Evaluation of Electrical Discharge Sound for Hammering Test

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ABSTRACT:

In this study, it was investigated that the possibility of electrical discharge pulse sound for new inspection technologies instead of hammering test. Electrical discharge pulse sound was applied for hammering sound and sensor by using sound detection was applied for optical fiber vibration sensor. The numerical analysis result using the FEM and the experiment result along with the single pulse discharge was compared. As the result, it was estimated that the generation factor of the elastic wave was same as the current duration. These results become possible to estimate the propagation characteristic of elastic wave. Evaluation of electrical discharge sound for hammering test by using optical fiber sensor was investigated. Defect shape and scale was estimated from comparison with detected waveform by using optical fiber vibration sensor and simulated waveform. As the results, it was considered that electrical discharge sound was available for hammering test.

INTRODUCTION

Hammering test has been applied for structural inspection. This technique is nondestructive inspection which was required special skill. In our country, many inspector who has these skill will be retired 2007 or later. So, these special skills do not pass down by oral tradition. It will be considered that a human life become impaired. There are great demands for new inspection technologies instead of hammering test. In Hammering test, important things were hammering sound and sensor by using sound detection. In our past research, it was found that electrical discharge sound contains wide band frequency and was good repeatability [1- 3]. Acoustic Emission (AE) method

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has been a focus of attention for various fields. AE is ultrasonic wave caused by energy release of material deformation, cracking and crack propagation. AE method has been applied to evaluate the healthiness of structure by using AE sensor. Almost all the AE sensors in practical use now are piezoelectric. While the piezoelectric sensor has various advantages, it is difficult to AE monitoring due to an indication of electrical noise. In order to overcome some problems of AE monitoring system, optical fiber sensor has been developed. AE monitoring system using optical fiber sensor is compact, light weight and free of electromagnetic hazard. In our laboratory, optical fiber sensor has been developed based on the Doppler Effect [4, 5]. The optical fiber sensor can be detected the displacement velocity in wideband frequency from 0.1Hz to several MHz. The displacement velocity was able to be measured by bonding manufactured optical fiber sensor on a surface of a specimen. The displacement can be calculated by integrating the signal detected by the optical fiber sensor, because of the optical fiber sensor is able to detect displacement velocity at the sensing point.

In this study, it was investigated that the possibility of electrical discharge pulse sound for new inspection technologies instead of hammering test. Electrical discharge pulse sound was applied for hammering sound and sensor by using sound detection was applied for optical fiber vibration sensor. The plate thickness was changed from 1mm to 10mm in order to research the effect of plate thickness on propagation characteristic of elastic wave. On the assumption that generation factor of elastic wave was only depending on a force, numerical analysis by using finite element method (FEM) was adapted. Moreover, evaluation of electrical discharge sound for hammering test by using optical fiber sensor was investigated. Defect shape and scale was estimated from comparison with detected waveform by using optical fiber vibration sensor and simulated waveform.

EXPERIMENTAL SETUP

Figure 1 shows experimental setup. The electrical discharges were made to fall on aluminum (1000 series) plate 400mm × 400mm × 1mm. Figure 2 show the optical fiber sensor. Optical fibers consist of core, cladding and coating. The core has a higher index of refraction than the cladding, so that total reflection occurs at the core–cladding interface. We used single-mode optical fibers with a coating diameter of 150μm and a cladding diameter of 125μm. The core diameter of the single-mode fiber is small (4.2μm), so we employed single-mode fibers in optical fiber sensor to improve sensitivity. Optical fiber sensor (Radius 8mm, Number of loop 2) was bonded on the aluminum plate. The optical fiber sensor was located at the center of an aluminum plate so as avoid the effect of reflection of elastic wave. Figure 3 shows schematic view of optical fiber sensor system. Laser Doppler Velocimeter (LDV) is used to detect the frequency shift. Light source is He-Ne laser (output power; 1mW, wavelength. λ_0: 632.8 nm), and heterodyne interference technique as shown in Fig. 1 is applied to the measurement in the present paper. An acousto-optical modulator (AOM) changes the frequency of the reference light source from f_0 to f_0+f_M (f_M = 80 MHz) in order to produce beating signals with frequency of f_D+f_M. The split light was fed into each sensor and the transmitted light signals were detected using photodiodes. The

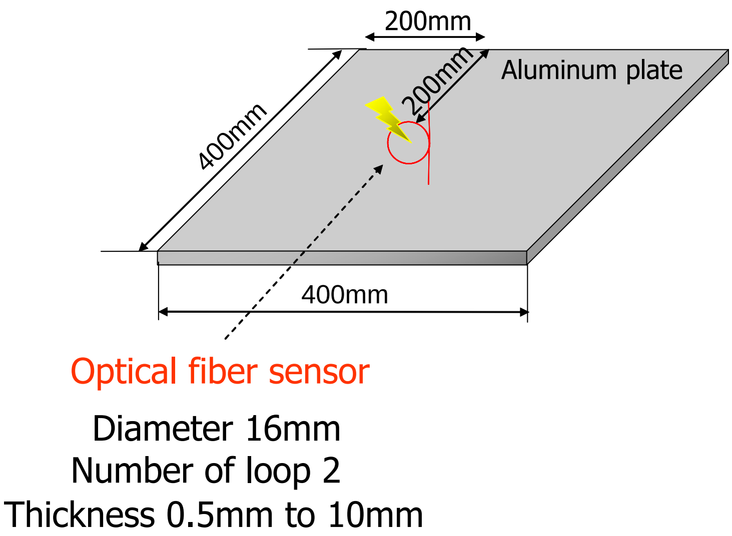


Fig. 1 Experimental setup

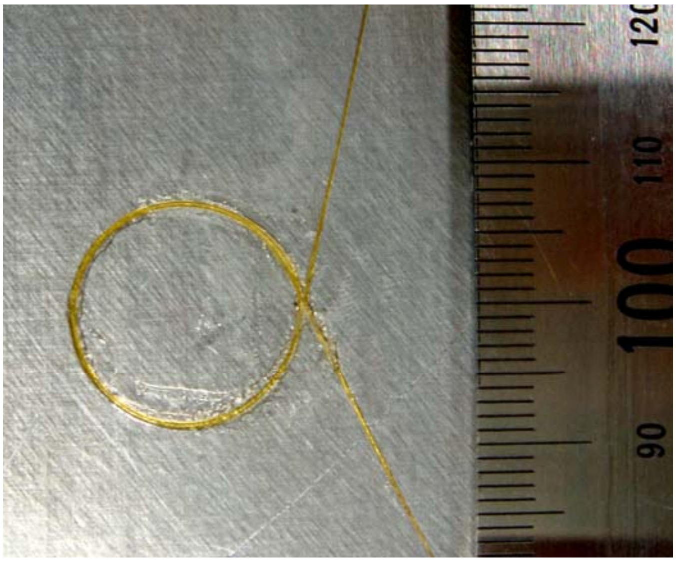


Fig. 2 Optical fiber sensor

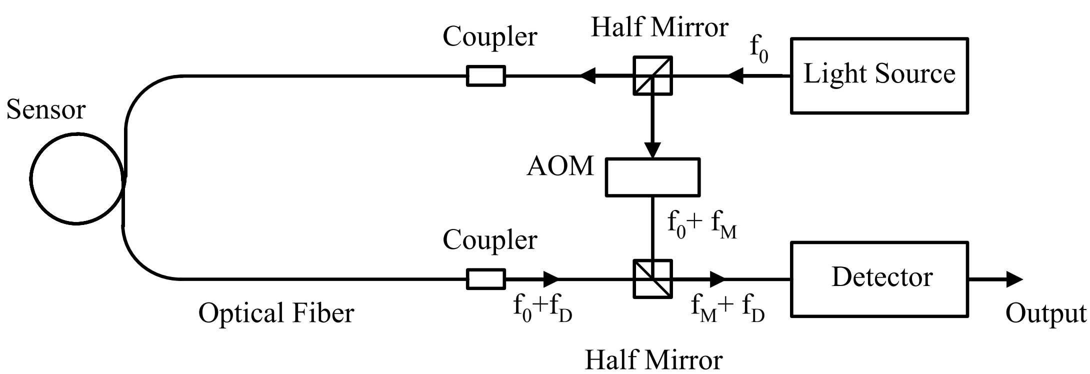


Fig. 3 Schematic view of optical fiber sensor system

fiber-optic signals received by the photodiode were transmitted to a PC. Data acquisition and analysis were carried out with 12 bit resolution and sampling rate of 10MHz.

The location of discharge point was the center of the sensor. It was considered that detected signal was almost same at each sensor point, because AE wave propagate concentric circle. In order to make 1 μs discharge duration, condenser circuit was applied. Electrode was cupper which diameter was 1mm. The current flowing through the anode is monitored with a current probe (Pearson Electronics, Model-110). The applied voltage was 100V (TKASAGO CO. Ltd, KX-100H) which is defined by the charging voltage of the capacitor. Condenser capacity was 65.8nF. Discharge interval time was controlled several 10ms by 1MΩ resistance. Aluminum thickness was changed from 0.5mm to 10mm. Based on the assumption that the AE wave was only depending on a force, the numerical analysis result using the FEM and the experimental result along with the single pulse discharge were compared.

ANALYSIS MODEL

In order to estimate the generation factor of the elastic wave during single pulse discharge, the simulation of elastic wave which propagate in the aluminum plate was carried out with the MSC. Marc. The finite element mesh arrangement is shown in Fig. 4. The elastic wave propagation is treated as an axisymmetric problem. Cylinder solid radius which is adapted calculation is 200mm and thickness is 1mm. The mesh size is important factor to simulate propagation of elastic wave. On the assumption that the elastic wave velocity was 3000m/s and maximum frequency was 1MHz, the wavelength was divided 24 parts. So, there was little simulation error. Cylinder edge is adapted to be traveling load. Input force is assumed to be a half sine. Maximum force is 1N. In order to obtain the entire time history of generalized displacement, time step of

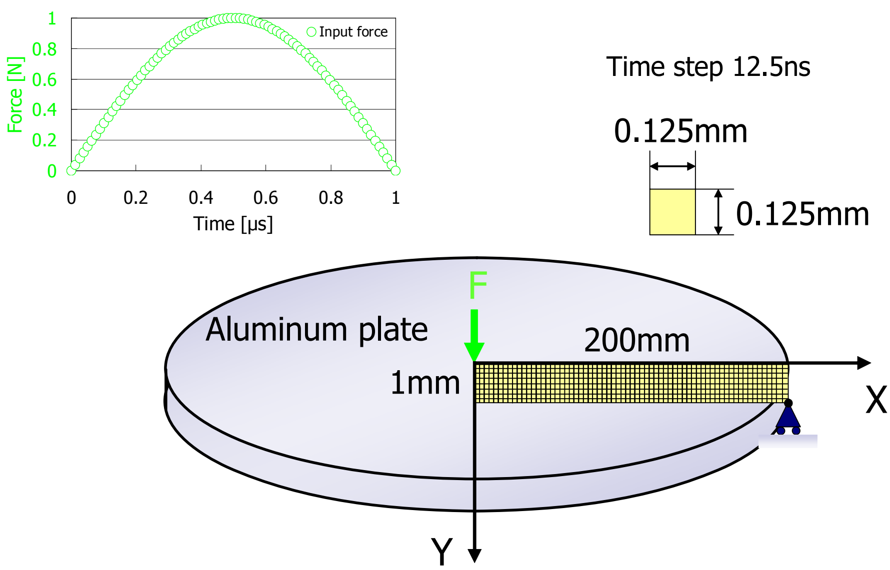
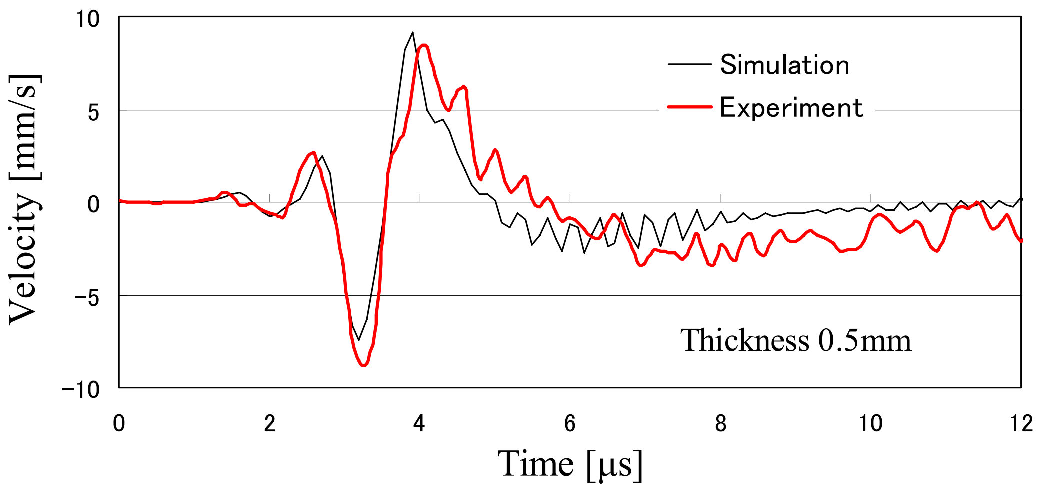


Fig. 4 Finite element mesh arrangement

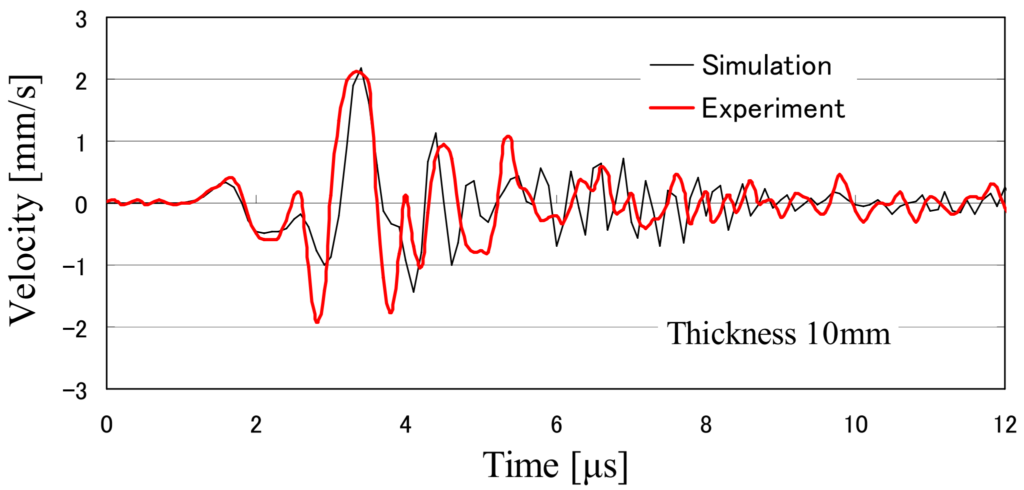
1.25ns has performed. On the basis of the hypothesis that acceleration of a variable field is always linear, a time integration procedure is employed to generate the time history of elastic waves. Here, the Newmark method is adopted. Generated waves are calculated in aluminum plates with 200 mm radius and 0.5 mm, 1 mm, 2mm, 5mm and 10 mm thicknesses, respectively. Discharge-generated surface acoustic waveforms in Al plates of various thicknesses are presented. The numerical model can capture the significant details of the transient features taking place in relatively thicker plates.

RESULTS AND DISCUSSION

Figure 5 shows the results of comparing with experimental signal and simulation one. The velocity of numerical analysis was made to be standard because detected velocities by optical fiber sensor varied widely. The experimental velocity show relatively. It is found that the behavior of detected waveform and simulated one is



(a) Plate thickness 0.5mm



(b) Plate thickness 10mm

Fig. 5 Comparing with experimental signal and simulation one almost the same. Experimental signal was good agreed with simulation one between 0.5mm and 10mm plate thickness. So, it is supposed that the generation factor of the elastic wave is the 1μs duration force. It is estimated that the generation factor of the elastic wave is the 1μs duration force. It was considered that numerical analysis was able to estimate the plate thickness. In order to evaluate electrical discharge sound for hammering test by using optical fiber sensor, quasi-defect was made to the plate.

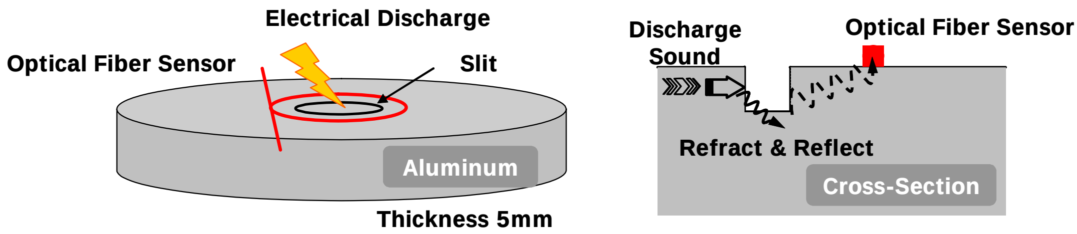


Fig. 6 Schematic view of experimenatl setup

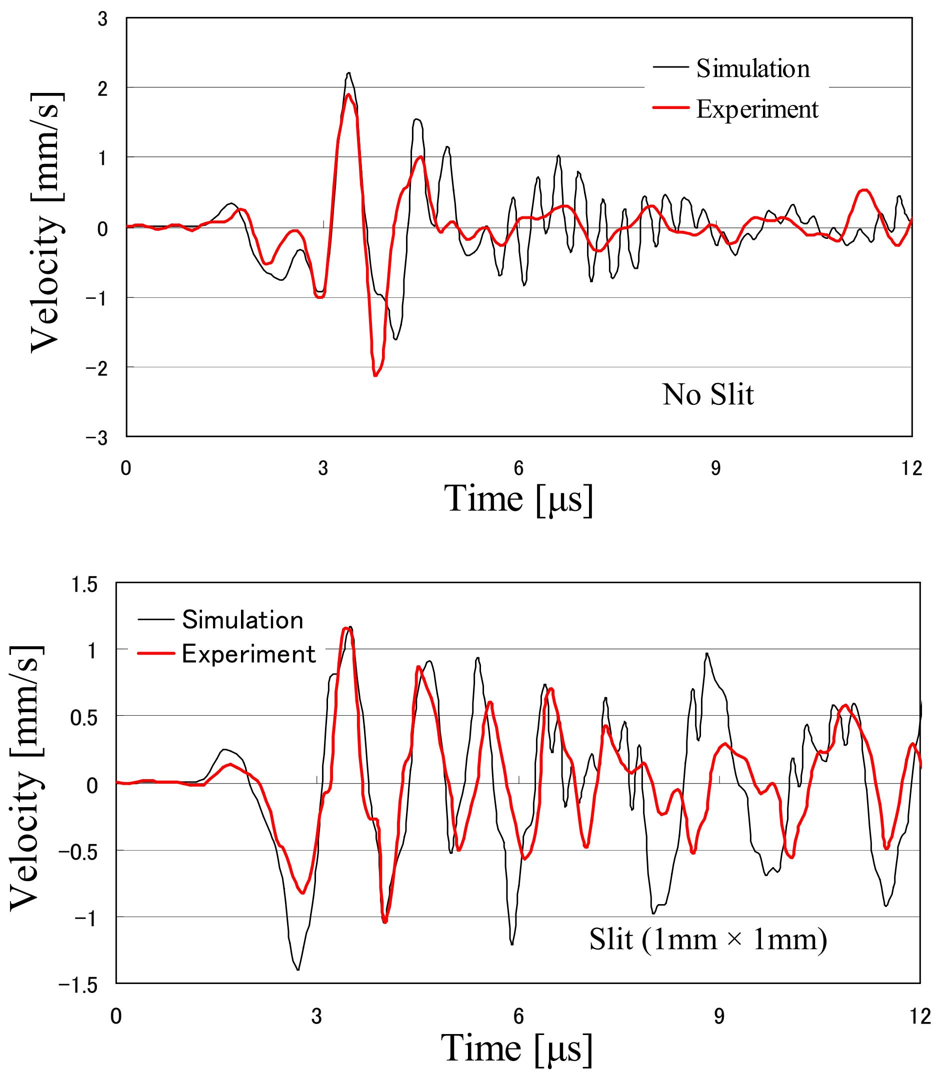


Fig. 7 Comparing with experimental signal and simulation one

Figure 6 show the schematic view of experimental setup. Defect shape and scale was 1mm width and 1mm depth. The plate thickness which made slit was 5mm. Electrical discharge were made to fall on the plate. It was considered that the detected waveforms by optical fiber sensor were different from slit shape because elastic wave were reflected and refracted at the slit. Figure 7 show the comparison with experimental result and simulation one. It was found that experimental signal was good agreed with simulation one. Especially, velocity change measured at 2.5μs become smaller with slit plate. It was confirmed that defect shape and scale was estimated from comparison with detected waveform by using optical fiber vibration sensor and simulated waveform. As the results, it was found that electrical discharge sound was available for hammering test.

CONCLUSIONS

In this study, it was investigated that the possibility of electrical discharge pulse sound for new inspection technologies instead of hammering test. Electrical discharge pulse sound was applied for hammering sound and sensor by using sound detection was applied for optical fiber vibration sensor. The plate thickness was changed from 1mm to 10mm in order to research the effect of plate thickness on propagation characteristic of elastic wave. Moreover, on the assumption that generation factor of elastic wave was only depending on a force, numerical analysis by using finite element method (FEM) was adapted. The numerical analysis result using the FEM and the experiment result along with the single pulse discharge was compared. As the result, it was estimated that the generation factor of the elastic wave was same as the current duration. These results become possible to estimate the propagation characteristic of elastic wave. Evaluation of electrical discharge sound for hammering test by using optical fiber sensor was investigated. Defect shape and scale was estimated from comparison with detected waveform by using optical fiber vibration sensor and simulated waveform. As the results, it was considered that electrical discharge sound was available for hammering test. It was expected that this technique would be proof the safety and reliability for human society.

ACKNOWLEDGEMENTS

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