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Basic Study about the Long Distance Non-Contact Acoustic Inspection Method using a Strong Ultrasonic Sound Source

強力超音波音源を用いた遠距離非接触音響探査法に関する基礎検討

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1. Introduction

The hammer method is still used for the non-destructive test of the concrete structures. However, difficulty had followed on the inspection of the high place so that it might be symbolic in the fall accident of the ceiling board of the Sasago tunnel in 2012. Therefore, the long distance non-contact acoustic inspection method with defective detection accuracy comparable as the hammer method has been examined[1-2]. This is the technique of having combined a scanning laser Doppler vibrometer (SLDV) and a long-distance acoustic device (LRAD). It is suitable for searching a comparatively narrow region precisely taking advantage of plane excition ability of LRAD, and the two-dimensional scanning capability of SLDV. On the other hand, since the two-dimensional scanning performance by SLDV needs to take alignment of laser light in the state where it was stood still, it is not suitable for measurement while moving. And although the directional characteristics of the LRAD itself are excellent in 1 kHz with ±15 degree, there are problems, such as angular dependence nature to a subject and noise to the circumference at the time of considering practical use. Then, the case where a strong ultrasonic sound source and LDV for a single point were combined as the 2nd construction of the non-contact acoustic inspection method was examined.

2. Angular dependence of the sound source

In the case of sine wave driving force, the denial effect by phase difference occurs, and restriction strong against an incidence angle is added. If the uniform mode is assumed, the excitation effect of an incidence sound wave is proportional to the surface integral of the incidence sound pressure about an object side. Here, if the incidence angle whose driving force is lost, the diameter of a defect, a wavelength, and ultrasonic beam width are set to θ, A, λ, and D. In the case of an ultrasonic beam, it is expressed as

$$D \tan\theta = \lambda \qquad (1).$$

As for θ, the diameter A of a defect will become unrelated.
On the other hand, in the case using a LRAD, it is expressed as

$$A \sin\theta = \lambda \qquad (2).$$

In this case, θ becomes a function of the diameter A of a defect. This relation shows that θ will become small if the diameter A of a defect becomes large, and restriction of an incidence angle becomes very severe to a degree especially in a high frequency drive. The above relation is shown in **Fig.1**. Here, a solid line is a permission incidence angle of ultrasonic system, and a dashed line is a permission incidence angle by the conventional (LRAD) system corresponding to each diameter A of a defect. From this figure, in the domain where exciting frequency is higher, it turns out that critical incidence angle will improve greatly.

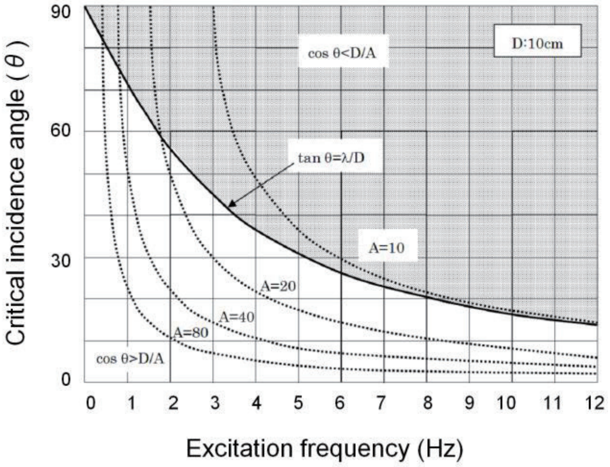

Fig.1. The critical incidence angle vs. excitation frequency. D：ultrasonic beam width (10cm), A：defect diameter (cm).

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3. Defect detection ability using a strong ultrasonic sound source

3-1 Strong ultrasonic sound source

The strong ultrasonic wave sound source with the investigation performance in a practical distance was made as an experiment as shown in **Fig.2** (diameter 600mm, focal distance 5m, ultrasonic element 3200). Moreover, in order to realize wide range scanning investigation which used single point laser (Polytec Corp. OFV-505) and a strong ultrasonic wave sound source, a hole for passing laser light was made on the central axis, and even if it changed direction of a sound source, it devised so that the focus of laser and the focus of acoustic radiation force might be in agreement.

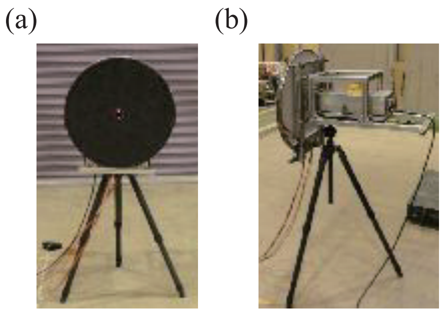

Fig.2. Strong ultrasonic sound source.
(a) Front view, (b) side view.

3-2 Sound pressure distribution

Sound pressure distribution at the focal plane (5m) is shown in **Fig. 3**. The half width of a focal region is about 30 cm. From this measurement result, the drive sound pressure of the maximum of about 120 dB was formed, and the characteristic independent of frequency which is the feature of an acoustic radiation force was also confirmed.

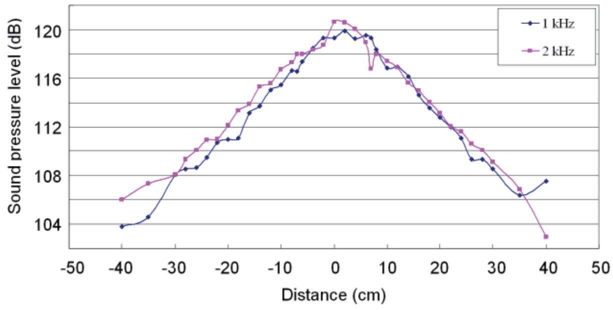

Fig.3. Sound pressure distribution at the focal plane (5m. SPL re 20 μPa).

3-3 Experiment using a concrete test piece

The inspection experiment was carried out using a 500 to 7000 Hz tone burst wave to the circular defective part (dia. 300mm, depth 80 mm) and the healthy part. The vibration velocity spectrum on a defective part and a healthy part is shown in **Fig.4**. From this figure, a clear resonance peak can be observed like LRAD.

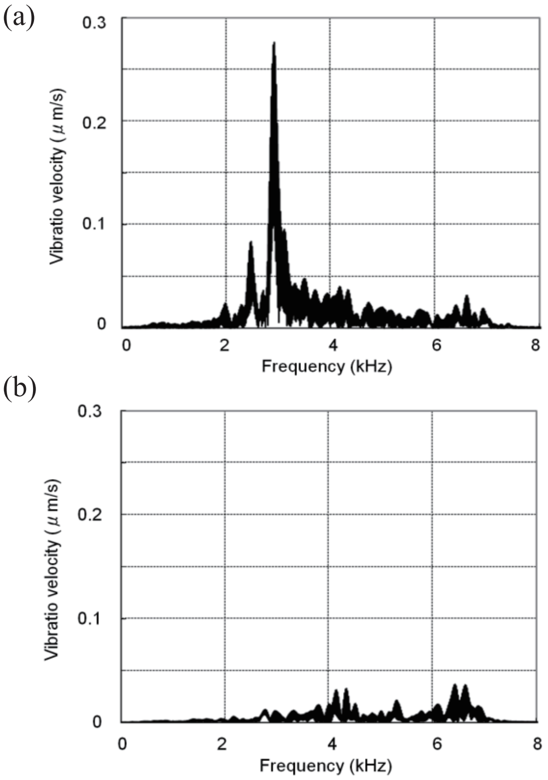

Fig.4. Vibration velocity spectrum.
(a) Defective part, (b) healthy part.

4. Conclusions

It became clear that the strong ultrasonic sound source can generate sufficient sound pressure for non-destructive investigation of concrete even with a 5m distance. From now on, occupying a very important position as a sound source of this method is expected.

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