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Experimental Results of Gravity Sensor using AT-cut Quartz Crystal MEMS Resonator

AT-cut MEMS 水晶重力センサの実験結果

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1. Introduction

This paper shows the result gravitational acceleration sensor.

An objective of this experiment is the detection of 0.1mgal, and "MEMS sensors for offshore exploration" is a realization of the objectives. This sensor device is used AT-cut quartz crystal. The principle of the VCXO is used in this sensor.

To achieve this sensor, the sensitivity of the user's request is 0.1mgal. For this request, we are considering the following methods.

The capacitance changes due to gravitational acceleration changes. This change is measured as one in the oscillation frequency. And this result is successfully that the sensor detected 20mgal [1, 2, 3]. This paper, is based on these results, we will aim below the detection of gravitational acceleration 0.5mgal as the next step. Then, the goal is set to detect 0.1mgal.

To achieve this target detection, the sensor element capacitance has been changed from 1.4pF to 14pF. The frequency is changed to read rate from 1sec step to 1msec step. On the other hand, data analysis software and , moving average are introduced. Under such conditions, the results show that the experiment confirm the 0.5mgal. The results show as below.

2. Sensor Structure

Fig.1 shows the concept drawing of the crystal sensor. This is cantilever of the single-sided support structure of AT-cut crystal blank with electrodes. This cantilever has a drive electrode and sensing electrode. Driving electrodes is interposed between the cantilevers. Sensing electrodes comprise a variable capacitor. Electrode A and B are used as the sensing part, and realize the variable capacitor. Electrode A for sensing is prepared in the end of this cantilever. Electrode B for sensing is formed also in the inside of the enclosure by the side of the contrary of the electrode.

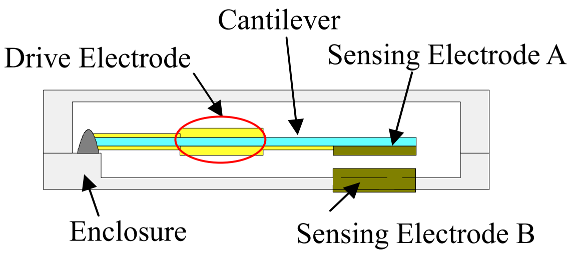

Fig.1 The basic structure drawing of a crystal sensor (cross section)

Specification of the crystal sensor is as follows.

Frequency	: 73 MHz
Mode	: Fundamental vibration mode
Culture quartz	: IEC60758 grade Aa
Surface	: Polishing
Crystal blank dimensions	: 20.0×1.6 mm
Electrode	: Cr, Au
Enclosure dimensions	: 27.0 × 12.0 × 1.0 mm

3. Measurement circuit system

From the numerical results, to detect the gravitational acceleration 0.5mgal, the change amount of capacitance is 10aF needs to be measured. Measurement system cannot detect small changes in capacitance found. Therefore, we have applied the techniques of VCXO. Then, capacitance change is measured as the frequency changes.

The system hardware is shows below.

(1) Analog oscillator is designed for communication to be applied to the crystal.
(2) Rb-oscillator is a reference source.
(3) Digital signal processing technology, the software of such sensors is essential.

Measurement system block diagram is shows in Fig.2.

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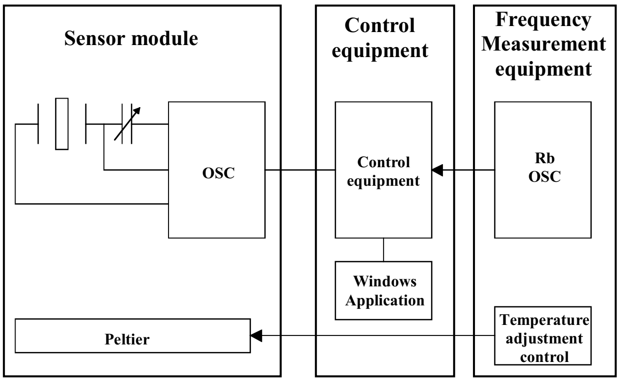

Fig.2 Measurement system block diagram

4. Result and Discussion

This paper shows the results of measurements at NDK Co., Ltd. Sayama plant. There are roads and highways near the plant, so, background vibrations occur many times. Therefore, the sensitivity is threatened to be reduced. We conducted an experiment in such the place. Using a gradient system is calibrated gravitational acceleration. And the frequency change as a result of the gravitational acceleration measurements is shows in Fig.3.

Fig.3 shows the oscillation frequency deviation versus measurement points. In addition, the oscillation frequency deviation is an absolute value. This result can be seen noisy.

We believe the peak near 1.3×10^4 points is slope noise.

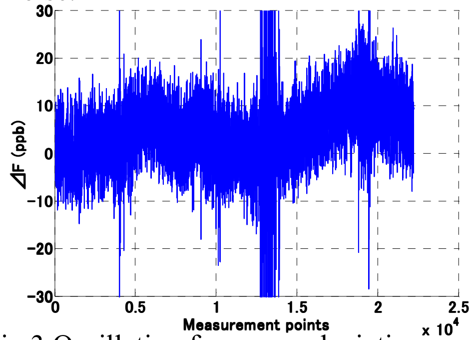

Fig.3 Oscillation frequency deviation versus measurement points

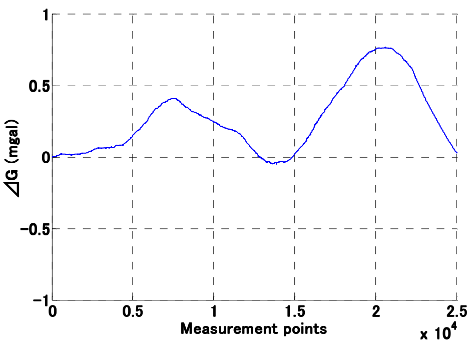

Fig.4 Gravity acceleration versus measurement points

Fig.4 is converted to gravity acceleration and the vertical oscillation frequency deviation of Fig.3, and is the result of moving average. The result is a smooth curve.

From Fig.4,

(1) Two peaks were identified.
(2) This peak is the result of a change in the cantilever due to changes in gravitational acceleration. When the capacitance increases, the peak is confirmed after the first measurement. The next peak is when the capacitance is smaller. Inclinometer calibration limit is due to differences in both peaks. Calibration limit is 0.02 degrees.
(3) This result can be seen that the measure could 0.5mgal.

Then, a measurement issue is the absolute value of gravitational acceleration. However, it is possible to measure tidal or below this level can assume 0.3mgal.

As a result, we believe realization of user requests 0.1mgal sensitivity is possible.

5. Conclusion

This paper shows the result of gravitational acceleration sensor. An objective of this experiment is the detection of 0.5mgal, and "MEMS sensors for offshore exploration" is the realization of objectives. This sensor device is made with AT-cut quartz crystal. The principle of the VCXO is used in this sensor.

As a result, the moving average is effective because the measurements are confirmed to be able to detect gravitational acceleration 0.5mgal.

On the other hand, the limit is also confirmed using calibration equipment to calibrate the acceleration due to gravity gradient.

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