The 8th TSME International Conference on Mechanical Engineering
12-15 December 2017
Bangkok, Thailand

AMM0012

The method for detecting damages of wire cables using guided waves

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Abstract. Wire cables are widely used in infrastructure and mechanical components. However, disruptive accidents can be caused by corrosion or frictional wear of these wires. Such accidents can be prevented by detecting small defects in the wire cables. In our previous studies, a rough detection of defects in six-strand wire cables using guided waves that can propagate long distance and detect internal damage was developed. However, this method is not practical as the inspection and implementation is time consuming. Therefore, the aim of this study is to develop an efficient method using waveguides for detecting defects in wire cables. We developed waveguides for a PZT sensor in order to excite a uniformly guided wave to all strands. The guided waves produced by the PZT sensor were detected by two PZT sensors. Two receivers each in contact with three strands were installed at the top and bottom of the six-strand wire cables. The propagation distance was 600 mm and defects were placed in the strands. We found that in the absence of defects, guide waves were excited uniformly to the entire wire cable when the waveguide is used, because there is no difference in amplitudes between the two receivers. The recorded amplitude on the sensor installed on the strand with defects decreased as the number of breaking wires increased. It was found that this method can effectively detect the defects in a fewer number of measurements as compared to the previous method.

1. Introduction

Wire cables are widely used in the industry because of their high tensile strength and flexibility. However wire cables are often damaged by frictional wear, corrosion and temperature changes due to aging [1]. Normally, periodic inspection are conducted by visual inspection, however visual inspection can find the damage only on wire cable surface and need an abundance of time. Then nondestructive inspection techniques such as guided wave inspection was required in order to detect damages at an early stage to prevent accidents [2]. Various studies have been conducted on guided wave inspection for wire cables [3, 4]. However, characteristic of wave propagation in wire cable are complex because wire cable is consist of many iron wires and have helical shape [5]. In our previous studies, simple type wire cable that consist of two strands was made to simplify propagation path of guided wave. The mode that have responsiveness for defects of wire cable was found by experimental method [6]. This mode was named L-like mode because it has characteristics similar to the longitudinal mode in the rod. Roughly detection of defects by L-like mode could carried out for six-strand wire cable. However, this method is not practical, because it is needed to be inspected by guided wave excited on each strand using pulse YAG laser in order to inspect all strands in wire cable. Therefore, the aim of this study is to develop an efficient method for the inspection of defects using waveguides.

2. Experiment

The experimental setup for detecting guided waves is shown in Figure 1. This wire cable consists of six strands. The tests were carried out with tensile force of 98 N. Figure 2 shows schematic representation of transducer installation and receiver installation. Guide waves were produced by a piezoelectric transducer (PZT) via the waveguide. This waveguide was developed in order to excite uniformly guided wave to all strands of the wire cable. Two receivers were installed at the top (Ch.1) and bottom (Ch.2) of wire cable, and each receiver is in contact with three strands in order to detect guided waves propagated each strand. Figure 3 shows that the time domain signal, its frequency spectra and its wavelet contour map of guided waves propagated in wire cable via waveguide detected by Ch. 2. According to the contour map, the group velocity of first wave packet is slower than that of L (0,1) mode of the rod having same diameter as the wire of this wire cable, and faster than that of F (1,1) mode. This mainly frequency is 360 kHz according to the frequency spectra. The mode of first packet is considered to be L-like mode because L-like mode has the same feature as these. As there result, it was confirmed that L-like mode can be detected using this experimental setup. The amplitudes of L-like mode detected by each sensor are shown in Figure 4. The variation in measurement of amplitude in each sensor decreased when a waveguide was used as compared with the case of not using a waveguide. Moreover, the output difference of each sensor was reduced. From these results, it was found that a stable signal can be propagated in the wire cable by using the waveguide.

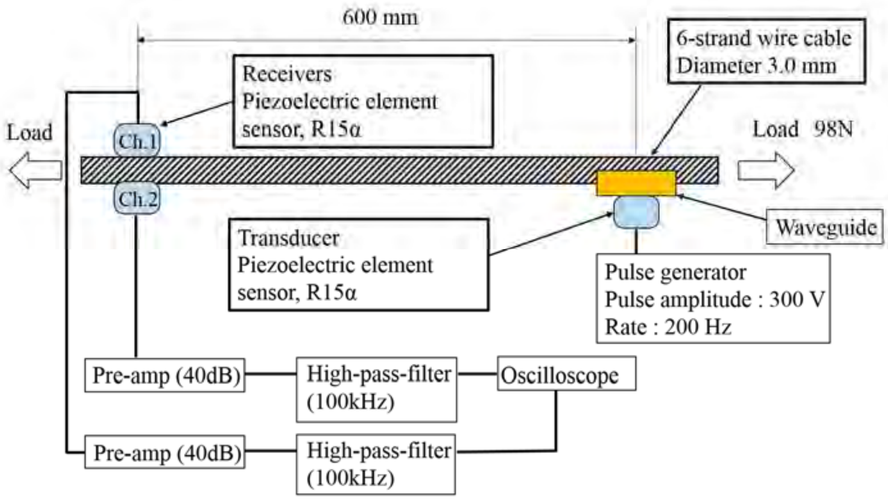

Figure 1. Experimental setup for detecting guided wave.

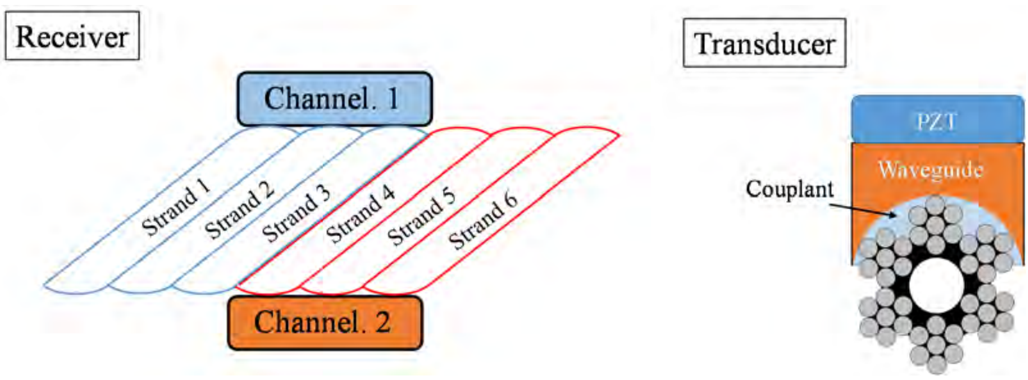

Figure 2. Schematic representations of receiver installation and transducer installation.

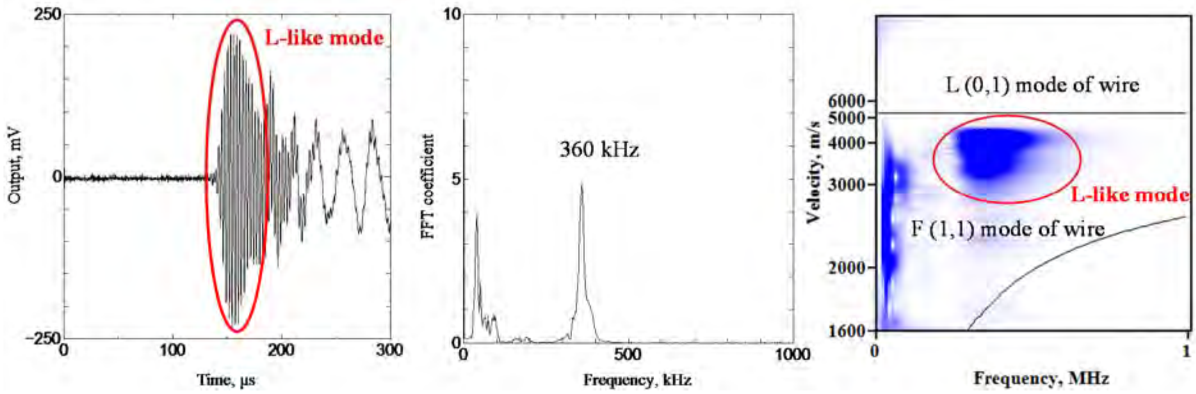

Figure 3. Time domain signal (left), its frequency spectra (center) and its wavelet contour map (right) of guided wave propagated in six strand wire cable via waveguide detected by channel. 2.

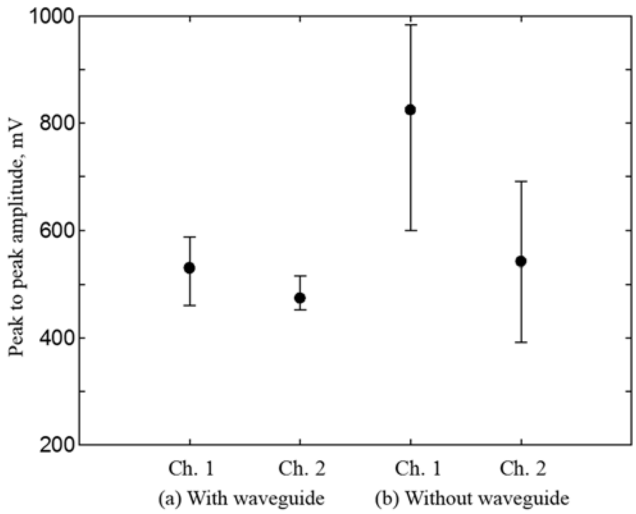

Figure 4. Wave amplitude detected by each receiver when excited (a) via the waveguide and (b) without waveguide

Next, a rough estimation of the defects in the wire cable was carried out using the waveguide. The defects were added by breaking the wires of one strand where the sensor of Ch. 2 was installed. Figure 5 shows time domain signal, its frequency spectra and its wavelet contour map of guided wave propagated in wire cable with seven wires broken in a strand. L-like mode can be detected, however the amplitude of L-like mode was decreased compared to without defects. The relationship between the amplitude of L-like mode and number of breaking wires is shown in Figure 6. The output of Ch. 2 decreased as the number of breaking wires increased. On the other hand, the output of Ch. 1 did not decrease though there was some variation in measurement. As s result, it was found that the damages to wire cable can be detected by using two receivers and the waveguide. The excitation method using PZT via waveguide is effective as the efficient method of guided wave excitation. A drawback of this technique is that the location of damages cannot be detected and the measurement accuracy is low. It is necessary to improve the position or the detection method of the receiver.

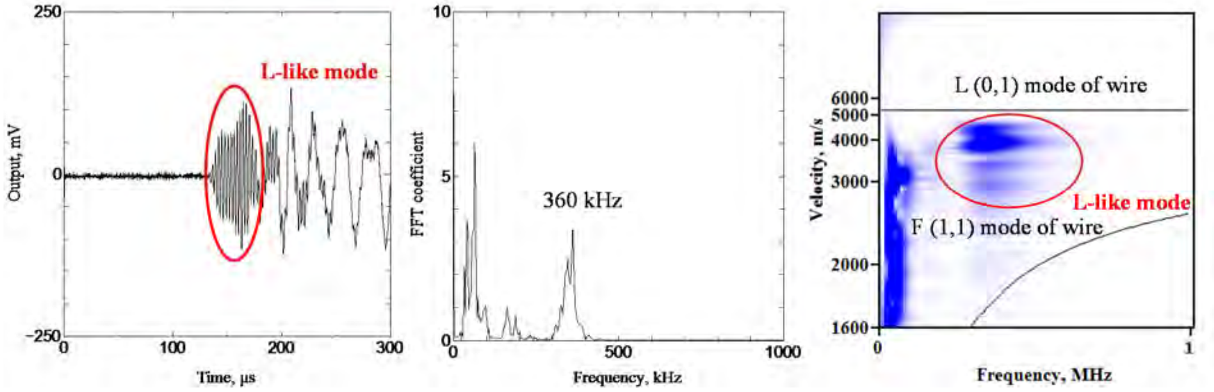

Figure 5. Time domain signal (left), its frequency spectra (center) and its wavelet contour map (right) of guided wave propagated in six strand wire cable with defects via waveguide detected by channel. 2.

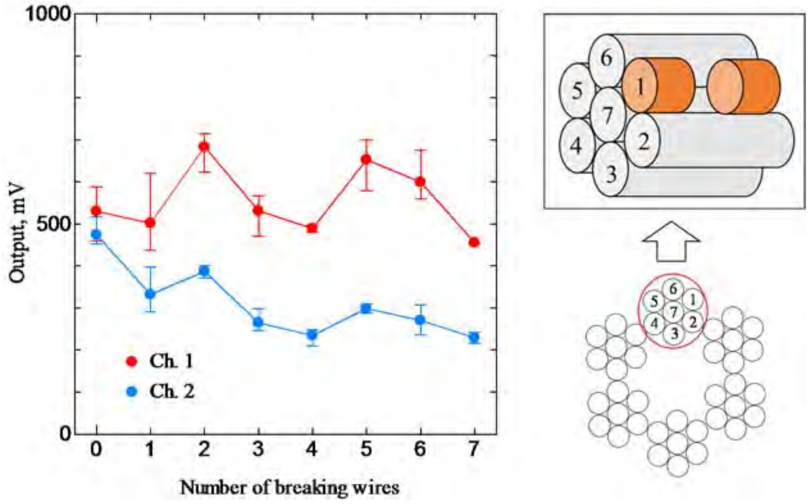

Figure 6. Relationship between the output of each sensor and number of breaking wires by using a waveguide.

3. Conclusion

From this study, we concluded that guided waves can be uniformly excited to the wire cable by using a waveguide. Moreover, the variation in measurement can be reduced. Thus, the waveguide was developed in order to efficiently inspect the defects present in a wire cable of six strands.

References

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