Development of the wide-range tiltmeter for volcanic deformation monitoring: Part 1. Resolution test by tidal analysis

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1. Introduction

Integrated ground deformation monitoring by many kinds of instruments; GPS, SAR, tiltmeters and strainmeters, is very important for us to constraint the location and the shape of magma reservoir beneath the volcano. When the volcanic activity starts earlier than the predicted time, temporary observation at volcanic surface is efficient. Surface-install type tiltmeters are useful in monitoring deformation of the volcano that is in hazardous situations with the internal magma has been risen up near the surface or during eruption. Developing a wide-range tiltmeter is the main purpose of this study that is needless to level controlling in installing. The tiltmeter makes us possible to deploy monitoring networks easily and quickly.

2. Wide-range tilt sensor

Shinko Electric Company has been made a small (55mm W x 63mm D x 49mm H), light (400g) and power saving (0.54W) tilt sensor that uses a servo-balanced horizontal pendulum. The most noticeable features of the sensor are its wide measuring range of 90 degree and ultra-high shock resistance of 1500G. These features are due to taut band that is adopted as the stay of the pendulum. It can be use in wide temperature ranges by using temporary resistant circuit.

3. Test Observation

We have carried out a test observation in order to estimate the resolution of the sensor using two sensors at Kesennuma station of Tohoku University for one month in the end of 2003. Water-tube tiltmeters have been deployed at the end of 40m-long tunnel. Tilt sensors were installed as to be parallel to the water-tube tiltmeters. The observed data are recorded by Hakusan Co. data logger LS-8000WD with 24bit A/D and are transmitted to Tohoku University by telemetric system with 16bit A/D to real time monitoring. Temporary observation of borehole type tiltmeter and temperature monitoring have also been carried out in the same room by Tachibana and Miura (2003).

4. Comparison with theoretical tide and other tiltmeters

In order to measure the resolution of the sensor, tidal calibration has been executed. Tidal component and temperature response of the sensor are estimated from the observed data by using a tidal analysis program BAYTAP-G (Tamura et al., 1991). Theoretical tide is calculated by using an oceanic tidal loading effect computation program GOTIC2 (Matsumoto et al., 2001).

Analysis results are (1) tidal component of the observed data shows the high correlation of 0.84-0.95 with theoretical tide, (2) temperature response is easy to correct by using recursive model with lag time of the effect. These results indicate that the tilt sensor has the resolution of 0.001 micro radian enough to detect earth tide of 0.01 micro radian order. However, the results also show that there are some differences of amplitude and phase from theoretical tide. These differences may be caused by trade-off between tidal component and temperature response. The temperature response component has the almost same amplitude with tidal component even in the tunnel where temperature change.

5. Summary

A test observation has been carried out using newly-developed tiltmeter in a tunnel. From the analysis of data, it is cleared that (1) the tile sensor has high resolution of 0.001 micro radian enough to detect earth tide, and (2) the tilt sensor shows linear response for temperature change that is able to correct by recursive model.

We are planning to evaluate the accuracy, temperature response and drift rate with other water-tube tiltmeter or borehole type tiltmeter. Field observation is also planned using the wide-range tilt sensors and the water resistant case that is appropriate for volcanic ground deformation monitoring.