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New Structure of Frequency-Change-Type Two-Axis Acceleration Sensor

周波数変化型２軸加速度センサの新構造

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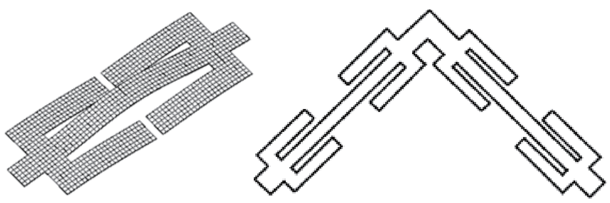
1. Introduction

The acceleration sensor suitable for a MEMS structure is required for application to the attitude control and navigation systems of moving objects such as a vehicle and a robot. As such a sensor, the authors have studied the frequency-change-type acceleration sensor utilizing the phenomenon that the resonance frequency of a flat-type bending vibrator changes by axial force.[1-8] It is important for these sensors to become a simple structure with high sensitivity and also small cross-axis sensitivity. In the frequency-change-type two-axis acceleration sensor, the motion of mass must be designed so as to become linear along the direction of applied acceleration to reduce the cross-axis sensitivity.[9, 10] Therefore, the new construction of sensor which can conquer such a problem should be devised. The frequency-change-type two-axis acceleration sensor using a new right-angled bending vibrator was proposed as one construction of the sensor which can conquer the problem mentioned above.[11]

In this study, the frequency-change-type two-axis acceleration sensor using the new right-angled bending vibrator connected to the center of gravity of the sensor is designed using the finite element method to reduce the cross-axis sensitivity. And the sensor characteristics are analyzed and confirmed experimentally.

2. Acceleration Sensor Using Right-Angled Vibrator

Fig. 1 (a) shows the structure and the vibration mode of the bending vibrator, and **Fig. 1 (b)** also shows the right-angled bending vibrator. Here the two bending vibrators are connected so as to become a right-angled and flat structure.



(a) Bending vibrator (b) Right-angled vibrator
Fig. 1 Structure of right-angled bending vibrator.

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Fig. 2 shows the structure of the two-axis acceleration sensor using the right-angled bending vibrator. The center part of right-angled vibrator is connected to the center of gravity of the mass of the symmetrical structure. The mass is supported by four bent-type support bars of the same dimensions. Under such structure, because a mass rotation of the sensor is suppressed when acceleration is applied, the cross-axis sensitivity becomes very small. The principle of operation of this two-axis acceleration sensor can be explained as follows. If acceleration is applied to the mass, the generated force will act on the two bending vibrators constructing the right-angled vibrator as axial force. As the resonance frequencies of two bending vibrators change with axial force, acceleration can be estimated from the frequency change.

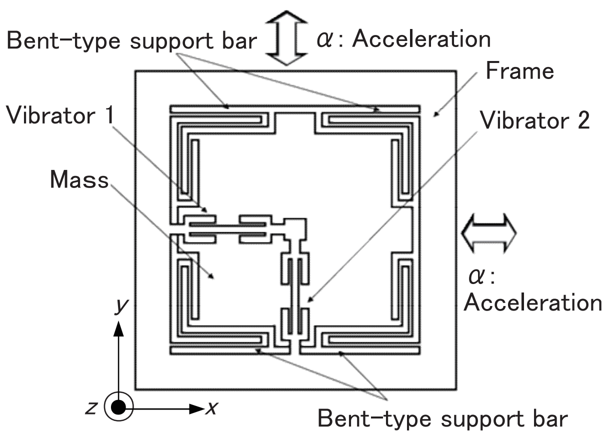
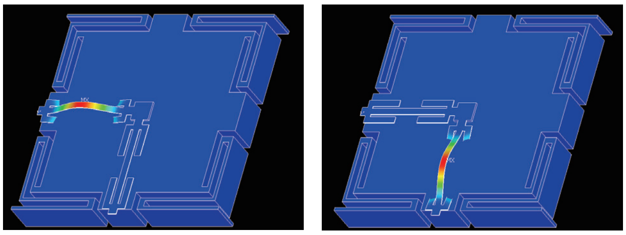


Fig. 2 Structure of two-axis acceleration sensor.

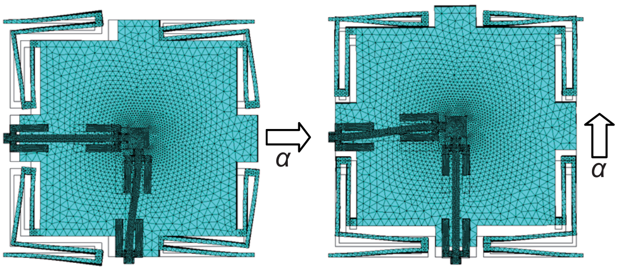
3. Design of Two-Axis Sensor

The two bending vibrators constructing the right-angled vibrator are designed so that the vibration displacements of both ends become very small. **Fig. 3** shows the analyzed mode of vibration of the sensor. A coupling phenomenon between the two bending vibrators is not observed and each vibrator vibrates independently. In this structure, the motion of mass becomes in parallel to the direction of applied acceleration as shown in **Fig. 4** and then the influence of the cross-axis sensitivity becomes very small. The sensor is made of stainless steel (SUS304), the external dimensions are about 90×90×10.7 mm^3. The thickness of vibrator is 0.2mm.



(a) f_{01} mode (b) f_{02} mode

Fig. 3 Vibration modes of acceleration sensor.



(a) α to the x axis direction (b) α to the y axis direction

Fig. 4 Analyzed motion of mass applying acceleration.

4. Characteristics of Sensor of Trial Production

Fig. 5 shows the top view of the two-axis sensor of trial production. Small piezoelectric ceramics ($5\times2\times0.2$ mm^3) are bonded for driving. The support unit is made of brass and the frame of sensor is fixed to the unit. **Fig. 6** shows the characteristics of the two-axis acceleration sensor

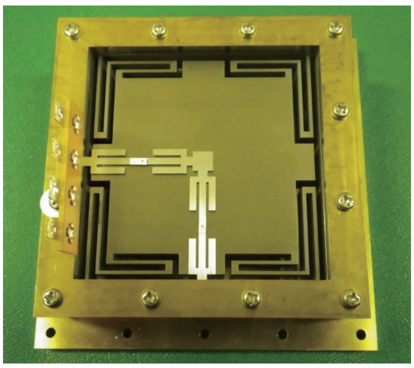
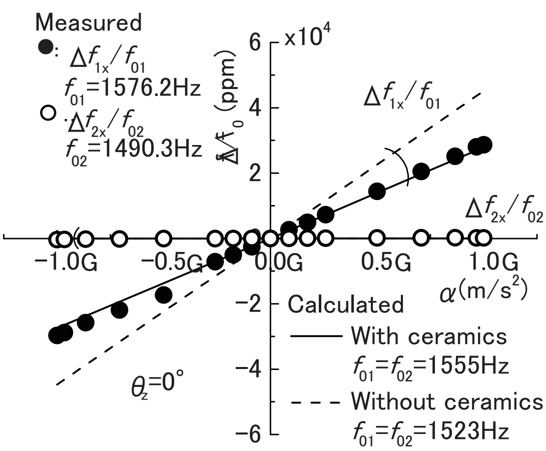
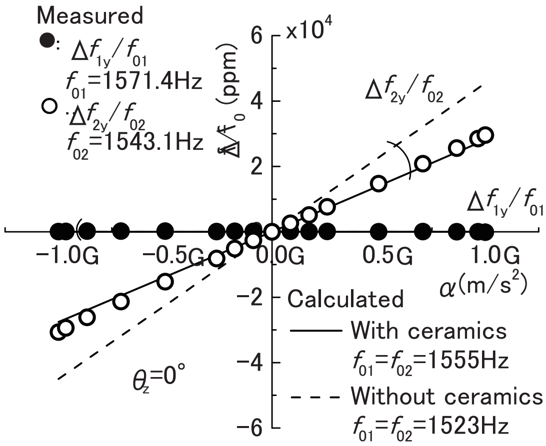


Fig. 5 Two-axis sensor of trial production.



(a) α to the x axis direction



(b) α to the y axis direction

Fig. 6 Characteristics of sensor of trial production.

of trial production. The solid lines are the analyzed characteristics with piezoelectric ceramics, and the broken lines are the analyzed ones without ceramics. The measured characteristics agree with the analyzed ones with ceramics.

5. Conclusions

The new construction of the frequency-change-type two-axis acceleration sensor was proposed here. The right-angled vibrator was newly developed to reduce the cross-axis sensitivity caused by a rotation of mass of the sensor. The design method for the sensor was investigated utilizing the finite-element analysis. As a result, it was clarified that a flat and simple construction of the sensor with high sensitivity is realized.

Acknowledgements

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