Optimization of the Accelerometer Design Using Ansys

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Abstract - **This article is aimed and investigated the optimization model of the capacitive accelerometer. To automate the process of research the bisection method has been suggested. Software implementation of the suggested solutions in the form of applications for ANSYS system allowed to automate the process of selecting the thickness of the seismic mass and spring elements accelerometer, so as to obtain the required displacement of the movable plate of the accelerometer.**

Keywords - **capacitive accelerometer, ANSYS, computer-aided design, MEMS, bisection method.**

I. INTRODUCTION

Microelectromechanical systems or contracted form MEMS are micro devices of diverse constructions and purposes. They are worldwide known as MEMS [1-3]. Microelectromechanical systems are made up combining mechanical elements, sensor and electronic engineering on the one silicon plate with the help of microfabrication technology [4]. All these elements can be implemented as a single product, dozens or hundreds right away, like microcircuit chips on the silicon plate [5, 6].

When designing capacitive accelerometer, a draftsman is aimed to design the construction which would provide the required coersion of the seismic mass during the variation in acceleration. Respectively, it takes much time to adopt optimum parameters for structural optimization aimed to obtain accelerometer's optimum initial specifications. There are a lot of ways for structural optimization, but most of these methods cannot be implemented to solve problems which have to be solved with the help of finite-element method [4].

The conducted analysis of the ways of structural optimization of MEMS-devices in the ANSYS system has made it possible to find out that the selection method is the easiest one to implement for the optimization of the structural parameters of MEMS devices, but this method is inefficient. As most of the output specifications ate are nonlinear, the implementation of interpolation techniques is impossible, therefore it is advisable to use the bisection method [5-6], which allows to find a solution much faster instead of selection method.

Consequently, the task is to develop the optimization model of the MEMS-device in terms of capacitive accelerometer, which would solve the problem how to select the required thickness of the elastic elements of accelerometer, thus two plates (movable and stable electrode) would not collide at the maximum acceleration and damage sensor. The optimization model offers to use the bisection method and implement suggested solutions. This will allow to automate the process of research in the ANSYS system.

II. THE DEVELOPMENT OF THE ACCELEROMETER OPTIMIZATION MODEL

In recent years, the technological level of micromechanical accelerometers has grown significantly. New integrated accelerometers are usually manufactured on a single crystal. This means an installation of both signal processing devices and sensor elements, sensitive towards three axes, on a single crystal. Current MEMS accelerometers with integrated electronics perform such functions as self-testing, gauging and programming.

A lot of new technologies are suitable for development of single-crystal micromechanical circuit structures and integrated micromechanical accelerometers with the output (micromechanical structures are circuit structures that undergo micromotion – about a microns or less).

During the process of perpetual micromechanics technology development a great number of new accelerometer technologies become successfully commercialized reaching the highest selling rates of MEMS-devices along with gyroscopes and pressure sensors.

For instance, at the automotive market today the most widespread accelerometers are capacitive MEMS-accelerometers, i.e. acceleration sensors based on the capacitive transformation of micromotion of an inertial mass. The reason for their commercial success is a simple design of the sensor element, moreover there is no need for materials with special properties, it's high sensitivity, low power consumption, good temperature stability, improved noise characteristics, low drift and low price.

When designing the accelerometer, a designer often meets design constraints; for example the distance between the plates of capacitive accelerometer cannot exceed a certain target value or there can be restrictions on overall dimensions, to install more accelerometers on one crystal. Consequently, there is the problem how to set, for instance, spring rigidity properly so that movable and stationary plates never collide at maximum acceleration. It takes long to optimize this design manually. There are a lot of ways for structural optimization, but most of these methods cannot be implemented to solve problems which have to be solved with the help of finite-element method. Conducted investigation of ANSYS system and numerical techniques allowed to establish that it would be suitable to use the bisection method to find out optimum thickness of the seismic mass [8-10]. This method is simple enough and thereafter can be easily implemented in ANSYS system. That's why the task was to develop an algorithm that would allow to set the rigidity of elastic elements, which would prevent movable and stationary plates from collision and therefore destruction of accelerometer at maximum acceleration for which the accelerometer is designed. The next step requires using the bisection method program and implementation of suggested solutions. The suggested solution will make it possible to investigate optimization models of MEMS elements using the ANSYS system in terms of capacitive accelerometer.

To provide an automation of the design optimization process of the accelerometer one should at first develop some software code for the ANSYS system, which will help to determine the coercion for the target design parameters of the accelerometer at maximum acceleration. In the developed software model for accelerometer stimulation at maximum acceleration the following stages are used: the description of geometric model with overall dimensions, defining types of elements and properties of materials, etc. All parameter values are read from the Variables. txt file, using the command «PARRES, NEW, 'Variables', 'txt',''». During its operation the code will build the geometry, establish material properties, provide partition into finite element mesh and set target boundary conditions, and ultimately assign maximum displacement of the movable plate of accelerometer to variable MaxDispl.

As a result, we get the schedule of accelerometer's plate deformation.

III. Implementation of the Bisection Method to Optimize the Design of the Accelerometer

The bisection method is as the following: let target equation $f(x)=0$ on the interval [a; b] has a unique solution, with continuous function $f(x)$ in this interval.

To find the desired solution let's bisect the segment [a; b], $c=\frac{a+b}{2}$. In this case, *a* and *b* are respectively a minimum and maximum thickness of the elastic elements of the accelerometer. If the function at this point is other than zero ($f(c)\neq 0$), then two cases are possible:

1. the function $f(c)$ changes sign on the interval [a; c];
2. the function $f(c)$ changes its sign on the interval [c; b].

Choosing the interval on which the function changes its sign and carrying on the bisection method we will get arbitrarily small interval with the root of equation $f(x)=0$.

Based on the algorithm the supervisor program for ANSYS system. was developed.

Prec – is an acceptable error in the optimization of the thickness of the elastic element and seismic mass, micron;

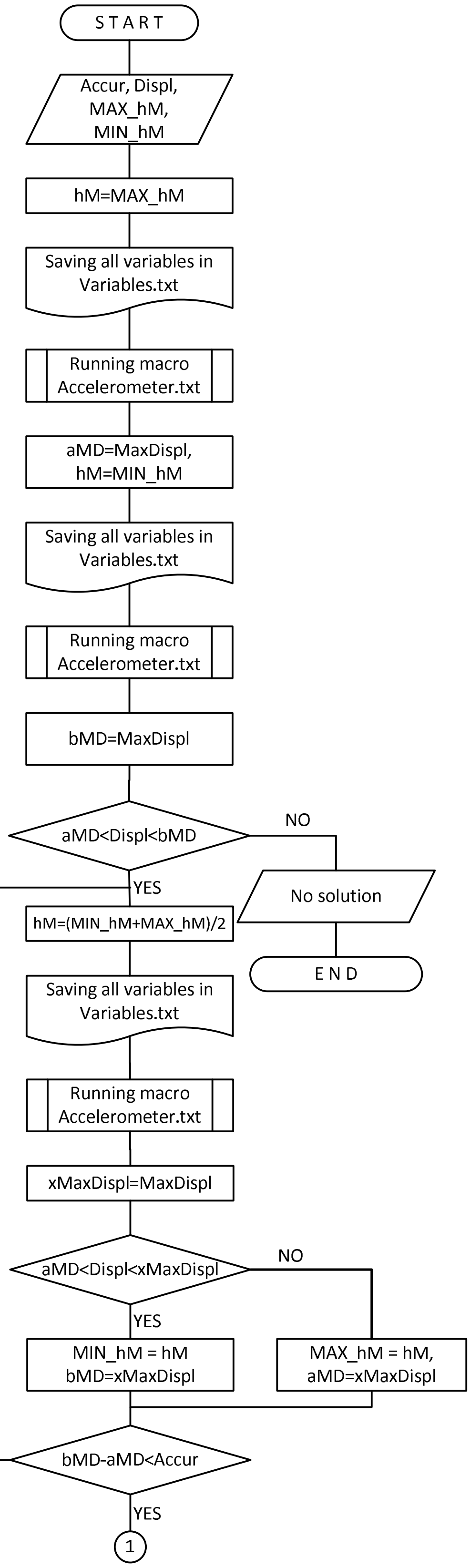
Displ – is the unknown coercion of the seismic mass;

MAX_hM – is the maximum thickness of the seismic mass, elastic elements and stable plate hM, micron;

MIN_hM - the minimum thickness of the seismic mass, elastic elements and the fixed plate hM, micron;

MaxDispl - displacement received in the current step;

Based on the algorithm, a block diagram of which is shown in Fig. 1. The supervisor program for ANSYS system. was developed.



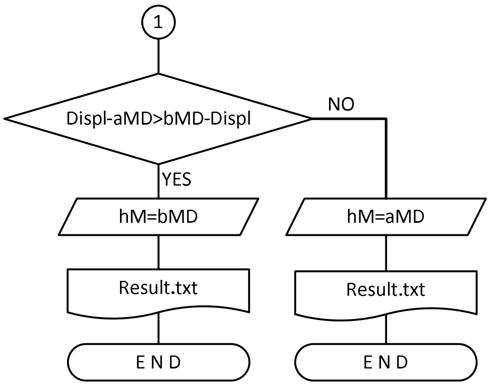


Fig. 1 Block diagram of accelerometer design optimization algorithm using the bisection method

Suggested and implemented solutions allowed to automate the process of optimizing the design of the accelerometer by not only changing the thickness of the elastic elements and can also be used for the selection of any other settings, and even for other MEMS-devices.

IV. The Analysis of the Results

Initially, the supervisor program determines the maximum coercion for minimum and maximum thickness of elastic elements. After the coercion for maximum and minimum thickness of the elastic element is defined, one conducts the check whether the required motion, in this case Displ = 5 microns exists within the prescribed limits, if not, the program stops and one needs to change the minimum or maximum value. If the required value fluctuates within the prescribed limits, the selection of optimum thickness of elastic elements for maximum displacement of 5 mm for the maximum acceleration has to be continued.

Having implemented the bisection method in the accelerometer optimization model for optimizing the design of the required accuracy for 9 iterations we found the required thickness of elastic elements of the accelerometer that will provide the desired displacement of 5 microns. As one can see from the results files the optimization was carried out from 13:12:52 pm to 13:15:30 pm, that is a solution for the problem took 2:38 minutes on the laptop with the Intel P8600 processor and 4GB of RAM. As a result, the required thickness of the elastic elements of the accelerometer is 2 microns, and the displacement of the seismic mass thus was 4.97 [mkm], with a required 5.0 [mkm]. To achieve greater accuracy, one has to change in the accuracy setting Prec in the supervisor program from the current 0.5 to 0,001 for example. Prec – is used as a condition for the termination of computing. If the difference between the last and the previous resulting value of displacement of the accelerometer is less than Prec, the calculation is terminated, but if not, they are repeated until full implementation of the conditions. So one has to be careful when setting accuracy, because having set great accuracy, one can significantly increase the calculation time.

The supervisor file states that the results of each iteration will be saved as graphic files and recorded simultaneously in a text file with results Result.txt.

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V. Conclusions

As a result of the developed programs, that used the method of bisection, to optimize the design succeeded in 9 iterations to find the required thickness of the spring elements capacitive accelerometer. This, in turn, has made it possible to assert that the movable plate will not be moved more than 5 mkm at the maximum acceleration, and accordingly, will not destroy the device. As a result of the automatic optimization of the design of the accelerometer, we got the following results: the thick of the spring elements equal to 2 mkm; moving at a thickness of 2 mkm and 5000e6 mkm/s^2 acceleration will be equal to 4.97 mkm. It was first proposed to use the bisection method to optimize the design of MEMS accelerometer in the ANSYS system, which made it possible to automate the process of selection of desired thickness spring elements accelerometer for receiving a predetermined displacement in the allowed error range. To automate the research process developed the code in the ANSYS system, which made it possible to automate the process of research of the optimization models.

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