Modeling and Simulation of MEMS based 3D Vibrating Gyroscope for Mobile Robotic Applications

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Overview

- A biomimetic vibrating 3D MEMS Gyroscope was modeled and simulated using COMSOL Multiphysics 4.1. The simulated results show that the displacement due to Coriolis effect, used for restoring the body back to its initial position, was greater when compared to that of the electrostatic force. These results let us to conclude that this gyroscope would provide valuable orientation information for robotic applications.
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• Introduction
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Gyroscope

• Angular rate sensors or angular velocity sensors
• Senses rotational motion
• Detects changes in orientation
• Used for guidance and control.
Types of Gyroscope

• Spinning Gyroscope

• Optical Gyroscope

• Vibrational Gyroscope
Vibrating Gyroscope

- Use vibrating mechanical elements to sense rotation, which contains no rotating parts

- Coriolis Effect – Newton’s third law
Principle

- Device rotating along rotational (y) axis
- Drive force applied in (z) axis
- Coriolis force induced in sense direction (x), perpendicular to drive and rotational direction

Fig.1 Basic principle of gyroscope
Coriolis Force

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

\[ F_c = -2m (\omega \times v) \]

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

- Proportional to rotation rate
How it works?

Fig. 2 Illustration of a vibrating gyroscope
Why MEMS Vibrating Gyroscope?

- Small
- Lightweight
- Inexpensive
- Higher resolution
Robot Balance Control

Moving forward, demand for vibration gyros is expected to grow in areas such as vehicle driver safety and support systems, and in robot motion control.

• Closed-loop control system
  • To maintain prescribed vibration
  • For reorientation

• Senses vibration produced by external factors, and transmits vibration data as electrical signals to a CPU
Biomimetic approach

- Flies- (*Drosophila, Calliphora vicina*)- halteres
- Halteres-
  - Evolutionary modified hind wings which beat antiphase to the wings
  - Serve a sensory function during flight
  - Sensitive to Coriolis force during rotational movements
- Campaniform sensilla

Fig.3 Haltere of an insect
Structural Design

Fig. 4 Adopted 3D model
Simulation Results
Displacement due to Electrostatic and Coriolis Forces

Fig. 5(a) Displacement field due to Electrostatic force

Fig. 5(b) Displacement field due to Coriolis Force
Z axis displacement field in the thinner membrane

Fig. 6 (a) Graphical representation of displacement field due to Electrostatic Force

Fig. 6(b) Graphical representation of displacement field due to Coriolis Force
Sensing Methodologies

Fig. 7(a) Piezoelectric Sensing

Fig. 7(b) Capacitive Sensing
Fig.8 Applications

Gyro sensors are used in products all around us.
Conclusion

• Displacement due to Coriolis effect, used for restoring the body back to its initial position, was greater when compared to that of the electrostatic force.

• Provides valuable orientation information for robotics applications.
References


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