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High speed non-contact acoustic inspection method for civil engineering structure using multi tone burst wave
マルチトーンバースト波を用いた土木構造物のための高速非接触音響探査法

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1. Introduction

The non-contact acoustic inspection method for having used flexural resonance using the airborne sound can detect the defect of the civil engineering structure from a long distance[1-4]. However, the length of the measurement time to search for the resonance frequency as a practical problem was pointed out. This is because only one frequency was used for one sound wave emission using the tone burst wave so that a high signal to noise (S/N) ratio could be obtained with the laser Doppler vibrometer of a weak laser power (e.g. He-Ne 1mW). On the other hand, it becomes possible by taking into consideration the difference of the propagation velocity of a sound wave and laser light to perform high speed measurement as compared with the conventional method by using the waveform which uses plural frequency at the time of one sound wave emission. Therefore, basic study about the validity of this technique is performed.

2. High speed measurement using the MTNB wave

The non-contact acoustic inspection method[1-4] has studied mainly as a substitute for the hammering test to the concrete surface in a tunnel. As shown in **Fig. 1**, the long range acoustic device (LRAD) generates a strong sound vibration and gives vibrational energy to an object structure. We measured flexural resonance vibrations occurred at the surface of cave or crack defects inside the concrete structure using the laser Doppler vibrometer (LDV) or the two-dimentional scanning laser Doppler vibrometer (SLDV) with high sensitivity. This method uses the flexural resonance which is theoretically the same as the hammer method. So it can essentially be substituted for the hammer method. In the hammer method, a skillful inspector beats the concrete surface by a hammer and distinguish a defect from healthy parts. Therefore experience is needed. Our method has an advantage that a quantitative measurement is recorded as a vibration velocity and we can measure more than 5 m apart from a measuring surface. Our method is non-contact and nondestructive inspection method. Degradation such as a cave or a crack of concrete structures (a bridge and a tunnel, etc.) can be detected.

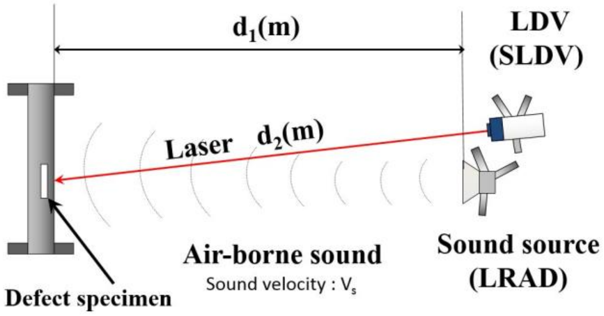

Fig.1. Non-contact acoustic inspection method.

The conventional emitting method using the tone burst wave was a method of covering a required frequency band, by changing the center frequency of the short burst wave about 3 ms for every sound wave emission, in order to look for the resonance frequency of a defective part. The measurement time chart of this emitting method is shown in **Fig.2**. Here, the conventional emitting wave is called the single tone burst (STNB) wave. From this figure, the measurable time (possible time length of a sound wave emission) is d_2/Vs after a sound wave reflects in the measurement surface until it reaches a laser head. That is, if the time length of a sound wave is less than d_2/Vs, not only one frequency but plural frequency can be emitted as a burst wave. The tone burst wave of the form which included plural frequency at the time of one sound wave emission is called the multi tone burst (MTNB) wave in order to distinguish from the STNB wave.

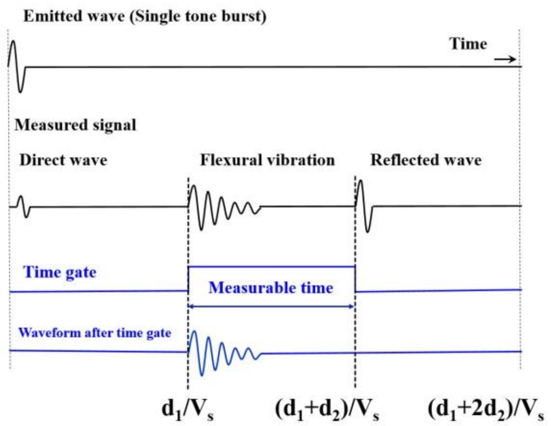

Fig.2. Measurement time chart of the STNB wave.

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Although various frequency arrangement can be considered, the example of the MTNB wave in the case of having arranged frequency discretely in one burst group is shown in **Fig.3**.

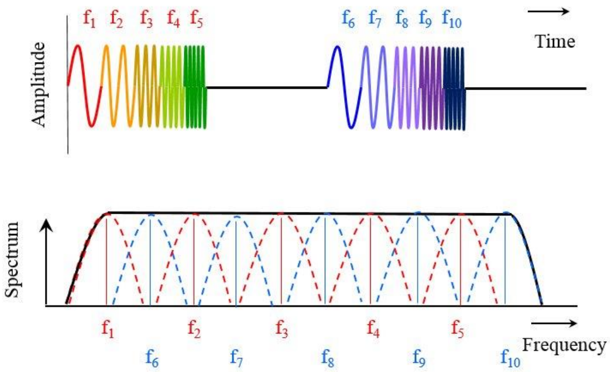

Fig.3. Schematic diagram of the MTNB wave.

3. Verification experiment using the MTNB wave

3-1 Experimental setup

To confirm the validity of the MTNB wave for high speed measurement, the verification experiment with the concrete test object was carried out. As shown in **Fig.4**, the object defective part has the styrofoam of thickness 25 mm and diameter 200 mm in the position of 80 mm from the concrete surface. An experimental setup was the same as **Fig.1** (d_1=5.0 m, d_2=5.3 m, and V_S=343.5 (m/s)). LRAD (LRAD Corp., LRAD-300X) was used as a sound source, and sound pressure was adjusted so that the maximum sound pressure on the surface of concrete can be set to about 100 dB (ref. 20μPa). By SLDV (Polytec Corp., PSV400-H4), the oscillating velocity of a part of concrete surface was measured at grid points spread in a measuring surface (about 56 mm pitch, 5×7 points).

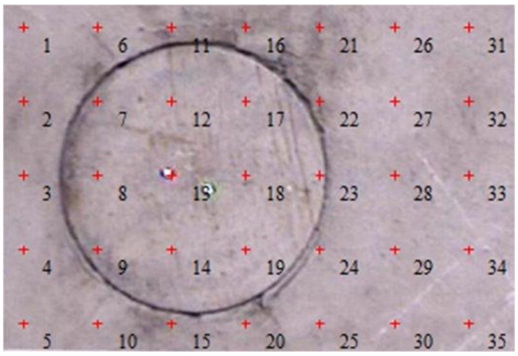

Fig.4. Photograph of the circular defect (200 ϕ 80mm depth).

The emitting interval of the STNB wave was 50 ms, and the number of average was five. The emitting interval of the MTNB wave was 30 ms, and in order to realize the same average effect as the STNB wave for a short time, the waveform which continued the same MTNB waveform 5 times was used. The frequency range and the frequency interval of both waves are 1000-4800 Hz and 200 Hz, respectively.

3-2 Experimental result

The distribution of vibrational energy ratio is shown in **Fig.5**. The white circle shows the size and position of the defective part. Form this figure, it turns out that the area where the vibrational energy ratio is high is both concentrating in the white circle, and it has performed almost equivalent defective detection. Since measurement time would be 28 seconds by the MTNB wave for 210 seconds by the STNB wave, 7.5 times as high speed measurement was realized.

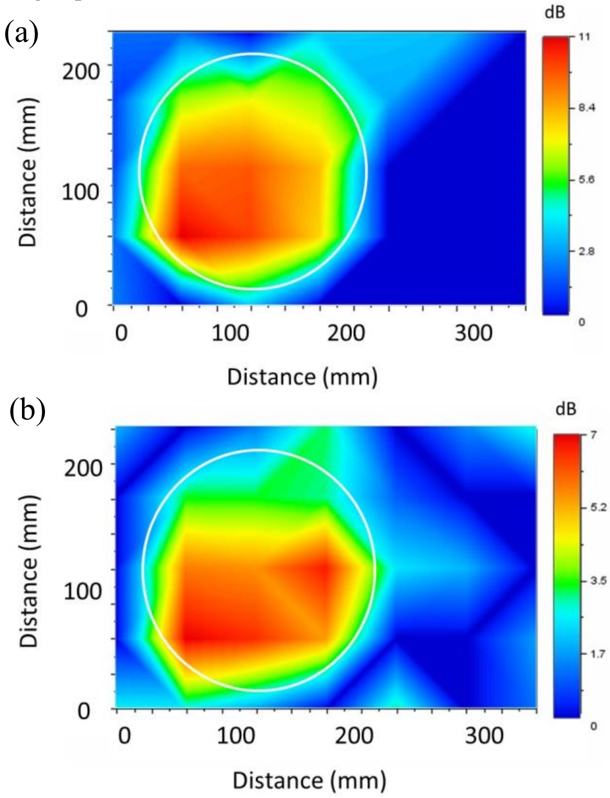

Fig.5. Distribution of vibrational energy ratio.
(a) STNB, (b) MTNB.

4. Conclusion

The high speed non-contact acoustic inspection method using the MTNB wave which improves measurement speed was devised by using plural frequency with the time and frequency gate validated which raises the S/N ratio. The validity has been confirmed from the experimental result using a circular defect.

References

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