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Construction of Frequency-Change-Type Two-Axis Acceleration Sensor

周波数変化型２軸加速度センサの構成について

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1. Introduction

Recently, 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. To develop such a sensor, the authors have studied the acceleration sensor that utilizes the phenomenon that the resonance frequency of a bending vibrator changes by axial force.[1-11] In the two-axis acceleration sensor, it is important that the motion of mass becomes linear toward the x- and y-axes. The motion of mass along the x-axis direction is especially important in the proposed sensor, and an undesirable signal due to the other axis direction is observed on the characteristics by a rotational motion of mass. On the other hand, the motion of mass along the y-axis direction becomes linear necessarily because the sensor proposed has a symmetric structure about the y-axis. Two methods for improving the characteristics were proposed and investigated by finite-element analysis.[12] The first method of moving the center of gravity in the sensor results in a small undesirable signal decreased from 5.1 to 0.4%, but the volume of the sensor increases by 28%. The second method of adjusting the dimensions of a bent-type support bar is very useful from the standpoint of realizing the same volume as the prototype sensor, but the characteristics of the sensor designed by this method has been not confirmed experimentally.

In this paper, the characteristics of the frequency-change-type two-axis acceleration sensor designed by adjusting the dimensions of a bent-type support bar are measured and compared with the calculated ones. Moreover, the new structures of the sensor without the undesirable output are proposed, and the sensor characteristics are investigated.

2. Structures of Vibrator and Sensor

Fig. 1 shows a vibration mode of the bending vibrator which was proposed by the authors. Displacements at both ends of the vibrator are designed so as to become very small. The vibrator is used as a force sensor of the acceleration sensor. In the case of the frequency-change-type acceleration sensor, the vibrators are arranged as shown in Fig. 2. This sensor has the improved characteristics reducing the undesirable signal due to a rotational motion of mass. The characteristics are realized by adjusting the dimensions of lower two bent-type support bars in order to realize a linear motion of mass.

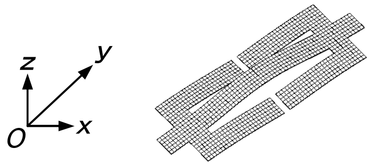

Fig. 1 Vibration mode of bending vibrator.

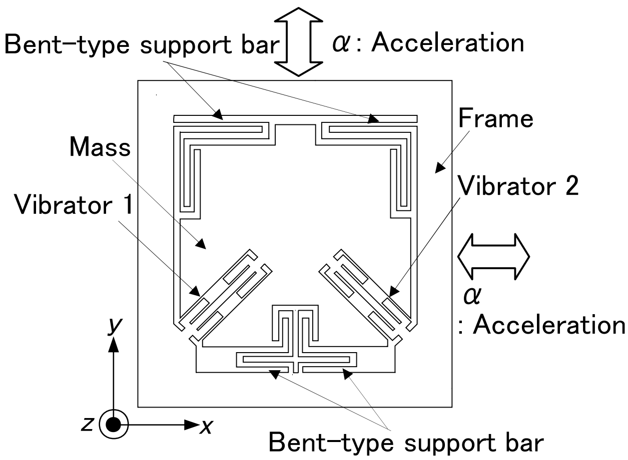

Fig. 2 Structure of two-axis acceleration sensor.

3. Characteristics of Sensor

Fig. 3 shows the characteristics of the sensor structure shown in Fig.2. The undesirable signals, $\Delta f_{2x}/f_{02}$ in Fig. 3(a) and $\Delta f_{1y}/f_{01}$ in Fig. 3(b), are produced by applying the accelerations α in the x- and y-axis directions. When the sensor is rotated -45° around the z-axis, these signals are observed clearly. The experimental data was measured by bonding small piezoelectric ceramics on the center arm of the bending vibrator. The broken lines show the calculated characteristics without piezoelectric ceramics, and the solid lines show the calculated ones with piezoelectric ceramics. The measured characteristics agree with the calculated ones with piezoelectric ceramics. The calculated ratio of $(\Delta f_{2x}/f_{02})/(\Delta f_{1x}/f_{01})$ is about 5. 1% in the prototype

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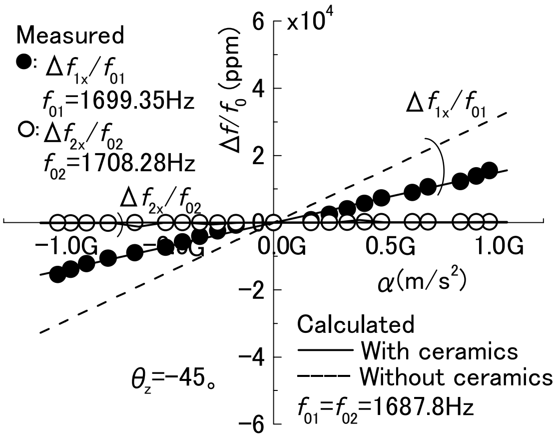
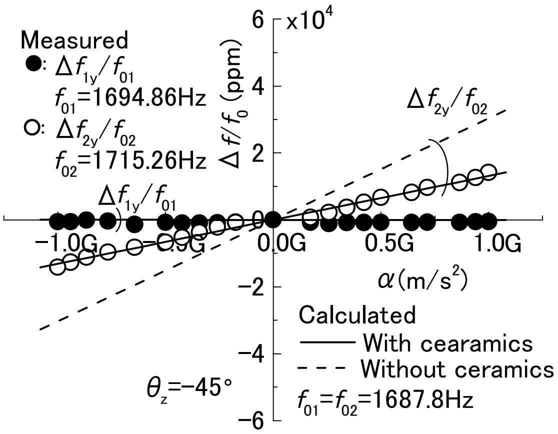
sensor and becomes 0.06% in Fig. 3(a). The measured values are 7.8 and 0.2%, respectively. These values are listed in **Table I**.



(a) α to the x-axis direction



(b) α to the y-axis direction

Fig. 3 Sensor characteristics of α - $\Delta f/f_0$.

Table I Undesirable signals of acceleration sensor.

	Prototype	Improved
Calculated value	5.1%	0.06%
Measured value	7.8%	0.2%

4. New Structures of Sensor

In the sensor structure shown in Fig.2, the dimensions of lower two bent-type support bars are adjusted so that the large value $\Delta f_{1y}/f_{01}$($\Delta f_{2y}/f_{02}$) coincides with the small one $\Delta f_{1x}/f_{01}$($\Delta f_{2x}/f_{02}$). As a result, the sensor volume becomes almost equal to the prototype sensor, but the sensitivity is reduced.

Figs. 4(a)~4(d) show some newly-developed sensor structures making up for a decrease in sensitivity and realizing a linear motion of mass.

5. Conclusions

The frequency-change-type two-axis acceleration sensor designed by adjusting the dimensions of lower two bent-type support bars to realize a linear motion of mass was produced experimentally. The sensor characteristics were measured and compared with the calculated ones. As a result, it was confirmed that the device to realize a linear motion of mass and to reduce an undesirable signal was very effective. Furthermore, some new sensor structures were proposed to make up for a sensitivity decrease and to realize a linear motion of mass.

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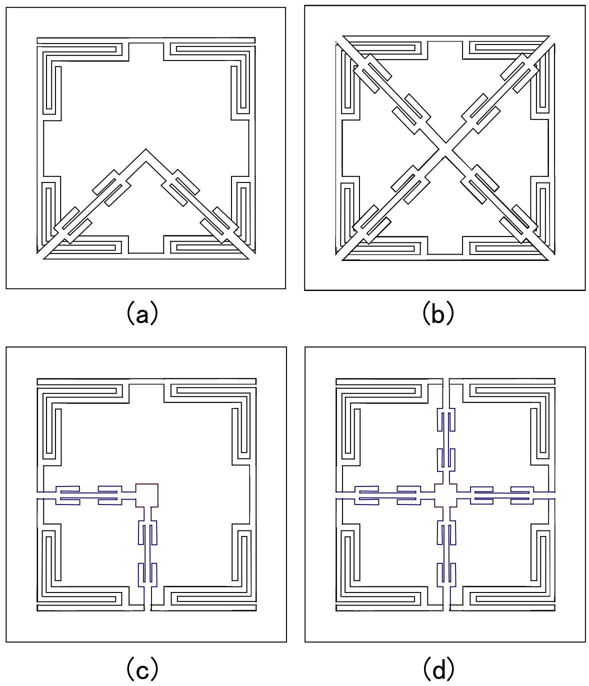

Fig. 4 Examples of newly-developed sensor structures.

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