Vibration Measurement Instrument Design Based on Fluxgate Sensor for Early Warning of an Earthquake Disaster

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Abstract

Earthquake phenomena can be observed and monitored using the presence of vibration. In order to monitor the vibration, fluxgate sensor can be applied based on magnetic flux change. In this research, a vibration measurement instrument based on the fluxgate sensor for an earthquake monitoring application has been made. It is supported by a personal computer for data control and output display in the real time measurement. The vibration amplitude sensitivity of the instrument is about 2.19 x 10-3 cm. The vibration test is conducted in laboratory using a certain vibration sources. We have similar wave pattern compared to seismograph data.

Keywords: fluxgate, vibration, sensor, earthquake, sensitivity.

1. Introduction

An earthquake is a natural event that can be caused by the movement of the earth's plate's activity and the volcano's activity. The propagation of an earthquake is in the form of seismic waves and it's a vibration phenomena. There are two types of seismic wave i.e. body wave and surface wave. Body wave is compression (P waves) or shear waves (S waves) and it is used in identifying the epicenter of an earthquake. In the other hand, the surface waves are the waves that generated from P and S waves in the earth surface. They propagate in the parallel direction to the earth surface[1].

In order to monitor the vibration, a certain type of vibration measurement tools is required. There are different methods and sensors are developed in the vibration measurement i.e. capacitance change, piezoelectric, position change of Linear Variable Displacement Transformer (LVDT), using lasers[2], ultrasonic[3].

Fluxgate sensor is a magnetic sensor that uses magnetic fields to produce and sense motion. Its measure the magnitude and direction of magnetic field (DC or AC low frequency) about 10^{-10} to 10^{-4}T. In addition, they are rugged, reliable, low energy consumption and work in a wide temperature range[4]. There are several developing research applications of

fluxgate sensor i.e. a magnetometer for low magnetic field[5], and a vibrating sensor for low frequency[6]. The aim of this study is to design and making a vibration measurement instrument based on the fluxgate sensor for an earthquake monitoring application. In this design, the double pick-up coils with an oval core model are used for the fluxgate sensor element.

2. Method

Earthquake vibration measuring tool system utilizes the principle of vibration sensor with spring applications and objects that have weight. If the vibration occurs, this tool also vibrates so it provides a response to the fluxgate sensor. The principle work of fluxgate sensor is a magnetic field change in the coil core (excitation coil) that generates a current (excitation current). As a proximity sensor, magnetic flux changes were caused by the object (magnet) movement position to the sensor as shown in Fig 1.

The instrument system design consists of a mechanical system, power supply circuit, fluxgate sensors, signal conditioning circuit, PIC 18F4550

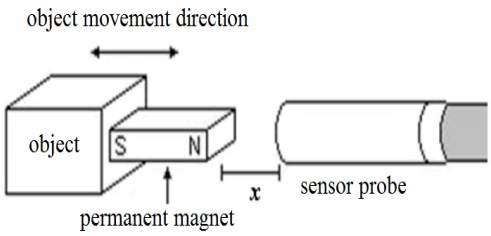

Fig. 1. Distance measurement principle by fluxgate sensor.

microcontroller and personal computer (PC). Mechanical system design of the instrument is shown in the Fig. 2. Fluxgate sensor is detecting the magnet position changes which influence the magnetic field of sensors. Fig. 3 shows the block diagram of the instruments system. In this design, the fluxgate element sensor type used is a double pick-up coil with an oval core model [7].

In addition, the interface programs are made using Visual C# and MPLAB X IDE language programs. For controlling data acquisition and output display in PC, there are two application programs are designed i.e. Log loader and Tool Driver Seismograph 12755 Display.

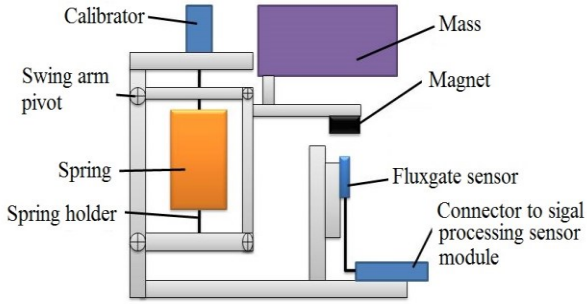

Fig. 2. Mechanical design of vibration measuring instruments.

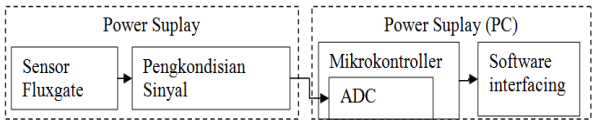

Fig. 3. Block diagram of the developed system.

3. Results and Discussion

In the present work, we have designed and made a vibration measurement instrument for an earthquake monitoring application as shown in the Fig 4.

The mechanical sensor system consists of (1) a central regulator of balance sensors in case of deviation, (2) swing arm, (3) oscillator effect, function as a result of vibrations from the vibration of the earth that will be the reference value of earthquake that occurred, (4) load and weighs about 1 kg, (5) magnets, which used as an indicator will be responded by the fluxgate sensor (6). When an earthquake occurs, seismic waves will form a pattern of vibration at a point. The pattern of the vibrations propagated to the mechanical systems and resulting vibration in objects in the tools system. This vibration is equal to the vibration of the magnet is on the tool.

This instrument utilizes a magnetic field measurement. In order to operate optimally, mechanical sensors need to be conditioned free from external magnetic fields such as magnetic materials and magnetic fields from the power lines.

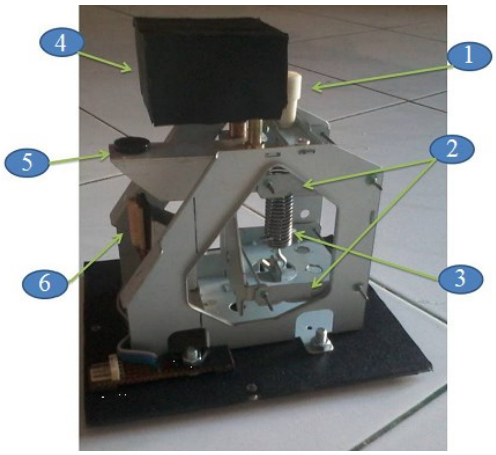

Fig. 4. Fluxgate mechanical sensor system..

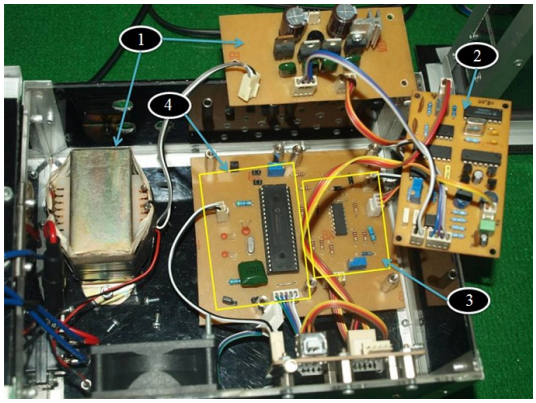

Fig. 5. Electronic circuit of data acquisition module..

Fig. 5 shows an electronic circuit of data acquisition modules. Supply power to the fluxgate sensor module and its signal processing module (2) was obtained through a voltage circuit (1). The power supply circuit outputs are ±6 V and ±12 V. While the power for the microcontroller is obtained from a PC via a USB bus serial. The signal processing circuit consists of a series differentiator, detectors, buffers, synchronization phase, integrator, and an amplifier. The input voltage for an ADC of the PIC18F4550 microcontroller (4) is the processing result of the voltage processing circuit (3). Digital data voltage output from the microcontroller will be sent to a PC via USB bus serial in the microcontroller. The amplitude vibration sensitivity of this instrument is about 2.19 x 10^{-3} cm.

In the vibration measurement test that has been conducted, there are real times of vibration patterns as

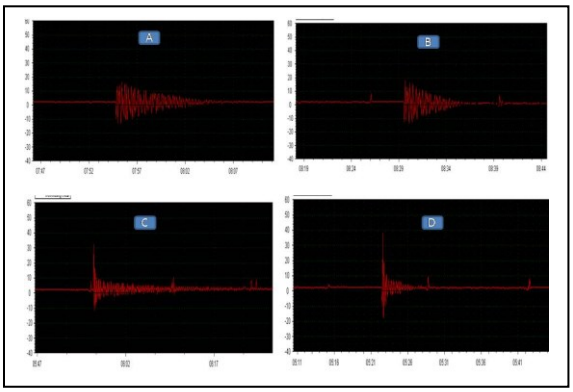

Fig. 6. Observed pattern result from the same distance (1 m) and same perturbation.

described in the Fig. 6-8. As shown in Fig. 6, there are four patterns result of the perturbation wave that recorded at a same distance (i.e. 1 m) from the buffeting source. It's showing the same pattern of propagation.

Fig. 7 shows the perturbation patterns of buffeting in different source position i.e. 0.5m, 1 m and 1.5 m, respectively. The amplitude change in the graph pattern is clearly observed. In other side, the separation between body wave and the surface wave is not visible clearly. Based on the pattern results that obtained, there are similarities with the data patterns recorded from seismic observation stations (Fig. 8 (A)).

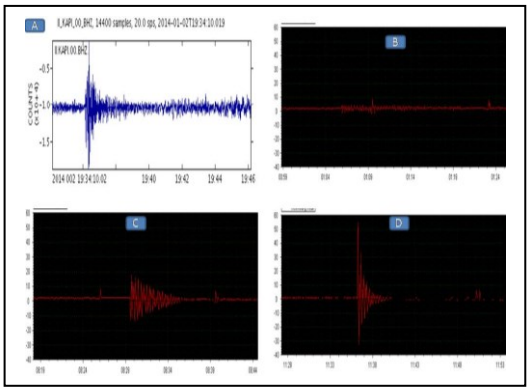

Fig.8 . Observed earthquake data (A), measured data (B, C, D).

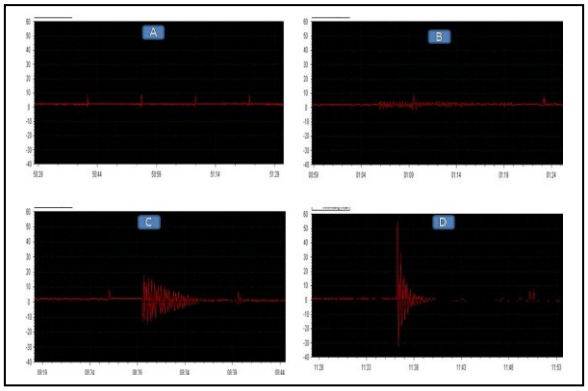

Fig. 7. Observed pattern result of the different distance (1.5 m (B); 1 m (C); 0.5 m (D)) with the same perturbation.

4. Conclusions

The vibration measurement system for an earthquake application by implementing a fluxgate sensor was successfully developed. The amplitude vibration sensitivity of this instrument is about 2.19 x 10^{-3} cm. The results of recorded wave pattern have similarities with the data from seismograph recordings.

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