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A method of detecting micro crack in shallow layer of solid material by harmonic component of very high-intensity aerial ultrasonic wave

超高強度空中超音波の非線形性を利用した固体浅層の微小き裂検出

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1. Introduction

We propose a non-destructive, non-contact method using high-intensity aerial ultrasonic waves and optical equipment to detect microcracks in a shallow layer of concrete.[1,2] We demonstrate our method by detecting a microcrack in an acrylic sample by using the harmonic components of high-intensity aerial ultrasonic waves.

2. Measurement principle

Fig. 1 shows a simple model of a rectangular crack in a shallow layer of concrete. **Figs. 2 (a),(b)** show cross sections along the width and length of the crack model. Along the width, the crack area requires a high-intensity sound wave to vibrate it because the area excited by the sound wave is narrow. In contrast, along the length, the crack area is expected to vibrate in a bending mode depending on the frequency of the sound wave. Therefore, the crack is imaged accurately by using higher harmonic components because the bending mode gap of vibration decreases as the frequency increases.

3. Experimental set up and method

Fig. 3 shows a schematic view of experimental device, which consists of the point-convergence ultrasonic sound source (26.8 kHz),[3] a laser Doppler vibrometer (LDV), a data logger, and a PC.

The ultrasonic waves generated by the acoustic source converge to a 10 mm diameter spot 326 mm from the opening of the acoustic source (point O). The aerial ultrasonic wave intensity is about 6 kPa at an input power of 15 W.

Under ultrasonic irradiation, the vibration velocity the sample surface is measured at point O on the x-axis with the LDV. The LDV data are filtered at each harmonic frequency of the sound wave with the digital filter of the data logger and saved on the PC. The vibration amplitude of each harmonic frequency at the measurement point is

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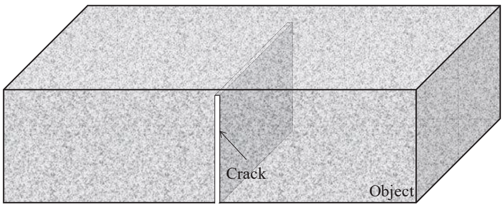


Fig.1 Crack model.

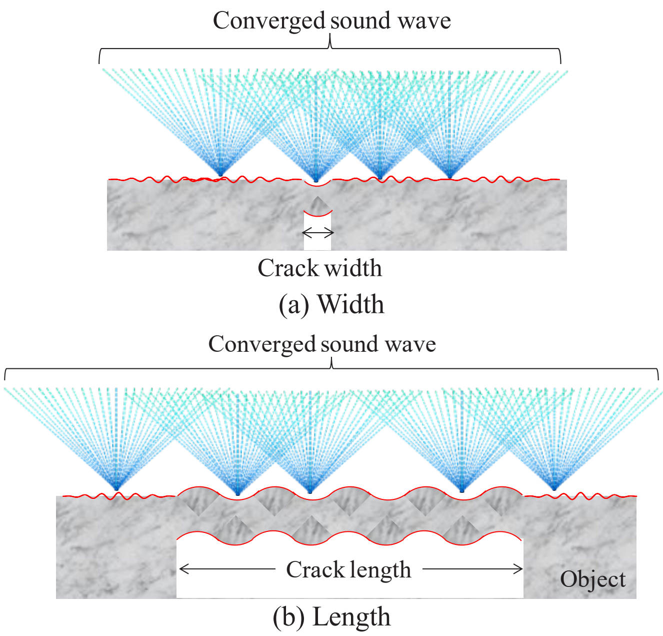


Fig.2 Measurement principle

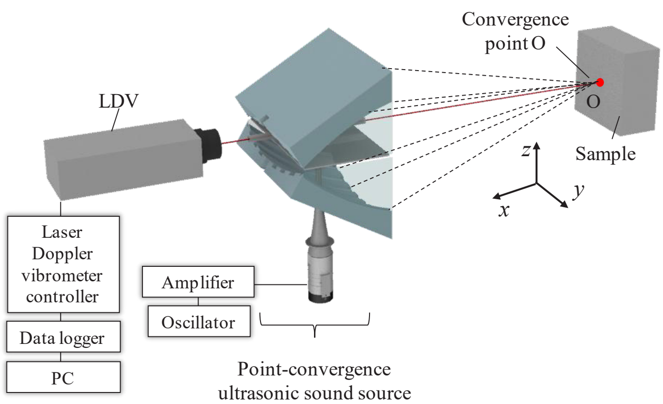
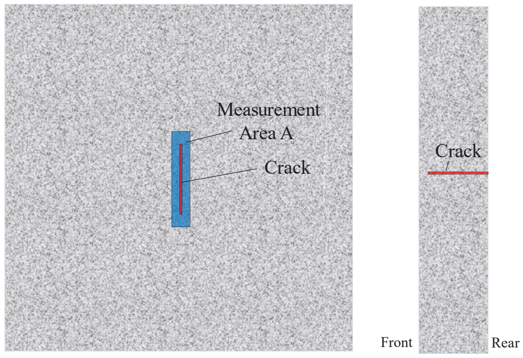


Fig.3 Experimental device.

used to image the crack shape on the PC in real time.

A 20-mm-thick acryl sample that is 150 × 150 mm with a uniform density is used to confirm the proposed model (**Fig. 4**). A micro crack is introduced into the acryl sample by boring a 1×30 mm line. The crack depth is 1 mm from the sample surface into the rear face. The measurements are taken in area A (10 × 50 mm). The input power is held constant at 15 W, measured at 1 mm intervals.



(a)Front side (b) Rear side
Fig.4 Sample detail.

4. Experimental results

Figs. 5(a)–(j) show the vibration velocity at the fundamental frequency and from the second to the tenth harmonic.

The vibration velocity distribution at the fundamental frequency does not image the crack shape. The vibration velocity distribution at the second frequency generates a bending vibration mode along the crack line, although it does not image the crack shape. The vibration velocity distribution at the third frequency roughly images the crack shape because the bending vibration mode along the crack area is different from the bending vibration mode in the other areas.

However, vibration velocity distributions above the fourth frequency image the crack shape. The higher frequency, the clearer the image of the crack shape.

As shown above, the measurement results agreed well with the results expected according to the measurement principle.

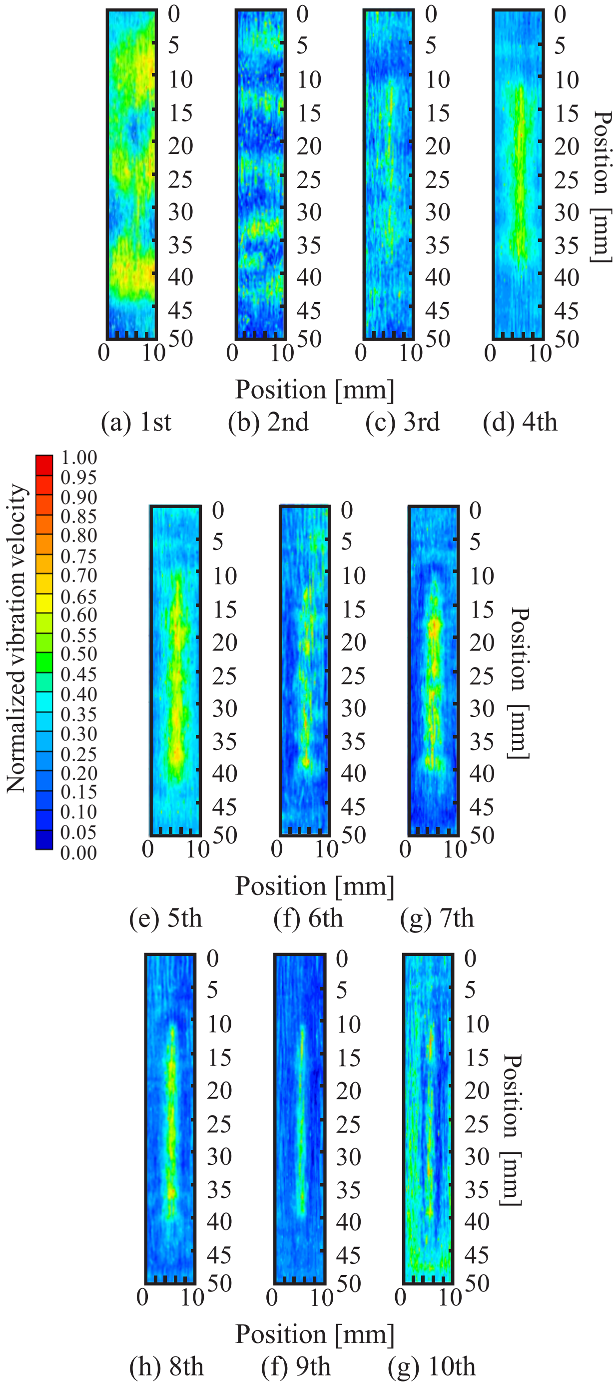


Fig.5 Vibration velocity distribution on area A

5. Conclusion

We focused on the nonlinearity of high-intensity sound waves and used them to image a crack with a harmonic component of vibration velocity.

The results can be summarized as follows.

(1) The crack in the shallow layer of the object was imaged by the proposed method.

(2) The higher the frequency, the clearer the image of the crack in the bottom of the sample.

Acknowledgment

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