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Ultrasonic power measurement by calorimetric method by using water as heating material - Comparison with radiation balance method -

水を発熱体とするカロリメトリ法による超音波パワー測定
－天秤法との比較－

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1. Introduction

The National Metrology Institute of Japan (NMIJ) has established ultrasonic power standard between 1 mW and 15 W by the radiation force balance (RFB) method.[1)] The RFB method is widely used for ultrasonic power measurement.

Recently, high power ultrasound have come into use in several fields. For example, high intensity therapeutic ultrasound (HITU) has been used in medical therapeutic filed. Therefore, a metrology standard for high ultrasonic power has been required. In order to meet the requirements, we have commenced the development of the metrology standard for high ultrasonic power.

The RFB method is not suitable for high ultrasonic power measurement because of thernal damage to the absorbing target. We have been studying a calorimetirc method as an alternative method for measuring high ultrasonic power using water as a heating material. In this method, ultrasonic power is calculated from the increase in temperature of irradiated target. We adopted water as the heating material because it has excellent features as a standard material. The physical properties of water are well known. Previously, we reported that heat dissipation from the ultrasound transducer adversely affects the calorimetric method.[2,3)] Specifically, excessively high temperature was measured owing to heat from internal loss in the ultrasound transducer. Consequently, the values obtained by the calorimetoric method were larger than those obtained by the RFB method. In this paper, we investigated a novel water vessel equipped with heat insulator. The effect of the dissolved oxygen (DO) level in water on the measured radiation conductance was also discussed.

2. Quasi-Free Field Water Vessel Equipped with Heat Insulator

We prepared a novel calorimetric water vessel equipped with a heat insulator. The calorimetric water vessel must fulfill following conditions.

1) Re-incidence of ultrasound to the vibrating surface of the ultrasound transducer is prevented.
2) All ultrasound energy contributes toward increasing the water temperature.
3) Heat loss from the water vessel is prevented.

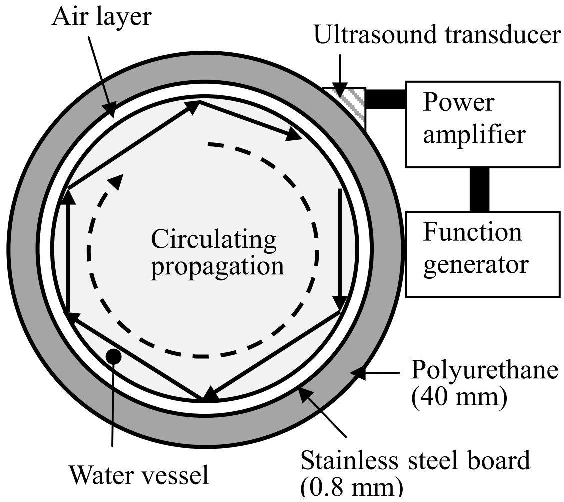

Fig. 1 Quasi-free field water vessel equipped with heat insulator (top view).

Figure 1 shows a schematic of the quasi-free field water vessel equipped with a heat insulator which meets the abovementioned requirements. The water vessel was cylindrical with a diameter of 150 mm and a height of 90 mm. The ultrasound transducer was attached at the wall surface of the water vessel, and ultrasound was irradiated in the horizontal direction parallel to the water surface. There was an air layer of about 10 mm at the wall surface and the underside of the water vessel. Ultrasound was propagated in a single direction by the air layer, and ultrasound was absorbed in water. Almost all of the ultrasound energy contributed toward increasing the water temperature. Moreover, change in the radiation characteristics of the ultrasound transducer was prevented because of propagation of ultrasound in a single direction.

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Furthermore, we prepared a water vessel equipped with polyurethane as a heat insulator to prevent heat loss from the water. Table 1 shows the ultrasonic power measured by the calorimetric method with and without a heat insulator. The values for ultrasonic power in Table 1 are averaged from 18 runs. Temperature sensor was positioned at the center and near the wall surface of the water vessel. The standard deviation of ultrasonic power measured in the water vessel with a heat insulator was smaller than that measured in a water vessel without heat insulator. This result indicated that reproducibility of the calorimetric method was improved.

Table 1 Ultrasonic power and standard deviation of the calorimetric method using a water vessel with and without a heat insulator.

	Ultrasonic power (W)	Standard deviation
With heat insulator	9.74	0.49
Without heat insulator	9.56	2.04

3. Effect of Dissolved Oxygen Level in Water

As air backing type ultrasound transducer with an operating frequency of 1 MHz and a diameter of 20 mm was used in this study. Ultrasound was irradiated onto saturated water with a DO level of about 8 mg/L and degassed water with a DO level of about 2 mg/L. The two types of water were examined by radiation conductance, which is defined as the ratio of ultrasonic power and the square of the RMS value of voltage applied to the transducer. The variation in radiation conductance was assessed from the standard deviation.

The difference in radiation conductance between saturated and degassed water is shown in Fig. 2, where the radiation conductance of saturated water was between 12 mS and 13 mS, while that of degassed water was between 11 mS and 12 mS. The radiation conductance of degassed water was about 6 % to 10 % lower than that of saturated water. The value of the specific heat capacity used in this study for calculating ultrasonic power from water temperature was 4.18 $J/K^{-1}g^{-1}$.[4)] From the systematic difference in radiation conductance of saturated and degassed water, the specific heat capacity was found differ between saturated and degassed water.

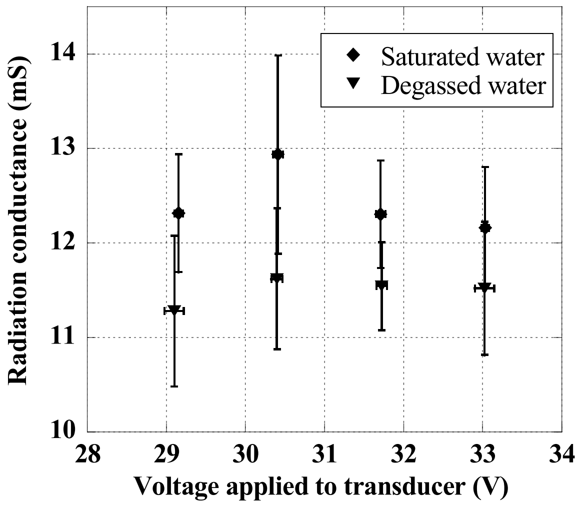

Fig. 2 Relationship between voltage applied to ultrasound transducer and radiation conductance.

4. Summary and Future Work

We have investigated a calorimetric method using water as a heating material, with the aim of establishing an alternative to the RFB method for ultrasonic power measurement. In this paper, we produced a novel calorimetric water vessel equipped with a heat insulator. As a result, the values measured by the calorimetric method were stable, and the radiation conductance measured by the calorimetric method using degassed water was lower than that of saturated water. This was attributed to the difference in specific heat capacity between saturated and degassed water. However, there has been almost no research comparing of the specific heat capacity of saturated and degassed water. Therefore, this will be further investigated in future work. Also, systematic differences in values measured by the RFB method and the calorimetric method will be investigated.

Acknowledgment

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