1Pb2-4

Ultrasonic power measurement using radiation force balance method with absorbing target for high ultrasonic power

Takeyoshi Uchida[1†] ([1]NMIJ, AIST)

1. Introduction

Recently, high-power ultrasound has been used in several fields. For example, in the medical field, high-power ultrasound by HIFU (high intensity focus ultrasound) device is applied to cancer treatment such as prostate cancer and breast cancer. HIFU is the device that give thermal coagulation treatment to cancer cell by thermal energy of high-power ultrasound. Also, in industrial field, high-power ultrasound is used for cleaning precision machine parts and so on. Shock wave and acoustic cavitation generated with high-power ultrasound are used for the cleaning.

High-power ultrasound also has the effect of destroying ultrasound irradiation objects. Therefore, it is necessary to accurately evaluate the output of ultrasound transducer for proper cancer treatment and cleaning.

Ultrasonic power is used as a quantitative evaluation index for characteristics of the transducer. Radiation force balance (RFB) is the precise measurement method for ultrasonic power. RFB has been adopted by national standards institutes. RFB is a method to precisely measure ultrasonic power below 15 W. RFB method cannot precisely measure ultrasonic power above 15 W because the receiving target which is the important part used in RFB device is destroyed for heat generated by ultrasound exposure.

Therefore, we focused on receiving target to solve the above problem. In this paper, we considered the improvement of RFB by using the absorbing material for high-power ultrasound as the receiving target.

2. Experimental method

Figure 1 shows a schematic view of RFB device. RFB relies on the following principle: a traveling ultrasonic wave striking an absorbing material generates an acoustic radiation force that can be averaged over time. This force changes the effective weight of the absorbing material, which can be measured by an electronic balance. Electronic balance and absorbing material are key parts in RFB. MC-1000 electronic balance (R&A) with weighing capacity of 1000 g and resolution of 0.1 mg was used. The resolution corresponded to an ultrasonic power resolution of 1.48 W. We used two kinds of absorbing materials as receiving target. One was HAM A (Precision Acoustics) absorbing material for low ultrasonic power. The HAM A had a diameter of 100 mm, and it absorbed ultrasound until about 15 W of ultrasonic power at frequency between 500 kHz and 20 MHz. The HAM A is used as receiving target to supply ultrasonic power standard in the NMIJ (National Metrology Institute of Japan). The other was Aptflex F28P (Precision Acoustics) for high ultrasonic power. The F28P has a diameter of 100 mm, and it absorbed ultrasound until about 100 W at frequency between 1 MHz and 20 MHz. The measurement values obtained by HAM A and F28 were compared in the range up to 15 W because HAM A is destroyed by ultrasonic power above 15 W. Also, the measurement by F28P was conducted in the range up to 100 W.

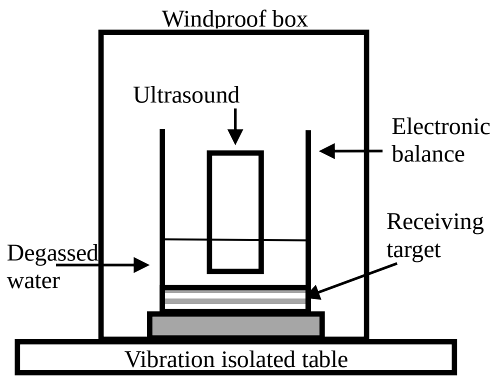

Fig. 1 Ultrasonic power measurement by RFB method

We conducted the experiments by using the operating frequency of 1 MHz which was generated by air backing ultrasound transducer with a diameter of 40 mm. The output signal from a function generator (Agilent, 33250A) was amplified by a power amplifier (R&A, CA010K010-5353R). The dissolved oxygen level of degassed water was below 2 mg/L. Room temperature was control within 23 °C±0.5 °C, and water temperature was controlled within 23°C ± 1.0 °C. Ultrasound exposure time was 30 s.

takeyoshi.uchida@aist.go.jp

3. Experimental results

At first, we compared the measurement values by absorbing materials of HAM A and F28P in ultrasonic power range up to 15 W. The result is shown in Fig. 2. As the results, quadratic curves at HAM A and F28P which were relationship between the voltage applied to the transducer and the resulting ultrasonic power were obtained. Also, the measurement values obtained by F28P agreed with the results of HAM A within the measurement uncertainty of HAM A. The measurement uncertainty of HAM A and F28P are 5 %. The results as shown in Fig. 2 indicated that ultrasonic power measurement by F28P had a high accuracy in the ultrasonic power range up to 15 W.

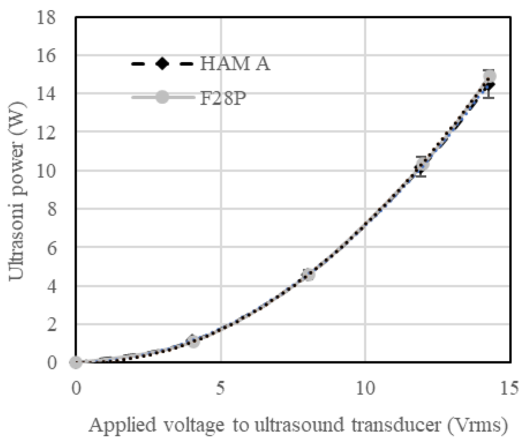

Fig. 2 Change of ultrasonic power by radiation force balance method with HAM A and Aptflex F28P

Next, we carried out measurement up to 140 W of ultrasonic power by F28P. The results of ultrasonic power measurement up to 140 W by F28P is shown in Fig. 3. The results by F28P are the measured values., and the results by HAM A are predicted values obtained by approximate curve calculated form measured values up to 15 W.

As the results, measurement by F28P could be performed up to 150 W without being destroyed by high-power ultrasound. HAM A was destroyed for heat generated by high-power ultrasound. The photographs of F28P and HAM A after measuring up to 140 W are shown in Fig. 4.

The measured values by F28P and the predicted values of HAM A were compared in the range of 140 W. The measured value of F28P did not agree with the predicted values of HAM A within 5 % of measurement uncertainty by F28P. The result shows that there is a possibility that a force other than radiation force by ultrasound is applied.

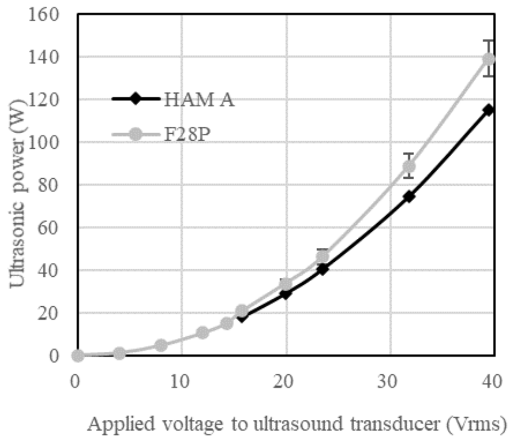

Fig. 3 Comparison of measured values by F28P and predicted values by HAM A.

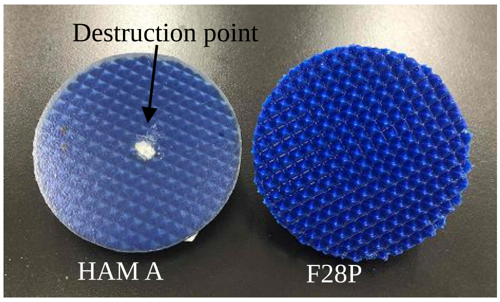

Fig. 4 Photographs of F28P and HAM A after measurement.

4. Summary

We considered evaluation of high ultrasonic power technique by RFB method with F28P of absorbing material for high power ultrasound. As the results, in case of ultrasonic power below 15 W, measured values of HAM A and F28P agreed. In ultrasonic power range above 15 W, measured values by F28P and predicted values by HAM A did not agree. In the future, we will compare the RFB with F28P and calorimetry method which is high ultrasonic power standard in NMIJ.

Acknowledgment

This work was supported by the Japan Society for the Promotion of Science, KAKENHI (Grant Number 20K04525)

References

1. IEC 61161 Ed.3: 2013.
2. K. Beissner, W. Oosterbaan: Acoustica. 82 (1996) 450.
3. T. Uchida, T. Kikuchi: Jpn. J. Appl. Phys. **52** (2013) 07HC01.