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Measurement of temperature rise in phantom using infrared imaging by varying pulse repetition frequency

熱画像によるパルス繰り返し周波数を変化させたときのファントム内部の温度上昇の測定

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1. Introduction

For the establishment of ultrasonic medical equipment's safety, it is necessary to measure the temperature rise in tissue caused by ultrasonic irradiation. The infrared imaging method as a method can measure the temperature distribution non-critically and spatially in split phantom[1]. We also measure temperature distribution by infrared imaging using split phantom[2]. In this study, an infrared camera measured the temperature distribution in split phantom, when the acoustic irradiation energy from transducer was changed by varying the pulse repetition frequency (PRF) of ultrasonic equipment.

2. Measurement

2.1 Tissue Mimicking phantom

The 90[mm] cubic phantom was made of agar whose concentration was specified by JIS T0601-2-37 for the temperature rise measurement. Before the irradiation experiments, the thermal and acoustical parameters were measured and shown in **Table1**. The phantom was split into two blocks along the sound propagation direction because the temperature distributions in the split center plane were measured. The phantom was spread by the gel on the cutting section and was put together in water to prevent air entering.

2.2 Measurement

The block diagram of measurement was shown in **Fig.1**. The unfocused circular transducer whose diameter was 20 [mm] radiated the pulse ultrasonic wave to phantom. The frequency is 3.5 MHz, the ultrasonic intensity is 0.4 [W], the wave length is 200 [μs]. The transducer was put on the top surface of phantom which was spread by the gel on the split surface. The phantom is set on absorber in air. After 20 minutes from ultrasonic irradiation stated, the phantom was opened and measured the temperature distribution on the cutting section by infrared camera. The infrared camera was located 300 [mm] from phantom. In measurement, PRF was varied from 0.5 [kHz] to 2.5 [kHz] at 0.5 [kHz] intervals.

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Table1 Parameters of phantom

Parameter	
Attenuation coefficient [dB/cm] at 2MHz	0.4
Heat capacity [J/kg・K]	4.1×10^3
Thermal conductivity [W/m・K]	0.58
Velocity of sound [m/s]	1514
Density [g/cm^3]	1.05

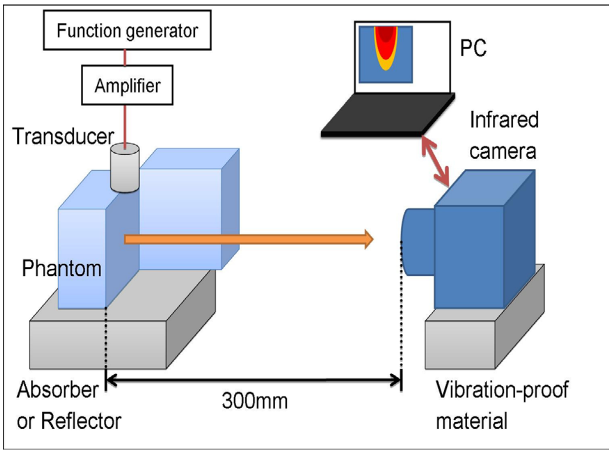

Fig.1 Block diagram of measurement

3. Results

Figure 2 shows the temperature rise distribution at 1.0 [kHz] and 2.5 [kHz] in PRF. As shown in **Fig. 2**, the temperature rise at 2.5 [kHz] is higher more than at 1.0 [kHz]. This reason was thought that the thermal energy caused by the acoustic energy in phantom is increase by PRF. **Figure 3** shows the temperature rise distribution on central axis of as a function of distance from the transducer when PRF was varied form 0.5 [kHz] to 2.5 [kHz]. In **Fig. 3**, the maximum temperature rise are shown in the vicinity of the transducer in every PRF. **Figure 4** shows the relation between PRF and temperature rise at 0, 10, 20, and 30 [mm] from transducer. These results show that the increments of temperature are proportional to PRF at all measuring points on a central axis of transducer. **Figure 5** shows the temperature distribution at the surface of transducer. **Figure 6** shows the width between two points whose increment is over than 1.5 degree in transverse direction at each PRF.

4. Summary

In this study, the infrared imaging camera measured the temperature distribution in phantom as varying the pulse repetition frequency of the ultrasonic equipment. The temperature rise in near area of transducer is higher than that in far area in phantom. Results show that the increment of temperature has the limit because the extension of heat has saturation.

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Reference

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3. JIS T0601-2-37, pp. 56-57.

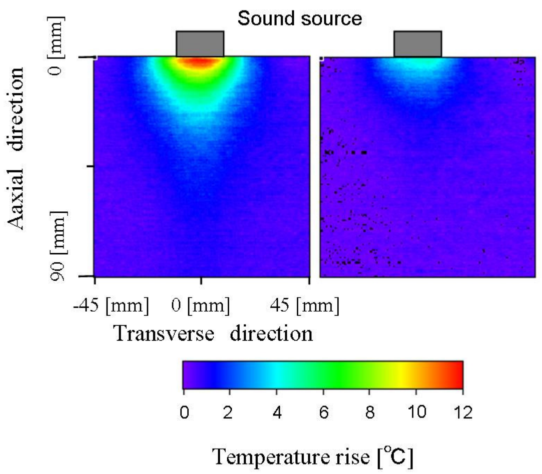

Fig. 2 Observed thermal image
(PRF : Left = 2.5 [kHz] , Right = 1.0 [kHz])

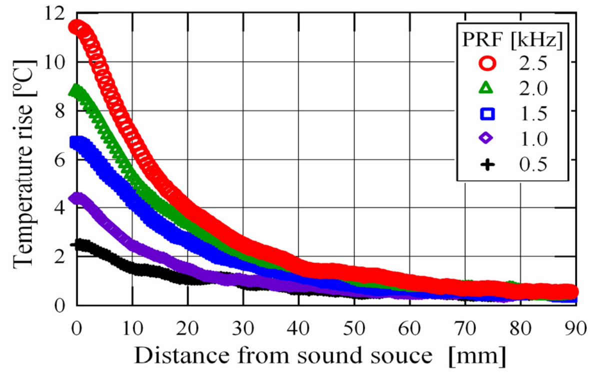

Fig. 3 Temperature rise distribution on central axis of transducer

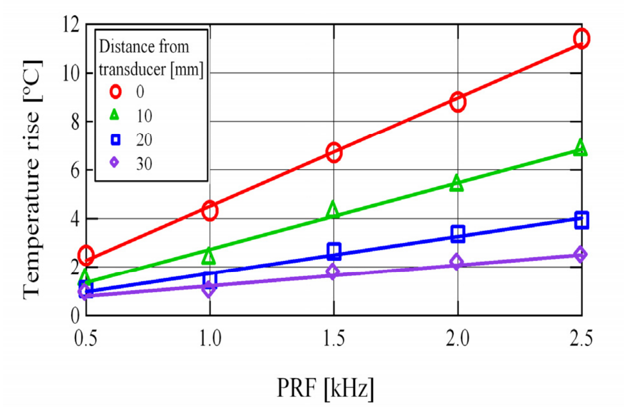

Fig.4 Relationship between PRF and temperature rise in central axis of transducer

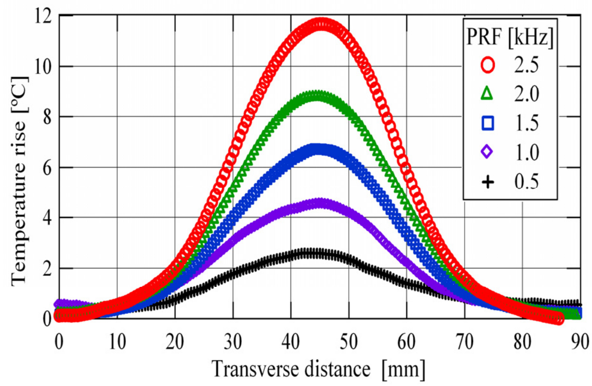

Fig. 5 Temperature rise distribution in transverse direction at the surface of transducer

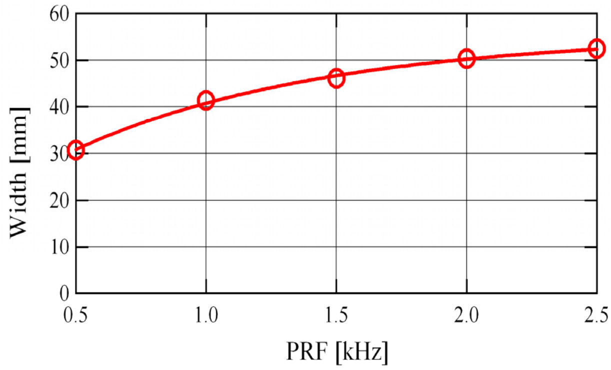

Fig.6 Relationship between PRF and width in transverse direction over than 1.5℃ rise