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# Consideration 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に関する考察

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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 an acceleration sensor that utilizes the phenomenon that the resonance frequency of a bending vibrator changes by the axial force.[1-12] It is very important that the motion of mass becomes linear toward the x-axis in the construction of two-axis acceleration sensor. A method for realizing the linear motion by using an increase of mass was proposed.[10] However, another method is still required.

The characteristics of the frequency-change-type two-axis acceleration sensor with some shapes of mass are analyzed here by the finite-element method. Another method of changing the dimensions of bent-type support bars is shown concretely, and the linear motions of mass are realized.

## 2. Structure of Sensor

**Fig. 1** shows the structure of the frequency-change-type two-axis acceleration sensor, which can detect two accelerations along the x- and y-axes. The sensor is constructed using two 45° -arranged bending vibrators, a mass ($M$), four support bars and a frame for fixation. The first out-of-plane mode of vibration is used in the vibrator.[1)]

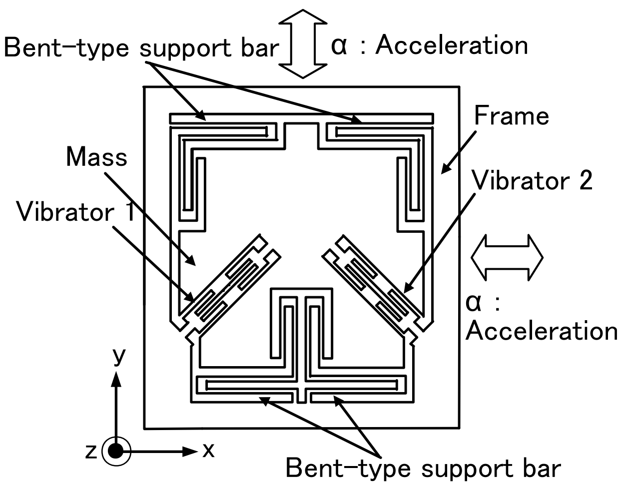


Fig. 1 Structure of two-axis sensor.

## 3. Rotation of Mass and Sensor Characteristics

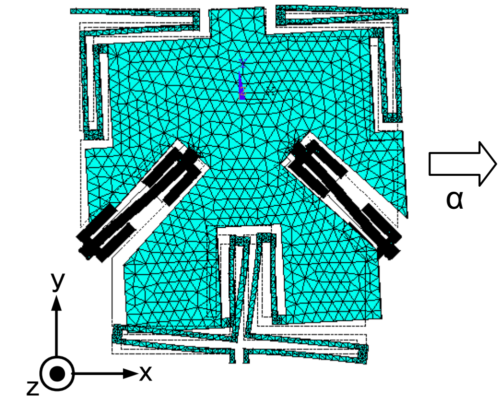


Fig. 2 Rotation of mass in two-axis sensor.

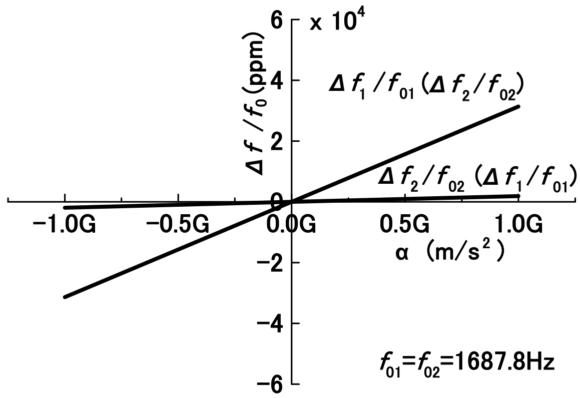


Fig. 3 Calculated characteristics of $\alpha - \Delta f/f_0$.

**Fig. 2** shows the analyzed result of the motion of mass in the two-axis sensor shown in **Fig. 1**. A slight rotation is caused by applying the acceleration of $\alpha$=1G toward the x-axis. At this point, the motion to the y-axis is completely parallel to the y-axis. On the other hand, the sensor characteristics of $\alpha - \Delta f/f_0$ are shown in **Fig.3**. When the frequency change of the sensor is given as $\Delta f_1/f_{01}$( or $\Delta f_2/f_{02}$), the undesirable change $\Delta f_2/f_{02}$ (or $\Delta f_1/f_{01}$) appears because the rotation of

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mass is caused. Therefore these undesirable changes must be greatly reduced.

## 4. Devices for Linear Motion of Mass

The sensor is made from stainless steel (SUS304). Young's modulus and the density are $E$=1.99×10$^{11}$ N/m$^2$ and ρ=7.9×10$^3$ kg/m$^3$, respectively. As software for the finite-element analysis, Ansys 12.0 of Cybernet System was used.

The center of gravity of the mass in the sensor was moved to the y-axis so as not to cause the rotation of mass.[10] Another method of changing the dimensions of bent-type support bars is considered here. In the first step, the dimensions of two lower support bars should be changed so that the motion of mass becomes parallel along the x-axis. **Fig. 4** shows the analyzed motion of mass. Only the lengths of two support bars are partially shortened and their stiffness values to the x-axis are increased. In the second step, the other lengths of support bars should be also changed so that their stiffness values to the y-axis agree with the values to the x-axis. The analyzed motion of mass is shown in **Fig. 5**. In the last step, the dimensions of the support bars should be adjusted so that the frequency changes along the x- and y-axes agrees well as shown in **Fig. 6**.

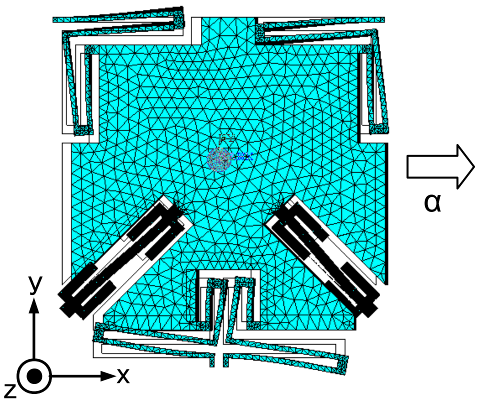

Fig. 4 Calculated motion of mass in two-axis sensor.

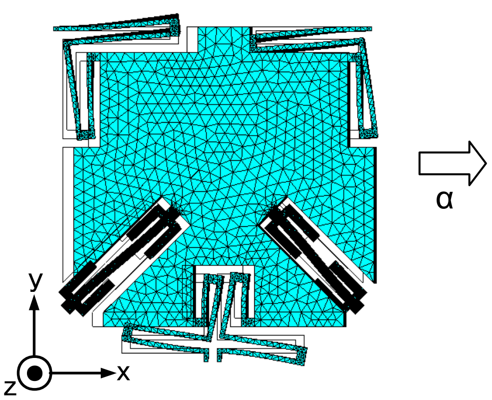

Fig.5 Calculated motion of mass in two-axis sensor.

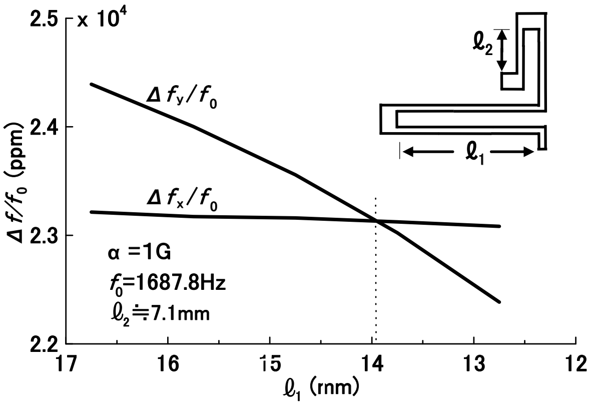

Fig. 6 Calculated characteristics of ℓ$_1$ − $\Delta f/f_0$.

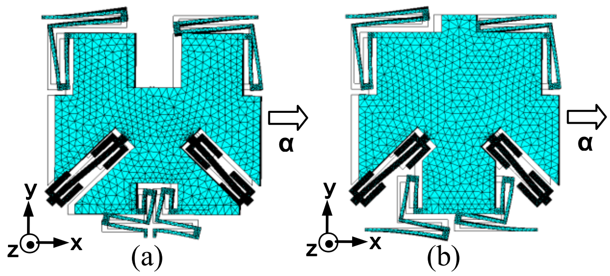

Fig.7 Sensors with different mass shapes.

## 5. Conclusions

A method of adjusting the dimensions of support bars was considered to realize a linear motion of mass in the two-axis sensor. As a result, it was clarified that the rotation of mass is not caused and then undesirable frequency changes do not appear. This design method can be applied to the sensors with various mass shapes.

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