869. R&D of the device for blind to conceive 2D graphical information

R. Bansevičius[1], **E. Dragašius**[2], **D. Mažeika**[3], **V. Jūrėnas**[4], **I. Skiedraitė**[5], **A. Žvironas**[6]
Kaunas University of Technology, Kaunas, Lithuania
E-mail: [1]*ramutis.bansevicius@ktu.lt*, [2]*egidijus.dragasius@ktu.lt*, [3]*darius.mazeika@ktu.lt*, [4]*vytautas.jurenas@ktu.lt*, [5]*inga.skiedraite@ktu.lt*, [6]*arunas.zvironas@ktu.lt*

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Abstract. Miniature piezoelectric thimble is described and investigated, based on friction control between PC screen and thimble's contacting surface. The contours of the image on PC screen switch on and off harmonic or non-harmonic electric signals, connected to the electrodes of bimorph piezoelectric transducer, generating bending deformations, affecting friction coefficient. While scanning the PC screen in two directions, these periodic variations of friction coefficient result in oscillations of the fingertip, related to the color or intensity of the image components on the screen. Another three cases of pin's oscillations normal to finger contacting surface are described.

Keywords: piezoelectric actuator, blind person, graphical information, friction coefficient.

Introduction

Over 40 million people in the world are blind, and over 120 million people have significant low vision conditions that cannot be corrected, cured or treated by conventional refraction, medicine or surgery. This number is expected to double by the year 2020 [1]. Their integration into society is primary task and we could mention here various means, partially helping this integration: the money marking, installed audible pedestrian crossings, special paving at pedestrian crossings, Braille, blind stick, etc. But the rapid development of information technologies makes it possible to create more advanced support tools to facilitate the blind and visually impaired people [2-6]. In a system, described in [3], the blind can examine the colors and the graphic figures, constructing the screen graphics. The system can extract several combinations of colors from the whole graphics selectively.

In the Manual, based on the work done at the Netherlands Library for Audio Books and Braille [4], it is emphasized that in creating graphics for the blind one has to take into account that the fingers' discerning ability is so much less than the eyes'. For instance, while the seeing person will generally have an overview of a picture at first glance, the blind reader has to go through most of the details in a picture to understand what it's all about. Similar objective of research, done in [6], was to maximize not only accessibility but also user comprehension of web pages, particularly those containing tabular and graphical information.

1. Piezoelectric thimble with controlled friction

When compared with similar electromagnetic device [7], piezoelectric transducers ensure higher speed and can be realized with smaller overall dimensions. Piezoelectric disc actuator (Fig. 1) works in bending mode [8] and may develop significant displacement and force, as well as the high bandwidth.

The displacement of the unimorph in response to an applied voltage is many times greater than the corresponding displacement of a single piezoelectric plate, in case when introducing built-in levers to provide much greater displacements, but less force, than single plates. The displacement of the disk center of the piezoelectric unimorph type actuator with clamped edges is given by [8]:

$$\Delta y = 0.45 d_{31} V (D/h)^2 \tag{1}$$

where d_{31} – transversal piezoelectric coefficient; V – applied voltage; D and h – diameter and thickness of disk type piezoelectric actuator. In the case of a bimorph actuator, when two layers of piezoceramic are active, the displacement of the disk center will be increased and is given by:

$$\Delta y = 0.75 d_{31} V (D/h)^2 \tag{2}$$

Unimorph's flexural vibration is stimulated through the converse piezoelectric effect in PZT ceramics and transferred to the metallic membrane through the joining layer.

Fundamental resonant frequency (first flexural mode) of isotropic circular membrane, clamped at the edge, is:

$$f_{rfx} = \frac{2.03\pi h \left(E/3\rho\left(1-v^2\right)\right)^{-2}}{D^2} \tag{3}$$

where E and v are Young's modulus and Poisson coefficient, ρ is membrane density.

Fundamental resonant frequency for plane-extension vibrations of PZT disc is:

$$f_{rex} = \frac{a\left(1/\rho_p\left(1-v^2\right)s^{E_{11}}\right)^{-2}}{\pi d_p} \tag{4}$$

where a – numerical factor, depending on vibration mode; $s^E{}_{11}$ – elastic compliance of PZT ceramic; ρ_p – PZT ceramic's density; d_p – PZT disc diameter.

Fundamental resonant frequency for unimorph is smaller than the resonant frequency of the membrane and much smaller than the frequency of planar PZT disc vibrations.

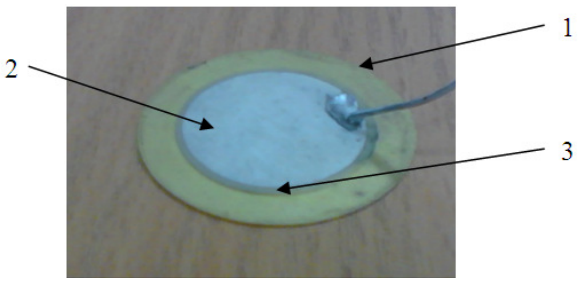


Fig. 1. Disc actuator (unimorph): 1 – bronze plate, 2 – electrodes, 3 – piezoceramic layer

The information to the blind operator can be transferred by several approaches, taking into account the specifics of rheological parameters and sensitivity of fingertips and direction of generated oscillations:

1. By tangential oscillations (equivalent to Braille effect), induced by friction control between PC screen and thimble's contacting surface. The contours of the image on PC screen switch on and off harmonic or non-harmonic electric signals, connected to the electrodes of bimorph piezoelectric transducer, generating bending deformations, affecting friction coefficient. While scanning the PC screen in two directions, these periodic variations of friction coefficient result in tangential oscillations of the fingertip, related to the color or intensity of the image components on the screen.
2. By oscillating the pin, interacting with the finger pad, while the vector of oscillation is perpendicular to the surface of finger pad.

3. By oscillating the body of a disc actuator. When the piezoelectric actuator exposed to a variable electric field, it vibrates the plate with attached mass element and the generated oscillations are transmitted to the finger.
4. By oscillating the plate using periodic impacts. In this case piezoelectric actuator, exposed to a variable electric field, is fixed to needle, impacting plate. The plate begins to vibrate on its own frequency and interacts with the finger pad by irritating it.

2. Selection of friction materials in the contact area between thimble and PC screen

During this research four materials with different friction coefficients were tested: paper, hard rubber, soft rubber, polyurethane coating. As piezoelectric thimble will work on a touch-sensitive PC screen, paper (in case of maps) and plastics, the frictional interaction was tested on these surfaces. The test device was designed with the ability to investigate different friction materials on the different surfaces (Fig. 2a).

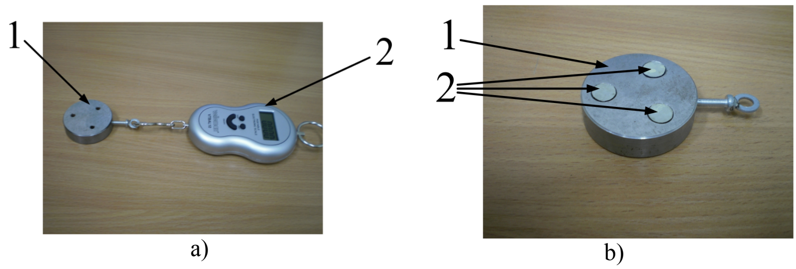


Fig. 2. Measurement of friction coefficient: (a) 1 – friction measuring device, 2 – the force measuring device; (b) 1 – loading element, 2 – friction elements

The experimental device is composed of the loading element, which is contacting on three points with the surface through test material elements and of the force measuring device (Fig. 2b). During research the force measuring device was pulled at a constant speed and the maximum value of the friction force was recorded. The experiment with chosen friction material was carried out 20 times, and the average value was found from received results. The test results are listed in Table 1.

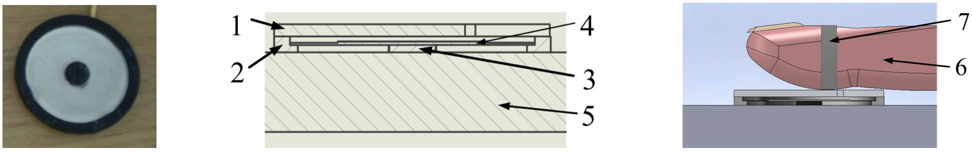
Table 1. Measured friction force

Material	Friction force, when interact with paper, N	Friction force, when interact with plastic, N	Friction force, when interact with PC screen, N
Paper	0.402	0.344	0.706
Hard rubber	1.326	1.260	1.330
Soft rubber	1.472	1.373	1.470
Polyurethane glue	1.444	1.320	1.423

3. Research of piezoelectric thimble with optimal friction element

When friction forces of different materials pairs were established, piezoelectric disc actuator was developed (Fig. 3), which controls the friction in contact zone from 0 (zero gap between the friction element and the screen) to a maximum value (at the maximum deformation of the piezoelectric actuator). Experimental research was carried out using special test stand (Fig. 4).

During the experiment, piezoelectric disc's deflections were measured with a laser distance meter (for hysteresis measurements of piezoelectric disc, f = 30 Hz were used), and the resonant frequency of the actuator membrane was measured. Experimental research has shown that the maximum frequency of tangential oscillations, conceived by blind operator and triggered by controlling friction in the contact zone, is 250 – 300 Hz, depending on the operator's age, sex and finger's sensitivity.



a) b) c)

Fig. 3. Piezoelectric thimble with friction element: a) photo, b) cross section, c) 3D model. 1 – cover, 2 – plastic ring, 3 – friction element, 4 – piezoelectric disc actuator, 5 – PC screen, 6 – finger, 7 – rubber ring

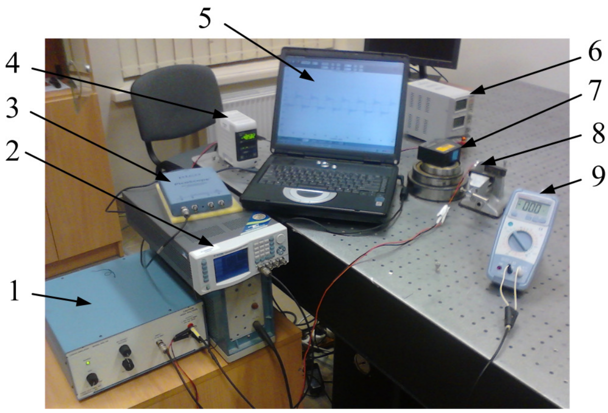
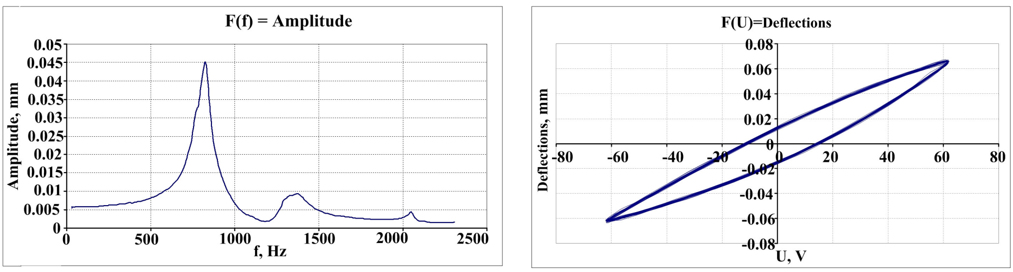


Fig. 4. Test stand: 1 – power amplifier EPA-104, 2 – signal generator WW5064, 3 – analogue-digital converter PicoScope-3424, 4 – controller of laser displacement meter LK-G3001PV, 5 – personal computer, 6 – power supply, 7 – laser displacement meter LK-G82, 8 – piezoelectric actuator, 9 – Mastech 8201H multimeter



a) b)

Fig. 5. Measured characteristics of the piezoelectric actuator: a) amplitude – frequency characteristics of piezoelectric actuator No. 1 (the first resonant frequency f = 816 Hz), b) results of hysteresis measurements when f = 30 Hz

4. Research of piezoelectric thimble with oscillating pin

Second solution was to make direct information transfer to blind people's finger. On the center of piezoelectric disk, pin was attached, realizing contact finger – oscillating pin (Fig. 6b).

In case of a thimble with oscillating pin (Fig. 6) maximum effect was noticed when frequency of the oscillation of the pin was in the area of 200 Hz (Fig. 7). It should be noted here that damping effect by placing the finger on the pin is sufficiently big.

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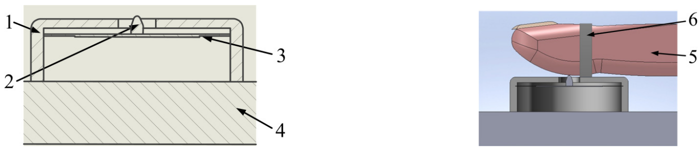

a) b)

Fig. 6. Piezoelectric thimble with a pin: a) cross section, b) 3D model. 1 – body, 2 – needle, 3 – piezoelectric disc actuator, 4 – PC screen, 5 – finger, 6 – rubber ring

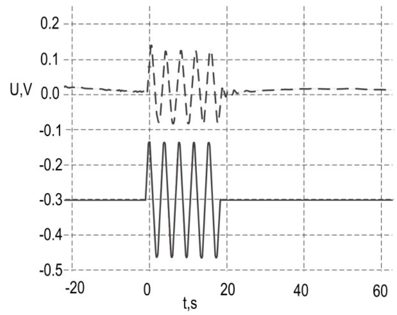

Fig. 7. Characteristics of vibrating pin in normal direction to the contact zone.
Frequency of oscillation – 250 Hz

5. Research of piezoelectric disk actuator with mass

Another solution is to reduce the damping by reducing the first resonant frequency (Fig. 8), which enables to work at resonance (batch harmonic signal mode). This solution is realized by introducing an additional mass, which is attached to piezoelectric transducer and by arranging the contact area with the surface of the actuator.

a) b)

Fig. 8. Piezoelectric disc actuator with mass: a) cross section, b) 3D model. 1 – cover, 2 – plastic ring, 3 – additional element, 4 – piezoelectric disc actuator, 5 – PC screen, 6 – finger, 7 – rubber ring

6. Piezoelectric thimble with periodic impacts

Effective approach is to make periodic impacts affecting directly blind people's finger. The actuator scheme was designed for increasing the oscillation amplitude and realization of quasi-harmonic vibrations with periodic impacts (Fig. 9). This actuator realizes much larger amplitudes of normal oscillations at the contact zone.

a) b)

Fig. 9. Piezoelectric disc actuator with periodic impacts: a) cross section, b) 3D model. 1 – body, 2 – pin, 3 – piezoelectric disc actuator, 4 – metal plate, 5 – PC screen, 6 – finger, 7 – rubber ring

Research was carried out by using all four modifications, during which a finger of blind person had to conceive the effects of four different frequencies. In this research different oscillation frequencies were generated by choice, and the operator, which touched pin or the surface, had to say if he feels or not difference between the frequencies. During the experiment it was established that most comprehensible difference between the frequencies of pin oscillations or actuator's surfaces were when they were oscillated in low frequency range. The four different frequencies: 25 Hz, 50 Hz, 100 Hz and 200 Hz were determined during experiments, which can be distinguished with high reliability by blind operator and can be used as additional information channel for recognizing colors and their intensity of lines and areas.

Conclusion

Four modifications of thimble driven by piezoelectric disc type actuator were designed and tested, using various methods to generate oscillations of the contact zone finger – thimble:

- oscillations, induced by friction control between PC screen and thimble's contacting surface;
- oscillations, induced by the pin, interacting with the finger pad;
- oscillations induced by the body of a piezoelectric disc type actuator;
- oscillations induced by the quasi-harmonic vibrations of the piezoelectric disc type actuator with periodic impacts.

Experiments with the induced oscillations have indicated that in low frequency range (from 25 Hz to 200 Hz) the blind operator with high reliability can feel the effects of four different frequencies: 25 Hz, 50 Hz, 100 Hz and 200 Hz, thus conceiving the color or intensity of various areas of 2D graphical information.

Acknowledgement

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