1P2-23

Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 61-62
18-20 November, 2009

Development of Inspection Equipment for Bottom Edges of Rails with Guided Waves

ガイド波によるレール底端部検査装置の開発

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1. Introduction

Inspections for railway rails are now done by an ultrasonic pulse echo method where transducers on a rail inspection car input ultrasonic waves from a rail head with wheel probes. This technique is very effective for inspecting defects in rail heads and webs, but bottom edges of rails are blind zones in this technique. Therefore, visual inspection is carried out for bottom edges of rails except in crossings where the bottom edges of rails are hidden by cover plates. Thus, the inspection technique for bottom edges of rails, especially in crossings, is indispensable in order to ensure the reliability as well as safety of transportation.

On the other hand, the ultrasonic guided wave technology attracts lots of attentions in recent years because it can propagate along the bar-like structures in the long distance. The "guided wave" technique have been widely used as a fast screening technique for such structures. It has been found that guided waves are also quite effective for NDE of rail edges in pitch-catch configurations1).

This paper firstly describes the effective guided wave mode and frequency for inspecting bottom edges of a rail using guided wave dispersion curves software developed by the authors2). The inspection equipment for bottom wedges of rails with guided waves was developed which chirp pulse waves were sweep. The sensitivity by the correlation processing has been improved. The developed inspection equipment was checked with bottom edges of a rail experiment.

2. Suitable frequency for inspecting bottom edges of a rail

Dispersion curves and wave structures of horizontally dominant modes for JIS 50kgN rail were obtained using our software based on the SAFE method1-2) as shown in Figs.1 and 2. Looking at the wave structures of horizontally dominant modes at 100, 150 and 200 kHz in Fig.2, we can find that these modes concentrate at the bottom edges. Comparing wave structures with different frequency 100, 150 and 200 kHz, more energy is concentrated at the higher frequency. Since these are typical characteristics of Rayleigh waves these modes can be considered Rayleigh-like modes propagation on the surface of rail edges in Fig. 2. In Fig. 2 (c), it can be expected that this frequency can avoid the interference with fastenings, and we can conclude that this frequency is the one of the most suitable frequency for inspecting bottom edges of a rail.

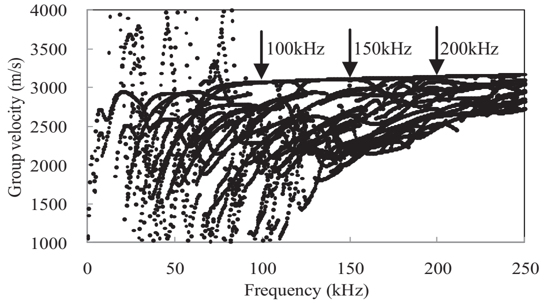

Fig.1 Group velocity dispersion curves at bottom edges of a rail (horizontally dominant modes).

(a) 100kHz (b) 150kHz (c)200kHz

Fig.2 Visualization of the vibrating modes corresponding to the arrow positions in Fig.1

3. Development of a transducer for bottom edge inspection

Since Rayleigh waves are generally excited and received by an angle beam transducer, we fabricated an angle beam broadband transducer consisting of a polyetherimide resin wedge (longitudinal wave c_w=2460m/s), 1-3 piezoelectric composite (200 kHz) and damper. The incident angle of the wedge is determined to approximately 56.8° by Snell' law for the phase velocity of the

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Rayleigh-like mode, about 2940 m/s at 200 kHz. The developed transducer for bottom edge inspection is shown in Fig.3.

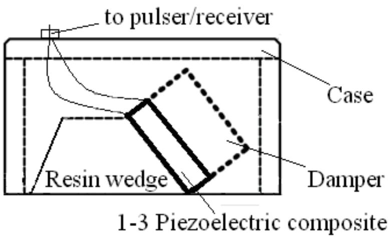

Fig. 3 Broadband transducer for a rail bottom edge.

4. Experimental result by developed transducer

Using the transducer, inspection experiments for the bottom edges of a rail were conducted. The configuration of the experiment is shown in Fig. 4. In these experiments we use abandoned rail where rust adheres of 3.6m. There were 6 fastenings (a) - (f) between the transducer and the edge of other hand. The fastenings were fastened about at every 600mm and the plates are placed on the rubber plates on the sleepers. Power to tighten is about 800N to each fasten. The transducer is located at the left end of a rail. Incident signals are square burst wave and square chirp wave at the center frequency of 200 kHz, which is excited by high power pulses / receiver (Japan Probe JPR -10C) in the experiments[3].

In the experiment, the effective of chirp waves incidence on avoid the interference with fastenings was investigated using the developed broadband transducer. Fig. 5 shows waveforms from the right end of a rail when incidence wave was square burst wave. Fig. 6 shows waveforms from the right end of a rail when incidence wave was square chirp wave, and chirp ratio is 1.75. Fig. 7 is a result that the result of Fig. 6 was correlation processed. The upper horizontal axis denotes propagation time by the group velocity of the Rayleigh-like mode 3000m/s. When all fastenings were fastened, waveforms were obtained as shown from the bottom to top. The right end echoes were observed at the correct location, the overlapping waves at the left end are reverberations within transducers and within epoxy resin wedge and the next ones are shape echo. Although the influence of fastenings was observed in the signals, echoes are sufficiently detected.

Comparison results of burst wave, chirp wave and correlation processing, we can understand that the Sensitivity of chirp wave is higher than one of burst wave 12.4dB, and S/N ratio is 0.23 up. In addition, the S/N ratio went up far by correlation processing, the S/N ratio is higher than one of burst wave 1.73, and is higher one of chirp wave 1.5.

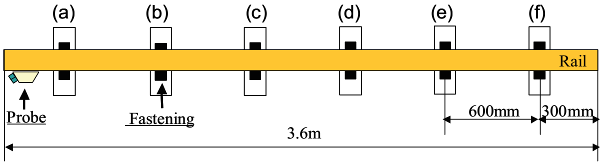

Fig. 4 Configuration of a rail and fastenings.

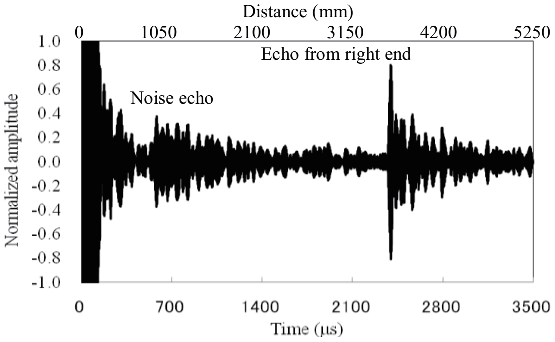

Fig. 5 Normalized amplitude with propagation despondences for square burst wave.

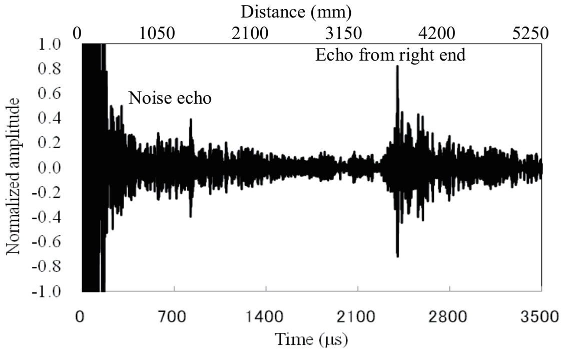

Fig. 6 Normalized amplitude with propagation despondences for square chirp wave.

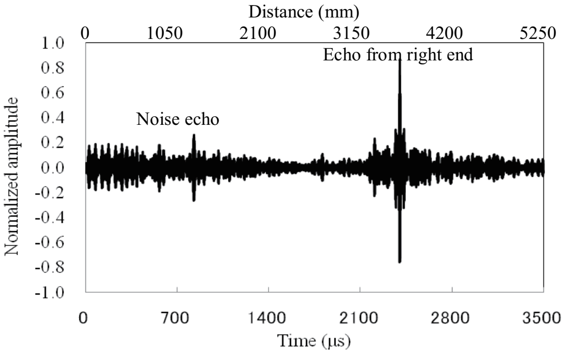

Fig. 7 Normalized amplitude with propagation despondences by correlation processing.

5. Conclusions

In this report, a broadband transducer was designed. The sensitivity and S/N ratio of chirp wave and correlation processing were investigated and defect inspection capability of the developed broadband transducer was checked. Good echo signals were obtained with the transducer at the correct location from end of a bottom edge of rail.

References

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