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APPLYING COMSOL MULTIPHYSICS FOR RESEARCH AND DEVELOPMENT OF CAPACITIVE PRESSURE SENSOR

Спроектовано та досліджено моделі давача тиску ємнісного типу в середовищі Comsol. Застосовано алгоритм побудови моделі за допомогою пакета Comsol.

Ключові слова: ємнісний давач тиску, конденсатор, чутливий елемент, COMSOL Multiphysics, система автоматизованого проектування, МЕМС –мікроелектромеханічні системи.

Article contains design and researching of capacitive pressure sensor's model in the Comsol environment. Model constructing algorithm applied by using Comsol package.

Key words: capacitive pressure sensor, capacitor, sensor, COMSOL Multiphysics, computer-aided design, MEMS – Microelectromechanical systems.

Introduction

In recent years, requirements for the design of different functionality purpose devices are greatly increasing. This applies particularly (MEMS) [1–2], because of their design and redesign (when the results are not satisfactory) need to use more resources. Therefore, the development of methods and algorithms of improving aided design MEMS [3] is an urgent task today.

The main cause of spreading microelectromechanical systems is relatively low cost of production, high reliability, group manufacturing technology, low price and others [5].

The main elements of any microsystem are actuators, microsensors and MP-device.

Analysis of recent researches and publications

A number of leading scientists of Japan, USA, Germany, UK, France, Russia and Ukraine operates for solving complex technical problems in the design of separate measurement devices and information-measuring systems (IMS). The first in this field in Europe started working British companies EEV Chemical Sensor Systems, Bloodhound Sensor and Aroma-Scan, German Lennartz, Swedish Nordic Sensor Technologies and Alpha MOS French. In the USA - Syrano Sensors, Electronic Sensors Technologies, Hewlett-Packard and Microsensor Systems.

With the growing of industry and the interest of scientists and researchers on the theme of capacitive pressure sensors, started to appear books and the publication on this topic and industry, which are available for a wide range of readers..

The book «Sensors» of M.V. Burshtyn, N.V. Haya and Harchishin B.M. is devoted to an integral part of modern management systems - sensors. The publication contains over 180 pages that presents information about common design and features of various types sensors. Along with the general concepts of sensors that are structurally related to devices and switching elements for circles control, are proposed study and laboratory testing of specific sensors: positional switches, displacementm transducers with analog output, current, temperature, pressure transducer of famous manufacturers.

In the book of Potapova L.A. «Comsol multiphysics: Modelling of electromechanical devices: tutorial» is successfully presented a summary of the program complex COMSOL Multiphysics and examples of construction 2D- and 3D-models of electromechanical devices.

Pryor R.W. «Multiphysics Modeling Using COMSOL: A First Principles Approach. Jones & Bartlett Publishers» describes modeling with using COMSOL. Quickly introduces senior students, PhD students or engineers in the art of computer modeling of physical systems and devices. The author offers the step-by-step modeling methodology with examples that are associated with the basic laws of physics approach using First Principles Analysis. The publication explores the range of Multiphysics models in systems, that range from 1D to 3D coordinates and introduces readers to the methods of numerical simulation analysis used in program ensuring COMSOL Multiphysics. Once readers have built and run examples, they will understand the concepts, skills, and benefits gained from the use of computer modeling techniques to solve their technological problems and explore new applications in their specific technological areas [7].

The formulation of article purposes

This article is devoted to the development and analysis of capacitive sensor membrane pressure for further optimization of the thickness of the membrane to improve sensor characteristics.

Characteristic of the design facility

The object of design is a capacitive pressure sensor (Fig. 1), which contains more detailed description of sensitive membrane.

The subject of research is a sensitive membrane of capacitive pressure sensor.

Capacitive sensors use an elastic pressure sensing element in the form of a variable capacitor gap due to displacement or deflection under pressure of membrane-electrode movable relative to the fixed electrode. It means that design of capacitive pressure sensors is flat and cylindrical capacitor. The principle operation of these pressure sensors is based on the change in capacitance of the capacitor, depending on the applied load on one of the electrodes [4].

It is known that the capacity of flat capacitor is directly proportional to the square cover and inversely proportional to the distance between them.

$$C = \varepsilon\varepsilon_0 \frac{S}{\delta}, \tag{1}$$

where: ε_0 – electric constant of the medium between the plates; ε – dielectric constant; S i δ – area and the distance between the plates.

Sensitive elements of capacitive pressure transducers are membranes and diaphragms, which convert the measured pressure in the movement [2]. The relative capacitance changing in diaphragm membranes is proportional to the measured pressure.

$$\frac{\Delta C}{C} = \frac{R^2}{8\delta W} P_x, \tag{2}$$

where: R – radius of the membrane; W – the magnitude of the deflection of the membrane; δ – the distance between the membrane and the movable cover in the absence of pressure.

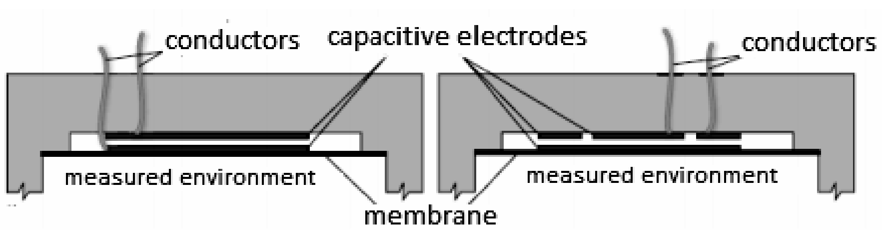

Fig. 1. The capacitive pressure sensor

Therefore, to improve properties such as sensor accuracy and increasing the range of measurements necessary to produce sensitive membrane of this size for maximum distance changing between the plates. Also it necessary to keep in mind the potential dielectric breakdown, when a significant approximation capacitor plates to one another and while appearance of the large stress, which can damage membrane.

Using COMSOL Multiphysics application package

Benefits of COMSOL Multiphysics package:

- modeling is based on differential equations in partial derivatives (PDE) and allows to solve equations finite element method;
- extends standard models that are using a single differential equation in multi physical models to calculate interconnected natural phenomena;
- PDE coefficients are specified as unknown conditions and physical properties such as thermal conductivity, heat capacity, heat transfer coefficient, volumetric capacity;
- using various mathematical methods for setting systems;
- different types of analysis (stationary and transient analysis, linear and nonlinear analysis, modal analysis and analysis of natural frequencies) [7];
- using finite element analysis with the grid that takes into account the geometrical configuration of bodies and error control with various and numerous additional solvers;
- allows using variable connection (coupling variables) connect models in different geometries and link the models of different dimensions [7].

In the process of building and researching models in the system Comsol, follow algorithm shown in Fig. 2.

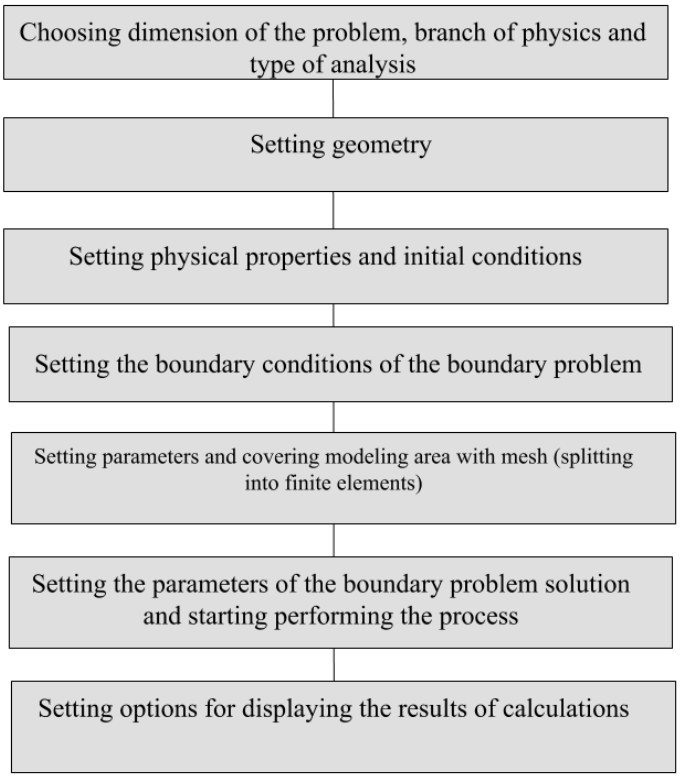

Fig. 2. An algorithm for constructing models in COMSOL

Analysis of the results

As the round plate radius is much bigger than its thickness, we assume that $w(r)$ is equal to the maximum displacement. Then,

$$w_{max} = \frac{3}{16} P \frac{(1-v^2)}{E} \frac{R^4}{h^3}, \tag{3}$$

where: R – plate radius; v – Poisson's ratio; E – Young's modulus; P – applied load; h – plate thickness.

Thus, as maximum stress will concentrate at $r = R$, stress determining expression should be written in the following form, namely:

$$\sigma_l(R) = \frac{3}{4} P \frac{R^2}{h^2}(1+\nu), \quad \sigma_t(R) = \frac{3}{4} P \frac{R^2}{h^2} \nu . \tag{4}$$

The formulas above can be used for comparing the results obtained with the help of Comsol and formulas.

The model of sensitive membrane pressure capacitive sensor was built with calculation of stress in Comsol. The results presented in Fig. 3.

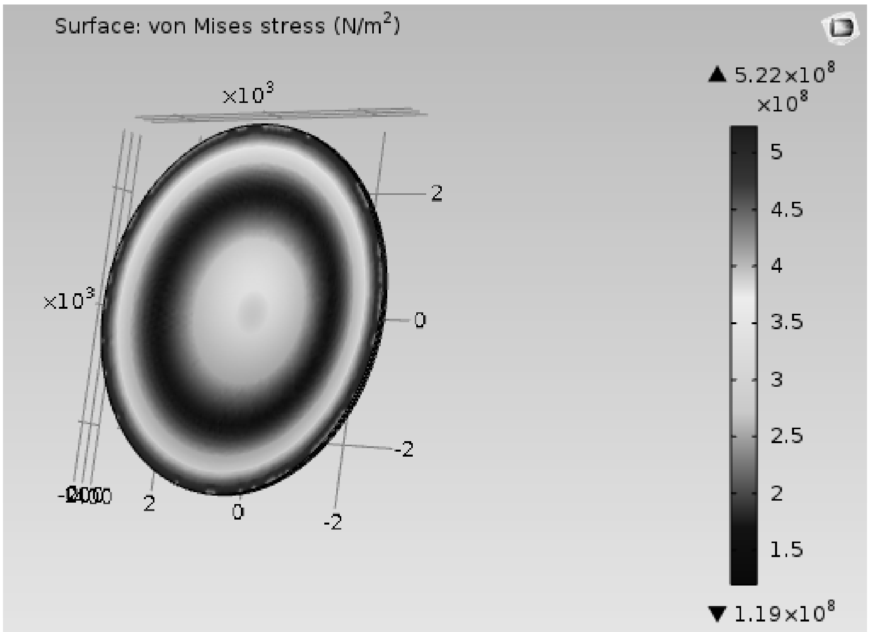

Fig. 3. The analysis results of stresses in thin plate model

Conclusion

In this paper is described development and analysis of capacitive sensor membrane pressure in the system Comsol. It includes review of references. Also described algorithm of constructing models in the system Comsol and their researching. Listed the benefits of system using.

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