Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 45-46
13-15 November, 2012

Visualization of Ultrasonic Fields Transmitted through Inhomogeneous Media and Evaluation of the Degree of Aberration
不均一媒質を透過した超音波音場の可視化と撹乱度の評価

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1. Introduction

Ultrasonic propagation in inhomogeneous media has been attracted much attention because of its theoretical profundity as well as its strong relevance to various practical applications in medical, underwater and underground acoustics. An instance is the ultrasonic evaluation of osteoporosis, which deals with very highly inhomogeneous media, cancellous bones. Field distribution in transmitting through cancellous bones is an important factor in determining the bone density.[1] We have been attempting to visualize ultrasonic fields transmitting through real bone samples.[2] However, it has been difficult to accumulate sufficient image data for many different kinds of bones, because the structure of real bones was unpredictable and uncontrollable. In this paper, we show a method of making parameter-controllable two-component(liquid/solid) inhomogeneous model samples, and show visualized ultrasonic fields transmitted through these samples. Results of evaluating field aberration by calculating autocorrelation are also described.

2. Model Making and Visualization

We chose agarose and glass bead for the liquid and the solid component, respectively. The method of making model samples is as follows: Agarose sol was first poured into a wide and shallow vessel, immediately followed by spreading glass beads, the diameter and the amount of which were previously determined, into it. After the agarose was solidified, this agarose/glass mixture was scooped up with a spoon by and by and was moved and piled up into an experimental cell. Being piled up after solidification, the glass beads contained in agarose did not sink but were distributed almost randomly and uniformly. A special care was taken not to include air in the sample. Three kinds of glass beads, having the mean diameter a of 0.4, 1, and 2 mm, were used. The amount of glass beads was determined so that their neighboring distance when they were assumed to be placed in perfect cubic cites became 1.5, 3, and 6 mm (referred to as mean bead diameter d).

Fig. 1 shows the experimental setup. The sample was contained in a cell windows of which were made of polystyrene. Tone-burst ultrasonic waves were radiated into it from a flat transducer. Ultrasonic field after transmitting through the sample was detected by a small hydrophone. The image of lateral (xy) distribution of the ultrasonic field was obtained by scanning the hydrophone synchronously with the emission of ultrasound. Experimental conditions were as follows: Incident ultrasound was 1 and 2 MHz tone-burst (duration 10μs) wave, transducer diameter was 16 mm, cell thickness was 20 mm, and the imaging area was $80(x) \times 80(y)$ mm with 256 detecting points both for x and y direction. The experimental setup can visualize either instantaneous or envelope-detected output voltages from the hydrophone.

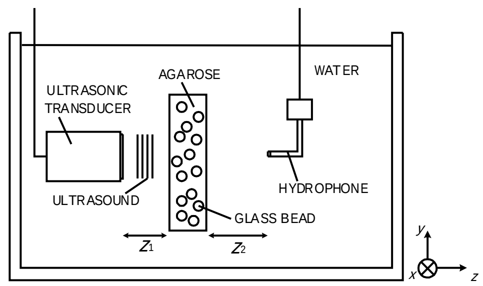

Fig. 1 Experimental setup.

3. Experimental Results

Fig. 2 shows ultrasonic fields at 1 MHz detected for z_1=15 mm and z_2=25 mm. Fig. 2(a) shows the field without the sample. Fig. 2(b), (c) and (d) are the fields transmitted from the agarose/glass sample for the glass bead diameter a=0.4, 1, 2 mm, respectively. The mean bead distance d was set to 3 mm for (b)-(d) experiments. All the figures show the envelope-detected voltage from the hydrophone. We observe distinguished aberration for a=2 mm. Fig. 3 shows the ultrasonic fields at 2 MHz under the same condition for a and d values. The aberration became prominent for a=1 and 2 mm.

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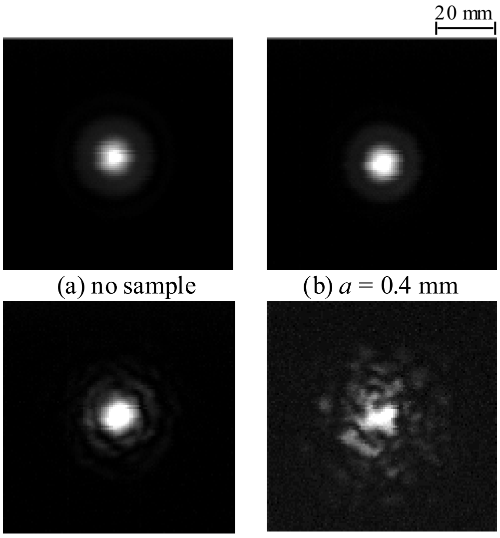

Fig. 2 Ultrasonic fields at 1 MHz for mean bead distance d = 3 mm.

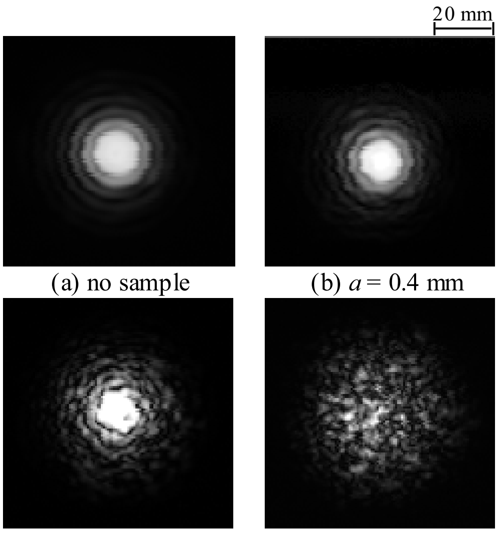

Fig. 3 Ultrasonic fields at 2 MHz for mean bead distance d = 3 mm.

To evaluate the degree of aberration of the ultrasonic fields, we calculated two-dimensional autocorrelation for each image. Fig. 4 and 5 show the autocorrelation for images in Fig. 2 and 3, respectively. Each curve shows the one-line distribution along the x-axis at the central part of the two-dimensional autocorrelation, with its peak value normalized to unity. It is obviously seen that the autocorrelation curve becomes narrow for the conditions that field aberration becomes large. To see this narrowing for more samples, we defined the correlation width X_c as the lateral distance for which the autocorrelation becomes 0.8 times the peak value, and show the variation of X_c for different a and d values in Fig. 6 and 7.

4. Summary

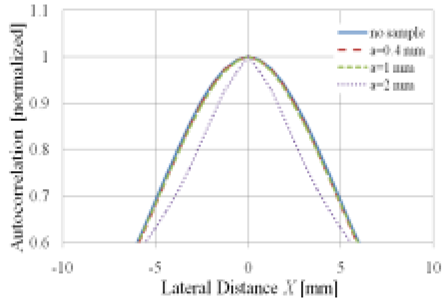

Fig. 4 Autocorrelation for Fig. 2 results.

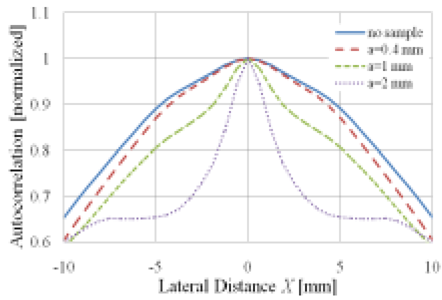

Fig. 5 Autocorrelation for Fig.3 results.

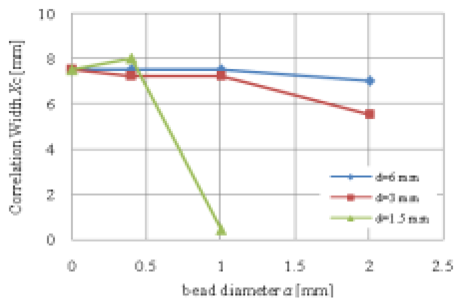

Fig. 6 Variation of correlation width X_c at 1 MHz.

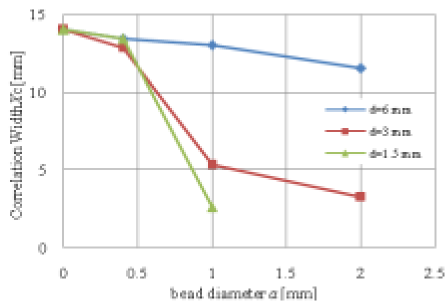

Fig. 7 Variation of correlation width X_c at 2 MHz.

Ultrasonic fields transmitted through model samples for liquid/solid inhomogeneous media have been visualized and field aberration was evaluated by calculating autocorrelation of images. This can be used for determining the structure parameters such as grain or pore size and density in practical ultrasonic measurement.

References

1. G. W. Petley *et al.*: Br. J. Radiol. **68** (1995) 1212.
2. M. Ohno *et al.*: Jpn. J. Appl. Phys. **49** (2010) 07HF27.