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Nonlinear dynamics of electrostatic comb-drive with variable gap

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Abstract: This paper is dedicated to investigation of nonlinear dynamics of electrostatic comb-drive with variable gap. Due to the fact, that electrostatic force is in nonlinear dependence on movable electrode displacement, the investigation of the system is provided by approximate asymptotic methods of nonlinear dynamics, in particular multi-scale method and methods of continuation theory. In paper the amplitude-frequency response and amplitude-force response were obtained for various values of parameters of elastic suspension's nonlinear force, DC, and AC constituents of electrostatic force amplitude. The area of parameter's values, in which comb-drive will provide a required amplitude of vibration, is obtained. An influence of second stationary electrode on dynamic of the system is appreciated.

Keywords: MEMS, electrostatic actuation, variable gap, multiple-scale method

1. Introduction

There are many types of microelectromechanical system actuation: electrostatic actuation, piezoelectric actuation, temperature actuation, magnetic actuation and so on. Electrostatic actuation is a most used version because it is easy in implementation and compatible with CMOS circuits. It is based on electrostatic attractive forces on plates with opposite sign electric charges and can be classified on two subtypes – perpendicular and parallel driving relatively to plane of electrodes. An advantage of variable gap actuator in comparison with variable area ones lies in value of created electrostatic force – with changing gap it is bigger. However, the disadvantage of such systems is limitation on displacement of movable electrode – when it will exceed the value equals one third of gap, the pull-in effect would perform, and system would break down.

2. Results and Discussion

A model of an electrostatic drive with a variable gap, consisting of a movable and one fixed electrode with a gap d between them, is considered. To equation of dynamics of an electrostatic drive considering the nonlinearity of an elastic suspension, the multiple-scale method was applied and equations in slow variables were obtained. Figure 1 shows the amplitude-frequency response when variable and constant component of voltage are changed.

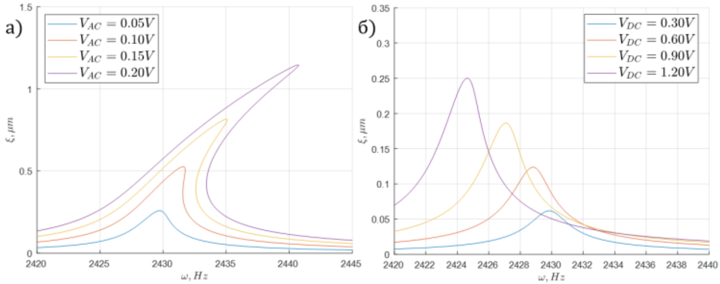

Figure 1. Amplitude-frequency response for different values of voltages

These dependences tilt to the right because the cubic nonlinearity of elastic suspension is included. Also, the resonant frequency become smaller with increasing constant component of voltage. Using the methods of bifurcation theory, the continuation of «limit-point» bifurcation by the parameters of variable and constant component of voltage was carried out and Figure 2 demonstrates meaning of this action.

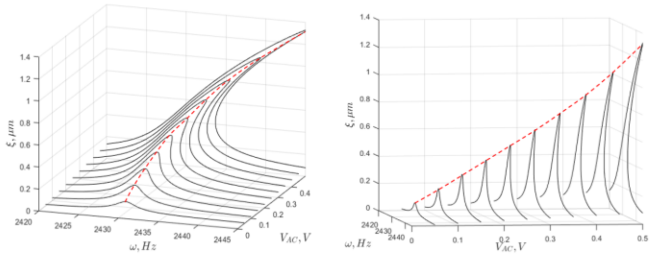

Figure 2. A series of amplitude-frequency responses for different values of voltages

In result the 3D graphs in parameters space were obtained and presented on Figure 3 for case without considering of influence of second stationary electrode is dash line and with considering this factor is solid line.

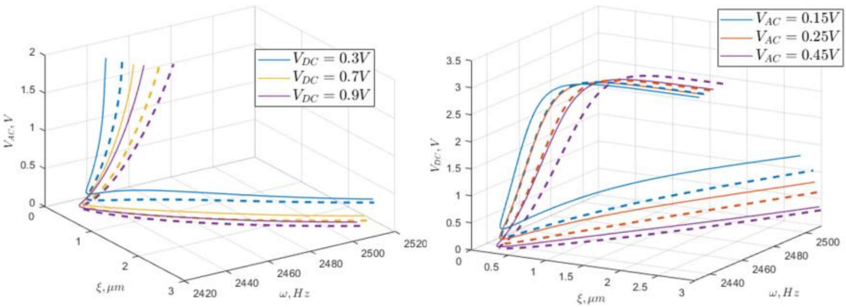

Figure 3. Dependence resonant aplitude and frequency on variable and constant components of voltage. Solid line – with of 2nd fixed electrode, dash line – without

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