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Measurement on Ultrasonic Power by Calorimetric Method -Comparison between Saturated and Degassed Water-

カロリメトリ法による超音波パワー測定 ー飽和水と脱気水の比較ー

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1. Introduction

Recently, ultrasonic theraputic equipment has been developed[1]. For example, HIFU (high intensity focus ultrasound) devices for the treatment of breast cancer and prostate cancer are already in clinical use. In many cases, the ultrasonic theraputic equipment uses thermal energy by high power ultrasound. but it also affects normal cells in human body. Thus, the precise measurement on ultrasonic power of the equipment is essential for evaluating the influence of high power ultrasound on human body. Ultrasonic power is a key quantity related to the thermal hazard on the body.

A method for measuring ultrasonic power is radiation force balance (RFB) method. The RFB can accurately measure ultrasonic power which is less than 15 W and used in ultrasonic diagnostic equipment. However, for ultrasonic power which is more than 15 W and used in ultrasonic theraputic equipment such as HIFU device, the RFB cannot be applied to the precise measuremernt on ultrasonic power due to problems including thermal damages by the ultrasound to absorber material, which is made of polyurethane rubber. Therefore, new technology for measuring high ultrasonic power is required.

We focused on the technique for measuring ultrasonic power by calorimetric method using water as heating materials. In previous study, we reported that heat generation of ultrasonic transducer affected ultrasonic power measured by calorimetric method[2,3]. In this paper, we considered the influence of dissolved oxygen (DO) level of water on ultrasonic power obtained by calorimetric method.

2. Experimental method

Figure 1 shows experimental system for calorimetric method. Cylindrical water vessel with the diameter of 150 mm and the depth of 90 mm is made of stainless. The water vessel has air layer with the thickness of 10 mm and inside wall with the thickness of 0.6 mm. The thickness of inside wall is negligible compared with the wavelength of the ultrasound. Therefore, if the ultrasound is irradiated from the transducer mounted through the hole at cylindrical wall of the vessel, the ultrasound is almost reflected by the inside wall and propagates along the circumference of the vessel. The ultrasound propagating along the circumference is almost entirely absorbed and attenuated in water. The transducer is mounted so that transmission surface of the transducer is perpendicular to the bottom of the vessel. Furthermore, a heat shield material of expanded polystyrene is used to prevent heat loss.

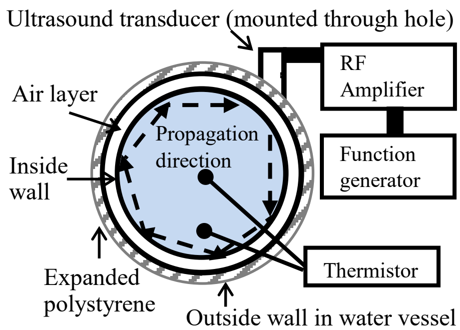


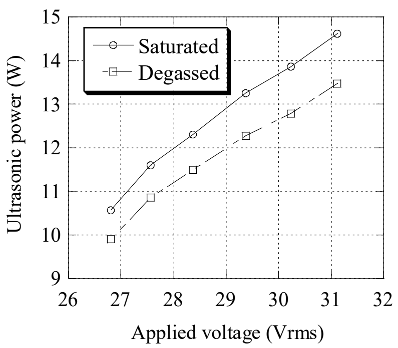
Fig. 1 Experimental system for measuring ultrasonic power by calorimetric method

On the principle of calorimetric method, if the specific heat capacity and volume of the ultrasound irradiation target is known, ultrasonic power can be calculated from temperature rise by the ultrasound irradiation. We use two types of water as the irradiation target with different DO levels. One is saturated water with more than 8 mg/l of DO level and the other is degassed water with less than 2 mg/l of DO level. We compare ultrasonic powers obtained using two types of water in the range of 1 MHz to 3 MHz of frequency and in the range of 10 W and 15 W of ultrasonic power.

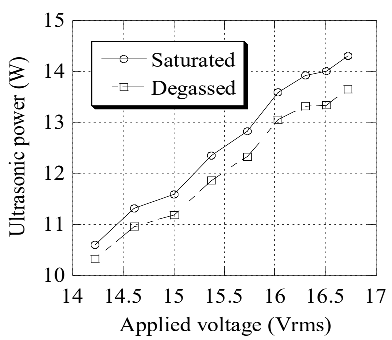
The volume of water is 1200 ml. Water temperature measurement starts from 23 ºC ± 0.5 ºC. Water temperature is measured by two thermistors which are placed at the center and near the wall of the vessel because there is a slight temperature gradient between the two places in the vessel. The water temperature is defined as average value of two measurements, and the ultrasonic power is calculated from the average value. We adopt the method of measuring ultrasonic power from water temperature before and after ultrasound irradiation to eliminate the influence of the viscous heating[2,3]. Each water temperature measurement time before, during, and after ultrasound irradiation is 180 s, 180 s and 480 s, respectively.

3. Results and discussion

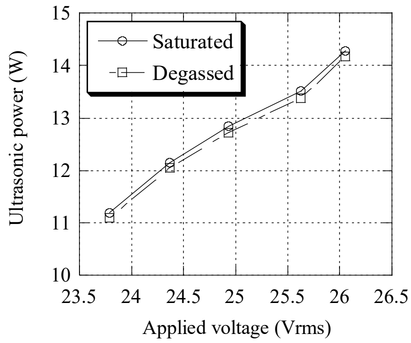
Figure 2 shows change of ultrasonic power by calorimetric method obtained by saturated and degassed water. It was found from the results that there were significant differences between ultrasonic powers obtained using two types of water at all frequencies. Ultrasonic power obtained by using saturated water was higher than those using degassed water at all frequencies. The differences between two types of water increased when the applied voltage to the transducer increased. The each average difference at 1 MHz, 2 MHz and 3 MHz was about 7%, 4%, and 1%.



a) 1 MHz



b) 2 MHz



c) 3 MHz

Fig.2 Change of ultrasonic power by calorimetric method obtained using saturated and degassed water.

The results suggest that the cause of the significant difference might be due to acoustic cavitation. In theory, the cavitation generation depends on DO level of water, frequency, and output power[4]. In this experiment, saturated water is more likely to generate the cavitation than degassed water, and the frequency of 1 MHz is more likely to generate the cavitation than the frequency of 3 MHz. Also, the higher the applied voltage to the transducer, the more the cavitation is likely to generate. It is inferred from the above theory and Fig. 2 that the significant difference is due to the cavitation.

4. Summary

We have been studying accurate measurement for ultrasonic power by calorimetric method. In this report, we considered the influence of DO levels of water by using saturated and degassed water on ultrasonic power by calorimetric method. The results showed that there were significant differences of ultrasonic power when changing DO level of water. It is possible that the cause of the differences is the acoustic cavitation. In the future, we plan to confirm the generation of the cavitation in the experiment.

References

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