Investigation of Dynamic Characteristic of Sensor Elements of Micromechanical System

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Abstract – **Sensor Elements of Micromechanical systems (SEMS) find out more and more application by measurement in the kinematical parameters of moving objects. In the study structures and schemes for investigation of accurately characteristics on known MEMS systems. On the base of structures systems are developed mathematical model to be investigated. Numerical determination model by the use of Simulink models on differential equation, description of dynamical characteristics.**

Keywords – **dynamic characteristics, structural schemes, imitation model, measurement accuracy.**

I. Introduction

The development of contemporary techniques in different domains requires formation of more quality and different information in measurement systems. Requirements for reduction of the mass and the measures of the systems are already of importance, because one of the sides of the objects have tendency for diminishing its proper characteristic and the other grow bigger in different points of already investigated objects in attends to achieve better accuracy, as well to measure more quantity, characterizing the object in its proper dynamic.

The wide development and application of gyroscopic systems and instruments for navigation and orientation in the aircraft systems, ships, automobiles, robots and other moving objects is connected with inherent autonomy, which consist in devises and systems, based on principle of gyroscopes and accelerometer. In contrast of radio-location and optical systems determine location of moving objects without using indispensably whatever physical connection with a stationary on-aground. Thanks the MEMS- technology become possible the contraction of those types of miniature dimensions. The last could propose possibility for simple decision before its complicated systems solutions in the field of measurements and management of dynamical quantities and processes thanks to there metrological characteristics, bud also in easy integration of that miniature component to each dynamic system.

On the other hand it is especially important to guarantee indispensability compatibility between the dynamic characteristics of the components and systems and the dynamical quantities, characterizing the measurement surroundings. The absent of such of compatibility could provoke appearance of dynamic error with unthinkable large value. Unfortunately in the catalogues of leading producers do not offer sufficient information on the dynamical characteristics of the systems, which in considerable extent diminish possibility for normalization of the dynamical accuracy.

That why the aim of the present is to work up a model of a system for investigation of a model of a system for investigation of the dynamical characteristics for MEMS-acceleration.

II. Structural Scheme of a System for Investigation of Dynamical Characteristics of MEMS-Accelerometer

The structural scheme is contracted on the base of already developed in the department of “Mechanical and precision engineering” of TU-Gabrovo: apparatus and machinery for investigation of dynamical characteristics of devises for measurements of parameters of moving objects [1].

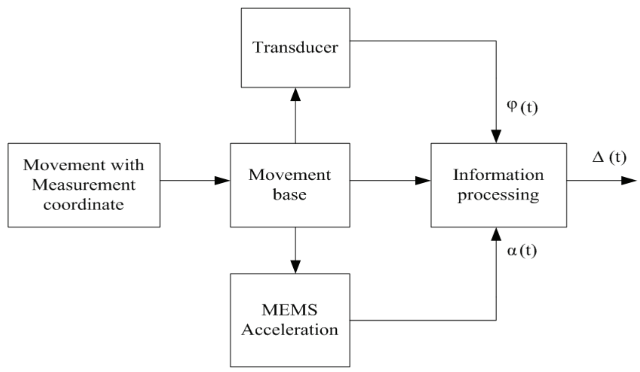

Fig. 1. Structural scheme

The Fig.1 presents a structure is a locked-tipped scheme. It consists of two channels for data transfer. The first channel is used for information transfer of standard, scheme movement on the base of the platform. On the second, the corps of MEMS-acceleration is mounted. The information from it proceeds to the processing block on the second channel.

The scheme is developed in attempt to solve problems of two basic directions. The first is used for investigation of dynamical deposition of micro-electro-mechanical systems, and the second for analysis of dynamic errors. For the purpose

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of standardize dynamical aracteristics of measuring instruments, mostly complete characteristics like transition, transmission, impulse, transitional functions. Also some cases could be used and specific private dynamic characteristics, like coefficient of damping, time-constant "and so forth". Composition of structural scheme is conformed according to the model, determine the formations of the dynamical error Δ(t), presented at [2]. That gives possibility for experimental study on the characteristics of that particular error: both on the temporal and the frequency coordinate.

III. Mathematical Model of the System in Examination

The investigation of the dynamical indicators of the measuring devises are unbearable without there mathematical models, adequate description of the basic property and characteristics. Even the results from the experimental investigation do not be analyzed exactly and precision towards the reason in separate formation of the dynamic error.

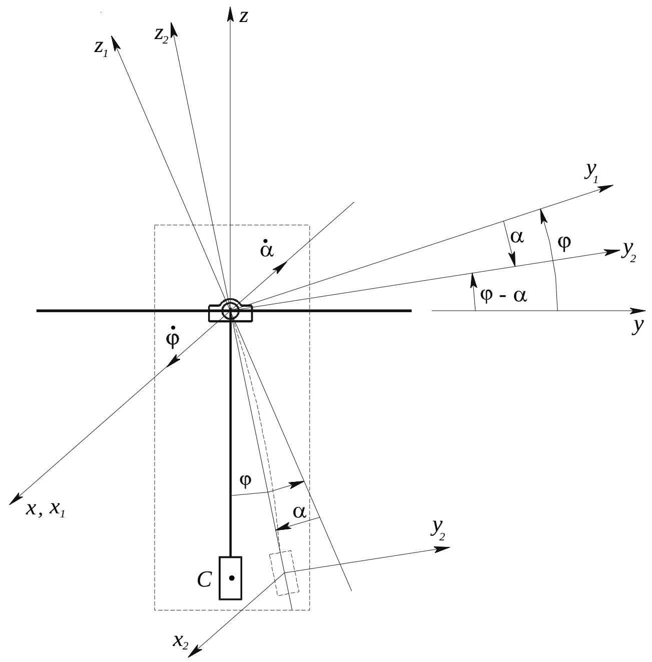

Fig.2. Dynamic systems

On the base of each mathematical model of dynamical system stands the differential equation, decrypting mostly the inertial properties of the system. In the concrete cause differentially equations of motion are composed on the base of the dynamical scheme from Fig. 2. Accepting the corps of the MEMS-accelero-meter is fastened firmly on the plate of the platform.

The measuring sensor of the instrument is determined as a physical pendulum, fixed by means of a plane spring on the corps of the accelerometer. That is generalizing of the sensors in known constriction and it could be accepted as a based model by investigation of the dynamic of the devises.

Then a generalized coordinate, could be assign by means of an angular quantityα. The last define the declination of the pendulum. Coordinate α is accepted as a generalization; bear the information changing of the measured quantity from MEMS-accelero-meter. In the schemes of the Fig. 2., dynamic system are introduced the followed coordinates systems: xyz, which coincide with inertial coordinate scheme and is immovable; x1y1z1 - is a movable coordinate, connected with the plate of the platform: x2y2z2- system, whose commencement coincide with the center of gravity C of the pendulum and move together with it.

In that instance the corps accomplishes rotation movement and consequently, kinetic energies will be:

$$E_{\kappa} = \frac{1}{2}.J_x.\omega_x^2 \quad (1)$$

Mass inertial moment of the sensing element towards the access x is determined from the theory of Steiner,:

$$J_x = J_C + M.l^2 = M.\left[1/12.\left(a^2 + b^2\right) + l^2\right] \quad (2)$$

where, the JC – moment of insertion of the sensing element towards the mass center C ; l- the arm of the sensing element: a and b – constructing parameters of the sensing arm.

The projection of the vector of the angular velocity of the sensing element over the action x will be:

$$\omega_x = \dot{\varphi} - \dot{\alpha} \quad (3)$$

where $\dot{\varphi}$ is the angular velocity of the plate of the platform.

Substituted (2) and (3) in (1), obtained the definitive formulae of the kinetic energy of the sensing element:

$$E_{\kappa} = \frac{1}{2}.M.\left[\frac{1}{12}.\left(a^2 + b^2\right) + l^2\right].\left(\dot{\varphi} - \dot{\alpha}\right)^2 \quad (4)$$

The potential energy Eп could finish the active forces, then:

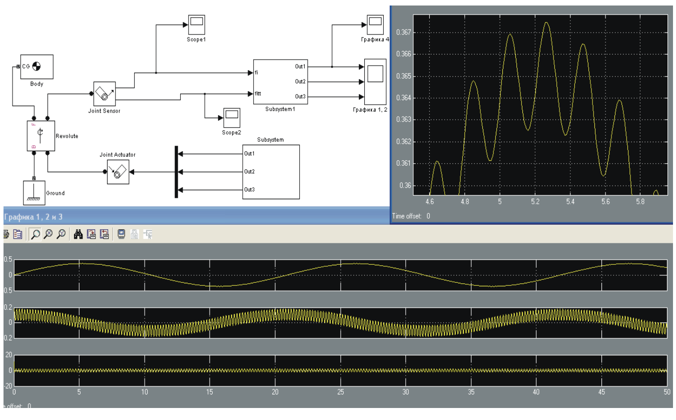

Fig.3. Sim Mechanics model of the investigated system

$$E_n = M.g.[l.\cos\varphi - l.\cos(\varphi-\alpha)] - \frac{1}{2}.c.\alpha^2 \quad (5)$$

where c is the spring constant.

After adduce of (4) and (5) in the usual form and substitution in the equation of Lagrange of second order, one obtained the following differential equation:

$$M.\left[\frac{1}{12}\left(a^2+b^2\right)+l^2\right].\ddot{\alpha} + c.\alpha - M.g.l.\sin(\varphi-\alpha) =$$
$$= M.\left[\frac{1}{12}\left(a^2+b^2\right)+l^2\right].\ddot{\varphi} \quad (6)$$

In the equation (6) are not take in foreseeing the damping forces, because do not exists sufficient data of them. The definite of the quantitative values of those forces for the concrete instruments could be able to perform such an experiment on the bases of the system of investigation.

IV. Imitation Model of the System for Investigation of Dynamical Characteristics

Imitation model is completed on the base of the structural scheme of Fig.1.1 and the mathematical model of the system, of investigation. That give possibility for adduce the real system to its mathematical analog on the base of the programming forms of its realization.

On that manner could be investigated as follows: compatibility of the theoretical and experimental model of the system; the influence of the functionality parameters on the instrument over the dynamic characteristics; the influence of the functional parameters; the influence of the embarrass quantity, definite in a format, which do not be suffocated experimentally.

On the Fig. 3 is presented Sim-Mechanics, the model of the dynamical system, the graphical results from the quantity solutions as well. On the block-schema of Fig. 3 the apparatus part is presented by the plate (block type Body), which offer rotational movement around the axes x, coincide with access x1 (Fig. 2). The ensure that motion of the plate is fulfilled by the block “Revolute”, determent the direction of the coordinate access, toward the body fulfilled rotational movement. The signals, defended the parameters of motion of the plate are registries using the block Joint Sensor and send to the Subsystem 1.

The moving apparatus are supposed to modeling of the block Subsystem. The Library Smolensk offer perfect possibility for choosing the parameters of the signals, formatting the moving system of the stand. Usually choosing of signals, determinate or accidental function in time with practically illimitable diapason of values of its functional parameters, which in practice is not possible to realize in experimental circumstances.

Numerical integrate of equation (6) towards summaries coordinate $\alpha(t)$ is realizing in a block Sub-System 1 (Fig. 4). In the base of the block-scheme are two pawnshops integrates. To the input of the first integrator is moved a signal, incorporate the functional mutual assistance between the constrictive parameters of the investigated instrument and the signal, characterizing the influence of the movements of the plate and the platform, which is definitude of the function on the right part of the differential equation (6).

Fig. 3 (Graphics: 1, 2 and 3) are shown graphical solutions, illustrated the movement of the sensing element of the MEMS- accelerometer, and its derivatives. The last are indispensable by the dynamical investigation because on the output of the real instrument, obtained signal, proportional to the second derivate. In the imitation model is foreseeing possible change of the scale graphics (Graphic 4). That offer possibility for analysis of its proper vibrations of the measuring instrument. That is illustrated by the example of Fig. 3, where the plenty of leers are seen on the measuring instrument again the constraint.

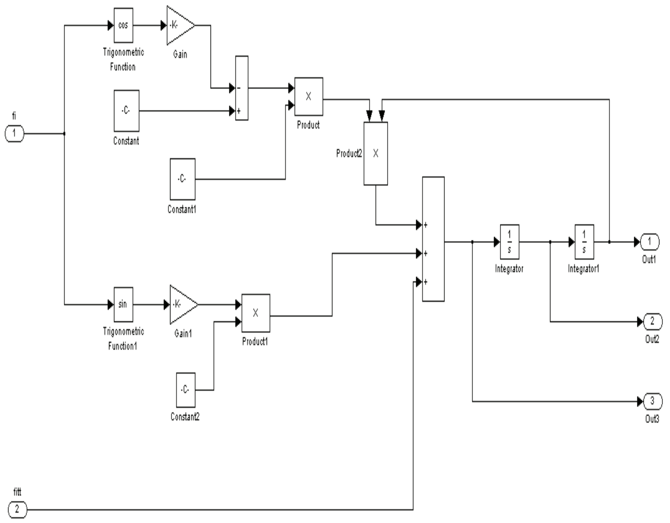

Fig. 4. Subsystem for solving the differential equations

The obtained results offer possibility for investigation of influence on the functional constructive parameters of the measuring instruments on the formation of the dynamical characteristics for analysis of the experimental results, for investigating conditions, usually are not obtaining experimentally, which increasing the affectivity of the model.

V. Conclusion

Structural scheme is constructed for the purpose of dynamical characteristics of MEMS-accelerometer, on the bases of developed in the Department of “Mechanical and Precision Engineering”, Technical University of Gabrovo.

Mathematical model of the concrete measuring instrument, investigated system is deduced.

On the base of the structural scheme differential equations imitation model for investigation of the dynamical model MEMS-accelerometer is developed.

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