Poster Presentation

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Guided Waves Response to the Defect in Wire Cables under Tensile Force

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Abstract

A nondestructive inspection technique utilizing a guided wave is required to evaluate the damage and degradation of wire cables. However, the calculation or simulation of characteristics of guided wave propagation in wire cables is complicated because many wave propagation paths exist in twisted threads. In this study, changes in propagation of guided waves were studied. First, changing wave propagation paths as a function of tensile force were studied using simplified cable made of wires with two strands. Guided waves were produced by a pulse YAG laser and detected by three PZT transducers. In the setup, guided wave excitation utilizes the adiabatic expansion at the irradiated position. The pulse energy was 200 mJ and the propagation distance was 560 mm. At the laser-irradiation strand, the first arrival waveform packet changed as a function of tensile force. The amplitude decreased, and the arrival time was later as tensile force increased. This propagation mode of guided waves was similar to the L(0,1) mode of a rod with the same diameter as a wire, according to a group velocity dispersion curve of the rod. The wavelet contour maps of detected waves nearly matched. Thus, L(0,1) mode of guided waves mainly propagated in the strands. The mode with a frequency close to the resonance frequency of PZT transducers was detected between the L(0,1) mode and F(1,1) mode. This mode was denoted as the L-like mode. We presumed that the L-like mode propagated in the entire wire cable. Second, the propagation of waves in a wire cable with and without defect were compared. We found that the amplitude of propagation in the L-like mode decreased in proportion to the magnitude of defect. As a result, the amplitude of the L-like mode has high responsiveness for defects of wire cables and defects can be discovered under tensile force.

Keywords*:* Wire cable, Guided wave, Nondestructive inspection, Wavelet transform

INTRODUCTION

Wire cables are widely used for mechanical and structural components. However, rupture accidents cause serious problems such as corrosion and frictional wear [1]. To evaluate the damage and degradation of wire cables, a nondestructive inspection technique utilizing a guided wave is required [2]. However, the identifying characteristics of guided wave propagation is difficult because of the complexity of twisted threads of wire cable. In order to overcome the problem, we constructed simple wire cables that consisted of two strands to simplify propagation paths. Then, we measured guided wave propagation in wire cables under tensile stress. Moreover, we experimentally evaluated the propagation of guided waves in wire cables with the defect.

1. EXPERIMENTS

In this study, a simple wire cable consisting of two strands with two wires was used (Fig. 1). The wire cable was made of SUS304, had a wire diameter of 0.9 mm, a wire length of 600 mm, a strand diameter of 1.8 mm, and an outer diameter of 3.6 mm, respectively. A defect was added in the center of the wire cable. The propagation behavior of guided waves in the wire cable under tensile stress was evaluated using the experimental setup shown in Fig. 2. Guided waves were produced by a Q-switched Nd:YAG pulse laser and detected by three PZT sensors (PAC, R15α) on each wire. In the setup, Ch.1 was installed on the laser-irradiated wire (wire-1), Ch.2 was installed on wire-2, which was placed in the same as wire-1, and Ch.3 was installed on the wire of a different strand in order to detect the different propagation paths of guide waves. Guided wave excitation utilizes the adiabatic expansion at the irradiated position. The pulse energy of laser was 200 mJ, the pulse duration was 6-9 ns, and the propagation distance was 560 mm.

The propagation of guided waves in the wire cable with the defect at wire-1 under tensile stress was first studied. Fig. 3 shows the waveforms and its wavelet contour maps of waveforms under a tensile force of 98 N, detected by receivers at Ch.1. According to the wavelet contour maps of the detected waves, the L(0,1) mode was detected. Moreover, the characteristics of propagation at Ch.1 and those at Ch.2 were similar. It is indicated that the L(0,1) mode of guided waves mainly propagated in the wire. The same propagation mode was detected between the L(0,1) mode and F(1,1) mode on all channels. This mode was denoted as the L-like mode [3]. We presume that this mode was a longitudinal mode of propagation in the whole wire cable, as the diameter increases, the group velocity of longitudinal mode reduces.

We next studied the propagation paths of elastic waves when wire-1 and wire-2 were damaged. Fig. 4 shows the waveforms and wavelet contour maps of waveforms under a tensile force of 98 N, detected by receivers at Ch.1. The L(0,1) mode was not detected. The amplitude of the L-like mode was much smaller than those of the wires with no defect, as well as wire-1 (Fig. 3). As a result, the L(0,1) mode mainly propagated in the strand. It was inferred that guided waves easily propagate through wires of the same strand and do not easily propagate between strands, because wires are in line contact, and strands are in point contact [4]. Additionally, propagation modes other than the L(0,1) mode, did not change frequency characteristics with the defect. Therefore, we estimated that defect detection by using the L(0,1) mode and L-like mode were possible.

The relationship between the size of the defect and amplitude of the guided wave was next evaluated. Fig. 5 shows the relationship between the breaking point, load and amplitude for L-like mode at Ch.1, Ch.2, and Ch.3. When the wire and the strand were broken, the amplitude of L-like mode is smaller than that with no defect at all channel of receivers under tensile force. In particular, this trend was observed under a low tensile force at Ch.1 and Ch.2. Without a load, the L-like mode mainly propagated in the strand because of the weak contact force between the strand and the other strand. Therefore, the amplitude of the L-like mode showed high response to the defect in the strand. In contrast, it showed high response at Ch.3 under a high tensile force because of the L-like mode of propagation through the entire wire cable. In addition, its amplitude decreased with increased load at Ch.1 and Ch.2 without the defect, and its amplitude increased with an increase in load. It can be said that the propagation paths of L-like mode changed from this trend. As a result, there was a correlation between the magnitude of the defect and the amplitude of the L-like mode. Moreover, the amplitude of the L-like mode can discover the defect in a wire cable under tensile force, and the periodic inspection and comparative amplitudes of the L-like mode are required in order to conduct the screening test of wire cables by using guided waves.

2. SUMMARY

In this study, the propagation of guided waves in a wire cable with defect was studied. The L(0,1) mode of propagation of guided waves was mainly observed in the strand. This is because the L(0,1) mode could be detected at Ch.1 and Ch.2 when the wire was broken. However, the L(0,1) mode could not be detected at all receivers when the strand was broken because they were cut off from the defect. The amplitude of the L-like mode can be used to discover a defect under tensile force, as there is a correlation between the size of the defect and the amplitude of the L-like mode. The amplitude of the L-like mode is smaller than those with no defect at all channel of receivers. As a result, the periodic inspection and a comparison of the amplitudes of the L-like mode are required in order to conduct a screening test of wire cables by using guided waves.

REFERENCES

[1] K. Sasaki, S. Iwakura, T. Takahashi, T. Moriya and I. Furukawa, (2005) Estimating Fatigue Life of Wire Rope with Stochastic Approach: Transactions of the Japan Society of Mechanical Engineers, Series A, 71 (707): 11-16.

[2] H. Nishino, F. Uchida, S. Takashina, M. Takemoto and K. Ono, (2000) A new method of acoustic emission source location in Pipes using cylindrical guided waves, Journal of Acoustic Emission, 18: 102-110.

[3] T. Matsuo, S. Ozono, (2015) Guided Wave Propagation in Wire Cable under Tensile Stress, paper presented in *the 14th International Conference on QiR*, Lombok, Indonesia.

[4] T. Endo, A. Okukawa, H.Takenouchi, C. Miki, (1994) Bending Fatigue Strength of Bridge Cable” Steel construction engineering, 1 (3): 91- 102.

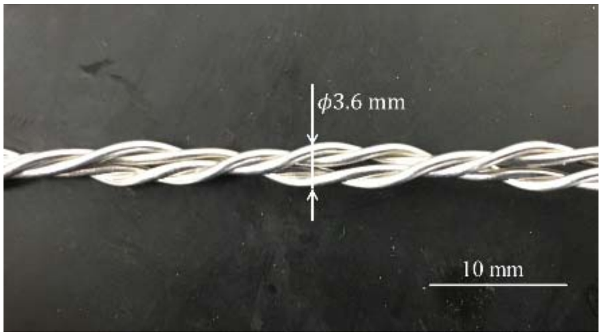

Fig.1 Photo of wire cable used in this study

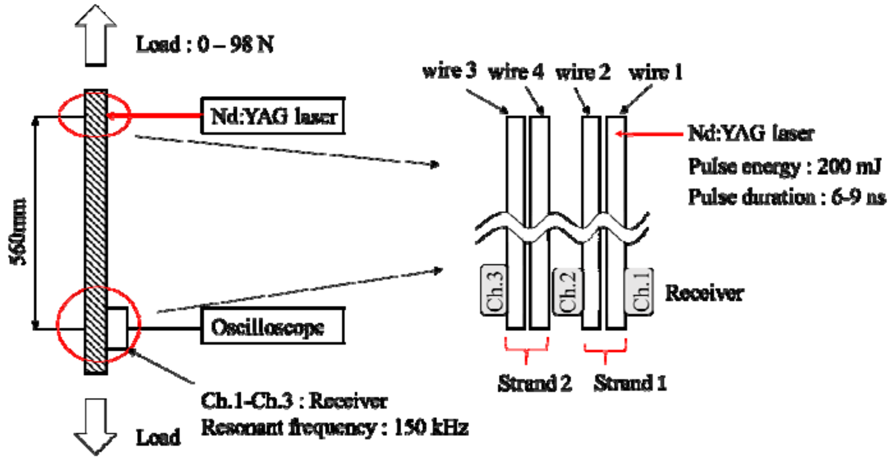

Fig.2 Experimental setup for detecting propagation of guided waves on the wire cable

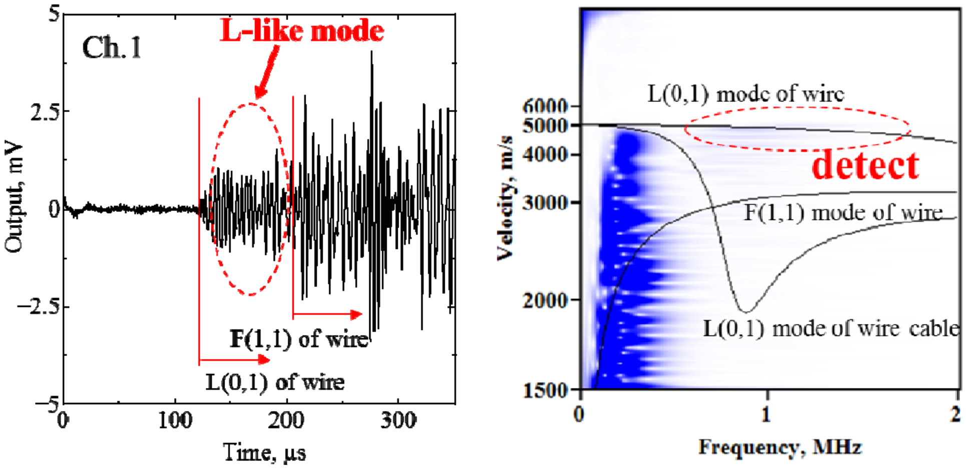

Fig. 3 Waveform (left) and wavelet contour map of waveform (right) at Ch.1 in test A

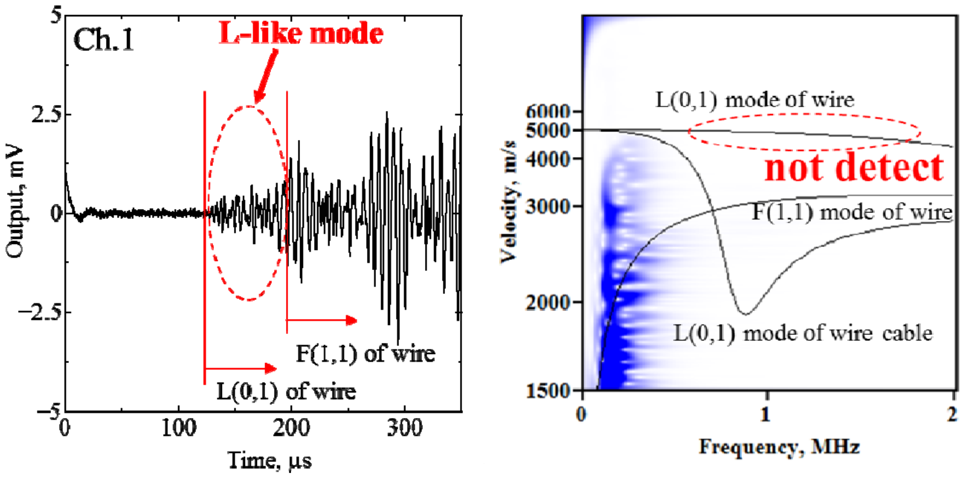

Fig. 4 Waveform (left) and wavelet contour map of waveform (right) at Ch.1 in test B

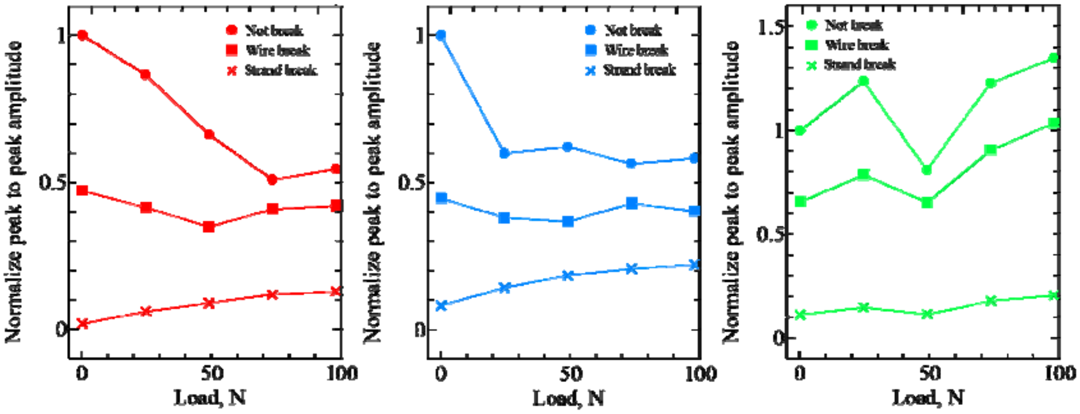

Fig. 5 Relationship between breaking point, tensile force, and amplitude of L-like mode at Ch.1 (left), Ch.2 (center), and Ch.3 (right).