UDC 004.942

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AUTOMATION OF ENGINEERING OF A MECHATRONIC SENSOR FOR A MANIPULATOR

Frequency analysis and results of a research of a force sensor of a mechatronic manipulator in stressed state are presented. The finite - analytical model of a sensor for holding finite element analysis was designed.

Key words: manipulator, mechatronics sensor, stressed state.

Наведено результати дослідження напружено деформованого стану та власних частот коливань датчика сили мехатронного модуля маніпулятора. Розроблено скінченно-аналітичну модель датчика для проведення частотного аналізу методом скінченних елементів.

Ключові слова: маніпулятор, мехатронний датчик, напружений стан.

Introduction

Application of microelectromechanical systems – MEMS (MicroElectroMechanical Systems) provides solutions for problems, which are connected to materials consumption and an electrical energy usage in new constructions. The construction reliability at a micro level requires from engineers the stressed-state analysis for main components of MEMS. Today, the special attention is concentrated on mathematical modeling of micro sensors based on a direct piezoelectricity effect [1-3]. Therefore the stress state research of sensor elastic units, which are used for a measurement of forces in mechatronic units, is the actual task at present.

Mechatronic sensors of micromechanical units

For handle systems it is expedient to have a migrations feedback on a steering mechanism (output link), speeds for both acceleration and strains in reference points of a system. The sensing elements, which are a part of the mechatronic module sensor, can be classified as optical, electromechanical or pneumatic. A feedback based on deformation, which is provided by sensors, allows determination of such parameters as: time moments when the output link interacts with the environment; mechanical loads on a working unit, deviation of an element's position with respect to predefined. The most perspective applications in a field of mechatronic construction are connected to piezoelectricity-based sensors, which uses changes of resistance on a sensor sensitivity layer [1]. This type of layer, caused by vacuum deposition, has a smaller size: not more than 1x1x0.02 mm, and sensitivity is relatively high (pressure is measured in a range 1÷50 kP, the maximal voltage on the output – 80 mV). In order to detect changes of a physical influence on a sensor, on its surface the piezoelectricity-based resistors are placed. They can be connected into a system in order to obtain the needed signal (voltage).

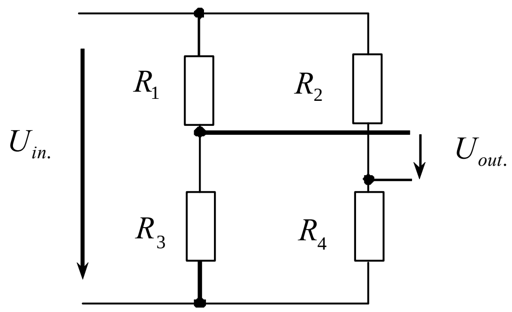


Fig. 1. Bridge circuit constructed from piezoelectricity-based elements in a microsensor

In order to determine changes in a piezoelectricity-based resistance such formula is applicable:

$$\frac{\Delta R}{R} = \pi_1\sigma_1 + \pi_t\sigma_t,$$

$$\pi_1 = \frac{1}{2}(\pi_{11} + \pi_{12} + \pi_{44}),$$

$$\pi_t = \frac{1}{2}(\pi_{11} + \pi_{12} + \pi_{44}), \quad (1)$$

Where σ_1, σ_t - strains, occurred under pressure on the plane in a parallel (along) and perpendicular (across) directions with respect to a current direction in a piezoelectricity-based; π_{11}, π_{12}, π_{44}- constants.

In order to increase the sensitivity of micro sensor, combinations of couples of piezoelectricity-based resistors connected to a bridge system can be used. Piezoelectricity-based resistors, organized in a perpendicularly with respect to a plate boundary, are affected by a positive change of resistance caused the deformation longitudinal effect. Respectively, the transverse effect is presented in a parallel oriented piezoelectricity-based resistors and its resistance decrease.

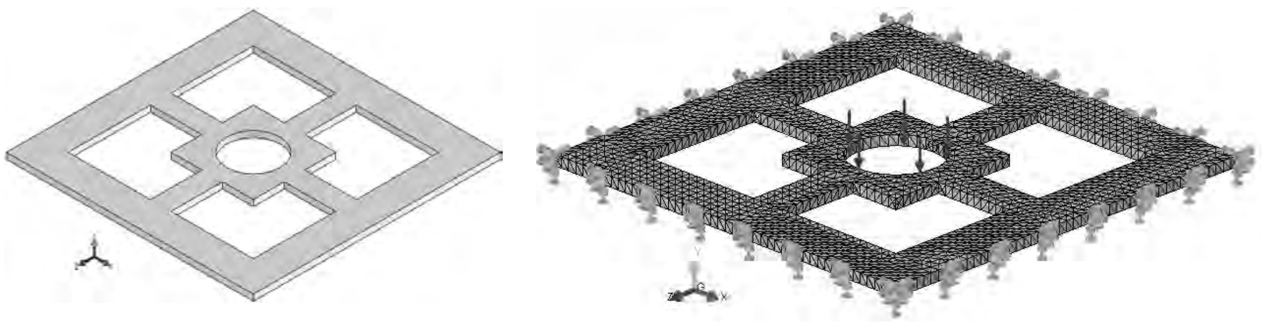
The output voltage can be obtained the equation:

$$U_{out.} = \frac{R_1R_4 - R_2R_3}{(R_1 + R_2)(R_3 + R_4)}U_{in.} \quad (2)$$

Automation of microsensor engineering

Design process of piezoelectricity-based sensor with the usage of CAD/CAM/CAE can be automatized by means of usage a control program based on a COM Server Application DLL, which use an API of the system. Construction of finite element model for a microsensor modeling with the usage of CAD/CAM/CAE should be automatized in three steps [4]:

– creation a solid model of a microsensor with a systems API (fig.2, *a*);



a *b*

Fig. 2. Microsensor solid and finite element models

– selection a type of analysis for making a sensor design;

– creation of a finite element model of a microsensor (fig. 2, *b*) by means of usage of API functions of a CAE-system and its calculation;

– analysis of results with an optimization module from the CAE system.

The main component in process of solid model construction is a sensor geometric control manager, which provides a control over the created geometry by means of obtaining it from the database or by a process of creation of it with the usage of the microsensor creation module. This model is used as a base for creation of a finite element model provided by the module of the automatized design for a microsensor.

The calculation results, obtained from the module of automatized calculation of a microsensor, are optimized and stored in the database (fig. 3).

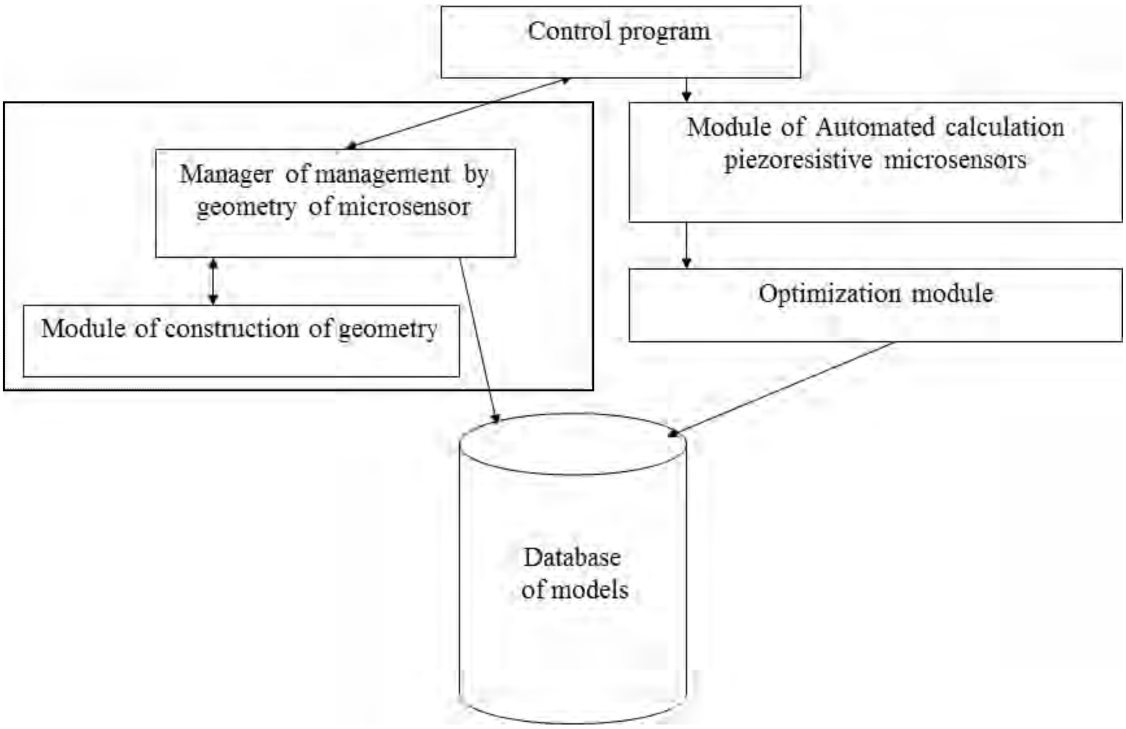


Fig. 3. Structure for a microsensors modeling system with usage of a CAD/CAM/CAE

FEM simulation

The sensor of force for a mechatronics unit consists of a crossed silicon diaphragm and 8 piezoelectricity-based units arranged in attachment points of diaphragms jumpers.

During the FEM analysis of a tension in a mechatronics sensor of force it is discovered that the maximum voltages arise in places of jumpers' curving of a crossed diaphragm and that stresses doesn't exceed from the permissible range of applied force to the output link, up to 25 N (fig. 4).

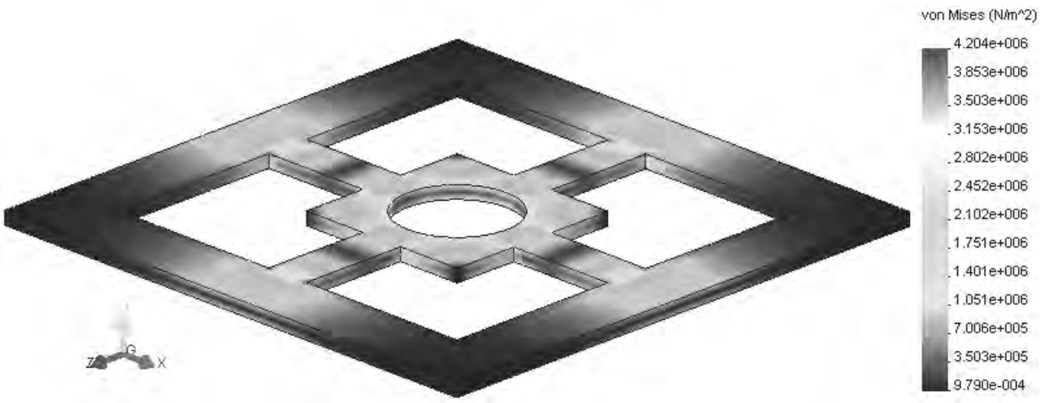


Fig. 4. Strengths in a crossed diaphragm of a mechatronics sensor

The results of deformation analysis showed, that the compliance of crossed structure of a mechatronics sensor is sufficient to provide for the initial link interaction with exterior plant. The fundamental frequency of oscillations of a sensor makes 5808 Hz (fig. 5).

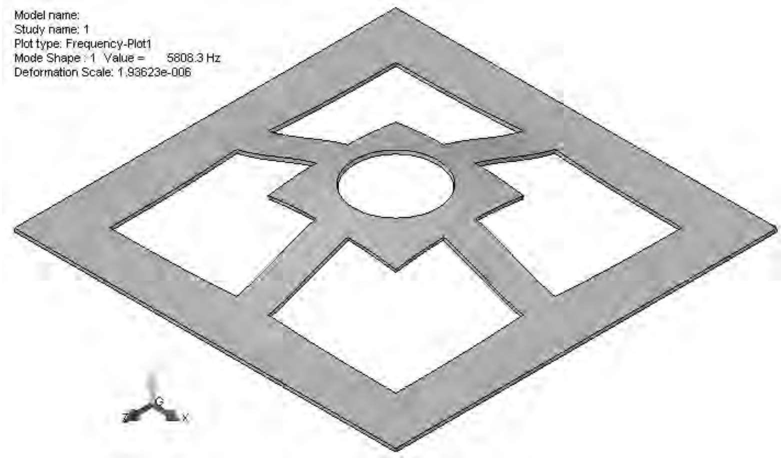


Fig. 5. Frequency analysis of microsensor

Conclusion

During the process of design of mechatronics units it is necessary to take into account elastic properties and a fundamental frequency of functional sensor units, which ensure a feedback.

1. Смирнов А.Б. Мехатроника и робототехника. Системы микроперемещений с пьезоэлектрическими приводами: Учеб. пособие. – СПб.: Изд-во СПбГПУ, 2003. 16 0 с. 2. Maluf, Nad im An introduction to m icroelectromechanical sy stem eg ineering // Lib rary o f C ongress Ca taloging-in-Publication Data. 2. Лучинин В.В. Микросистемная техника. Направления и тенденции развития // Научное приборостроение. 1999 . – Т. 9. № 1. – С. 3–18. 3. Va syl Tes lyuk, My khaylo L obur, Pav lo Denysyuk, Konst antin Ko lesnyk M ethodology of t he Automat ed MEMS De sign / / Proc. of th e II Id International Conference of Young Scientists (MEMSTECH'2007). – Lviv–P olyana, May, 23–26, 20 07. – P. 84–85. 4. Колесник К.К. Автоматизована технологія розрахунку мікросенсорів пє'зорезистивного типу // Вісн. Нац. ун-ту "Львівська політехніка" "Комп'ютерні системи проектування. Теорія і практика", № 651. – Львів: Вид-во Нац. ун-ту "Львівська політехніка", 2009. – С. 221–224.