DESIGN AND ANALYSIS OF MEMS GYROSCOPE

Preethi.B., V.S. Selvakumar, Dr.L. Sujatha.

Rajalakshmi Engineering College, Thandalam, Chennai.

Excerpt from the Proceedings of the 2012 COMSOL Conference in Bangalore

Overview

- A Tuning- fork MEMS gyroscope is designed with a perforated proof mass.
- The proof mass used in the design enables the reduction of damping effect.
- The perforation enables the release of the proof mass during etching process in the fabrication.

Contents

- Introduction
- MEMS Gyroscope
- Types of Gyroscope
- Tuning fork Gyroscope
- Working principle
- Structural Design
- Simulated results
- Displacement
- References

Introduction

Microelectromechanical system (MEMS) gyroscopes have gained popularity for use as rotation rate sensors in commercial products like cars and game consoles because of their cheap cost, small size and low power consumption compared to the traditional gyroscopes. Several MEMS gyroscopes have been commercialized. As for structure designs, tuning- fork gyroscopes (TFG) are the most popular choice.

MEMS Gyroscope

- A gyroscope is a device for measuring or maintaining the orientation, based on the principles of the conservation of momentum.
- It uses vibrating mechanical element to sense the rotation.
- Transfer of energy between two vibrating resonator is by coriolis acceleration.
- The apparent acceleration that arises in the rotational reference frame is directly proportional to the rate of rotation.

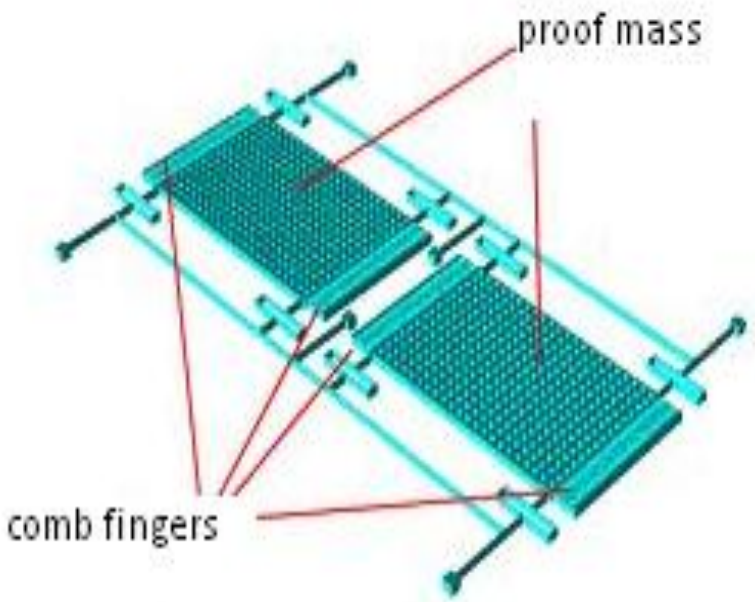
Types of Gyroscope

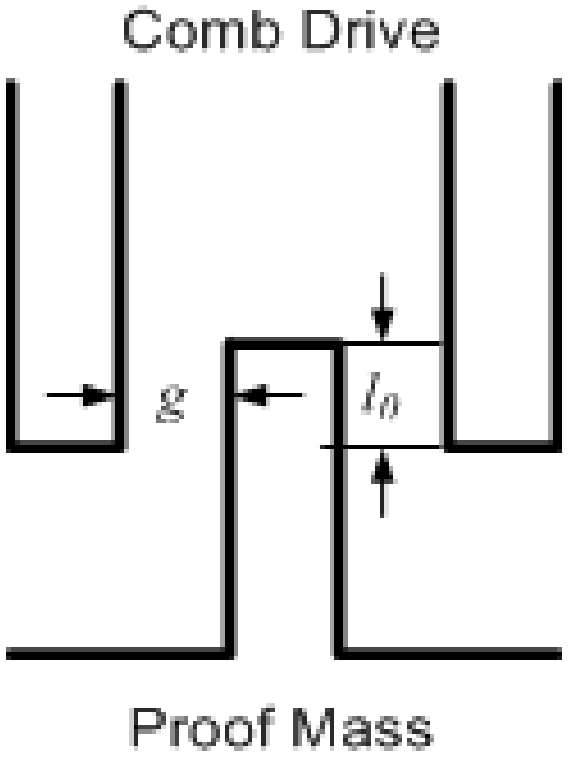
- Spinning Gyroscope
- Optical Gyroscope
- Vibrating Gyroscope

Tuning fork Gyroscope

- Contain a pair of masses that are driven to oscillate with equal amplitude but in opposite direction.
- When rotated the coriolis force causes a differential sinusoidal force, on individual tines, orthogonal to main vibration.
- These forces are proportional to applied angular rate, from which displacements can be measured.

Tuning fork gyroscope

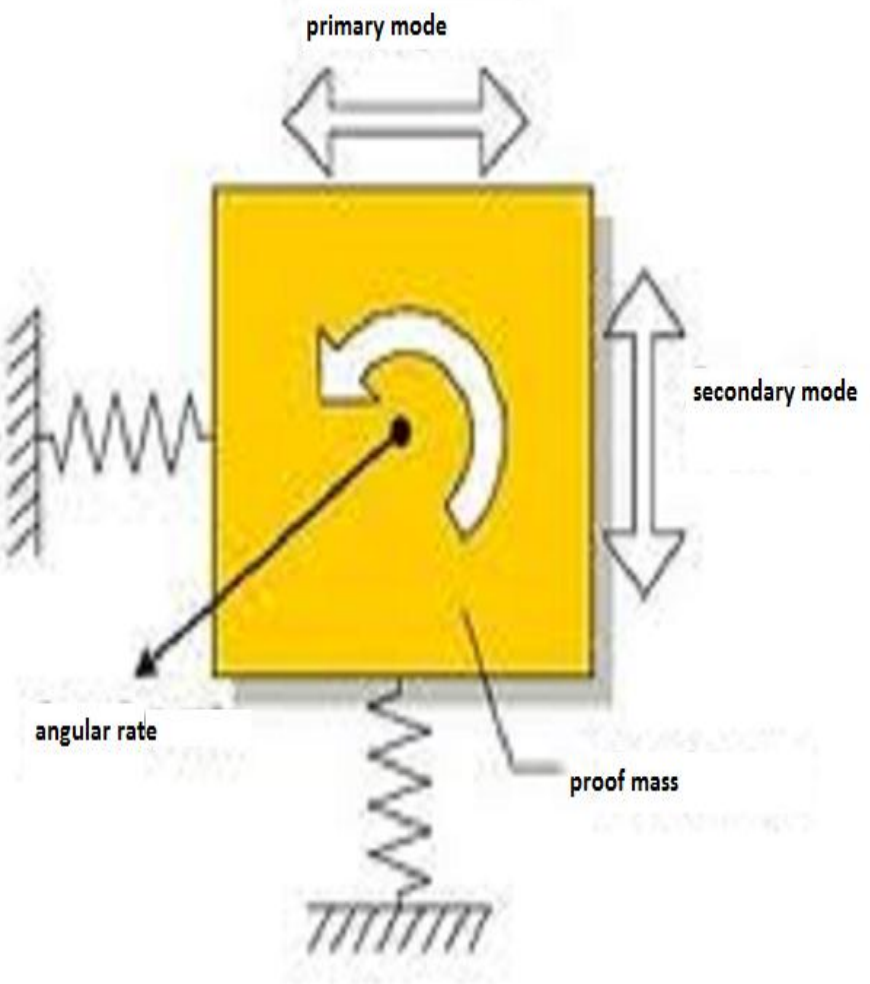




Working principle

- Coriolis Effect:

  - Coriolis effect is the deflection of moving objects when they are viewed in a rotating reference frame.



Coriolis force

- Force exerted on a body when it moves in rotational reference frame

$$F_c = -2m(\omega \times \upsilon)$$

- Acts perpendicular to rotation axis and velocity of body in rotating frame

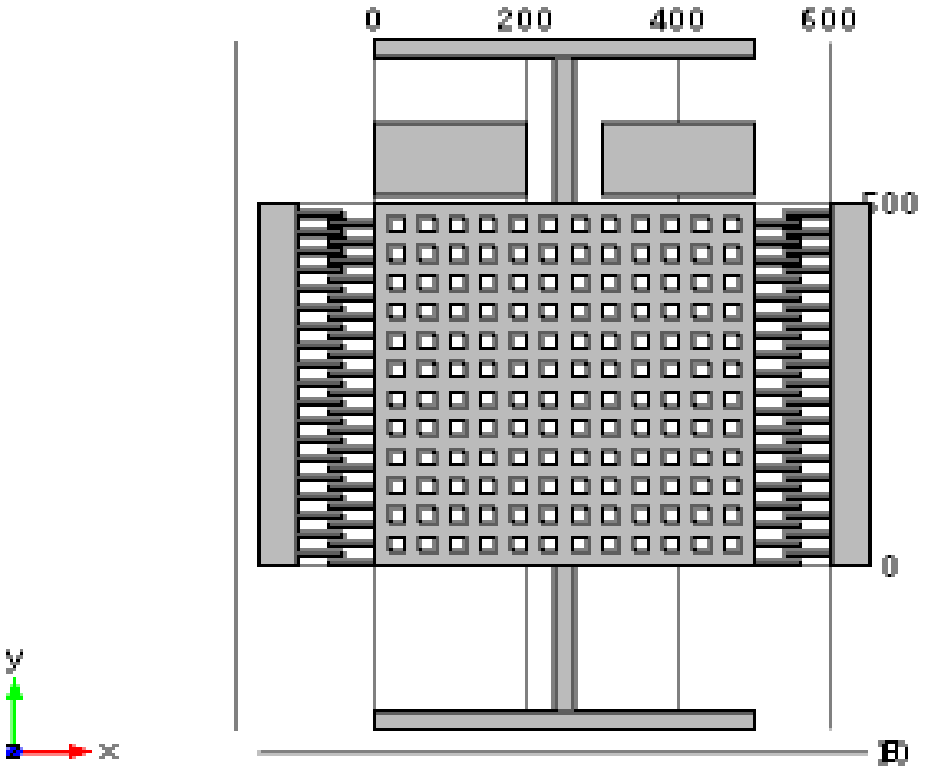
- Proportional to rotating rate

Applications

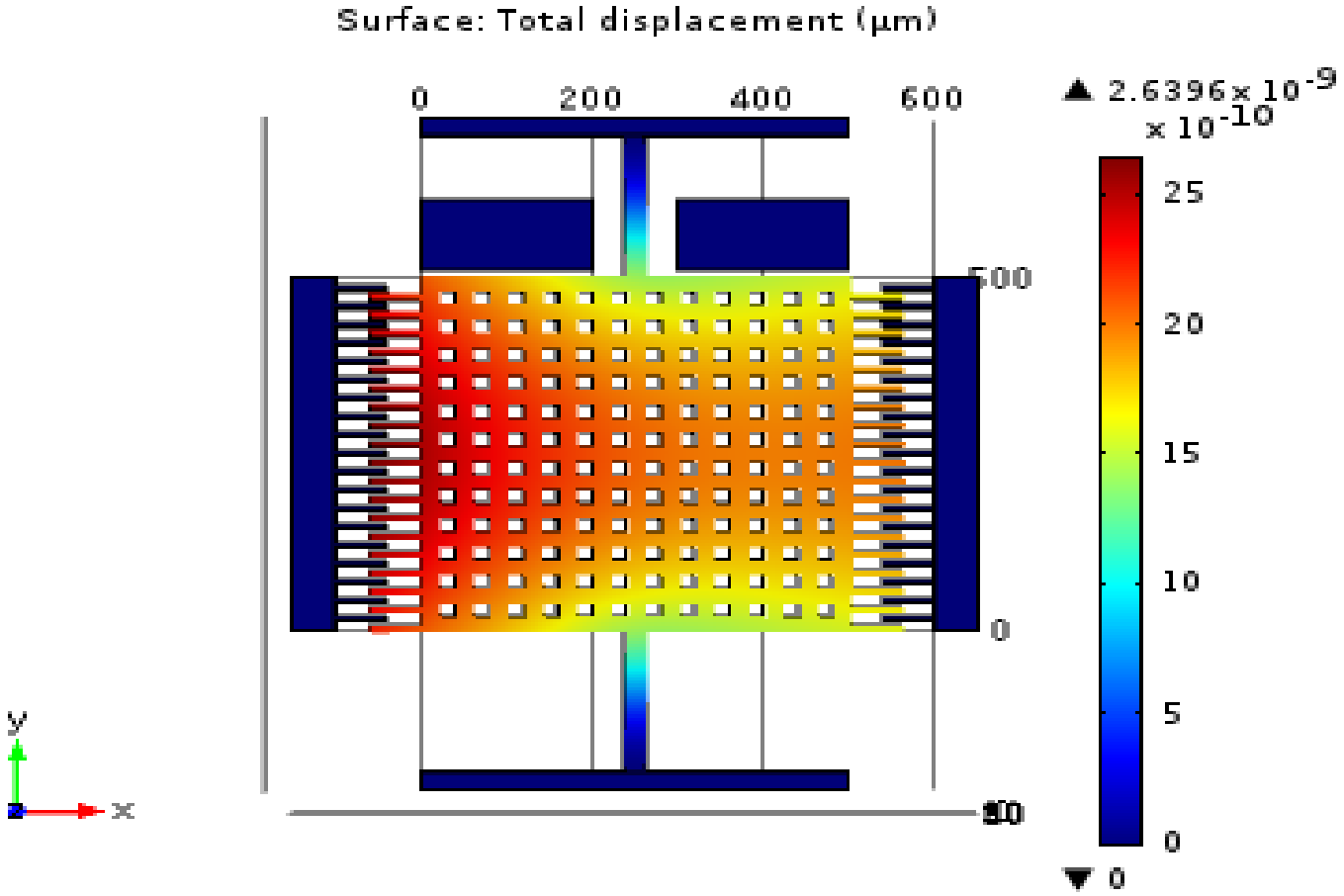
The general applications of the tuning fork gyroscope are:

- Yaw rate sensor for skid control in antilock braking applications for automobiles.
- Inertial navigation systems.
- Smart cruise control.
- Guiding gun launched munitions.
- Detection of roll over detections.

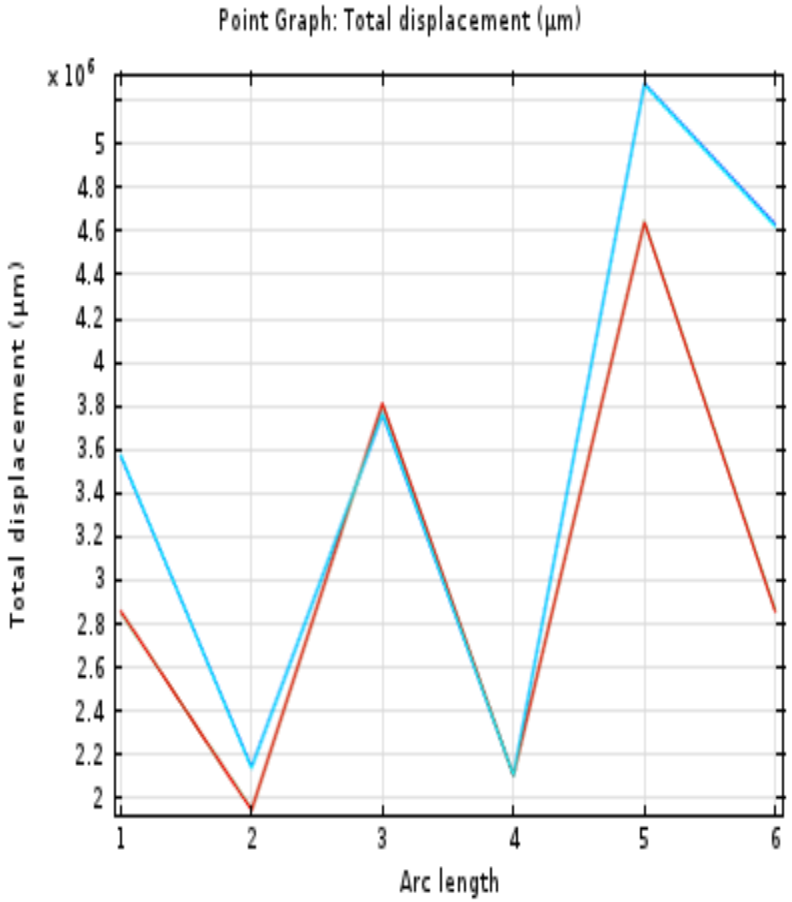
Structural Design

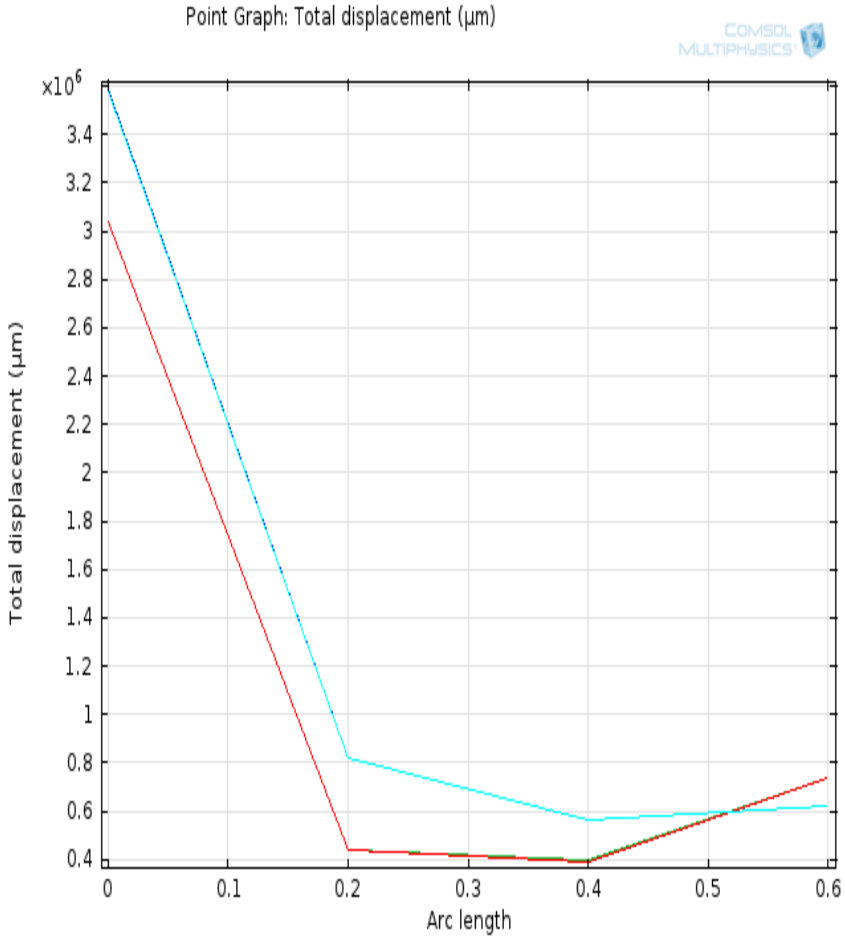


Simulated Results



Displacement





References

- Marc S. Weinberg, Member, ASME , and Anthony Kourepenis, “Error sources in In-Plane Silicon Tuning Fork MEMS Gyroscope”.
- A.S.Phani, A.A. Seshia, M.Palaniappan, R.T.Howe, J.Yasaitis, “Coupling of Resonant Modes in Micromechanical Vibratory Rate Gyroscopes”.
- W.Geiger, W.U. Butt, A.Gaiber, J.Frech, M. Braxmaier, T.Link, A.Kohne, P.Nommensen, H.Sandmaier, W.Lang, “Decoupled Micro gyros and the Design Principle DAVED”.
- Z.Y.Guo, Z.C. Yang, L.T. Lin, Q.C. Zhao, J.Cui, X.Z.Chi, and G.Z. Yan, “Decoupled Comb Capacitors for Micro electro mechanical Tuning-Fork Gyroscopes”.

References

- Chris C. Painter, Andrei M. Shkel, “Active Structural Error Suppression in MEMS Vibratory Gyroscopes”.
- Braxmaier. M, Geiger. W, Butt. W. U., Gaiber. A, Frech. J, Link. T, Kohne. A, Nommenson. P, Sandmaier. H, Lang. W, “Decoupled Micro Gyros and the Design Principle DAVED”, Sense. Actuators A, phys., vol. 95, no. 2/3, pp. 239- 249, January 2002.
- Changjoo Kim, Woon- Tahk Sung, Sangkyung Sung, Sukchang Yun , and Young Jae Lee, “On the Mode- Matched Control of MEMS Vibratory Gyroscope via Phase- Domain Analysis and Design”, IEEE / ASME .

THANK YOU