2P3-3

Study on the Construction of Frequency-Change-Type Three-Axis Acceleration Sensor

周波数変化型３軸加速度センサの構成に関する研究

Sumio Sugawara†, and Yoshifumi Sasaki (Ishinomaki Senshu Univ.)
菅原 澄夫†, 佐々木 慶文 (石巻専修大)

1. Introduction

For attitude control and navigation of moving objects such as automobiles and robots, a compact and inexpensive sensor for detecting acceleration and angular velocity suitable for the MEMS structure is required, and furthermore, a vibration type sensor capable of simultaneously measuring them is required. As one of such acceleration sensors, a frequency-change-type acceleration sensor utilizing the resonance frequency change due to the axial force of the flexural vibrator has been proposed,[1)] and a composite type vibration sensor combining this with an angular velocity sensor has also been proposed.[1)] However, a frequency-change-type three-axis sensor has not yet been proposed and its development is required.

Here, one method for triaxializing the structure of the already proposed frequency-change type two-axis acceleration sensor is proposed.[2)] Then, the sensor characteristics are clarified by using the finite element method, and experimentally verified.

2. Structure of Two-Axis Acceleration Sensor

Fig. 1 shows an example of the structure of the frequency-change-type two-axis acceleration sensor using a right-angled vibrator consisting of two flexural vibrators. The joint portion of the two vibrators is connected to the center of gravity of the mass through a spacer, and the other ends are fixed to the frame. The mass is fixed to the frame through four bent-type support bars. When the acceleration α_x or α_y is applied to the sensor along the x-axis or y-axis direction, the resonance frequency of each flexural vibrator is changed by the generated axial force. From the change amount Δf, it is possible to know the applied acceleration.

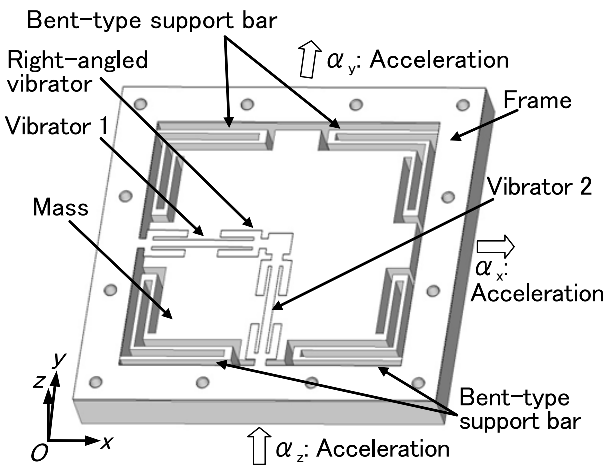

Fig. 1 Structure of two-axis acceleration sensor.

3. Triaxialization of Sensor

As one method for triaxializing the two-axis sensor, the thickness of the upper two support bars in Fig. 1 was designed so as to differ from the lower support bars. By such a device, the mass is inclined around the x axis as shown in the analyzed result of **Fig. 2** by the acceleration α_z along the z axis direction. Here, Fig. 2 representing a side view of the sensor is shown in a state of being divided into elements for finite element method analysis. The support bars with different thicknesses are displayed overlapping on the left and right sides of the mass respectively, and the vibrator is connected to the upper surface of the mass through the spacer. In this case, the frame is omitted. From the result of Fig. 2, the axial force along the y axis direction is applied to the vibrator by the inclination of the mass.

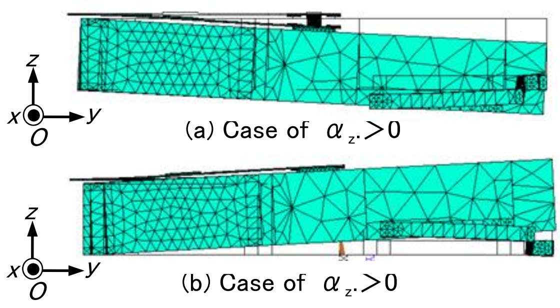

Fig. 2 Mass movement when α_z is applied.

Fig. 3 shows the analyzed results of the frequency change rates $\Delta f_{1x}/f_{01}$, $\Delta f_{2y}/f_{02}$, and $\Delta f_{2z}/f_{02}$ of the vibrator when the accelerations in the x-, y- and z-axis directions are applied to the sensor

E-mail : ssumio@isenshu-u.ac.jp

independently. The suffix numbers correspond to the vibrators 1 and 2. Even if the thickness of the upper support bar is changed, the frequency change rates in the x- and y-axis directions hardly change. In this case, the change rate $\Delta f_{2z}/f_{02}$ in the z-axis direction is considerably smaller than those and its characteristic becomes linear.

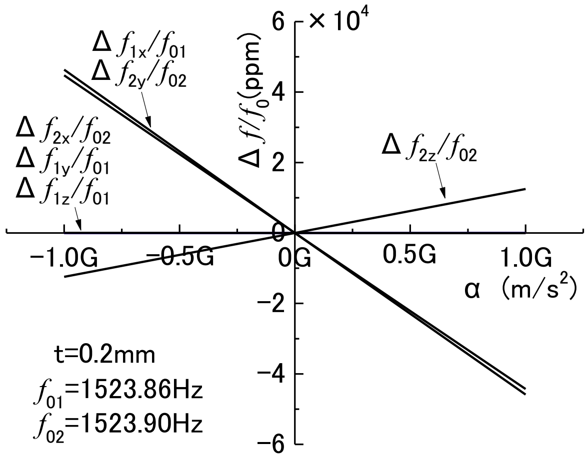

Fig. 3 Characteristics of sensor shown in Fig. 2.

Next, since the axial force due to α_z is in the same direction as the force due to α_y, it is necessary to separate the influence of both. The frequency change rate $\Delta f_{2yz}/f_{02}$ when accelerations were simultaneously applied along the z- and y-axis directions was compared with the change rates when they were individually applied. **Fig. 4** shows the analyzed change rate $\Delta f_{2yz}/f_{02}$ when α_y and α_z are simultaneously applied. From this result, the change rate $\Delta f_{2yz}/f_{02}$ is equal to the sum of change rates $\Delta f_{2y}/f_{02}$ and $\Delta f_{2z}/f_{02}$. On the other hand, the sensor characteristics when the vibrator is connected to the same position on the lower surface of the mass were analyzed. As a result, it was found that only the sign of the change rate $\Delta f_{2z}/f_{02}$.in the z axis direction differs from that in Fig. 3.

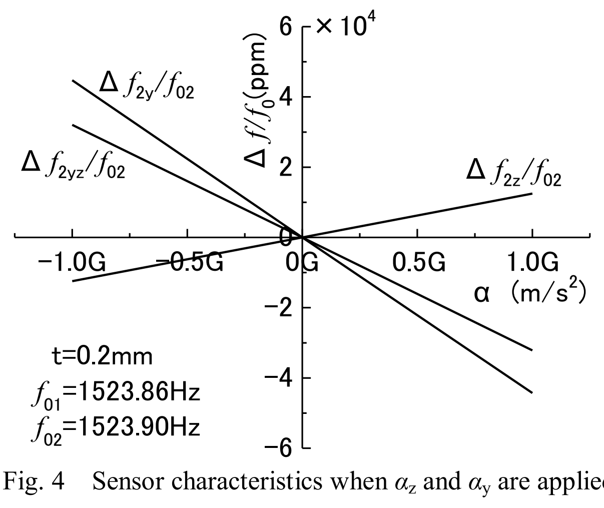

Fig. 4 Sensor characteristics when α_z and α_y are applied.

From the above results, the signals caused by α_z and α_y can be separated by detecting the difference and sum of the signals from each vibrator by constructing the sensor in which the vibrators are connected to the upper and lower surfaces of the mass. Therefore, the connected position and the thickness of the upper two support bars were designed so that the frequency change rates in three axis directions became equal.

Fig. 5 shows the characteristics of the three-axis sensor with the vibrators bonding piezoelectric ceramics for driving. The analyzed characteristics are shown with the solid lines, and correspond to that of the vibrator bonded to the upper surface of the mass. In the figure, measured values with the prototype sensor are also shown, and agree with the solid lines. The sensor is made of stainless steel, its external dimensions are about $90 \times 90 \times 10.7$ mm^3 from the ease of handling.

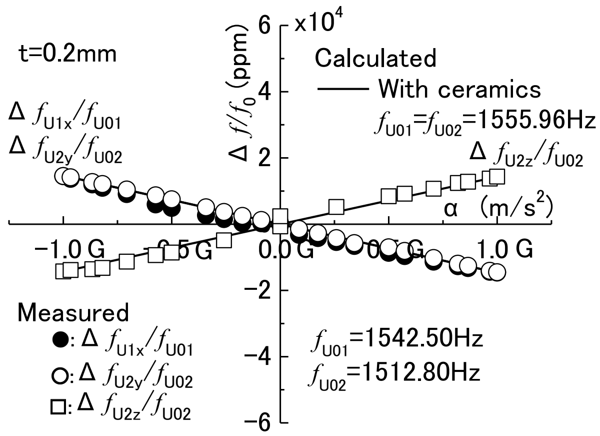

Fig. 5 Example of characteristics of three-axis sensor.

5. Conclusions

A method for changing the thickness of the support bars of the frequency-change-type two-axis acceleration sensor to achieve its triaxialization was proposed and the sensor characteristics are studied in detail using the finite element method. As a result, it became clear that by using a sensor structure in which the right-angled vibrator is connected to both surfaces of the mass, the frequency-change-type three-axis acceleration sensor with equal sensitivity in three axis directions can be realized. In the future, it is expected that the structure of the three-axis sensor will be further improved as a structure more suitable for the MEMS structure.

References

1) S. Sugawara, Reps. Spring Meet. Acoust. Soc. Jpn., 2015, 2-9-5. [in Japanese].
2) S. Sugawara, Reps. Autumn Meet. Acoust. Soc. Jpn., 2016, 1-Q-16 [in Japanese].