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Basic Study on Location Estimation of Drill-bit Using Giant-magnetostrictive Vibrator on Simulated Ground
模擬地盤を用いた超磁歪振動子によるドリルビットの位置推定手法の検討

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1. Introduction

Recently, methods to maintenance of various lifelines with the sophistication of urban functions have become important. Horizontal directional drilling (HDD) will be a method for laying electricity, gas, water-supply life-lines, etc. as it avoids the need to make an open cut. Therefore, less waste soil problem or blockage, this method is expected to spread further. However, when this method is used, the location of the drill-bit must be known at all times. Furthermore, the accuracy of this determination affects the location of the buried pipe directly.

The most widely used method for determining the location of the drill-bit involves electromagnetic waves. However, as this method can only determine the location just above the drill-bit, it cannot be used if there are houses or other buildings in the line of a construction. In addition, as it involves the use of electromagnetic waves, its accuracy is affected by numerous factors, including the moisture content of the ground and the presence of steel towers near the construction site. An improved method which can estimate the location of the drill-bit in such situations is therefore required.

In this context, although reflection-based methods [1-4] are commonly used for underground exploration, a direct method would be needed for this purpose. The aim of this study is therefore to measure the elastic wave generated by the drill-bit underground by placing multiple sensors aboveground, and to establish an approximate 3D drill-bit location method based on the difference between the arrival times of the elastic wave at each sensor. Finally, we aimed to operate this system in a full-scale test [5-6].

The experiment that was described in this paper is basic study how the elastic wave generated by the source which generates the forward and back movement like a giant-magnetostrictive vibrator is observed by 3-axis accelerometer on surface of the simulated ground.

2. Experimental method

In this experiment, the measurement was conducted on a simulated ground. **Fig. 1** shows the overview of the simulated ground. The size of the form was L2.7m × W0.7m × D0.9m. Silica sand (No. 6) has been paved to a depth of 0.5 m in this form. **Fig. 2** shows a schematic of experimental setup. Elastic waves were measured with 3-axis accelerometers. **Fig. 3** shows the setup of the giant-magnetostrictive vibrator and sensors. The " × " mark indicates a location of the giant-magnetostrictive vibrator. The depth was 0.3 m. The five sensors were set on the ground surface every 0.5 m. The input waveform to the vibrator was generated by the function generator. The waveform was sine waveform whose frequency was 500 Hz. Its input times was 3 wavelengths.

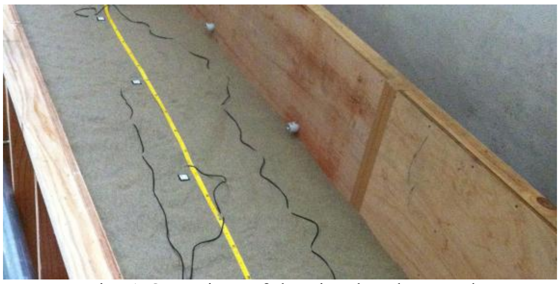

Fig. 1 Overview of the simulated ground

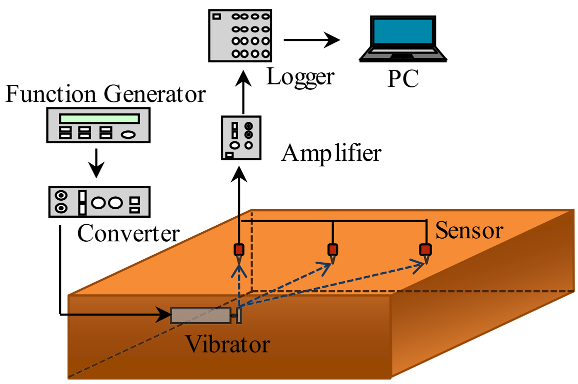

Fig. 2 Schematic of the experimental setup

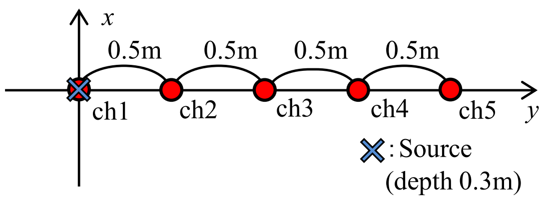

Fig. 3 Setup of the vibrator and five sensors

3. Result of experiment

Fig. 4 shows the output waveform of the vibrator measured by a sensor directly attached to the vibrator. **Fig. 5** shows the measured waveforms at ch1 and ch5 filtered by band pass filter whose range of frequency is 300-700 Hz. Sensor at ch1 was set up just above the vibrator. Therefore, (y1) shows the s-wave and (z1) shows the p-wave. However, from comparison of (y1) and (z1), both waveforms have very similar waveforms. This indicates that p-wave and s-wave almost simultaneously arrive at sensor. By contrast, a difference between two waveforms of ch5 is clearly seen. Waves are observed in the waveform of (z5) from 0.02 s to 0.03 s but it is not observed in the waveform of (y5). However, it is not possible to say that this difference is it between p-wave and s-wave because a major component measured by z-axis gradually shifts from p-wave to s-wave and it also measured by y-axis shifts from s-wave to p-wave with increasing distance from the vibrator. Therefore, it would be said that precise location estimations with components only of the z-axis are hard. For these reasons, to perform precise location estimations, it is necessary to extract needed components from waveforms measured by 3-axis accelerometers and to apply it to estimations.

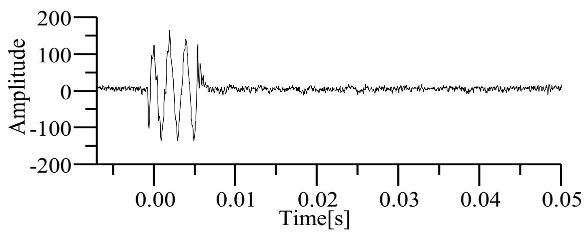

Fig. 4 Output waveform of the vibrator

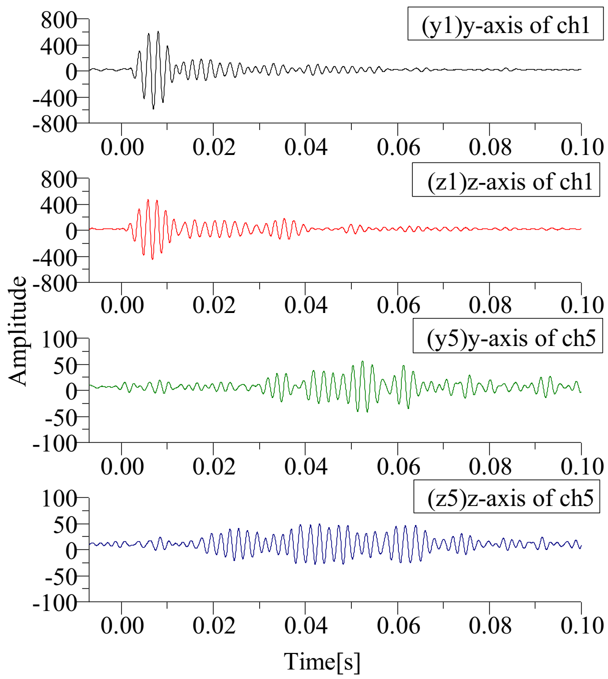

Fig. 5 Filterd waveforms of y-axis and z-axis (ch 1, 5)

4. Conclusions

The purpose of this research is to measure the elastic wave generated by drill-bit from underground with multiple sensors placed on the ground and to establish the method of 3D location estimation of drill-bit. In this experiment, the availability of measured waveforms by 3-axis accelerometers on the simulated ground is examined. As a result of this experiment, there is no significant difference between measured waveforms of z-axis and y-axis at ch1 but there is the difference at ch5. However, since ratios of components between p-wave and s-wave of the waveforms measured by each axis sift with increasing distance from the vibrator, it is not possible to say that the difference is it between p-wave and s-wave. Therefore, it is necessary to use 3-axis sensors and it is expected that the accuracy of location estimation improve by using 3-axis sensors.

Acknowledgment

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