Designing of reed switches for sensors and security alarm devices

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Abstract. The article is devoted to the actual problem of designing a highly reliable domestic elemental reed switch base of devices designed to create sensors for monitoring fluid flow and detectors for car alarm systems. The developed method of analyzing the statics and dynamics of contact groups of reed switches is implemented when designing new types of magnetically controlled contacts. New designs of reed switches have successfully passed technical tests and are protected by patents in the Russian Federation.

1. Introduction

The development of modern road transport is steadily leading to an increase in technical and metrological requirements for detectors, distributors and reed switch devices, which are an integral part of fluid flow control systems and security alarm devices. It should be noted that important characteristics of magnetically controlled contacts (reed switches) such as speed, absence of chatter, mechanical stability indicators are ensured by a high quality of the elastic elements of the switching groups of magnetically controlled contacts included thereto [1-4].

A further increase in requirements of quality and safety of fire alarm and alarm devices leads to the need to develop new computational and experimental methods for studying the most important, in terms of reliability and metrological characteristics, elastic element base of reed switches.

The writings of the following domestic scientists were devoted to the analysis of statics and dynamics: Korsunov V.P., Andreeva L.E., Khazazova K.I., Shoffa V.N., Karabanova S.M., Mayzelsa R.M. other.

In modern models of automotive vehicles reed switches are widely used in various liquid level sensors (gasoline, antifreeze, water), as well as in security alarm systems, which makes them a highly sought-after element in the global market of magnetically controlled contacts. Automotive reed sensors comprise membranes and platelike sensitive elements. The reliability of these elastic sensing elements requires the improvement of methods for their calculation, as well as the creation of computer-aided design systems of the switching groups of magnetically controlled contacts in the ANSYS environment and the SolidWorks environment, which allows an automatic construction of 3D models of reed switches.

A combination of properties and profitability of reed detectors and security devices are in many ways better than semiconductor analogs, which leads to their widespread use in automotive vehicles.
The development of models of shell and platelike switching groups of magnetically controlled contacts for the static mode can be carried out using deterministic or stochastic models.

In order to build mathematical models of shell and platelike switching groups of magnetically controlled contacts in a dynamic mode, it is necessary to analyze the amplitude and phase-frequency characteristics.

In this document new mathematical models of switching groups of magnetically controlled contacts in the devices of automotive vehicles for static and dynamic modes of operation are developed.

2. Formulation of the problem

Modern systems of physical protection of objects include security and fire alarm and alarm signaling detectors, namely magnetic contact and reed sensors comprising a modernized membrane and platelike elastic-deformed element base with a programmable strain value.

The authors of the work carried out the development and study of methods for analyzing thin wall sensitive elements of a multilayer structure. This goal is achieved due to the use of a multiparameter approach for the numerical simulation of dynamic processes occurring in the control and measuring sensors of the alarm system. In the course of numerical modeling of the processes of elastic deformation of the thermobimetallic membrane element of the microsensor, a number of design schemes were used, which ensured required operational characteristics and high reliability indicators of the physical protection systems of the objects.

Experimental verification of the developed theoretical models has been carried out.

A Russian patent application "heat fire detector" was prepared and a patent in the Russian Federation for a "temperature sensor" was received.

The development of a methodology for designing a membrane and platelike elastically deformable element base for fire alarm and alarm signaling detectors has been carried out.

3. Tasks to be solved

The goal solved by the authors is analyzing the statics and dynamics of the shell and platelike switching groups of magnetically controlled contacts devices of automotive vehicles. To achieve this goal the following tasks were solved:

• analysis of the patent and scientific literature dedicated to the problems of analysis of statics and dynamics of contact groups of reed switches was carried out;

• new elements were introduced into the classification of platelike and membrane contact sensitive reed switch groups;

• an analysis of the trends and prospects for the development of fire alarm and alarm sensors based on reed switches was carried out;

• analysis of the advantages and disadvantages of the existing methods of analysis of statics and dynamics, as well as the design and technological features of the switching groups of magnetically controlled contacts fire alarm and alarm signaling sensors were carried out;

• development of new mathematical models for the analysis of statics and dynamics of switching groups of magnetically controlled contacts was carried out;

• a library of finite elements of flat and membrane reed switches was created for the development of automated systems for designing sensitive elements of magnetically controlled contacts in the ANSYS environment;

• mathematical models of the attached and concentrated masses of the switching groups of magnetically controlled contacts were developed.

Obtained results are based on a systematic approach to the problem in question. They are based on numerical methods for calculating shell and platelike structures. For the construction of mathematical models of the added fluid masses, the methods of sections and electromechanical analogies were used. For the creation of mathematical models of the switching groups of magnetically controlled contacts when working in a static mode, methods of probability theory were applied. When
calculating the amplitude-frequency characteristics of the elements of the switching groups of magnetically controlled contacts, the half-division method was used.

In the course of the work, an extended classification of modern types of switching groups of magnetically controlled contacts for liquid flow detectors and security devices of motor vehicles was carried out, the development of mathematical models of shell and platelike switching groups of magnetically controlled contacts for static operation was carried out, mathematical models of shell and platelike switching groups of magnetically controlled contacts during the dynamic mode were developed, derivation of the switching groups of magnetically controlled contacts equations for mercury wetted contacts was made; a finite element library has been developed for computer-aided design of switching groups of magnetically controlled contacts detectors and security alarm devices of motor vehicles.

4. Results
As a result of the work, the authors of the article obtained the following results:
1. Mathematical models for the analysis of static and dynamic processes in switching groups of magnetically controlled contacts detectors of fluid flow and alarm sensors in automotive vehicles were developed;
2. Equations for calculating added and concentrated masses to eliminate errors in estimating the dynamics of the switching groups of magnetically controlled contacts are derived;
3. Criteria are derived and conditions for the stability of membrane and platelike switching groups of magnetically controlled contacts liquid flow detectors and security alarm sensors in automotive vehicles are specified.

This study is of great importance due to the ever-growing requirements for alarm systems, namely their reliability characteristics, since reliability is determined by the quality level of the elastic elements of the switching groups of magnetic contacts included in their composition.

A new reed switch model has been developed and patented with improved reliability indicators for use in liquid flow detectors and security alarm sensors in automotive vehicles.

Thus, the use of modified elastically deformable elements in magnetic contact and heat detectors starts a new line in the design of modern fire alarm and alarm signaling devices, which once again confirms the relevance of the problem under consideration.

The resulting models can be used in computer-aided design of reed switches for the case of mass production or individual production.

The correctness and adequacy of the results obtained in the work was confirmed in the course of an analytical comparison with the data of experimental studies and results presented in other scientific sources.

References
[1] Labkovskaya R Ya, Pirozhnikova O I and Tkalich V L 2014 Condition and stability criterion of elastic sensitive elements of reed switches News of higher educational institutions. Instrument Engineering 57 (10) 34-37
[2] Labkovskaya R Ya, Tkalich V L, Kozlov A S and Pirozhnikova O I 2016 Analysis of the dynamics of multilink sensitive elements of reed switches of control systems Almanac of scientific works of young scientists of ITMO University 3 88-90
[3] Tkalich V L, Labkovskaya R Ya and Pirozhnikova O I 2012 Analysis of the attached masses of elastic sensitive elements of mercury reed switches News of higher educational institutions. Instrumentation 55 (7) 32-35
[4] Kozlov A S, Shmakov N A, Tkalich V L, Labkovskaia R I, Kalinkina M E and Pirozhnikova O I 2018 Development library of finite elements for computer-aided design system of reed sensors Journal of Physics: Conference Series 1015 032080
[5] Lepeshkin O M, Kopytov V V and Beetle A P 2009 Integrated security and technical equipment for fire alarm Helios M ARV 288
[6] Rude I I 2012 Alarm systems Technical means of detection M 220
[7] Kalinkina M.E., Kozlov A.S., Labkovskaia R.I., Pirozhnikova O.I., Tkalich V.L., Shmakov N.A. Development of computer-aided design system of elastic sensitive elements of automatic metering devices // Journal of Physics: Conference Series - 2018, Vol. 1015, pp. 052018
[8] Klaassen C 2008 The basics of measurements Sensors and electronic devices Intellect M 352
[9] Hashemian H M 2008 Sensors of technological processes. Characteristics and methods for improving reliability Binom M 336
[10] Kozlov A.S., Shmakov N.A., Tkalich V.L., Labkovskaia R.I., Kalinkina M.E., Pirozhnikova O.I. Development library of finite elements for computer-aided design system of reed sensors // Journal of Physics: Conference Series - 2018, Vol. 1015, pp. 032080
[11] Kashkarov A P 2017 Microelectromechanical systems and elements DMK Press M 114
[12] Raspopov V Ya 2007 Micromechanical devices Mechanical Engineering M 400
[13] Tkalich V.L., Labkovskaia R.I., Pirozhnikova O.I., Kalinkina M.E., Kozlov A.S. Analysis of errors in micromechanical devices // 14th International Scientific-Technical Conference on Actual Problems of Electronic Instrument Engineering, APEIE 2018: Proceedings - 2018, pp. 272-276
[14] Rude I I 2012 Alarm systems Technical means of detection M Solon-Press 220