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Research on improving defect detection performance using signal processing during movement measurement with noncontact acoustic inspection method

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1. Introduction

Currently, we are studying movement measurement using a sound source and a laser Doppler vibrometer (LDV) mounted on a cart. In this movement measurement, large amplitude noise caused by the surface condition of the measurement target is measured. Therefore, sound waves with high sound pressure are used to perform defect detection. However, we have confirmed cases where the defect detection performance is reduced due to the LDV resonating with sound waves. This time, we studied the improvement of defect detection performance by reducing the effect of resonance using vibration waveforms measured at the healthy part of the measurement target.

2. Experimental setup for movement measure ment

The concrete specimen (2000 x 1500 x 300 mm^3) used for the movement measurement is shown in Fig.1. A green solid line shows the measurement line. Polystyrene foam (25 mm thick) was embedded inside the specimen to simulate a cavity defect (diameter: 300 mm, depth: 40,60,80 and 100 mm).

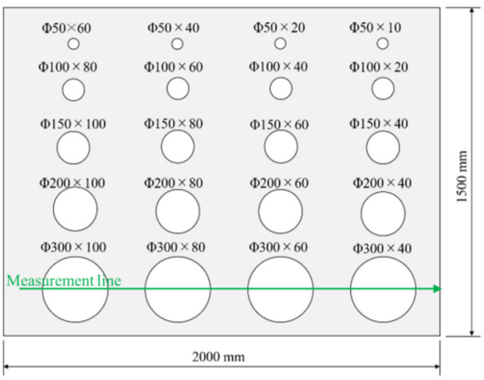

Fig.1 Specimen with circular cavity defect.

Next, Fig.2 shows the positional relationship between the specimen and the measuring equipment. Vibration measurements were performed using an LDV (Polytec GmbH, MLV-I-120) and an LRAD (Long Range Acoustic Device, Genasys Inc. LRAD-100X) as the sound source. In addition, the cart (Egripment Support Systems B.V.) carrying the measuring equipment moved on rails, and the distance between the specimen and the LDV was kept almost constant. At this time, the laser was irradiated perpendicularly to the specimen. The distance between the specimen and the measuring device is 3.36 m. The average speed of the cart is 0.26 m/s.

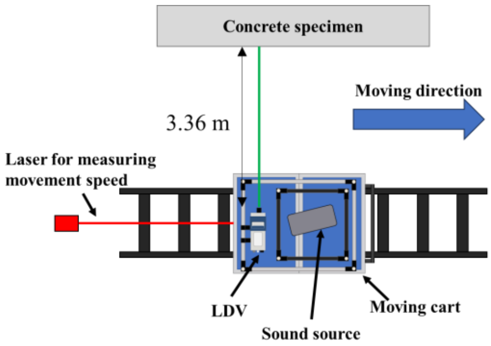

Fig.2 Experimental setup.

A multi-tone burst wave[1)] was used for vibration measurement (frequency range: 500 to 4100 Hz, pulse width: 3 ms, frequency interval: 200 Hz, total waveform length: 59 ms, maximum sound pressure near the test specimen was approximately 120 dB (maximum Z characteristic value)). The center of the defect was measured when the cart was stopped, and the resonant frequency (depth 40 mm: 883 Hz, depth 60 mm: 1617 Hz, depth 80 mm: 2017 Hz, depth 100 mm: 2783 Hz) was calculated.

3. Method for estimating defect position

3.1 Defect detection method using cross-correl ation processing [1)]

When measuring vibration while the LDV is mounted on a cart, noise caused by the surface condition of the measurement target is measured. The vibration velocity amplitude of this noise is larger than the response of the defective part and increases in proportion to the moving speed of the cart. Therefore, in order to estimate the response of the defective part from the noisy acquired waveform,

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cross-correlation processing was performed between the emitted waveform and the acquired waveform. Figure 3 shows a conceptual diagram of the cross-correlation processing used in this study. The reference signal used for correlation processing was a multiple burst wave with a single frequency. The frequency of the reference signal is changed by 10 Hz for each process, and the correlation waveform is calculated in the emission frequency band of 500 to 4100 Hz. This reference signal was determined based on the fact that the resonance frequency of the actual defect is unknown and resonance vibration is measured multiple times on the defect during movement measurement. Finally, the correlation waveform showing the maximum correlation value in each time period are extracted, and the defect position is estimated.

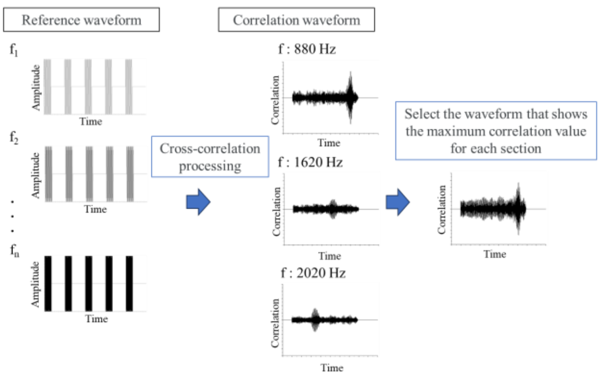

Fig.3 Conceptual diagram of cross-correlation processing.

3.2 Reducing the effect of LDV resonance u sing subtraction processing

The spectrogram after correlation processing is shown in Fig.4. The color scale indicates the maximum correlation value. The response of each defect can be seen in the white arrows in Fig.4. However, the frequency band indicated by the red arrow always shows a correlation value equivalent to the response of the defective part during the measurement time. This is because the LDV is resonating with sound waves from a sound source placed near the LDV. This LDV resonance makes it difficult to identify the response of the defect. Therefore, we studied the reduction of the effect of resonance on LDVs using waveforms measured at the healthy part when the cart is stationary. The specific method was to perform subtraction processing using the vibration waveforms measured in the healthy part for each time period during which the waves were emitted. Figure 5 shows the spectrogram after subtraction processing. Figure 5 shows that the correlation value of the resonance frequency of the LDV (red arrow) was reduced by using the subtraction process, and the response of the defects became easier to identify.

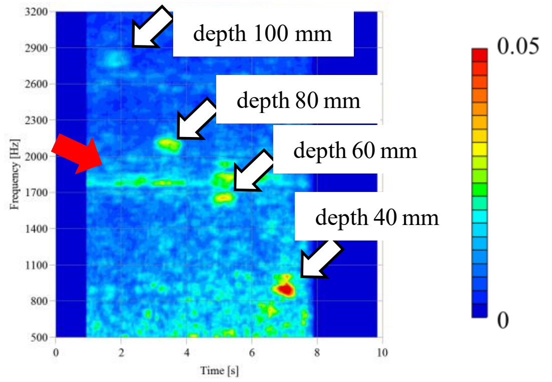

Fig.4 Spectrogram calculated by cross-correlation processing
(Red arrow: resonance frequency of the LDV).

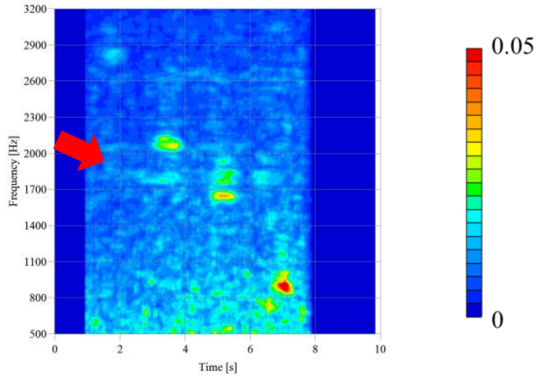

Fig.5 Spectrogram calculated by cross-correlation processing after subtraction processing.

4. Conclusion

In this study, we investigated the improvement of defect detection performance by reducing the effect of resonance using vibration waveforms measured in the healthy part of the measurement target. As a result of performing subtraction processing using the vibration velocity waveform of the healthy part, it was confirmed that the effect of LDV resonance was reduced and the detection performance of defective parts was improved. In the future, we plan to consider the placement of the LDV and sound source as well as vibration isolation measures.

Acknowledgment

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Reference

1) T.Sugimoto, Y.Nakagawa, K.Sugimoto, I.Uechi, H.Takagi, N.Utagawa and Y.Nihei, Jpn. J. Appl. Phys., Vol. 63, 04SP45, April. 2024.