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Construction of Vibration Sensor for Detection of Two-Axis Acceleration and One-Axis Angular Rate

２軸加速度及び１軸角速度検出用の振動型センサの構成

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1. Introduction

Now, the vibration sensor suitable for a MEMS structure which can detect acceleration and also angular rate is required for application to the attitude control and navigation systems of moving objects such as a vehicle and a robot.

Various kinds of sensor construction are proposed as such a sensor. For example, the sensor which detects acceleration and angular rate by using only one vibrator is proposed. In such construction, although the sensor can be miniaturized, the use of a complicated and expensive signal-processing circuit is indispensable. Moreover, if a trouble arises in the sensor, both of acceleration and angular rate will become undetectable in many cases. In such case, it will be more desirable if the signal of acceleration or angular rate is detected. As such a vibration sensor, the sensor for detection of one-axis acceleration and one-axis angular rate was proposed.[1)] The authors have considered about a low frequency angular rate sensor,[2)] and also the frequency-change-type two-axis acceleration sensor.[3-11)] In this research, the new piezoelectric vibration sensor which can detect two accelerations and one angular rate is proposed, the sensor is designed by using the finite element analysis and the sample of trial production is realized.

2. Structure of Vibration Sensor

Fig. 1 shows the construction of the new vibration sensor which can detect the two accelerations along the x and y directions and also the angular rate around the z axis. This is realized by combining the frequency-change-type two-axis acceleration sensor and the one-axis angular rate sensor so as to become a flat structure. Therefore, the new vibration sensor has the characteristics which combine the characteristics of two sensors.

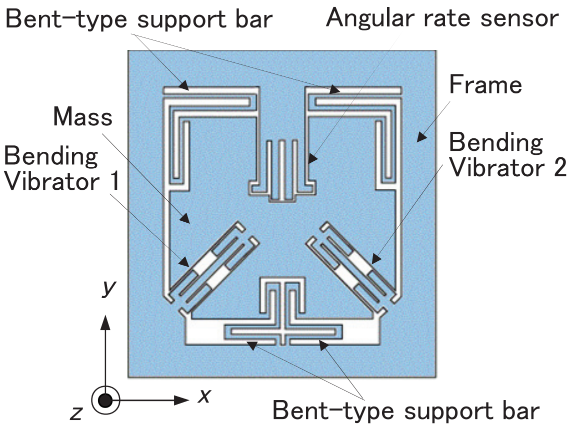
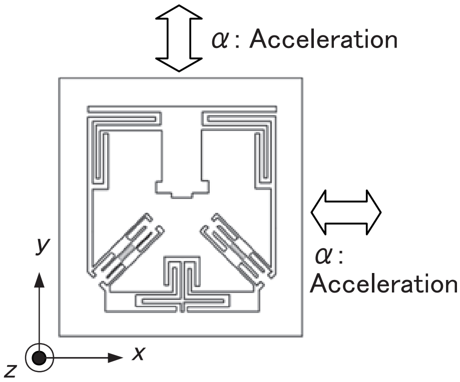


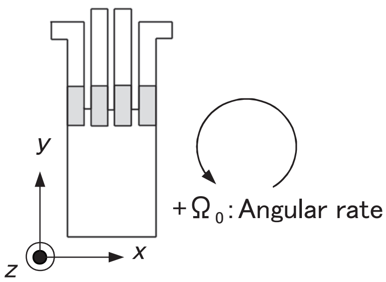
Fig. 1　Construction of vibration sensor.

3. Design and Trial Production of Sensor

The vibration sensor proposed here can be divided into the two parts of acceleration and angular rate sensors as shown in Fig. 2. The part of acceleration sensor is shown in the figure (a), the upper part of the mass is cut by the contour of one-axis angular rate sensor. In the sensor having such an asymmetrical mass to the x axis, because the mass causes a rotational motion by acceleration along the x axis direction, the sensor is designed so that the mass moves linearly to the x axis direction by adjusting the dimensions of the two support bars connected at the lower part of mass. The sensor is made of stainless steel (SUS304), the external dimensions



(a) Two-axis acceleration sensor



(b) One-axis angular rate sensor

Fig. 2　Two-axis acceleration sensor and one-axis angular rate sensor.

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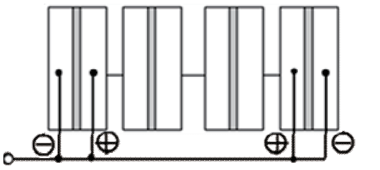
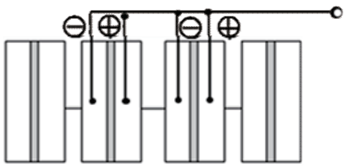
are about 95.8×90×10.3 mm^3. Moreover, the part of the angular rate sensor shown in Fig. 2(b) detects the angular rate around the z axis. In this case, the sensor is also made of stainless steel, the external dimensions are about 27×15×0.3 mm^3.

A drive and detection for these sensors are realized by bonding piezoelectric ceramics as shown in the figure. In the acceleration sensor, small ceramics (5×2×0.2 mm^3) are bonded to the center part on the upper surface of each vibrator. The resonance frequency of the vibrator is about 2,550 Hz. The sensor is fixed to the support unit. On the other hand, the out-of-plane modes of vibration are used for driving and detecting the angular rate sensor. The electrode of each ceramics (10×2×0.2 mm^3) bonded on four arms is divided into two parts, the direction of a polarization of each part is reversed mutually, and the electrode is wired as shown in Fig. 3. Fig. 4 shows the top view of the sample of trial production of the one-axis angular rate sensor fixed to the support unit. The resonance frequencies in the drive and detection modes are about 9 kHz, and the difference between both frequencies is designed so as to become about 150 Hz.

Fig. 5 shows the top view of the sample of trial production of the proposed vibration sensor.



(a) For driving



(b) For detecting

Fig. 3 Piezoelectric ceramics for angular rate sensor.

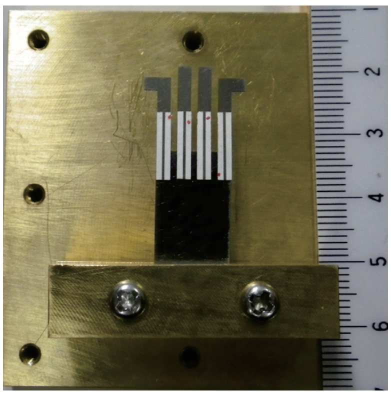


Fig. 4 Angular rate sensor of trial production.

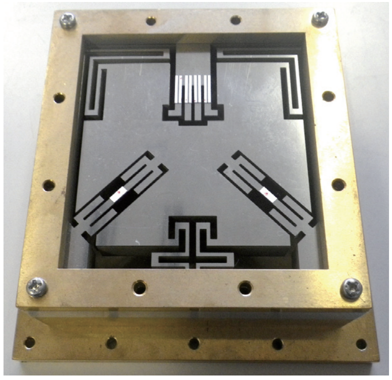


Fig. 5 Vibration sensor of trial production.

5. Conclusions

The new piezoelectric vibration sensor which can detect two accelerations and one angular rate was proposed here. The design method of the sensor was clarified using the finite element analysis, and the example of trial production of the sensor was shown. The sensor is constructed using the frequency-change-type two-axis acceleration sensor and the one-axis angular rate sensor, and becomes a flat and simple structure suitable for a MEMS device. Because the sensor can detect acceleration and angular rate individually, the interference between both signals is not observed and therefore signal-processing becomes quite easy.

Acknowledgements

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