Model of a micromechanical accelerometer based on the phenomenon of modal localization

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Abstract. In the present work, a model of a microelectromechanical accelerometer with two movable beam elements located between two stationary electrodes is proposed. The action of portable inertia forces in the longitudinal direction leads to a change in the spectral properties of the system, which is a useful output signal of the sensor. The dynamics of the system in the presence of a weak electrostatic coupling between the sensitive elements is characterized by the phenomenon of modal localization - a significant change in the amplitude relationships for the forms of in-phase and antiphase oscillations with small changes in the measured component of the object's acceleration vector. It is shown that the sensitivity of a sensor based on modal localization can be orders of magnitude higher than the sensitivity of known systems based on measuring the shift of natural frequencies.

Introduction

Currently, microelectromechanical systems (MEMS) are widely used in various technical applications, as well as for the study of fundamental physical phenomena. In weakly coupled resonators, the phenomenon of modal localization of oscillations is known. The mode localization phenomenon is defined as the limitation of the vibrational energy of one element of a coupled system when disturbances appear in the system in the form of a change in the rigidity of the structure. Another phenomenon of coupled systems in which mode localization is manifested is a change in the eigenvalue curve veering [1]. Veering occurs when the frequencies of the two modes approach and deviate from each other when the external control parameter changes. The sensitivity of sensors in which mode localization is implemented can be 1–4 orders of magnitude higher than that of sensors based on measuring the frequency shift [2], that is, it becomes possible to create ultra-high sensitivity sensors. Also, sensors of this type, to a small extent with respect to sensors based on the measurement of frequency shift, are sensitive to environmental factors: temperature, pressure, etc. A useful signal in sensors with modal localization is a change in the components of the eigenvector corresponding to the working form of oscillation under the action of an external disturbance [3]. In work [4], various approaches are presented for increasing the sensitivity of the resonator for sensory applications. An analytical and numerical study of a MEMS resonance accelerometer is presented in [5].

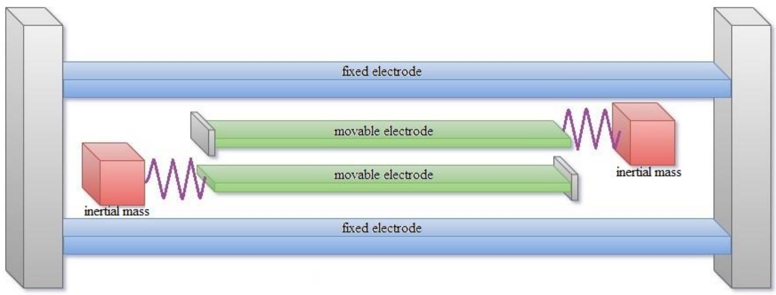

Figure 1: Scheme accelerometer

In the present work, a model of a microelectromechanical accelerometer with two movable beam elements located between two stationary electrodes is proposed. It is shown that the sensitivity of the sensor, based on the phenomenon of localization of oscillations in loosely coupled systems, can be orders of magnitude higher than the sensitivity of the system in the mode of measuring the shift in natural frequencies. The symmetry of the proposed sensor architecture also ensures its high resistance to environmental changes (temperature disturbances, pressure changes).

References

[1] C. Pierre, E. H. Dowell. Localization of vibrations by structural irregularity. Journal of sound and vibration. (1987) 114(3), 549-564

[2] C. Zhao, G.S. Wood, J.Xie, H. Chang, S.H. Pu, and M.Kraft, "A three degree-of-freedom weakly coupled resonator sensor With enhanced stiffness sensitivity," J. Microelectromech. Syst., vol. 25, no. 1, pp. 38–51, Feb. 2016.

[3] S. Ilyas and M.I. Younis, Theoretical and experimental investigation of mode localization in electrostatically and mechanically coupled microbeam resonators, International Journal of Non-Linear Mechanics (2020), doi: https://doi.org/10.1016/j.ijnonlinmec.2020.103516.

[4] A. Z. Hajjaj, N. Jaber, S. Ilyas, F.K. Alfosail, M.I. Younis. Linear and nonlinear dynamics of micro and nano-resonators: Review of recent advances. International Journal of Non-Linear Mechanics. 2019

[5] H. Zhang, M. Kraft. An acceleration sensing method based on the mode localization of Weakly Coupled Resonators. 2017