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Abstract

Influences of Dissolved Oxygen and Microbubbles on Heat Generation at Defect under Immersion Sonic-IR Testing

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Abstract: Sonic-IR method is an innovative approach to defect detection. Ultrasonic waves are input to the inspection object, and the frictional heat generated by friction with the defect interfaces is detected by an infrared camera. A notable advantage of this method is its superior detection ability to detect closure defects that are often missed by other inspection methods. However, the conventional Sonic-IR method pressing an ultrasonic transducer directly against the inspection object may cause deformation or surface damage, depending on the material and shape of the object.

As a method to solve this problem, the immersion Sonic-IR testing, in which ultrasonic waves are input to the inspection object through a water, has been proposed. However, this method has a problem in defect detectability because of the small frictional heat at the defects. Large-diameter bubbles in water are difficult to collapse, and also cause scattering and attenuation of ultrasonic waves. In contrast, small-diameter bubbles are easily collapsed so that cavitation, which is a source of vibrational energy, is likely to occur.

The objective of this study is to investigate the influences of dissolved oxygen and microbubbles on the sound pressure level in the water and heat generation at defects in order to improve the defect detectability of the immersion Sonic-IR testing.

Keywords: Sonic-IR, non-destructive testing, cavitation, dissolved oxygen, microbubbles

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1. Introduction

In this study, we focused on the immersion Sonic-IR testing, which is one of the non-destructive inspection methods [1, 2]. When ultrasonic waves propagate in water, bubbles are generated in the water and eventually collapse, causing cavitation. The vibrational energy generated by cavitation causes the inspection object to vibrate, and the temperature rise at the defect is generated by the friction between defect interfaces. This non-destructive inspection method detects defects by observing the temperature rise with an infrared camera. However, this method has a problem in defect detectability because the frictional heat at the defect is small. Large-diameter bubbles in water are difficult to collapse. Large-diameter bubbles also cause scattering and attenuation of ultrasonic waves. In contrast, small-diameter bubbles are easily collapsed so that cavitation is likely to occur. Therefore, we hypothesized that the formation of large-diameter bubbles could be suppressed by reducing the dissolved oxygen by boiling, which would increase the sound pressure level in the water and improve defect detection. In addition, focusing on microbubbles, we considered that defect detection could be improved by injecting ultrafine bubbles (UFB) with a diameter of less than 1μm into the water.

The objective of this study is to investigate the influences of dissolved oxygen and microbubbles on the sound pressure level in the water and heat generation at defects in order to improve the defect detectability of the immersion Sonic-IR testing.

2. Experimental methods

The following six types of water were used in the experiment. Each water was degassed by ultrasonic vibration, and cooled to 20 °C. The sound pressure level during ultrasonic oscillation in each water and heat generation by Sonic-IR test using each water testing were measured.

(A) Tap water (Normal)
(B) Boiling water (Boiling)
(C) Water mixed with (A) and (B) in a volume ratio of 1:1 (Half)
(D) Tap water added UFB (UFB)
(E) Water in which (D) was left for 1 hour (UFB 1h)
(F) Water in which (D) was left for 2 hours (UFB 2h)

(A) was prepared for the purpose of comparison with other waters. (B) and (C) are water samples in which the dissolved oxygen was reduced by boiling. (D) is water in which UFB was generated by the pressurized dissolution method. When UFB is produced by the pressurized dissolution method, large bubbles of micro-order are also generated. According to Stokes' equation, bubbles with larger diameters were expected to rise to the water surface and disappear after about 2 hours. Therefore, (E) and (F) were prepared, respectively.

An ultrasonic sound pressure meter was used to measure the sound pressure level of each water. The sound pressure meter was fixed at the center of the water tank, and the change in sound pressure level in the depth direction of each water was measured. The water depth L varied from 2mm to 50mm at 2mm intervals, and the sound pressure level was measured for 20 seconds during ultrasonic oscillation at each depth. The average of the sound pressure level at each depth L was defined as the average sound pressure level.

The specimen with fatigue crack was also placed in the center of the tank, and the immersion depth d was varied from 2mm to 50mm at 2mm intervals to measure the temperature change at the crack. These measurements were carried out twice at each immersion depth d, and the average temperature change for each depth was evaluated. An infrared camera with a temperature resolution of 25mK was used to measure the temperature change on the specimen surface during ultrasonic oscillation at a frame rate of 113Hz.

3. Experimental results

Figure 1 shows the average sound pressure level in the tank and the average temperature change at the crack for each water type. In general, it is known that the sound pressure level during ultrasonic oscillation increases when dissolved oxygen is reduced. Boiling water (B) caused the highest sound pressure level and temperature change. This is due to the reduction of large diameter bubbles that cause attenuation of ultrasonic waves by reducing dissolved oxygen through boiling. Immediately after the UFB was added, there was no significant change in the sound pressure level and the temperature change. However, after a certain period, the sound pressure level and the temperature change tended to increase. It was thought that the large diameter bubbles floated and disappeared after a certain time, and small diameter bubbles, effective for cavitation, remained in the water. By these, the increases of the sound pressure level and the temperature change could be explained. The results are omitted, but the addition of UFB increased the sound pressure level and the temperature change despite the increase in dissolved oxygen.

From the above, it is considered that the sound pressure level in the tank and the heat generation at the cracks are affected not only by the dissolved oxygen but also by the microbubbles contained in the water.

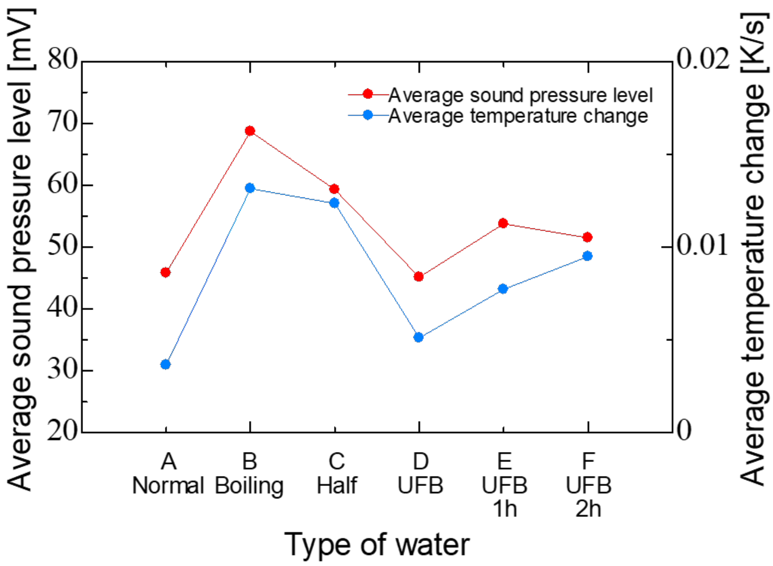

Figure 1. Average sound pressure level and average temperature change for each type of water.

4. Conclusions

In this study, the effects of dissolved oxygen and microbubbles in the water on defect detectability of immersion Sonic-IR testing were investigated. As a result, when the dissolved oxygen was decreased by boiling, the sound pressure level in the water and the heat generation at the cracks increased. Furthermore, the addition of microbubbles also increased the heat generation at the cracks.

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