Control of an electrostatically actuated micro portal frame with 2:1 internal resonance subjected to damping disturbances

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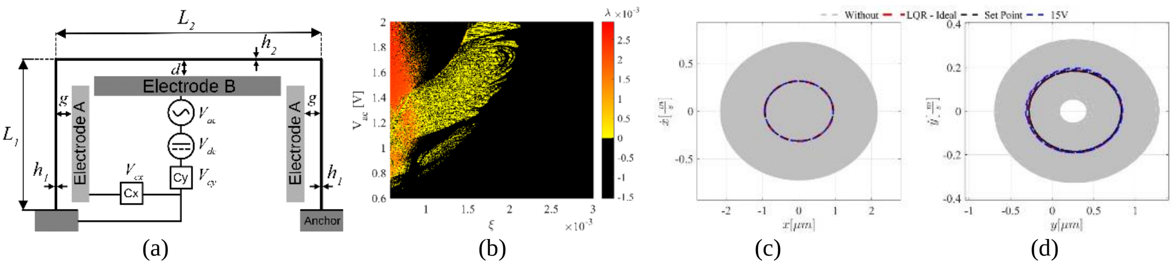
Abstract. This work aims to electrostatically control a micro portal frame, modeled as a two-degrees-of-freedom (2DOFs) system with 2:1 internal resonance between the second (Y-direction motion) and first (X-direction motion) modes. To avoid the irregular behaviors under the saturation phenomenon within the internal resonance, we propose to use the Linear Quadratic Regulator (LQR) control technique to create an electrostatic force that alleviates the damping effect. A comparison between the efficiency of an ideal control and considering the actuator in the control is highlighted.

Introduction

The dynamics of microelectromechanical systems (MEMS) have been extensively investigated due to the presence of many nonlinear behaviors that arise from excitation and geometric nonlinearities. One of the most intriguing nonlinear phenomena observed in MEMS resonators is internal, or autoparametric, resonance, which occurs when there is a commensurate ratio of the resonance frequencies between two modes of vibration [1,2]. Micro compound resonators have rich dynamics and are very promising to be used in applications, such as the U-shape (portal frame), in which the saturation phenomenon has been shown recently due to 2:1 internal resonance [3]. However, this nonlinear dynamic phenomenon is strongly affected by damping [3], either being suppressed or leading to irregular behaviors due to environmental pressure variations, which compromises the potential practical usage of the device. Therefore, we propose the application of the Linear Quadratic Regulator (LQR) control technique to create an electrostatic counter force that alleviates the pressure effect. The schematic of the utilized micro portal frame is shown in Fig. 1a. The microstructure is subjected to an electrostatic force, by a DC actuation voltage V_{dc} and an AC harmonic voltage V_{ac}, which actuates the 2nd mode, through two electrodes. One electrode is placed on top of the supported beam (Electrode B) and the other is placed on the column (Electrode A), which is used only for control purposes in the 1st mode direction. Control signals V_{cx} and V_{cy} are applied to electrodes A and B to control the 1st and 2nd modes of vibration, respectively. After validating the experimental results, numerical simulations showed that the 2:1 internal resonance is activated and the saturation phenomenon occurs when the structure is actuated with V_{dc} = 46V. However, the dynamic behavior can highly change depending on the damping ratio [3]. Fig. 1b shows the Maximum Lyapunov exponent map to the variation of the damping coefficient (ξ) and the AC excitation. Note that at high the AC and the smal ξ (lower environmental pressure), chaotic behavior is observed. To control the chaotic behavior, the LQR control technique is implemented to actuate both 1st and 2nd modes. Fig. 1c and 1d show the 1st and 2nd modes phase portraits, respectively, with and without control. Note that applying V_{cx} = V_{cy} = 15V is sufficient to control the chaotic behavior and maintains a stable periodic orbit, which yields a clear signal that improves the readability of the electrical signal for sensing purposes.

Results and discussion



(a) (b) (c) (d)

Figure 1: (a) Micro portal frame schematic. (b) Maximum Lyapunov exponent map depending on the damping coefficient and the AC excitation. (c), (d) 1st and 2nd modes phase portraits, respectively, with and without the controls. Red lines show the ideal control applied to the system while the blue dotted lines are the control implemented as an electrostatic force.

This work showed the control of the chaotic behavior when there is 2:1 internal resonance activation. The control shown to be very efficient in converting chaos into a periodic orbit, mainly when the control is implemented as the electrostatic force (V_{cx} and V_{cy}).

References

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