Chapter 10

Sensitivity and response to temperature changes of selected smart materials

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Abstract
The paper presents research intended to applications of piezoelectric materials to measure the parameters of hand-arm vibration. The measurements take into account both the vibration energy passed into the hand-arms and the working conditions. The following piezo films were selected: DT4-052K/L polyester film with a thickness of 52 microns PVDF, and LDT4-028K with a thickness of 28 microns PVDF. The research of piezoelectric smart materials was based on determining the frequency characteristics of piezo films. The materials were excited without hand-arm system load and using noise signal from the range 2 to 1600 Hz. The sensitivity for different sizes of the piezo films and response time to temperature changes were presented.

Keywords: piezoelectric materials, hand-arm vibration, piezo film sensors

1. Introduction

Piezoelectricity is the charge that accumulates in certain solid materials in response applied mechanical stress. These materials generate an electric charge proportional to that stress. This is called *the direct piezoelectric effect* and it may be used for example to construction of piezoelectric, vibration forces or temperature sensors [1-7].

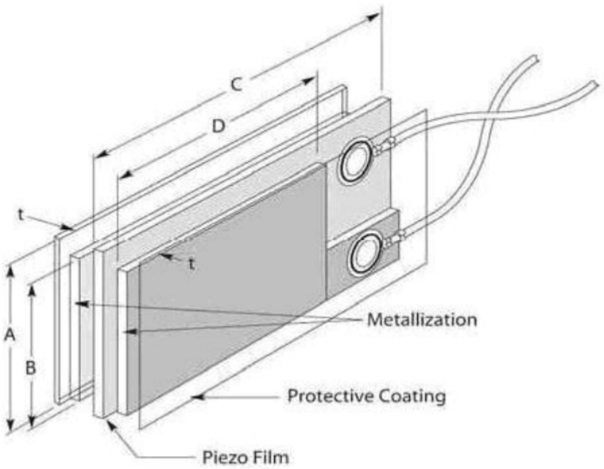
There are many areas where piezoelectric phenomena is used extensively. A dynamic development of new piezoelectric materials has been seen in recent years. One of the most popular piezoelectric material is polyvinylidene fluoride – PVDF [8-10]. PVDF is usually performed in a thin film of thickness from a few to several hundred microns (so-called piezo film). Due to its properties as both PVDF and its copolymers [11] have found applications in many fields, such as the manufacture of underwater acoustic transducers, seismographs, pumps and valves, sensors, traffic, switches. They are also used for nondestructive testing of materials and often in medicine, including the manufacture of artificial muscle, skin, and human organs [1, 12, 13].

Research carried out at CIOP-PIB intended to applications of piezoelectric materials to measure the parameters of hand-arm vibration. These measurements take into account both the vibration energy passed into the hand-arms and the working conditions (forces exerted by the operator of the tool, ambient temperature, personal protective equipment). Practical application of PVDF film as a vibration sensor is involved with their frequency characteristics during exposition to vibration, sensitivity to electromagnetic interferences and the response to temperature variability.

2. Tested objects

The following piezo films from among smart materials available on the market were selected: DT4-052K/L polyester film with a thickness of 52 microns PVDF, and LDT4-028K with a thickness of 28 microns PVDF. The parameters of both piezo films were shown in Table below.

Table. Parameters of selected piezo film sensors



Description	Dimension (mm)				Metalization, µm	Capacitance, nF
	A film	B electrode	C film	D electrode		
DT4-052K/L	22	19	171	156	70	5.70
LDT4-028K	22	19	171	156	205	11.00

Research were carried also with smaller elements: 19 mm × 86 mm and 19 mm × 43 mm. Preliminary tests confirmed the sensitivity of film to interference caused by electromagnetic fields from the vibration exciter and the electrical grid in the laboratory. Application of thin aluminum shield (thickness 0.2 mm) caused 99% elimination of electromagnetic interference. PVC tape was used as an insulating layer.

3. Test method

3.1. Determination of the frequency characteristics

The research of piezoelectric smart materials was based on determining the frequency characteristics of piezo films. The materials were excited without hand-arm system load and using noise signal (PSD 0.1 $(m/s^2)^2/Hz$) from the range 2 to 1600 Hz, which include frequencies analysed in the assessment of exposure to hand-arm vibration at workplace – 5.6 ÷ 1400 Hz. Tests were carried out at ambient temperature 21 ÷ 23°C.

Diagram of the measuring system to determine the frequency characteristics of piezo films without hand-arm system load is shown in Figure 1.

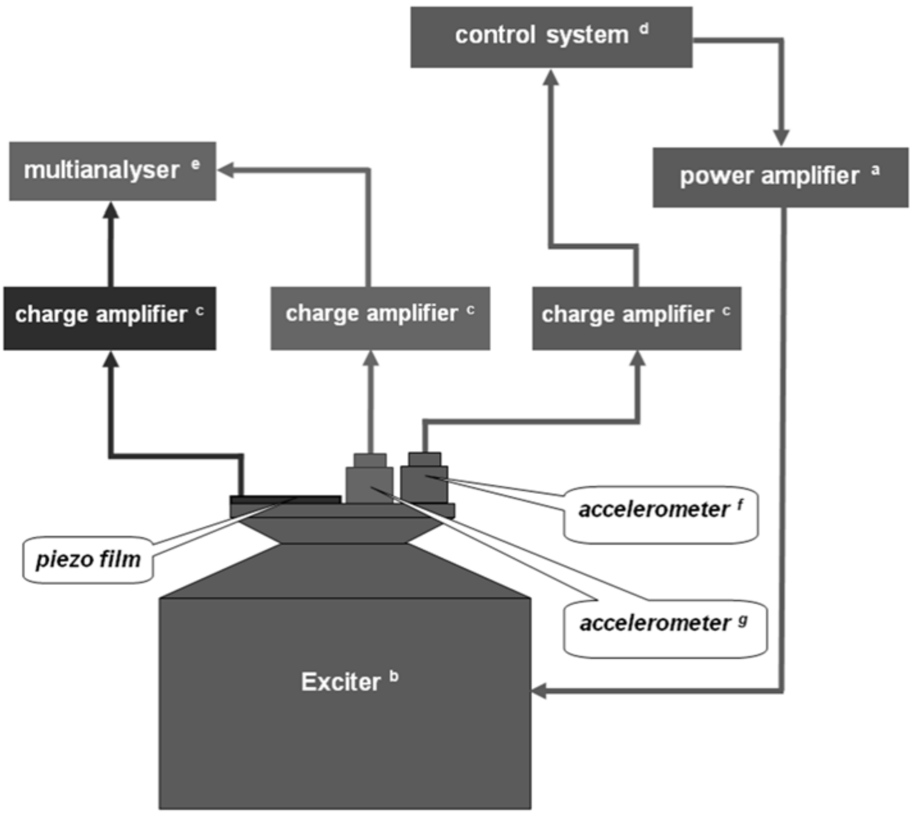


Figure 1. Diagram of the test stand for determining the frequency characteristics of piezo films; a – PA 2000 (LDS), b – V721 (LDS), c – 2626 (B&K), d – VibPilot (M+P International), e – PULSE (B&K), f – 4371 (B&K), g – 4384V (B&K)

The analysis of the recorded signals was performed in the frequency range from 1 Hz to 1600 Hz (with a resolution of 1.0 Hz) using multianalyser PULSE. Frequency characteristics of selected piezo films are shown in Figure 2.

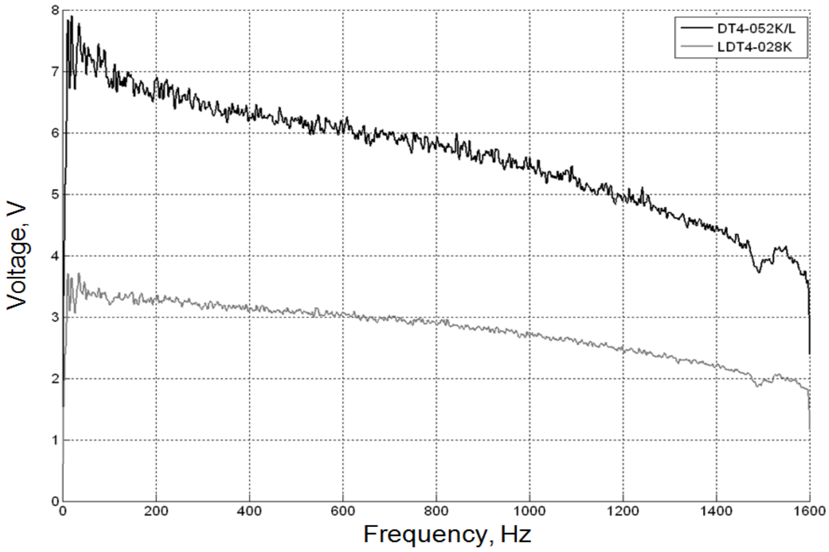


Figure 2. Frequency characteristics of piezo films type LDT4-028K and DT4-052K/L

In order to check how the sensitivity of the piezo film changes when its dimensions are reduced, the frequency characteristics (Figure 3) for piezo film strips with dimensions: 171 mm × 19 mm (complete), 86 mm × 19 mm (a half), 43 mm × 19 mm (a quarter) and the strip folded in half were compared.

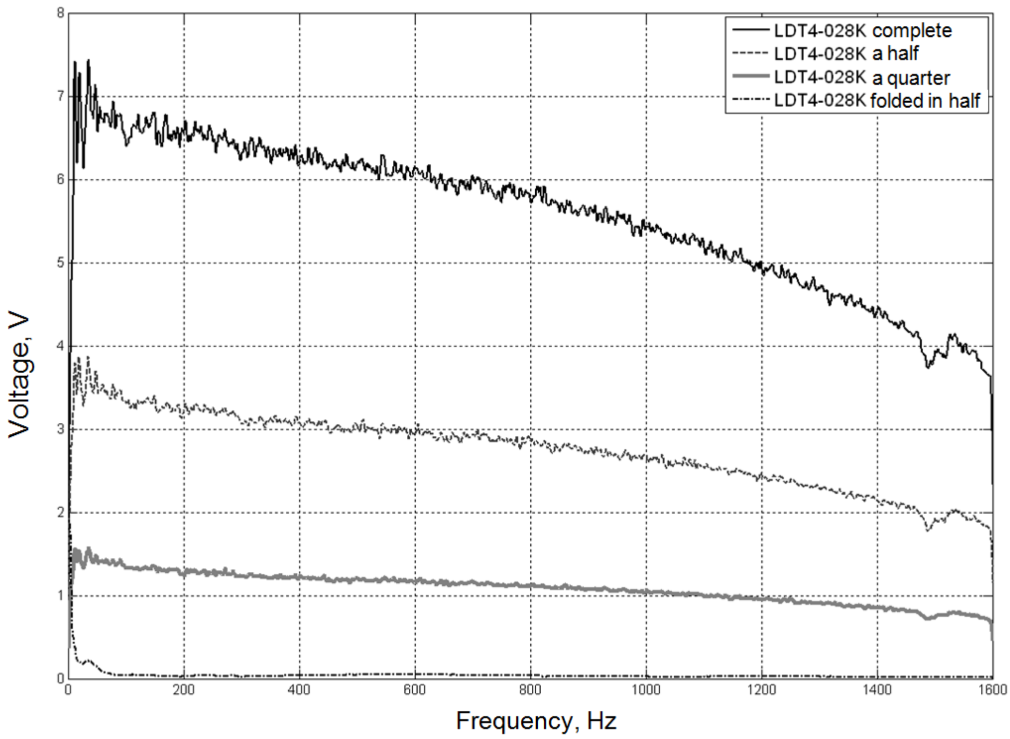


Figure 3. Frequency characteristics for different dimensions of piezo film type LDT4-028K

3.2. The response to temperature change

Determination of response time to temperature changes of direct piezo element environment was carried by reason of expected employee hand contact with the adaptor made of piezo film. As a heat source, 12 V / 50 W bulb was used, which at a distance of 20 mm from the piezo film surface allowed to obtain the temperature ca. 70°C. Thanks to the insulation of piezo film, electromagnetic field generated by the bulb, exciter or grid in the laboratory can be excluded.

A Figure 4 presents timing of the DT4-052K/L response to cycle of turning on and off the light bulb. In both cases, the reaction time was less than 20 ms. Frequency characteristics of the item DT4-052K/L during series of turning the bulb on and off were shown in Figure 5. The dominant components appear at frequencies below 1 Hz.

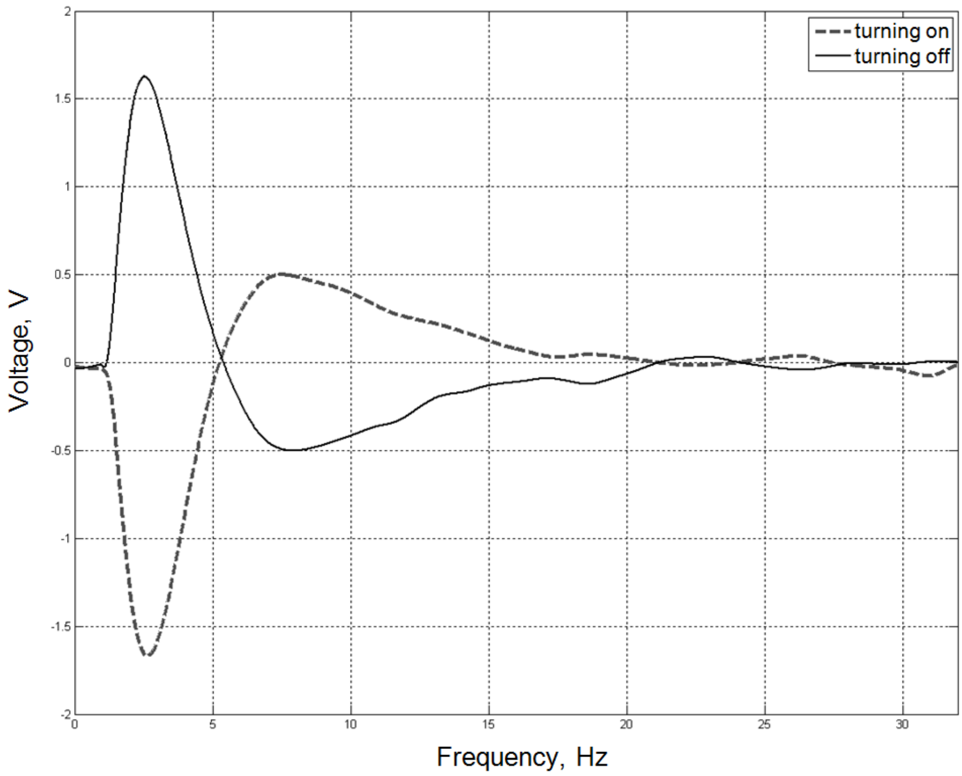


Figure 4. Timing of the DT4-052K/L response to cycle of turning on and off the light bulb

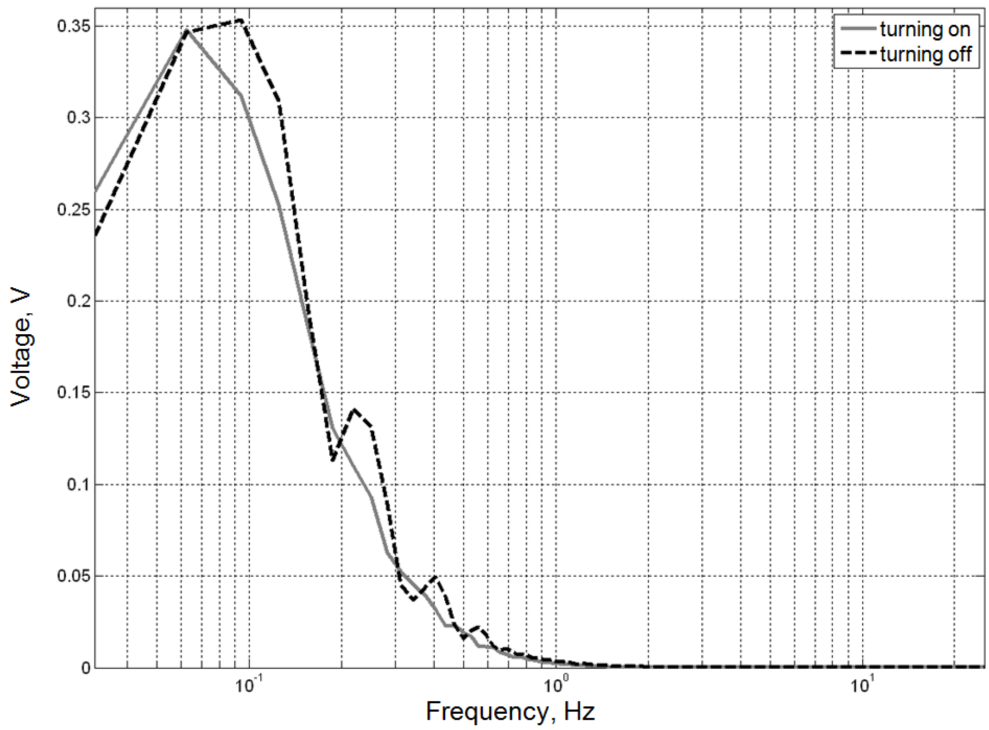


Figure 5. Frequency characteristics of DT4-052K/L during turning on and turning off the light bulb

A similar test was performed using a camera flash as a source of heat. In this way, even shorter time duration of pulse thermal was obtained. Figure 6. shows the timing of the DT4-052K/L response to the camera flash.

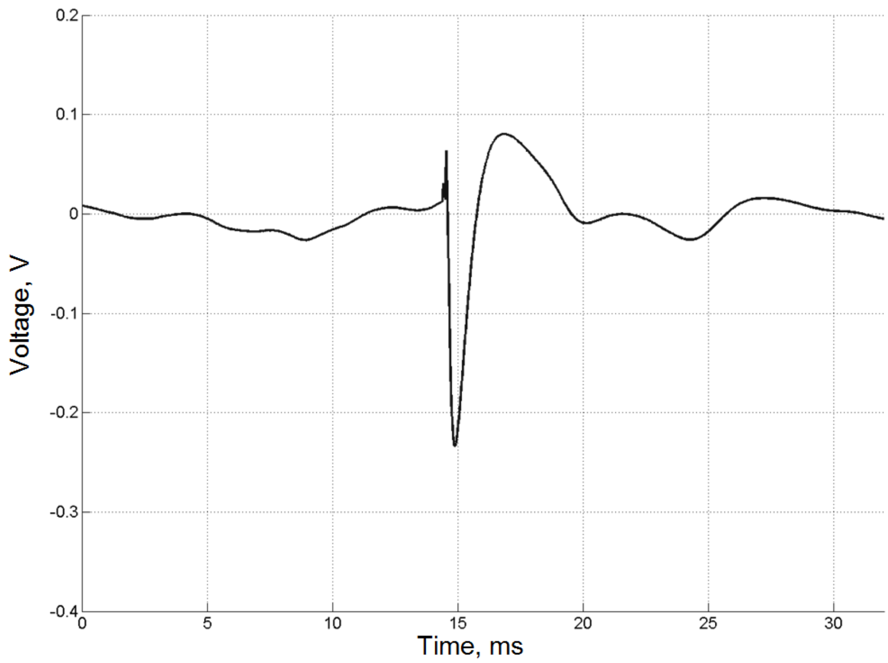


Figure 6. Timing of the DT4-052K/L response to the camera flash

Recorded reaction time of piezo film was approximately 5 ms.

4. Conclusions

The results confirmed the sensitivity of the tested piezo films to the noise signal stimulation and also to temperature changes of direct environment. Frequency characteristics for LDT4-028K are a bit more flat than for DT4-052K/L. The output voltage in almost entire measurement range is two times lower. It means that the DT4-052K/L has almost throughout the frequency range two times greater sensitivity than the element LDT4-028K. It is associated with higher (1.86-times compared to LDT4-028K) piezo film thickness.

The obtained characteristics have also shown how the charge sensitivity changes depending on the size of piezo film. Reducing the surface of the tested strip causes more and more flat frequency characteristics, but also it reduces the charge sensitivity: about 2-times for half of the strip, 5-times for the quarter and 20-times when the strip is folded in half. The results will be used in further studies on applicability of piezoelectric materials to vibration measurements in work environment.

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