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Improvement of Characteristics of Frequency-Change-Type Two-Axis Acceleration Sensor
周波数変化型２軸加速度センサの特性改善

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1. Introduction

A small low-cost acceleration sensor with high sensitivity has been required for application to the attitude control and navigation systems of moving objects, such as vehicles, and tended to be a multi-axis-type sensor. The authors have studied an acceleration sensor that utilizes the phenomenon that the resonance frequency of a bending vibrator changes with axial force. Then, the structures of one- and two-axis acceleration sensors were proposed, and investigated experimentally.[1-8] But, the characteristics of the two-axis sensor shoud be improved on the point that an signal from the other axis is detected.[9] As this reason, it is clarified that mass of the sensor rotates by acceleration in the plane. Therefore, the rotation should be reduced to become zero.

In this study, the characteristics of the two-axis acceleration sensor are improved and investigated experimentally.

2. Structure of Sensor

Fig. 1 shows the structure of the frequency-change-type two-axis acceleration sensor, which can detect accelerations along the *x*- and *y*-axes. The sensor is composed of two 45° -arranged bending vibrators, a mass (*M*), support bars and a frame for fixation.

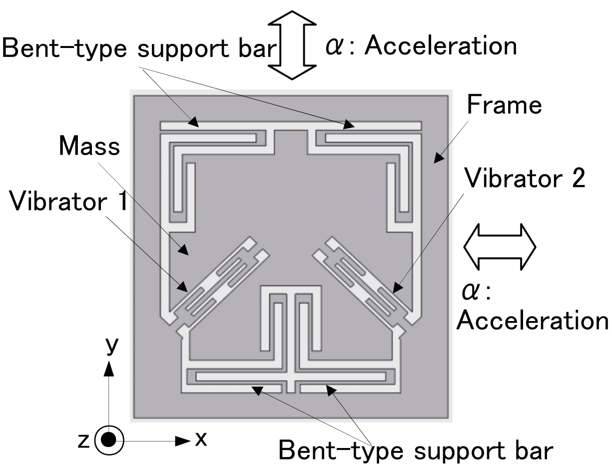

Fig. 1 Structure of two-axis sensor

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The out-of-plane modes of vibration in the vibrator are shown in **Fig. 2**, and the first mode of vibration is used here. A higher mode of vibration can be also used. In this sensor, one end of the bending vibrator is fixed at the frame, and axial force F ($=M\alpha$), which is the product of the mass M and the acceleration α, is applied to the other end of the vibrator. The resonance frequency f_0 of the vibrator is changed by this axial force F. The acceleration α is determined from the frequency change Δf ($=f_0' - f_0$).

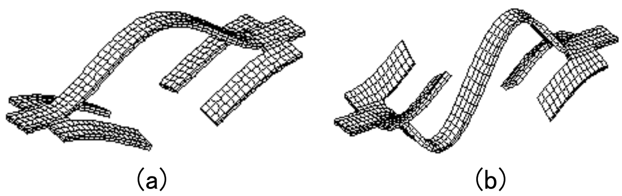

Fig. 2 Out-of plane modes of vibrator.

3. Improvement of sensor characteristics

Sensor Material is stainless steel (SUS304). The young's modulus, Poisson's ratio, and the density of the material are E=1.99×10^{11} N/m^2, σ =0.34, and ρ =7.9 × 10^3 kg/m^3, respectively. Although the sensor may be miniaturized in the future using a single crystal, it is fabricated with large dimensions for ease of handling in this case. The sensor is driven electrically by small piezoelectric ceramics bonded on the central arm of the vibrator. As software for the finite-element analysis, Ansys 11.0 of Cybernet System was used.

To realize high sensitivity, the characteristics were measured under the condition of the -45° rotation around the z-axis. **Fig. 4** shows the characteristics of $\alpha - \Delta f/f_0$ of the two-axis sensor of the experimental sample shown in **Fig. 3**. Here, only the characteristics under the acceleration along the y-axis are shown, and G=9.8m/sec^2. The measured characteristics agree well with the calculated ones. But, the undesirable frequency change $\Delta f_1/f_{01}$ is observed, therefore should be removed. It was clarified that the undesirable frequency change appears when the mass rotates around the z-axis.[9] To realize the preferable characteristics, the center of gravity in the mass was moved along the *y*-axis so as not to cause the rotation. The length of the mass to the *y*-axis was increased, as shown in **Fig. 5**. The characteristics realized by such device are shown in **Fig. 6**. The measured characteristics agree with the calculated ones. The undesirable change in **Fig. 4** hardly appears in **Fig. 6**. The ratio of $(\Delta f_1/f_{01})/(\Delta f_2/f_{02})$ was theoretically reduced from 5.3% to 0.4%, and experimentally from 7.8% to 0.3%, respectively. Moreover, the sensor sensitivity becomes higher because of the increase in the mass.

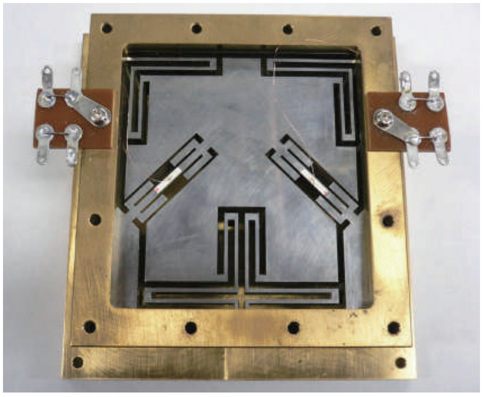

Fig. 3 Experimental sample of prototype sensor.

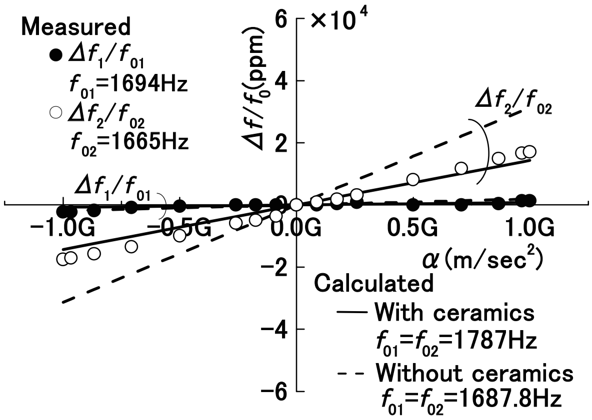

Fig. 4 Characteristics of prototype sensor.

4. Conclusions

The characteristics of the two-axis acceleration sensor were improved and investigated experimentally. The undesirable frequency change due to the sensitivity along the other axis is caused by the rotation of the mass around the z-axis. To improve such the sensor characteristics, the center of gravity in the mass was moved along the *y*-axis. As a result, it was clarified that the undesirable frequency change is not almost observed.

Acknowledgment

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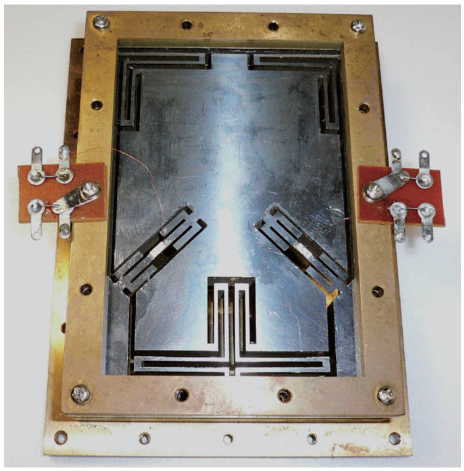

Fig. 5 Experimental sample of improved sensor.

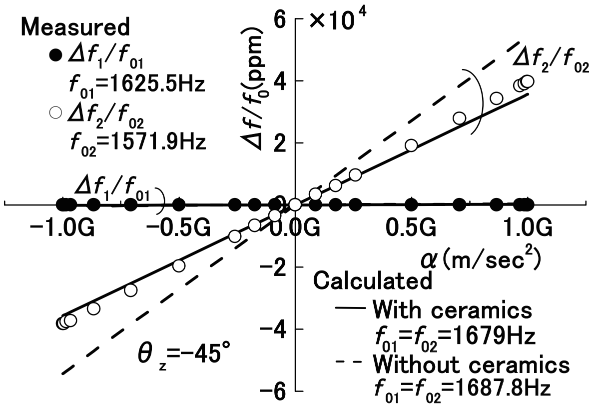

Fig. 6 Characteristics of improved sensor.

References

1) S. Sugawara, K. Masuda, and Y. Tomikawa: Jpn J. Appl. Phys., **40** (2001) 3683.
2) S. Sugawara, J. Takahashi, and Y. Tomikawa: Jpn J. Appl. Phys., **41** (2002) 3433.3
3) J. Takahashi, S. Sugawara, and J. Terada: Jpn J. Appl. Phys., **42** (2003) 3124.
4) J. Takahashi, and S. Sugawara: Jpn J. Appl. Phys., **43** (2004) 3035.
5) S. Sugawara, H. Suzuki and T. Saito: Jpn J. Appl. Phys., **46** (2007) 4652.
6) S. Sugawara, T. Watanabe, and J. Terada: Jpn J. Appl. Phys., **47** (2008) 4048.
7) S. Sugawara, and J. Koike: Jpn J. Appl. Phys., **47** (2008) 6578.
8) S. Sugawara, M. Yamakawa, and S. Kudo: Jpn J. Appl. Phys., **48** (2009) 07GF04-1.
9) S. Sugawara, and Y. Kajiwara: Jpn J. Appl. Phys., **49** (2010) 07HD02-1.