

Analysis of High Temperature Pipe Thinning with Various Fluid Conditions using the Ultrasonic Monitoring System

Se-Beom Oh^{a*}, Yong-Moo Cheong^a, Jong-Beom Kim^a, Dong-Jin Kim^a, Jong-Yeon Lee^a, Kyung-Mo Kim^a
^aKorea Atomic Energy Research Institute, Safety Materials Technology Development Division
^{*}Corresponding author: osb1216@kaeri.re.kr

1. Introduction

Pipe wall thinning and leakage due to flow accelerated corrosion (FAC) are important safety concerns for nuclear power plants. Because pipe wall thinning due to FAC is very slow (a few tens of μm per one year), it is necessary to monitor the piping walls for delamination, cracks and leaks as well as the piping thickness with very high accuracy. Presently, an ultrasonic method is used, which is one of the nondestructive inspection techniques for measuring the piping wall thickness. The ultrasonic technique is widely used to assess the safety of nuclear piping and to measure the piping wall thickness [1-5].

2. Methods and Results

2.1 Waveguide On-line Monitoring System

Method to measure pipe thickness at high temperature is to use an ultrasonic waveguide strip in this work. This method was attempted using a waveguide strip to reduce the acoustic parameters between the ultrasonic transducer and the specimen. The shear horizontal vibration mode was chosen to ensure that there was proper ultrasonic wave transmission at the strips. This ultrasonic vibration mode is advantageous for obtaining sensitive and accurate experimental data at high temperatures [6]. The shear horizontal wave transducer was attached to the edge of the waveguide strip shown in Fig. 1. When the transducer and the waveguide strip contacted each other exactly at a perpendicular level, the shear horizontal mode was stably transmitted to the waveguide. On the opposite side of the waveguide strip, a clamping device was designed and fabricated to precisely hold the specimen, and two waveguide strips were installed in parallel to divide the transmitter and receiver. The transducer used a waveguide strip that was far from the specimen, which was maintained at about 35 °C when the temperature of the pipe was 150 °C. This meant that the developed system is completely free from the constraint of the high temperature for the transducer.

This method had no main bang signal, and the signal reflected from the end of the waveguide strip was very small. Additionally, the multiple reflected signals on the back wall of the pipe, which was to be inspected, had a high S/N ratio.

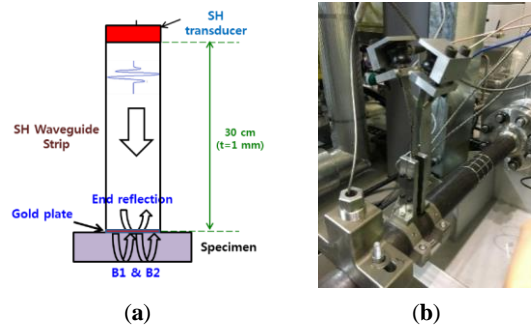


Fig. 1. (a) Conceptual diagram of the waveguide strips for high temperature thickness monitoring; (b) installed waveguide system on a pipe.

2.2 Thickness Measurement Program

The thickness measurement program was designed as a moving gate in real time to accurately measure the reflected flight time. The first gate was set to the signal from the end of the transmitting waveguide strip shown in Fig. 2. The second gate was set to the first back wall echo signal, and the third gate was set to the second back wall echo signal. The second and third gates were set as the moving gates to follow the first gate setting.

The peak of the first and second back wall echoes was automatically determined by the flight time and denoted as t_1 and t_2 shown in Fig. 2. The ultrasonic wave velocity was constant and the path length of the actual reciprocating wave can be seen by the strip and pipe wall thickness. Thus, the time of the received rf signal can be calculated. All ultrasonic rf waveforms are in the time domain and displayed on the PC screen. This system inspects the signal quality and is designed to display an alarm indicator on the screen when receiving unwanted signals. Between t_1 and t_2 , the flight time was automatically calculated on average, hundreds of times to obtain accurate thickness data. Because ultrasonic velocity is a function of temperature, variation in the ultrasonic velocity at high temperatures can be a main problem in terms of measurement data errors. Therefore, to measure the thickness in real time at high temperature, pre-calibration is required to reflect the relationship between the ultrasonic velocity and the temperature.

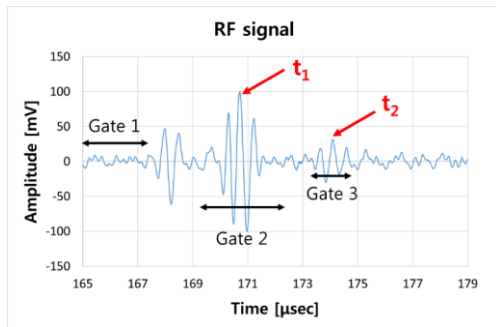


Fig. 2. Typical ultrasonic rf signals by a developed waveguide with the pitch/catch method.

2.3 Verification Experiment in the FAC Proof Facility and Results

A waveguide was placed on the top of the pipe to observe the tendency to pipe thinning. The operating conditions of FAC proof facility were designed to analyze the difference in thickness thinning rate due to the influence of the internal fluid conditions. It changed the internal flow rate and pH, which is known to affect FAC was changed during the operation.

During the first three time periods, another conditions were fixed and only the flow rate was changed to 7-12 m/s. As a result, we were able to clearly confirm that the thickness reduction rate was high at the period where the flow velocity increased. In the later three time periods, the experiment was conducted by raising the pH to above 9. When the pH was 7, the thickness reduction rate was maintained as in the previous experiment, and when the pH was 9 or more, the thickness reduction rate by FAC was suppressed (Fig. 3, Table I)

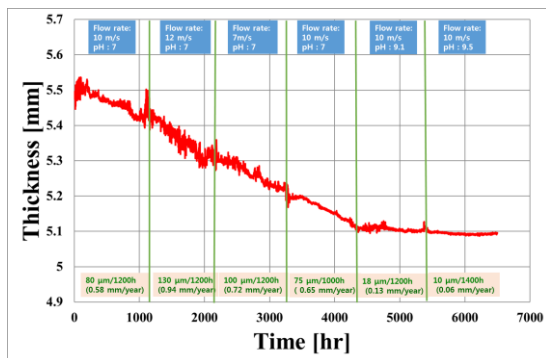


Fig. 3. The pipe thickness measurement data using the waveguide system

Table I: The pipe thickness thinning rate

Conditions		Thinning rate [mm/year]
Flow rate [m/s]	pH	
10	7	0.58
12	7	0.94
7	7	0.72
10	7	0.65
10	9.1	0.13
10	9.5	0.06

3. Conclusions

A shear horizontal ultrasonic pitch/catch waveguide system was developed for the accurate online monitoring of the pipe wall thickness in the FAC certification test facility in KAERI. This system was confirmed with a stable operation at high temperature with a long period, such as a measurement error less than $\pm 20 \mu\text{m}$ at 150°C for 6600 hours of continuous operation. This result demonstrates that a waveguide system is sensitive to the flow of internal fluid conditions and can measure thickness. The ultrasonic waveguide system could be applied to high temperature thickness monitoring in the various industries as well as in nuclear power plants.

ACKNOWLEDGEMENT

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