Analysis of possibility of applying the PVDF foil in industrial vibration sensors

A Wróbel[1]

[1] Institute of Engineering Processes Automation and Integrated Manufacturing Systems Faculty of Mechanical Engineering, Silesian University of Technology, Konarskiego 18a Street, 44-100 Gliwice, Poland

E-mail: andrzej.wrobel@polsl.pl

Abstract. There are many machines using the piezoelectric effects. Systems with smart materials are often used because they have high potential applications for example transducers can be applied to receive required characteristic of projected system. Every engineer and designer know how important it is properly mathematical model and method of the analysis. Also it is important to consider all parameters of analyzed system for example glue layer between elements. Geometrical and material parameters has a significant impact on the characteristics of the all system's components because the omission of the influence of one of them results in inaccuracy in the analysis of the system. In article the modeling and testing of vibrating systems with piezoelectric ceramic materials transducers used as actuators and vibration dampers. The method of analysis of the vibrating sensor systems will be presented, mathematical model, and characteristics, to determine the influence of the system's properties on these characteristics. Main scientific point of the project is to analyze and demonstrate possibility of applying new construction with the PVDF foil or any other belonging to a group of smart materials in industrial sensors. Currently, the vibration level sensors are used by practically all manufacturers of piezoelectric ceramic plates to generate and detect the vibration of the fork.

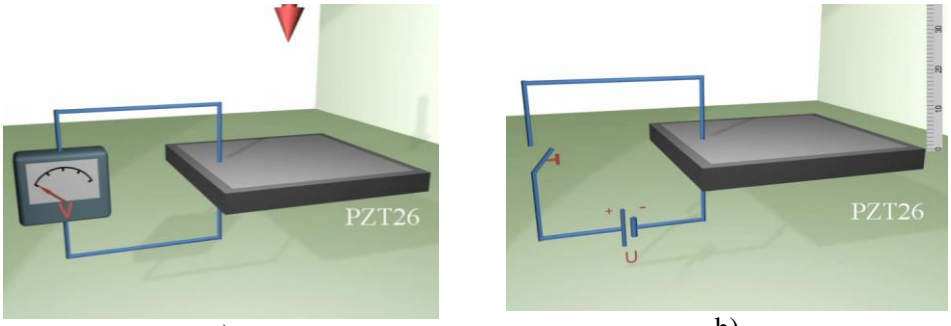
1. Introduction

What is the piezoelectricity? By the force action on some crystals you can make electricity flow through them. It is simple piezoelectric effect presented on figure 1a. In other way if you pass electricity through the same crystals they change geometry (figure 1b). Piezoelectricity was found in 1880 by a French physicists and now it has a lot of apps. Direct piezoeffect it is generation of an electric potential when stress is given to the piezoelectric material, also other way the reverse piezoeffect it is production of deplacement when an electric is fixed. In this paper analysis of possibility of using the PVDF foil in industrial vibration sensors will is presented.

In the existing vibration sensors direct and reverse piezoelectric effects are presented. In those level sensors piezoelectric plates are used as actuators and as vibration dampers with the external electric circuit. Usually the plates are fixed on the surface of a mechanical subsystem or only press by mechanical elements to generate vibrations or also to control amplitude of vibrations. Electric potencial is produced by external box and applied plates. A passive electric circuit is adjoined to transducer's clamps. Piezoelectric topic is often described by the authors of the publication [8-11].

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There are two basic applications of this idea. What is more there are many commercial applications of this idea presented for example in [6, 11].



a) b)

Figure 1. Direct (a) and converse (b) piezoelectric effect.

Mechatronic systems with piezoelectric sensors or actuators are widely used because piezoelectric transducers can be easy controled in order to obtain required dynamic characteristic of designed system [2-7]. A very convenient method of analysis of mechatronic systems are non-classical methods presented in publications [1-3]. The model under examination with the description of input and output parameters is shown in figure 2.

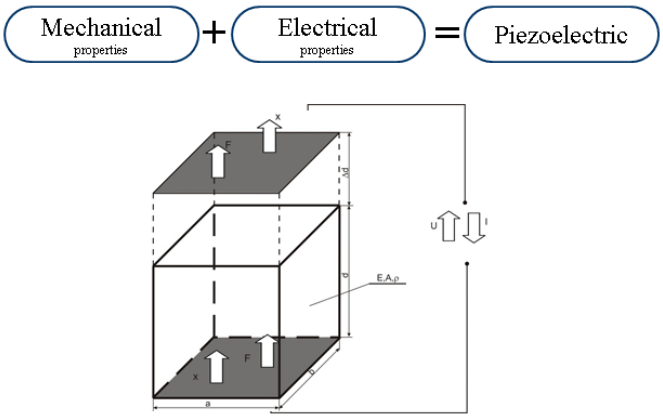


Figure 2. Model under examination.

This article is a theoretical consideration of possibility of applying the PVDF in industrial sensors. The article does not contain mathematical calculations and computer simulations of new construction, which will be the subject of future studies. The discussed subject is important due to increasing number of applications, both simple and reverse piezoelectric phenomena in various modern technical devices. The process of modeling of technical devices with piezoelectric is complex and requires large amounts of time because of the complexity of the phenomena occurring in these systems. The correct interpretation of the system by mathematical model during the design phase is fundamental condition for proper operation of designed system.

2. Vibration sensor unit and proposition of changes

Currently proposed detectors (presented in figure 3) have many important defects using the piezoelectric ceramic elements consists of two pairs of plates, and receiver of two or three plates broadcasting connected as a stack. An alternating voltage fed into the transmitting plate, the thickness changes proportionally to the applied voltage.

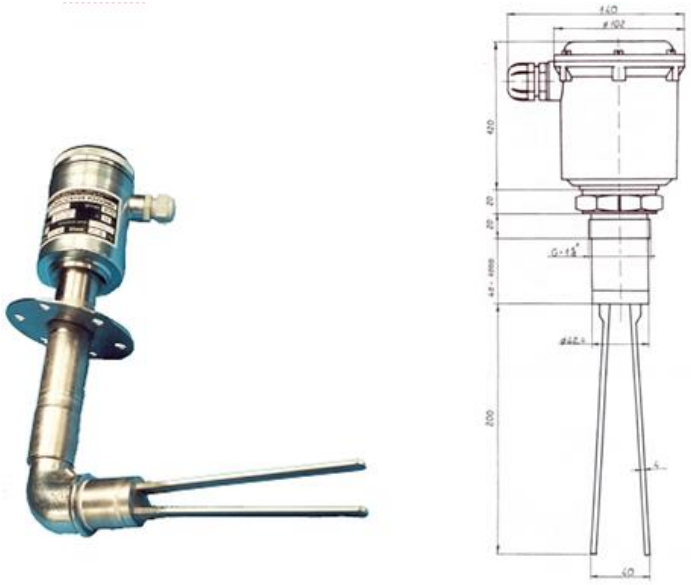


Figure 3. Construction of currently used level detectors.

Changes in thickness of the plate lead the vibration of the mechanical element, so-called fork. If the fork is not buried by the material deformation of the full tiles broadcasting is transmitted to receiver plate. As a result of crushing and stretching of the plates receiver the cladding is formed on the potential difference proportional to the force. The value of this voltage is processed by an electronic circuit. In the case of backfilling forks, tile receiving cease to be crushed and stretched. At the same time is not generated the potential for cladding tiles. New construction of level sensor is composed exclusively of a single beam which is fixed to a piezoelectric layer, it was presented in figure 4.



Figure 4. Proposition of new construction of level detector.

Utilitarian the scientific purpose of the project is to analyse and demonstrate possibility of applying the PVDF foil or any other belonging to a group of smart materials in industrial level sensors. Currently, tey are used by practically all manufacturers of piezoelectric ceramic plates to generate and detect the vibration of the fork. This approach is associated with a number of drawbacks, including:

- The need to use several piezoelectric, with the increase number of components is increased defect sensors. The plates are made of brittle materials which also causes crashes and damage,
- After laying the tiles in the so-called piezoelectric stack, use the calibration screw perform tuning fork resonance frequency and the frequency of an electronic circuit that generates vibrations.
- Sensors are produced with two forks resonance, using these in moist materials is often the case that the material remains between the forks and at the same time causes a measurement error, and

sometimes the need for intervention conservator. Given the fact that currently produced sensors should be characterized by high accuracy and reliability.

- Vibration sensors are performe as complex construction, two separate forks welded to the so-called membrane. On the other side of the membrane a stack of ceramic innovation proposed by the present design allows for a considerable simplification of the device is mounted.

The main reason to take consideration of this subject are researches done by many years on Faculty of Mechanical Engineering, Silesian University of Technology conducted by author and other. The proposed research problem is therefore a continuation and extension of previous work carried out by the applicants whose aim is to develop new mathematical models and universal methods of analysis and synthesis of complex mechatronic systems.

3. Mathematical model of new design of level sensor

The aim of future work will be to develop the most exact mathematical model and geometrical new sensor industry. In programm CAx it is possible to conduct simulations and the natural frequency of the sensor. The analysis will also be a mathematical model that will confirm the accuracy of the computer simulation done.

The different ways of restraint systems investigated, and the impact of geometric parameters and plastic on their characteristics will be presented.

Mechanical system will be described in the equation taking into account the weight of the continuous distribution. The transmitter will be presented in while using appropriate electrical schematics replacement and the corresponding equation. In the case of continuous models, both the mechanical subsystem and describe the piezoelectric transducer, having a continuous distribution of their mass. In addition, developing various mathematical models will refine them, starting with the assumption of ideal attaching the transducer to the surface of the mechanical subsystem, to take account of the phenomena occurring in the adhesive connecting the system components.

In the future strings of mathematical models of industrial sensor models with varying degrees of detail mapping real circuits will be developed. This approach is the result of inability to use the exact method for the analysis of mechatronic systems, which is why using approximate methods, determines the characteristics of the individual components and shall examine the effects of the changes in the parameters of plastic, geometrical and electromechanical compared to and evaluate the mathematical models developed in terms of the impact of the level of detail of the complexity and time-consuming calculations performed and the results obtained. In terms of the adopted criteria, indicate the most appropriate place to attach a piezoelectric foil of the developed models.

The main idea of future work will be to designate dynamic characteristics of a mechatronic system with piezoelectric transducer used as an actuator or passive vibration damper. It is a cantilever beam which has a rectangular constant cross-section, length, width and thickness. Young's modulus of the beam is denoted. Piezoelectric of length l and it is fix to the beam's surface within the distance. The transducer is bonded by a glue layer of thickness hp and Kirchhoff's modulus G. The glue layer has homogeneous properties in overall length. The system under consideration in both cases (with piezoelectric actuator) is presented in figure 5.

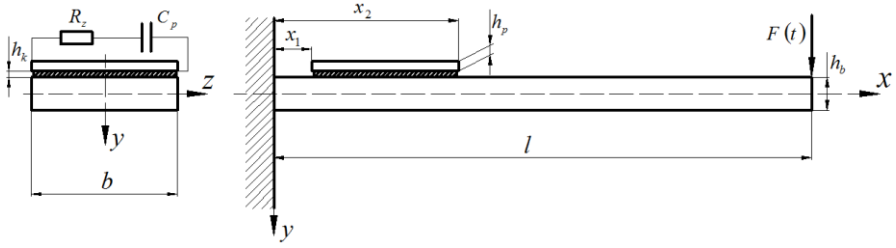


Figure 5. Model of new sensor construction.

In order to analyse vibration of the systems following assumptions were made:

- material of which the system is made is subjected to Hooke's law,
- the system has a continuous, linear mass distribution,
- the system's vibration are harmonic,
- planes of sections that are perpendicular to the axis of the beam remain flat during deformation of the beam – an analysis is based on the Bernoulli's hypothesis of flat sections,
- displacements are small compared with the dimensions of the system.

4. Conclusions

Piezoelectricity has found a lot of applications, for example, it is used in vibration level sensors.

Main point of this article was to demonstrate possibility of applying the PVDF foil or any other belonging to a group of smart materials in industrial sensors. Currently, the vibration level sensors are used by practically all manufacturers of piezoelectric ceramic plates to generate and detect the vibration of the fork. This approach is associated with a number of drawbacks. The new design of presented sensor eliminates the problems of the currently used sensors. For example in new type of sensors the need of use ceramic piezoelectric stacks will be eliminated, it will cause a longer service life of sensors and their reliability. By use just one vibrating element it will be eliminate locking material into forks. This article is only an attempt to deliberations on a new design of level sensors. In future work mathematical model will be calculated and author will try to create a prototype. This article is only an attempt to deliberations on a new design of level sensors. In future work mathematical model will be calculated and author will try to create a prototype.

Acknowledgments

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