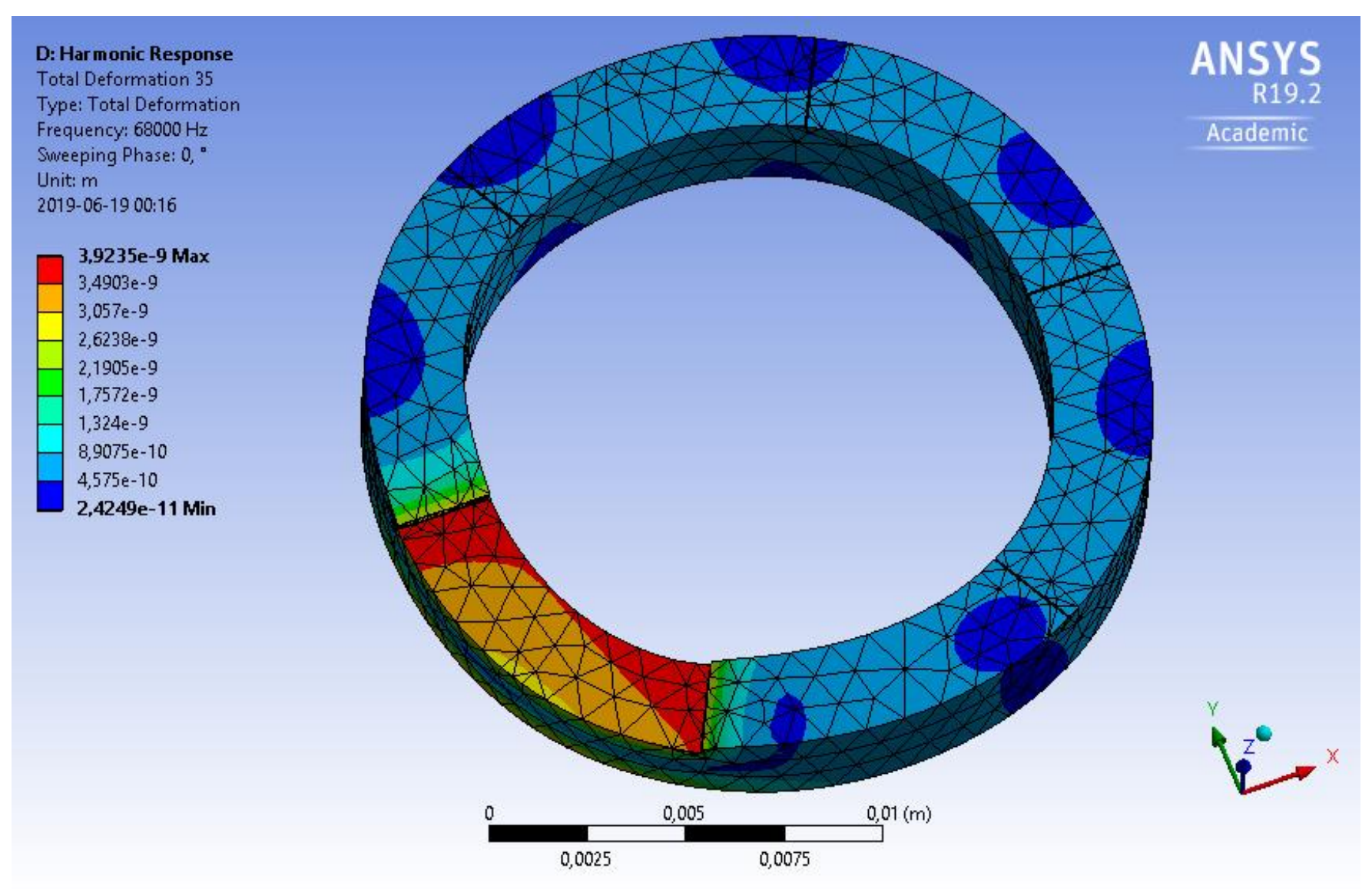

Fig. 2. Sample of deformations of piezoelectric actuator. 3,925 *10^{-9} *m* @ ~68 *kHz*.

Frequency response analysis

Frequency response analysis was executed experimentally using scanning vibrometer. Two resonance frequencies were found at ~66 and 92 kHz. Results of these experiments are represented in Fig. 3-6.

Fig. 3. Deformation mode of the piezoelectric ring at the operational frequency of ~65 *kHz*

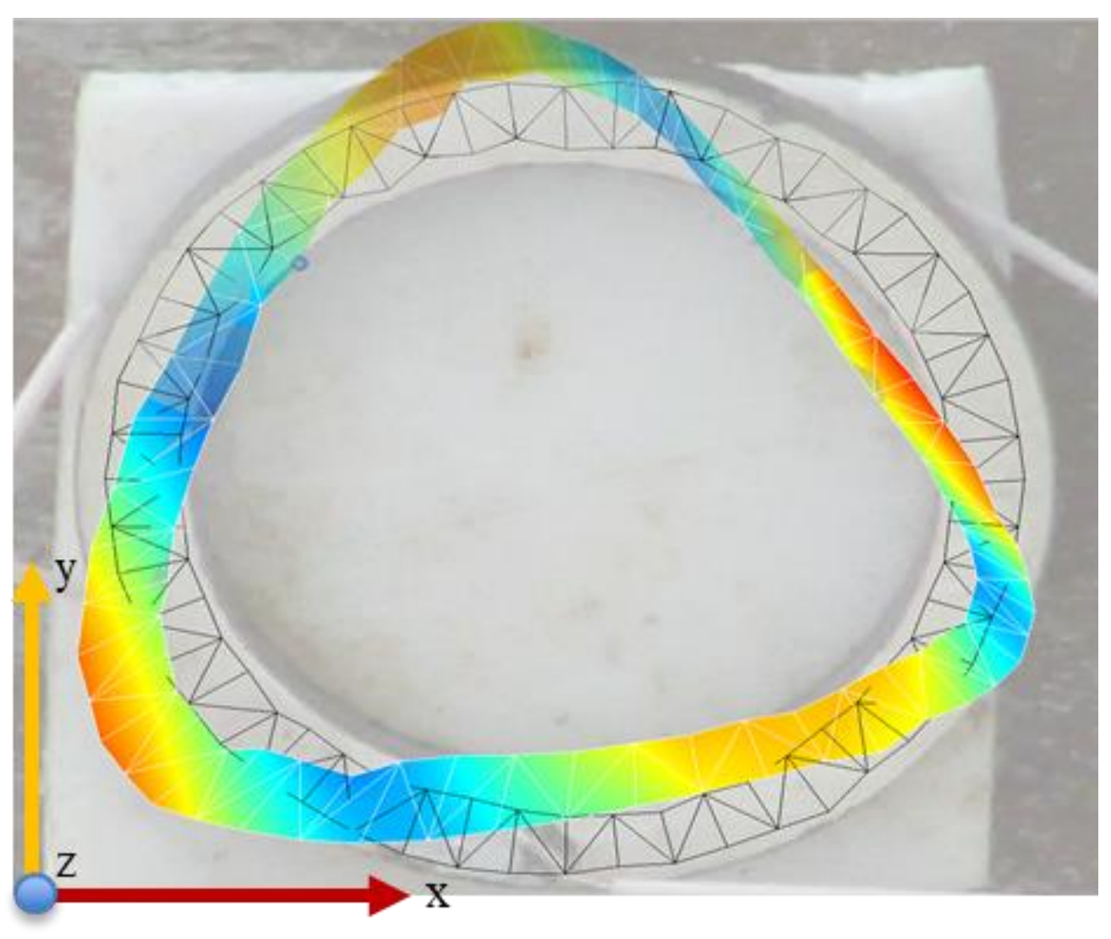

Fig. 4. Deformation mode of the piezoelectric ring at the operational frequency of ~92 *kHz*

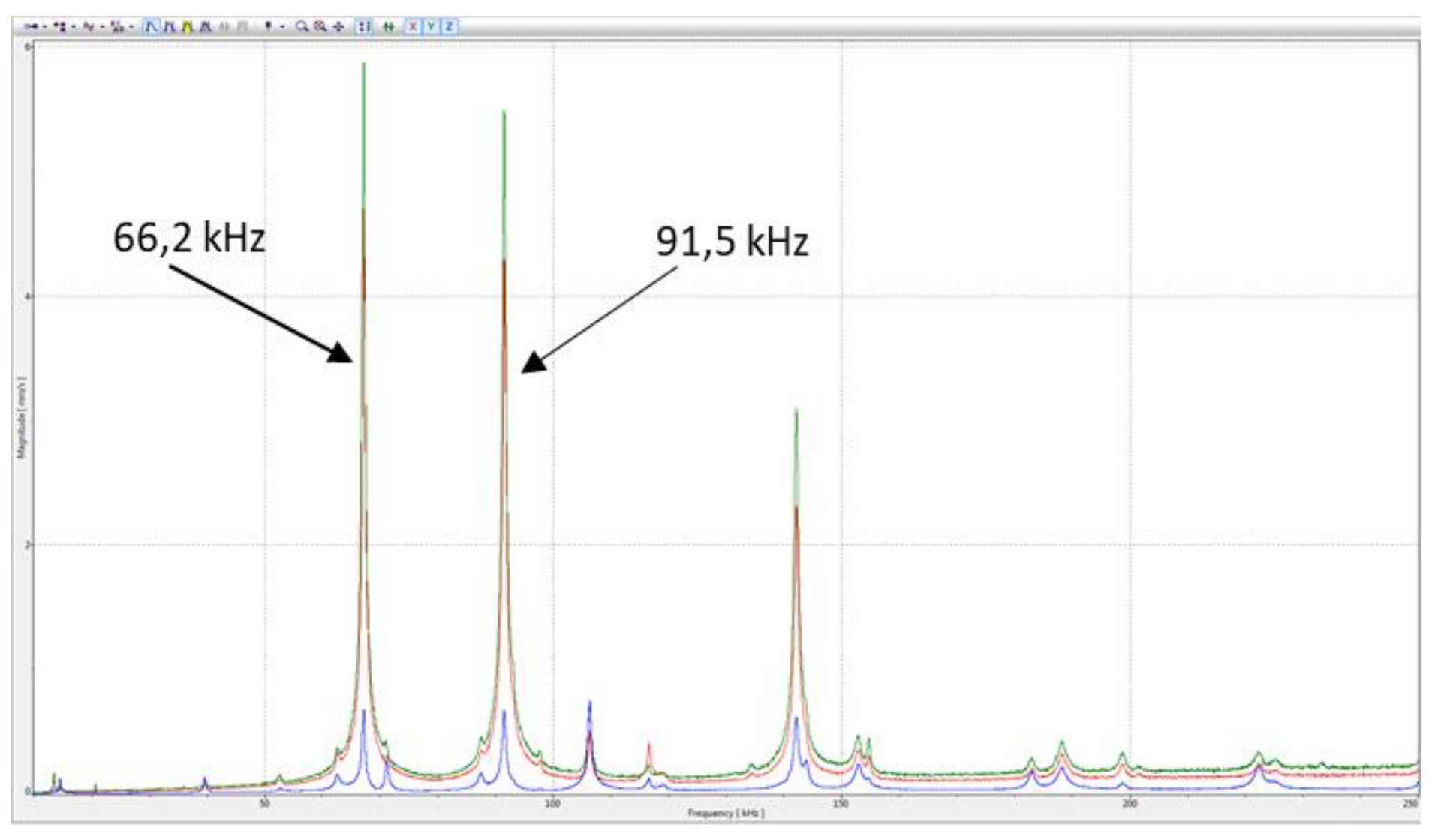

Fig. 5. Frequency response of investigated piezoelectric ring-shaped actuator.

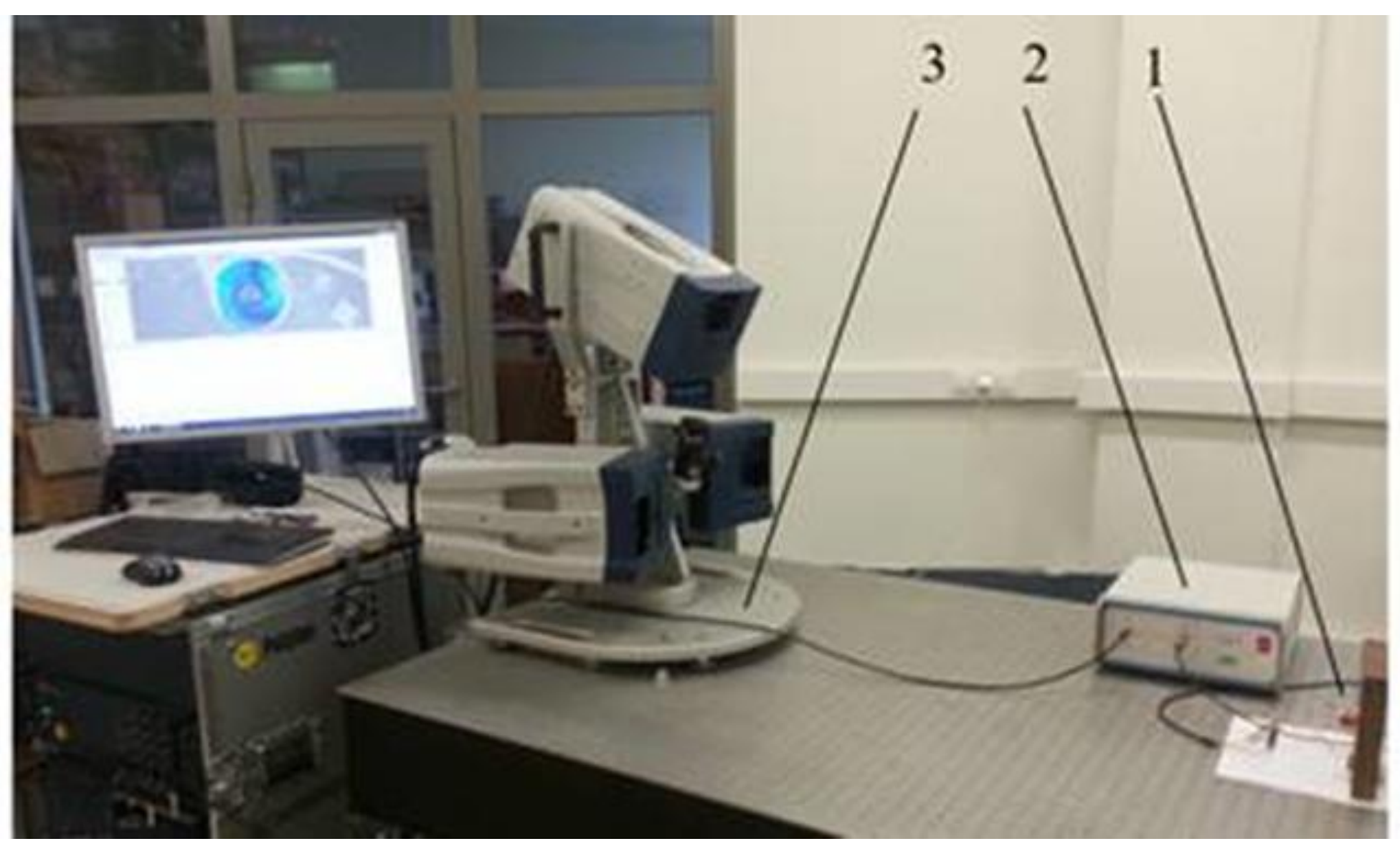

Fig. 6. Experimental setup for frequency response of the piezoelectric actuator: 1 – piezoelectric actuator; 2 – liner amplifier P200; 3 - 3D scanning vibrometer PSV-500-3D-HV

Conclusions

A novel design of spherical piezoelectric drive was represented. This drive consists of two piezoelectric actuators and spherical rotor. When harmonic burst-type electric signal is applied, piezoelectric actuators deforms in necessary shapes and generates rotational motion of the spherical rotor with very high resolution.

For calculations and real life experiments PZT-4 piezoceramics was chosen. Numerical simulations were executed with the purpose to find out resonance frequencies and vibration modes of the piezoelectric actuator which generates 3D rotational motion of the spherical rotor. These calculations shown that exists two resonant frequencies at ~68 and ~92 kHz, which were verified experimentally using scanning laser vibrometer and shown, that the frequencies of ~65 and ~92 *kHz* are operational frequencies of the developed piezoelectric drive.

Biography

G. Kazokaitis

Grazvydas Kazokaitis has experience in design and R&D fields developing small and precise mechanisms for ultra-fast laser beam control and machining apparatus. This experience allows provide solid foundation and knowledge creating possible solutions for laser beam orientation mechanisms between small units in space, attitude control and other control tasks.

prof. dr. V. Jurenas

Vytautas Jurenas is senior researcher in Kaunas University of Technology. The main areas of R&D are dynamics and diagnostics of mechanical systems. His research interests include piezomechanics and its application in hi-tech mechatronics.

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