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Ultrasonic Immersion Test Parameters for Detection of Hydride Blisters on Zirconium Pressure Tube

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1. Introduction

Since Zr-2.5Nb pressure tubes have a high risk for the formation of blisters during their operation in pressurized heavy water reactors, there has been a strong incentive to develop a method for the non-destructive detection of blisters grown on the tube surfaces. However, because there is little mismatch in acoustic impedance between the hydride blisters and zirconium matrix, it is not easy to distinguish the boundary between the blister and zirconium matrix with conventional ultrasonic methods. The ultrasonic velocity ratio method has been developed, which can be applicable in the laboratory experiment [1]. In order to be more realistic field examination, an automated ultrasonic immersion technique is desirable with a least modification of the fuel channel inspection system.

This study has focused on the development of a 3-axis ultrasonic immersion system. A variety of ultrasonic parameters were tested to get the optimum parameters with the same condition in the fuel channel inspection.

2. Methods and Results

2.1 3-Axis Ultrasonic C-scan Immersion System

A 3-axis ultrasonic c-scan immersion system was developed for the detection of hydride blister on the zirconium pressure tube as well as the general purpose ultrasonic research. Both 3-axis motor driver and controller and ultrasonic signals are controlled and signal-processed with the software 'Winspect' and industrial personnel computer. A high frequency ultrasonic pulser/receiver up to 100 MHz is used for the generation and reception of ultrasonic signal. The system has a capability of several moving gate in connection to the base gate in the time domain, has many advantages to acquire the target signal data. Also various ultrasonic parameters, such as maximum or minimum amplitude, time-of-flight (TOF), fast Fourier transform (FFT), can be selected for the c-scan display.

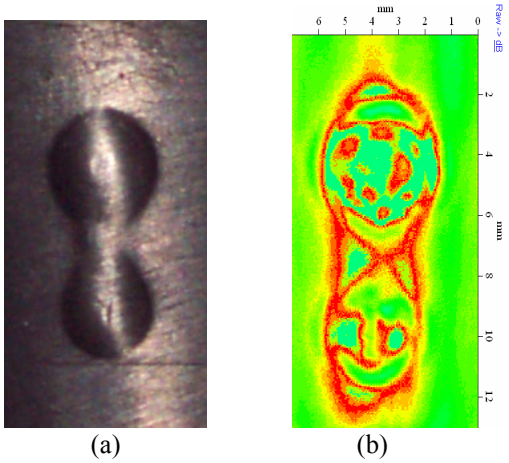
2.3 Preparation of blister specimen

Curved rectangular specimens were cut out of Zr-2.5Nb pressure tube and charged with hydrogen of 200 ppm by an electrolytic method in accordance with our procedures for characterization of Zr-2.5Nb pressure tubes [2]. Vacuum annealing was conducted at the temperature above thermal solid solubility to homogenize the distribution of charged hydrogen within the specimens. As a result, hydrides were found to uniformly distribute over the whole cross section of the specimen. The hydride blisters were grown on the outer surface of the curved specimen by applying thermal gradients across the thickness. The inner surface of the specimen sits on the aluminum block kept at 415 ± 2°C, while cold spot was made by keeping the outer surface in contact with the aluminum finger cooled by flowing water of 14 ~ 16 °C. The hydride blisters grew during 7 ~ 42 days under temperature gradient [3].

2.3 Results of c-scan image of hydride blisters

Various ultrasonic parameters were tested to distinguish the blister. Theoretically, the parameter of the velocity ratio, i. e. the ratio of longitudinal wave velocity to shear wave velocity, is expected to show the best result, and is agreed to the experimental result.

In addition, considering to the viewpoint of applicability to the field examination, the mode-converted back-reflected shear wave signal is one of the convenient and accurate parameter for the c-scan image with good quality. An ultrasonic c-scan image with the parameter of amplitude minimum of reflected shear signal compared to the optical image of a blister, shown in Fig. 1.



(a) (b)

Figure 1. A comparison of (a) an optical image of outer surface of a blister specimen, and (b) ultrasonic c-scan image of blister with the reflected-shear amplitude minimum mode.

3. Conclusion

A 3-axis ultrasonic c-scan immersion system was developed for detection of the hydride blister on the zirconium pressure tube.

The parameter of the velocity ratio shows the best result, however, the mode-converted back-reflected shear wave signal is also one of the convenient and accurate parameter for the c-scan image with good quality, considering to the applicability in the field examination.

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