Influence of Model Nonlinearities on the Dynamics of Ring-type Gyroscopes

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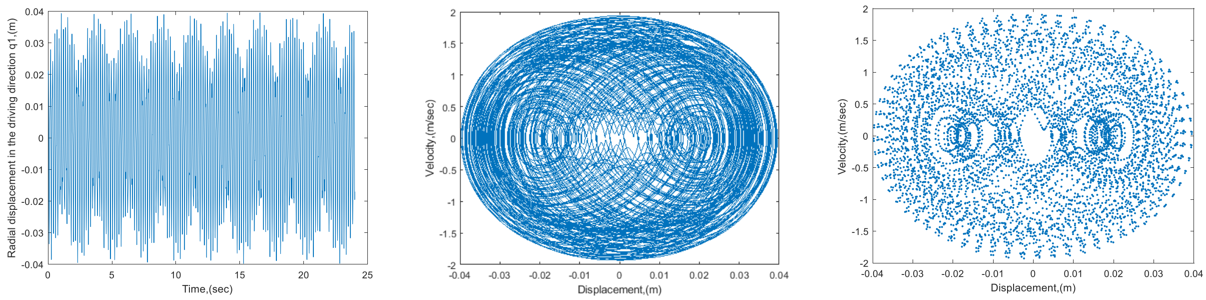
Abstract. This paper investigates the nonlinear dynamic response of a rotating ring that forms an essential element in macro ring-based vibratory gyroscopes that utilize oscillatory nonlinear electromagnetic forces. The mathematical model for ring-type gyro, as well as a model to generate nonlinear electromagnetic forces that act on the ring structure, is formulated. Understanding the effects of model nonlinearities is considered important for characterizing the dynamic behavior of such devices. Nonlinear dynamic response in the driving and the sensing directions are examined via time responses, phase diagram, and Poincare' map when the input angular motion and the nonlinear electromagnetic force are considered simultaneously.

Introduction

In the present paper, nonlinear dynamic behavior of rotating thin circular rings for use in vibratory angular rate, sensors have been investigated via numerical simulations. A homogenous, isotropic ring is chosen as the resonator. Dynamic response and stability behavior of rotating thin circular rings for use in vibratory angular rate sensors have been investigated previously by Cho [1] and Gebrel at el [2] by employing the linearized model considering the second flexural mode. In the latter study, a suitable theoretical model to generate nonlinear electromagnetic excitation forces are developed. The schematic of the rotating ring geometry used in present study have been described in detail in [1, 2].

Results and Discussion

In the present study, a nonlinear model which includes a complex nonlinear inertia/stiffness terms as well as a nonlinear electromagnetic force have been employed. In order to illustrate the applicability of the analytical results, typical parameters associated with a macro ring-type angular gyroscope as used in [2] are considered. When the Gyroscope is subjected to an input angular velocity $\Omega = 2\pi\ (rad/sec)$, under nonlinear oscillatory electromagnetic excitation, the time response as well as the phase portrait for the ring in the driving direction are depicted, respectively, in Figures 1 (a) and1(b). The effects of nonlinearities are evident from the plots. The corresponding Poincare' map shown in Figure 1(b) illustrates the influence of nonlinear terms in the model as well as the actuator.



(a) (b) (c)

Figure 1: (a) Radial displacement, (b) Phase diagram, and (c) Poincare' map.

Results on the dynamic response obtained via time-response, Phase portraits, and Poincare' maps indicate that the nonlinearity in the model, as well as actuation plays an essential role in shaping the ring dynamic behavior. Comparison with the linear model study [2], it can be concluded that the inclusion of model nonlinearities in the presence high vibration amplitudes has a strong influence and hence greatly demonstrates its significance.

References

[1] Cho, J.; Asokanthan, S.F. (2009) Nonlinear Instabilities in Ring-Based Vibratory Angular Rate Sensors. *PhD. Thesis,* Department of Mechanical Engineering, University of Western Ontario, Canada.

[2] Gebrel, I.F.; Wang, L.; Asokanthan, S.F. (2018) Dynamics of a Ring-Type Macro Gyroscope under Electromagnetic External Actuation Forces. *Proceedings of the ASME International Design Engineering Technical Conferences IDETC/CIE*, Quebec, Canada, 86334, pp.V008T10A028.