16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Synchronization of oscillations of weakly coupled elastic elements of a differential resonant MEMS-accelerometer in the mode of a two-circuit self-oscillator

IGUMNOVA V.S.[1*], LUKIN A.V.[2], POPOV I.A.[3], SHTUKIN L.V.[4]

1. Peter the Great St. Petersburg Polytechnic University (SPbPU) [0000-0001-7531-0220]
2. Peter the Great St. Petersburg Polytechnic University (SPbPU) [0000-0003-2016-8612]
3. Peter the Great St. Petersburg Polytechnic University (SPbPU) [0000-0003-4425-9172]
4. Peter the Great St. Petersburg Polytechnic University (SPbPU)

* Presenting Author

Abstract: In this paper we investigate the qualitative features of the nonlinear dynamics of a resonant differential MEMS-accelerometer, consisting of two resonators and an inertial mass, which are connected to each other by means of two elastic elements (springs). Excitation and maintenance of resonator oscillations occurs with the help of self-oscillators. When acceleration appears in the system, a longitudinal force of inertia arises in the moving elements, and therefore the natural frequency of one resonator decreases, while the other increases. The acceleration of the object is measured by the difference between the natural frequencies of the resonators, which is determined by tracking the envelope of the beat mode in the output signal of the sensor. In this work the evolution of the amplitude and phase difference in slow variables from the parameters of the initial detuning of the stiffness of the sensitive element (SE) and the magnitude of the axial inertia force is obtained. The transition from a two-frequency mode (beat mode) to a single-frequency mode (synchronization mode) is shown, using analytical methods of nonlinear mechanics, regions in the parameter space corresponding to two-frequency beat modes and phase synchronization are determined, which determines the range of sensor sensitivity to the measured component of the acceleration vector of a moving object.

Keywords: Synchronization, MEMS-accelerometer, self-oscillator, weakly coupled elastic elements

1. Introduction

A model of a MEMS accelerometer is proposed, which consists of two resonators and an inertial mass, which are connected to each other by means of two elastic elements (springs). Excitation and maintenance of resonator oscillations occurs with the help of self-oscillators.

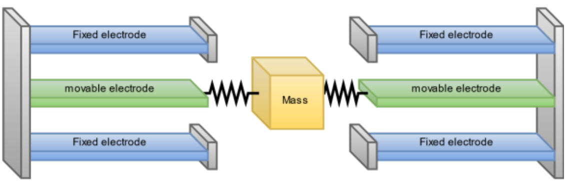

Fig. 1. MEMS accelerometer model

Under the action of portable acceleration, the moving mass is deflected and a longitudinal compressive force appears in the system for one of the resonators and a tensile force for the second resonator, which is a useful signal and allows one to obtain the measured acceleration component with high accuracy.

2. Results and Discussion

Figure 2 shows a bifurcation pattern that demonstrates the transition from dual-frequency mode (limit cycles) to single-frequency mode (synchronization).

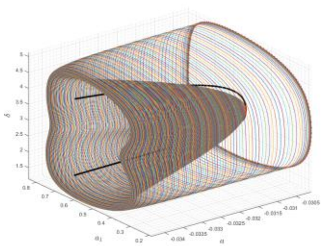

Fig. 2. The two possible modes of operation of the sensor are synchronization (black line) and beating (limit cycles). Where $\boldsymbol{a}$ – is the difference in the frequencies of the first and second resonators, $\boldsymbol{a_1}$ – is the amplitude of one of the resonators, $\boldsymbol{\delta}$ – is the phase difference between the first and second resonators

3. Concluding Remarks

In this paper, we investigate the qualitative features of the nonlinear dynamics of a resonant differential MEMS accelerometer, consisting of two resonators and an inertial mass, which are connected to each other by means of two elastic elements (springs). In this work, the evolution of the amplitude and phase difference in slow variables from the parameters of the initial detuning of the stiffness of the sensitive element (SE) and the magnitude of the axial inertia force is obtained. Shown is the transition from a dual-frequency mode (beat mode) to a single-frequency mode (synchronization mode).

The work was supported by RFBR grant 20-01-00537

References

[1] S.Wirkus, R.Rand: The Dynamics of two coupled var der Pol Oscillators with Delay Coupling. *Nonlinear Dynamics* 2002, 30:205-221.

[2] M.Kovaleva, V.Pilipchuk, and L.Manevitch: Nonconventional synchronization and energy localization in weakly coupled autogenerators. PHYSICAL REVIEW E **94**, 032223 (2016). *DOI: HTTPS://DOI.ORG/10.1103/PHYSREVE.94.032223*

[3] I.B. Shiroky, O.V. Gendelman: Modal synchronization of coupled bistable van der Pol oscillators. *Chaos, Solitons and Fractals Nonlinear Science, and Nonequilibrium and Complex Phenomena*, 2021.