Nonlinear investigation on the dynamics and effectiveness of multifunctional energy harvesting gyroscopes

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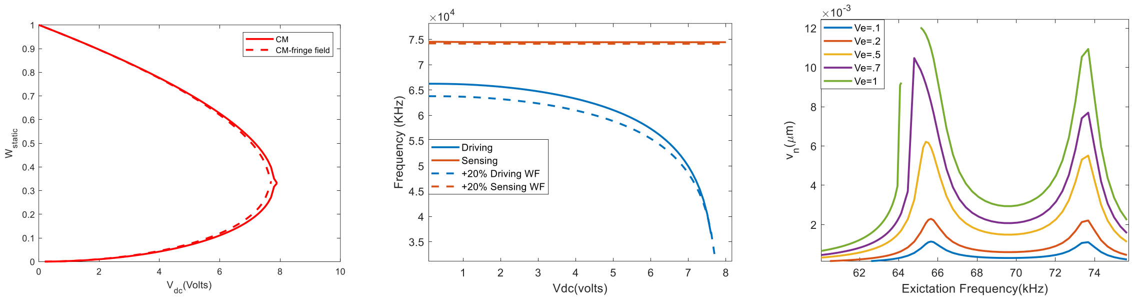
Abstract. Harvesting energy from wasted mechanical vibrations can reduce or possilbly eliminate the need to replace power sources in small devices in remote or hard to reach locations. In this work, a novel multifunctional energy harvesting gyroscope system using perovskite piezoelectric materials is proposed. This work focuses on developing a reliable nonlinear reduced-order model for the design of microelectromechanical (MEMS) inertial sensing gyroscopes with broadband energy harvesting capabilities. The Hamilton's principle and Differential Quafrature Method are used in order to derive the reduced-order model. Then, the nonlinear responses of the multifunctional system are obtained and discussed.

Introduction

Portable and miniature equipment attracts widespread attention due to its potential for wireless, remote sensing, mobile electronics, wearable health devices, aerospace, and military applications [1]. Energy harvesters can convert wasted mechanical energy into usable power. Inertial micro/nano-sensors like gyroscopes are perfect candidates for multifunctional energy harvesting MEMS/NEMS devices [2]. In this study, the unique characteristics of piezoelectric materials are leveraged for energy harvesting and sensing purposes. A piezoelectric patch is used in place of a standard sensing electrode employed in many previous gyroscope designs [3]. Doing this will allow for the piezoelectric patch to perform two tasks simultaneously, sensing changes in angular velocity and harvesting energy (EH), thus removing the requirement to replace batteries or running wires to charge the device. The static pull-in, natural frequencies, and nonlinear frequency response of the system are investigated to determine the energy harvesting the sensing potential of the proposed multifunctional EH gyroscope, as shown in Figure 1.



(a) (b) (c)

Figure 1. The (a) static pull-in, (b) natural frequencies for a microgyroscope with increasing DC voltage, and (c) sensing displacement of the energy harvesting micro gyroscope for varying values of Vac with Vdc=2Vand Ω= 80 rad/s. Dashed lines represent with fringe field.

Results and Discussion

The pull-in voltage is an important design parameter to prevent the system from collapsing due to a large electrostatic force, as seen in Figure 1(a). The analysis of the natural frequencies (Figure 1(b)) aids in system design, as one of the primary objectives is to adjust the distance between the driving and sensing frequencies the EH gyroscope. If the driving and sensing resonance frequencies are close enough, a boardband frequency responce can be formed in the sensing direction (Figure 1(c)) which is diserable for energy harvesting for energy harvesting. Deeper investigations will be performed in order to show the capability of this design compared to classical gyroscopes and the impacts of the coupling on the nonlinear performance of the system.

References

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