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Non-contact Inspection Method for Structure using High Power Sound Source —Improvement of S/N Ratio by Time and Frequency Gating Method—

強力音源を用いた構造物の非接触検査法—時間周波数ゲート法による S/N 改善—

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1. Introduction

Nowadays, hammering method is the most popular for non-destructive testing of concrete structures. In this method, however, it is difficult to inspect the places where people cannot reach. Therefore, we study a non-contact inspection method[1], which consist of a high power sound source and a scanning laser Doppler vibro-meter (SLDV). In our previous study, a problem, that a laser head of an SLDV is vibrated by an exciting sound wave, is pointed out. This vibration affects a signal-to-noise ratio (SNR) of a measured result. To eliminate the vibration noise and obtain a high accurate detection, this paper describes time and frequency gating method.

2. Methodology

2.1 Fundamental concept

The fundamental concept is shown in Fig.1. A concrete surface is excited by a sound wave emitted by a sound source. If a defect like a void or a crack exists under the concrete surface. The defective part has a resonance frequency of a flexural vibration. Vibration velocities on the concrete surface are measured two dimensionally by an SLDV (Polytec Corp, PSV 400-H4). Therefore, a position of the defect is estimated by a measured vibration velocity distribution. In this study, a Long Range Acoustic Device: LRAD (LRAD Corp., LRAD 300-X) is employed as a high power sound source.

2.2 Difficulty in the acoustic measurement method and time and frequency gating method

A difficulty arises in improving SNR, because the exciting sound wave shakes the laser head of the SLDV. To acquire a strong signal from the defect, a strong sound pressure or a long duration time of a waveform is required. This means the laser head is also vibrated. However, the vibration noise of the laser head will be able to temporally separated, because the propagation velocities in air of a sound wave and an optical wave are extremely different. In our previous method, a chirp wave, which has a broadband of 500-5000 Hz and a duration time of 2 s, is used for an excitation. It was difficult to temporally separate the noise, because a duration time of the waveform is too long. Thus, we propose a new time and frequency gating method for the acoustic measurement method. This method is based on the devise of tone burst wave transmission. Primary undesired signals caused by the exciting sound are a direct wave from the sound source and a reflect wave from the concrete surface. If distances between the devices and concrete surface are known, appearance times of the undesired signals can be estimated. Therefore, the signal of the defect can be extracted by applying time gate.

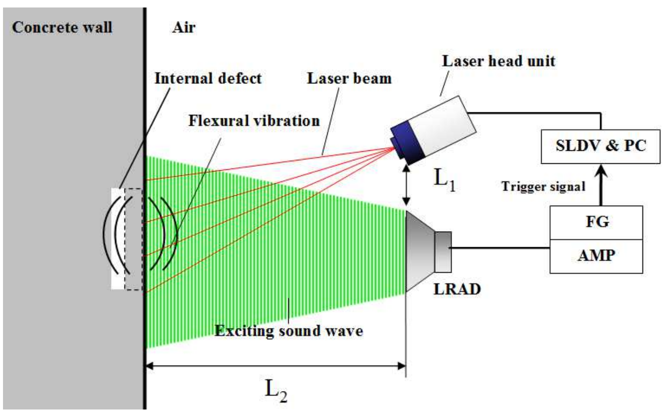

Fig. 1 Fundamental concept.

A wide bandwidth is necessary, because a resonance frequency of defects is unknown in practice. Owing to this, sound waves which have a different center frequency are sequentially transmitted as shown in Fig. 2 (a). Such a waveform makes up for each other’s deficient frequency component as shown Fig. 2 (b), so that a flat broadband spectrum can be obtained.

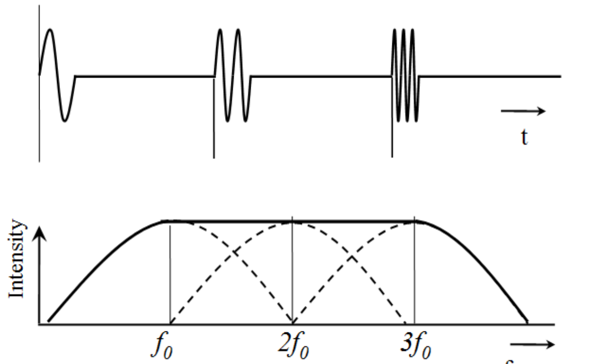

Fig. 2 Tone burst waveform for the frequency response measurement. (a) Temporal waveform, (b) Frequency spectrum.

Assuming that the acoustic measurement method is applied in a closed place, reflected wave from surrounding structures will incident to the laser head. This reverberation will through the time gates. In such a case, time and frequency gating method is proposed. In this method, time and frequency gates are applied each time gate. The frequency gate width is adjusted to the bandwidth of the transmitted signals. Using the time and frequency gating method, highly accurate detection will be acquired.

3. Confirmatory experiment

The effectiveness of our proposed method is confirmed in field demonstration using a concrete test piece, which has styrofoam boards as a cavity. A size of a targeted specimen is 300 mm^2, and it is buried in the depth of 75 mm. A formed tone burst waveform is shown in Fig. 3. Each pulse duration is 3 ms (bandwidth : 330 Hz), and the each center frequency of the pulses is transformed from a one frequency to a higher one. The frequency of transition is 200 Hz in a bandwidth of 500-5100Hz.

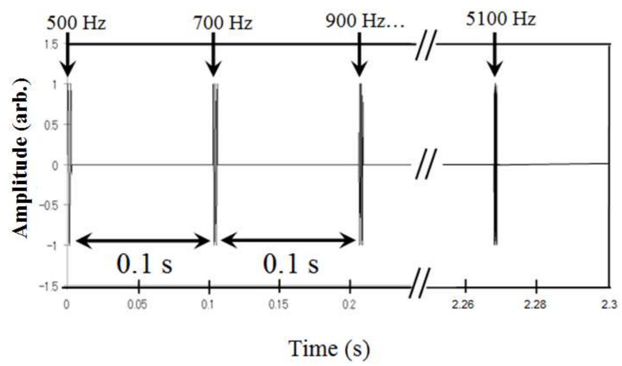

Fig. 3 Actual used tone burst waveform.

Fig. 4 (a) shows measured vibration velocity spectra on the damaged part using a chirp wave. The signals at around 1000 Hz are thought to the resonance frequency of the laser head. In this figure, obvious signal cannot be seen. Fig. 4 (b) shows a result using tone burst with time and frequency gate. Noise floor in Fig. 4 (b) is very low compared to Fig. 4 (a), and the signal at around 2700 Hz can be observed. Each SNR in Fig. 4 is 4 dB and 19 dB, respectively.

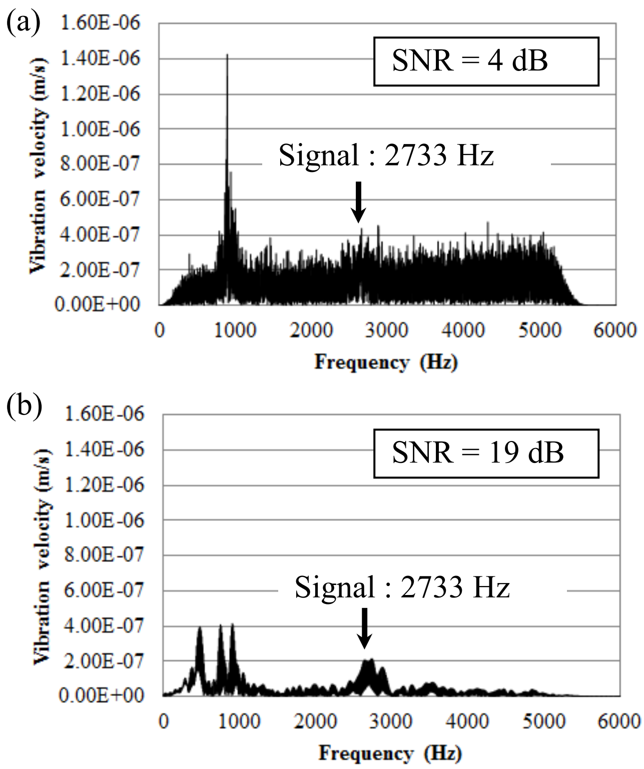

Fig. 4 Vibration velocity spectra on the damaged part. (a) Chirp wave , sample time : 2 s, bandwidth : 500-5000 Hz. (b) Tone burst wave with time and frequency gates, sample time : 2.5 s, bandwidth : 170-5430 Hz.

4. Conclusions

In this paper, time and frequency method is proposed for improving the SNR. This method is based on the tone burst waves transmission for excitation. As a result, the SNR of 15 dB is improved than our previous method.

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References

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