Dynamics of disk-based MEMS Coriolis vibrating gyroscope

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Abstract. The paper investigates the dynamics of a micromechanical wave solid-state gyroscope with a disk resonator. The problem of free plane oscillations of the resonator on a fixed and rotating base is solved. Using projection methods, a discrete resonator model is constructed that takes into account the anisotropy of its mass and stiffness properties, as well as the action of the electrical balancing and vibration control system. The mode of parametric excitation of oscillations is investigated, the regions of parametric resonance are found.

Introduction

Micromechanical resonators are of great interest for a wide range of problems of measuring physical quantities and frequency filtering. Currently, disk resonators operating in the resonant mode on rigid volumetric forms of disk oscillations in their plane are becoming more promising. An analytical statement of the problem of free oscillations of the disk was considered in [1]. In [2], a discrete model of a wave solid-state gyroscope was constructed, and an algorithm for parametric excitation of oscillations was considered, which leads to an analysis of a system of two coupled oscillators. Using the multi-scale method, a generalized solution of this system was presented in [3]. The purpose of this work is to analytically and numerically study the dynamics of disk-based MEMS Coriolis vibrating gyroscope (CVG).

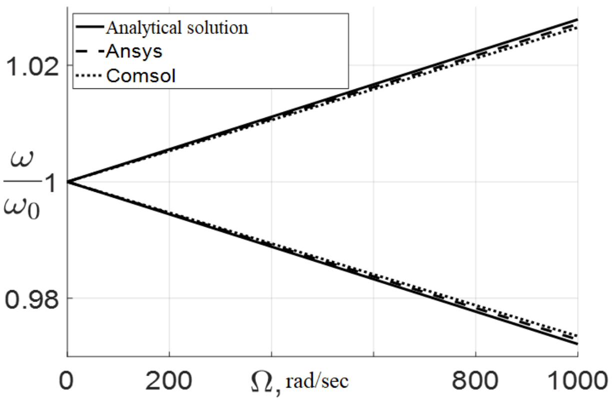

Figure 1: Dependence of the referenced natural frequency on the angular velocity (ω_0 - natural frequency at $\Omega = 0$).

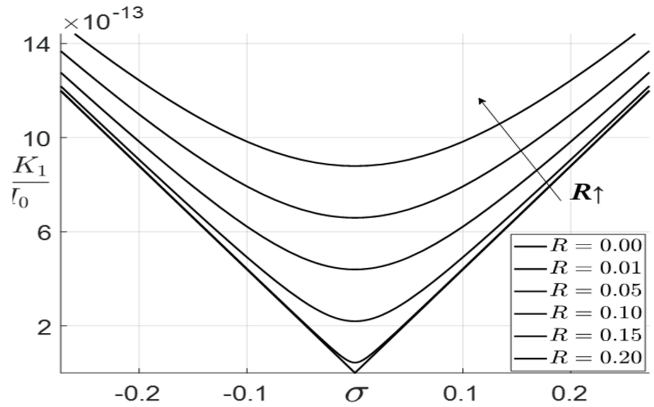

Figure 2: Transition curves parametric excitation (σ- frequency detuning parameter

Results and discussion

At the first stage of constructing a dynamic CVG model, the eigenfrequencies and modes of the disk were found using the numerical method of integrating systems of differential equations in the MATLAB software package. The problem was also solved in Ansys using the finite element method. For a sufficiently thin disk, the solution agrees well with the formula known in the literature, obtained for a thin ring. For an ideal isotropic disk, the influence of the Coriolis inertia forces on frequency splitting is studied. The problem is solved analytically and numerically in the Ansys, COMSOL software systems. The results showed that in the presence of the angular velocity of rotation of the base of the gyroscope, two frequencies correspond to the same mode of vibration, Fig.1. To excite the desired waveform, the electrode structure proposed in [2] was used. The structure under study consists of 24 electrodes with a round surface, and it contains 4 independent groups of electrodes located symmetrically relative to the resonator. Each electrode is placed in such a way that its surface is "parallel" to the cylindrical surface of the disk. The voltage at each group of electrodes varies in harmonic law. Assuming that the disk has inevitable mass imperfections, and also taking into account the preliminary stress state, we can write down the system of differential equations of motion of the resonator in the Lagrange form. Using the multi-scale method, the region of the main parametric resonance was found, and transition curves were constructed, Fig.2. The presented models and methods for studying the dynamics of micromechanical disk CVG can be further used to solve the problems of developing calibration test algorithms and methods of dynamic and electronic balancing of the sensor's sensitive element.

References

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