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Efficient nondestructive evaluation of pipes by Multireflecting Guided wave Energy Trapping (MGET) method
ガイド波の多重反射エネルギー閉じ込め法による パイプの高効率非破壊検査方法

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1. Introduction

The authors have reported a novel method of an efficient transduction method [1, 2] for guided waves [3] using the wave reflector just located near the sensor. The sensitivity of the method with the reflector has been 2.0-2.5 times larger than that without the reflector. This paper describes a much more efficient method for defect detection using guided waves with two reflectors. The novel method called Multi-reflecting Guided wave Energy Trapping (MGET) method is evolved from the above-described efficient method [1, 2]. When the guided waves are trapped between the two reflectors, *n* combinations of propagation paths having same path length are principally existed. Therefore the defect signals are overlapped each other and the amplitude are enhanced. Details of the principle and experimental verifications are shown. The sensitivity of the MGET method has been evaluated about 14 times larger than that of the conventional guided wave method.

2. Principle of MGET method

In the MGET method, two reflectors are important roles to enhance the amplitude of defect signals. The guided wave (normally the T(0,1) mode) is generated in a necessary region of a pipe between the two reflectors. Multireflections are then occurred between the two reflectors and the defect as shown in Fig. 1. The necessary region means a desired inspection region, which can be determined and restricted by the two reflectors. The indices ①-⑥ in Fig. 1 indicate the propagation paths and the corresponding wave packets in time domain signals, respectively. ① is the defect signal usually used in a conventional guided wave testing. ②, ⑤ and so on are the reflected signals at the reflectors. Utmost important propagation paths in the method are ③ and ⑥. It is obviously confirmed that the two different propagation paths having the same propagation length are existed as shown in Fig. 1. One signal is reflected first at the defect and then the left-side- and the right-side-reflectors in order. The other signal was reflected first at the right-side- and the left-side-reflectors, finally at the defect. Thus the two wave packets totally overlapped each other and the amplitude of ③ is two times larger than that of ①, when the reflection coefficients at the reflectors are total and propagation decay is free. Similarly in ⑥, the amplitude takes threefold because of the existence of the three different propagation paths having the same propagation length. Due to the simple manner described above, the amplitude takes larger at larger number of reflections at the reflector. The estimated amplitude *A* in the MGET method is formulated in eq.(1).

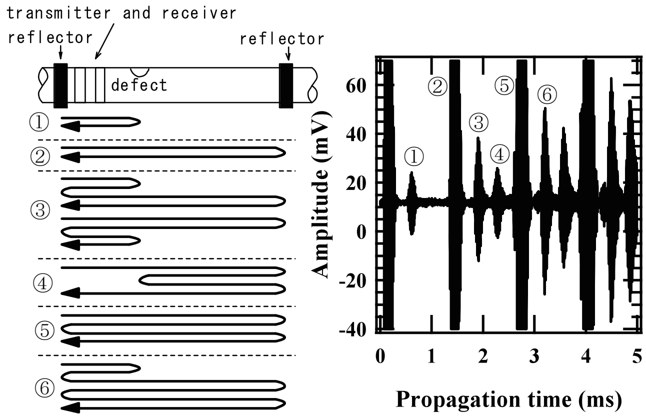

Fig. 1 Propagation paths and corresponding wave packets.

$$A = \left(\frac{n}{2}+1\right) r (tR)^{n}, \qquad (1)$$

where *n*, *r*, *t* and *R* are number of the reflection, reflection and transmission coefficients at the sensors, and the reflection coefficient of the reflectors, respectively. It is obviously confirmed in the formulation that the amplitude linearly increases in smaller number of n, however, that decreases in larger number of n due to the *n*-th power of *tR*.

3. Experiments

Experimental setup is shown in Fig. 2. A 60.5 mm outer diameter and 4 mm thick aluminum (Al) pipe was used as a specimen. In the experiments, pipe ends were used as the reflectors whose reflection coefficients were almost total. The 50 kHz T(0,1) mode 6 cycle tone-burst signals were used. The measured group velocity of the mode was 3120 m/s. The artificial defect was gradually increased (about 0.05 mm step).

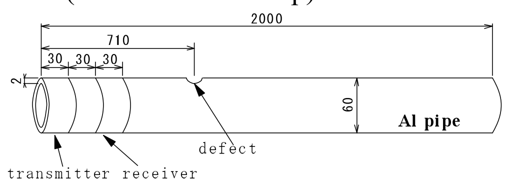

Fig. 2 Schematic illustration of the Al pipe, sensors and a defect used in the experiment.

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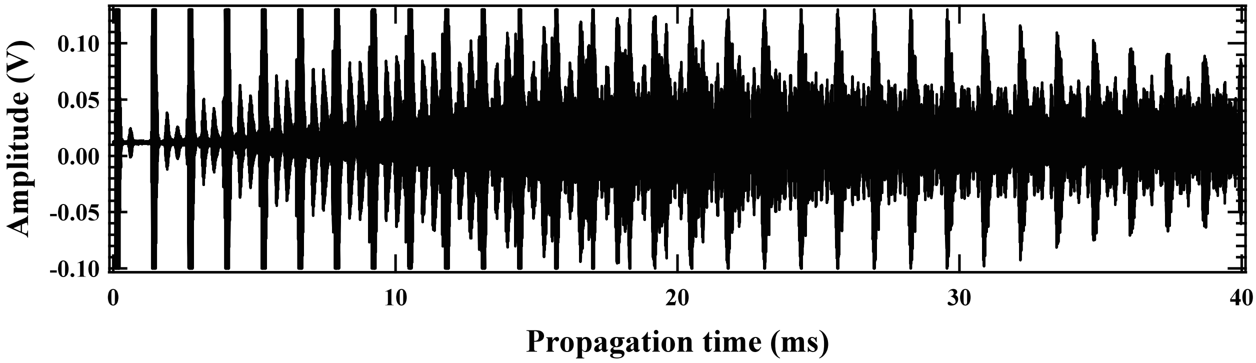

Fig. 3 Typical time domain signal obtained by the Multireflecting Guided wave Energy Trapping (MET) method.

4. Results

Figure 3 shows the time domain signal of 1.5 mm depth (5.17% cross sectional loss; CSL) defect. The multireflected signals at the pipe ends were shown as saturated signals as shown in Fig. 3, however, the signals gradually decreased with an increase of the reflections of the reflectors. Conversely, it was confirmed that the defect signals were gradually increased and then decreased. Normalized amplitude as a function of number of the reflections is shown in Fig. 4. The squares and line indicate the experiments and calculated values by eq. (1), where t = 0.985, r = 0.032 and R = 0.985. The maximum sensitivity increased up to 5.6 times larger than that obtained by the previous reported method [1,2] having about 2.5 times efficiency against conventional method. Then, the sensitivity of the MGET method could be estimated as much as about 14 times larger than that of the conventional guided wave transduction. Figure 5 shows the time domain signals for smaller regions of CSL's. However, it is too difficult to confirm the signals in the no reflection region (~1.3 ms), we can confirm the signals of 1.18%CLS between the 1st and 2nd reflections. Furthermore, the signals of 0.44%CSL can be confirmed between the 3rd and 4th, nevertheless no signals are found before the 3rd.

5. Conclusions

Highly sensitive Multireflecting Guided wave Energy Trapping (MGET) method has been developed and evaluated. The sensitivity can be remarkably increased while the guided wave energy is trapped between the two reflectors. It was estimated that the sensitivity increased up to about 14 times against the conventional transduction.

Acknowledgement

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Reference

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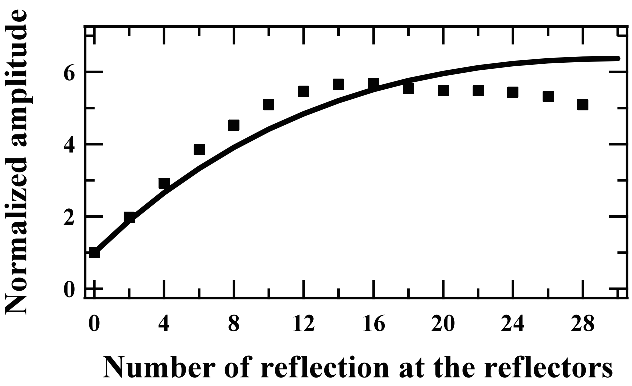

Fig. 4 Normalized amplitude obtained in region labeled as number of reflection at the reflectors.

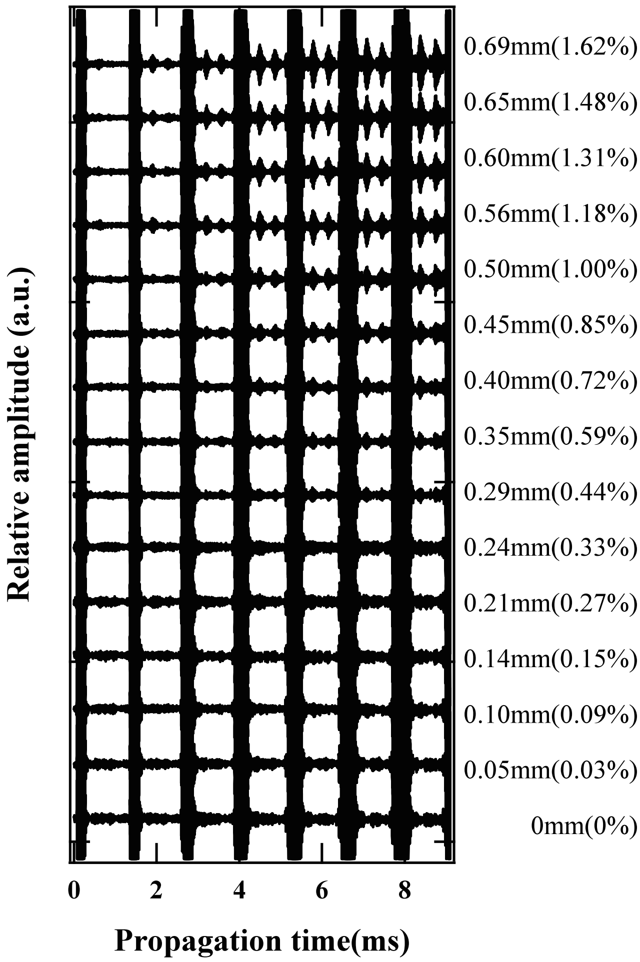

Fig. 5 Time domain signals for different cross sectional losses. Larger amplitude can be obtained at later propagation time as well as deeper defects.