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Sensitive Tint Visualization of Ultrasonic Propagation in the Glass with a Crack
鋭敏色法によるき裂を有するガラス中の超音波伝搬の可視化

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1. Introduction

Visualization of ultrasonic propagation is very useful tool for the understanding of sound field. Strobe photoelastic method is one of the most often-used visualization methods of dynamic sound field in solids. This method[1)] is generally used stress-strain analysis. The birefringence by stress in solids can easily be observed by this method. Sign of sound pressure would be discriminated introducing sensitive tint method into strobe photoelastic system.

In this paper, ultrasonic propagation in a glass possessing a closed crack is observed using strobe photoelastic system introducing sensitive tint method. Using this system, sign of sound pressure can be visualized.

2. Visualization method

Fig.1 shows ultrasonic visualization system. Expanded strobe light through a pinhole is collimated by the concave mirror and incidents on a sample glass. The polarizer and the analyzer were orthogonal Nicol state. λ plate was placed between the glass and the analyzer.

Voltage signal from a function generator (KEYSIGHT 33600A)(CH1) was designed to be a 30-cycles, 1.08 MHz burst sine wave pulse and amplified to 125 V_{pp} by an amplifier (NF HSA4101). Amplified voltage signal was applied to the piezoelectric transducer on the glass. Rectangular type piezoelectric transducer used here was PZT (Fuji Ceramics, C-9), and was resonance frequency of 1.08 MHz. Thickness, width and length of the transducer is 2 mm, 7 mm and 30 mm, respectively. Transducer was fabricated on the glass surface using silver conductive paste. The glass sample was soda lime glass. Thickness, width and length of the glass is 50 mm, 19 mm and 100 mm, respectively. Pulsed light (SUGAWARA Lab. NP-1A) with flash time duration of 70 ns was delayed using a pulse delay generator(SUGAWARA Lab. FG-310) with a time resolution of 10 ns. The repetition period of ultrasonic pulse was set to 10

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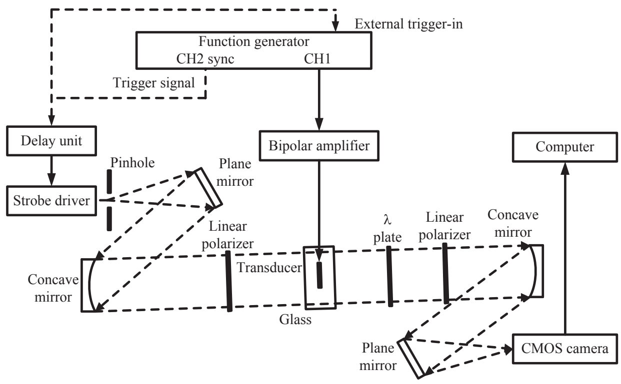

Fig.1 Ultrasonic visualization system using sensitive tint method

ms. Time transition of ultrasonic propagation can be observed by varying delay time ΔT of the delay unit. Observation results can be obtained by the CMOS camera (Artray ARTCAM-200CMV-USB3) being connected to a computer.

In this experiment, the contrast of ultrasonic wavefront of obtained images is low because the piezoelectric transducer is driven by low voltage. To enhance the contrast of images, they were processed with integration, subtraction and normalization[2),3)].

3. Result

The result of observing the static stress in the glass by the commercial sensitive tint system is shown in Fig.2. In this figure, the pink and blue areas correspond to compressive and tensile stresses by the closed crack, respectively.

Fig.3(a), (b) and (c) show the results using visualization system shown in Fig.1 by varying delay times, ΔT, of 3.4, 5.1, and 8.0 μs, respectively. The time transition images that ultrasonic waves radiate from the transducer and propagate downward in the glass are observed. The red and green areas correspond to compressive and tensile stresses by ultrasound pressure. Therefore, a pair of red and green corresponds to one wavelength (indicated by λ). Moreover, Fig.3(b) and (c) show the behavior of ultrasonic reflection at the opened crack (indicated by dotted line) where discontinuity of acoustic characteristic impedances of the glass

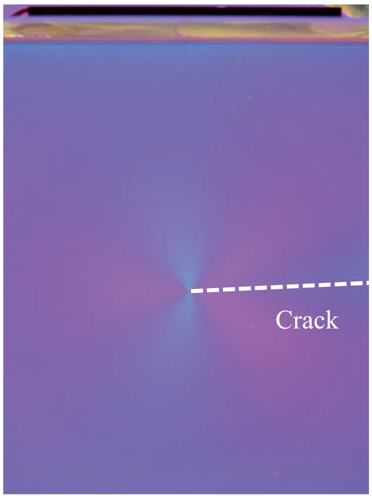

Fig.2 Visualization result of stress using static sensitive tint method

and air exists. In Fig.3(c), it can be observed that ultrasonic wave transmit through the crack (dotted line).

Additionally, in Fig3(b), brightness of wavefront above the crack is higher. Static stress by the closed crack observed in Fig.2 and dynamic stress by ultrasonic are superposed when ultrasonic is propagating. Additional compressive and tensile stresses are occurred around the crack tip which corresponds to the illuminous part (indicated by the square box).

4. Conclusion

MHz range ultrasonic propagation in the glass with a crack is visualized by using the strobe photoelastic visualization system introducing the sensitive tint method. Sign of sound pressure of ultrasonic can be easily determined by this method. The behavior that reflection and diffraction are caused by the crack and stress around the crack tip is higher by ultrasonic propagation is revealed.

In the future work, quantitative measurement of birefringence by stress and visualization of higher harmonic caused by the crack will be investigated.

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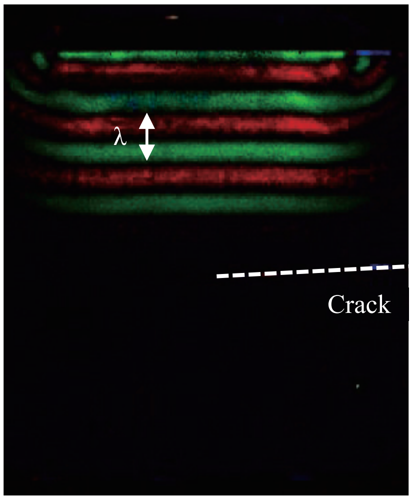
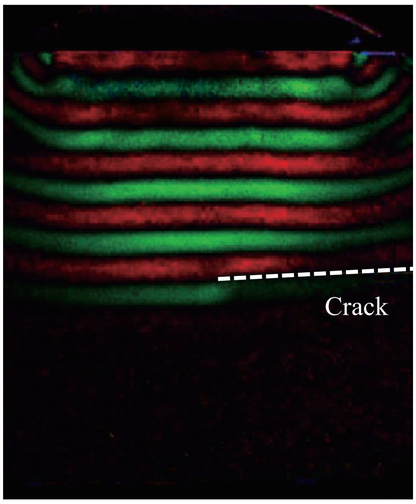
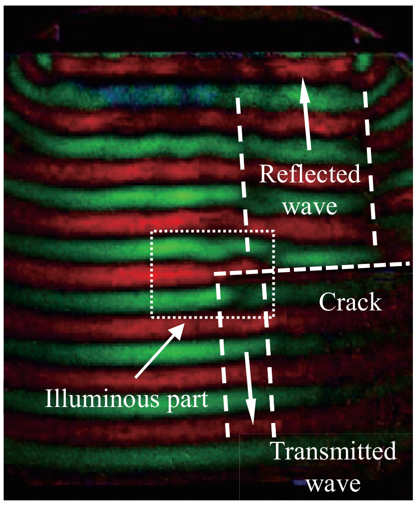


(a) ΔT=3.4 μs



(b) ΔT=5.1 μs



(c) ΔT=8.0 μs

Fig.3 Visualization results of ultrasonic propagation