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A Study on Sludge Cleaning of a Nuclear Steam Generator by an Ultrasonic Transducer

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1. Introduction

The broach hole, sometimes called quarter-foil, of the flow distribution plate (FDP) of nuclear steam generator (S/G) is often blocked by gradual accumulation of scale. Blocking of the broach hole causes serious fluctuation of secondary coolants. Therefore, we started a project to remove the scale in the broach hole by ultrasonic means. Simulated sludge for testing ultrasonic cleaning is used. A means for removing the scale by cavitation of ultrasonic transducer is reviewed, and the results are examined.

2. Experiment and Results

In this section, a feasibility test of ultrasonic cleaning of nuclear S/G is presented.

2.1 Scale and Sludge in S/G

Sludge in secondary side nuclear S/G is formed mainly from abrasion of the pipes, tubes, turbines and pumps composing secondary cooling loop. Sludge may be accumulated on the tube-sheets, tubes, tube support plates. When it is piled up, it prevents heat dissipation from the surface of the tubes. When sludge is heated and dried, it solidifies. Solidified form of sludge is called scale. Scale and sludge in S/G worsen its performance as a heat exchanger. Therefore utilities operating nuclear power plants are trying to clean up scale and sludge during each plant outage.

2.2 Ultrasonic Sludge Cleaning

Ultrasonic transducers submerged in water cause cavitation. Cavitation breaks sludge particle into very minute particles which can be mixed into water. We could gradually clean S/G by removing mixture of sludge particles and water repeatedly.

Westinghouse model-F S/Gs have broach holes between the tubes and the tube support plate. The broach holes of the tube support plates of Kori #3, #4 nuclear power plants have been observed to be blocked. ASCA (Advanced Scale Conditioning Agent) is used to remove scale deposit from the broach holes in 2007. By using ASCA, the scale was successfully removed. However, the process was time consuming and very expensive. Therefore, we started a project for developing a new process for removing scale without using ASCA.

2.3 S/G Mock-up

We developed a S/G mock-up to test cleaning efficiency of a ultrasonic transducer. The tube-sheet of the mock-up was made up of 500mm thick carbon steel to simulate the actual S/G tube-sheet. Four magneto-strictive transducers are used to activate the tube-sheet and the tubes as shown in figure 1.

Fig. 1. A Mock-up for Testing Ultrasonic Cleaning of a Nuclear Steam Generator

2.4 Test Results

We filled the S/G mock-up with water and made cavitation occur using the transducers as shown in figure 1. Cooking foil was used to visually determine whether cavitation occurs or not at inspection points as in figure 2. At the test point “g” where acoustic pressure of 30kPa, we could see cavitation happened because the cooking foil was removed. Therefore, we could say that cavitation happens at acoustic pressure of 30kPa or more at 16.4kHz for our S/G mock-up. We used TC4013 hydrophone of RESON co. for measuring acoustic pressure. Three different transducers of 16.4, 13.4, and 12.2kHz were used for the test.

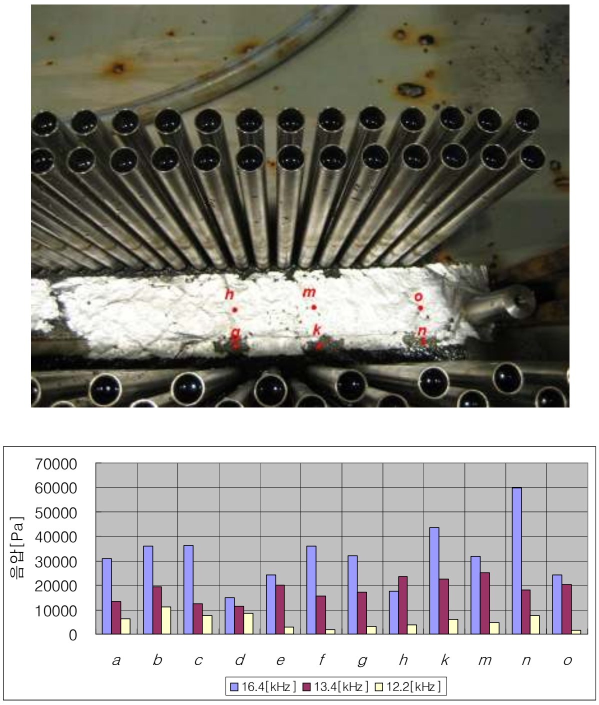

Fig. 2. Test Points at the S/G Mock-up (above) and Measured Acoustic Pressure (below)

2.5 FEM Model for Numerical Simulation

A FEM model of the S/G mock-up was made as shown in figure 3. The software ANSYS was used for numerical analysis. By giving a vibration at the location of the ultrasonic transducers as shown in figure 1, we tried to figure out the amplitude at various locations of the model. We tried various numerical analysis for different vibration frequencies.

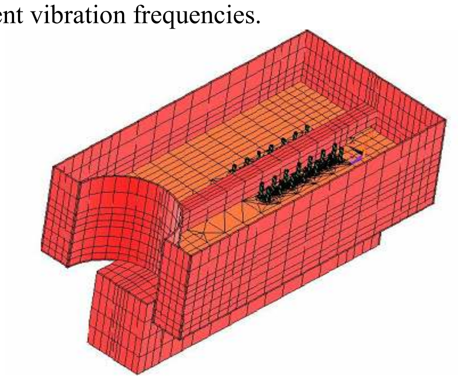

Fig. 3. FEM model of S/G mock-up

2.6 Simulation Results

From numerical analysis, we could see that a bidirectional vibration is more effective in spreading acoustic energy over the S/G mock-up as shown in figure 4(b). However unidirectional vibration is effective for transmitting energy in limited region as in figure 4(a). In figure 4, bright color shows smaller amplitude, and dark color larger amplitude. Here, bidirectional vibration means that the two transducers vibrate at the same amplitude and frequency without any phase shift. However, unidirectional vibration means that the two transducers have 180 degree phase shift.

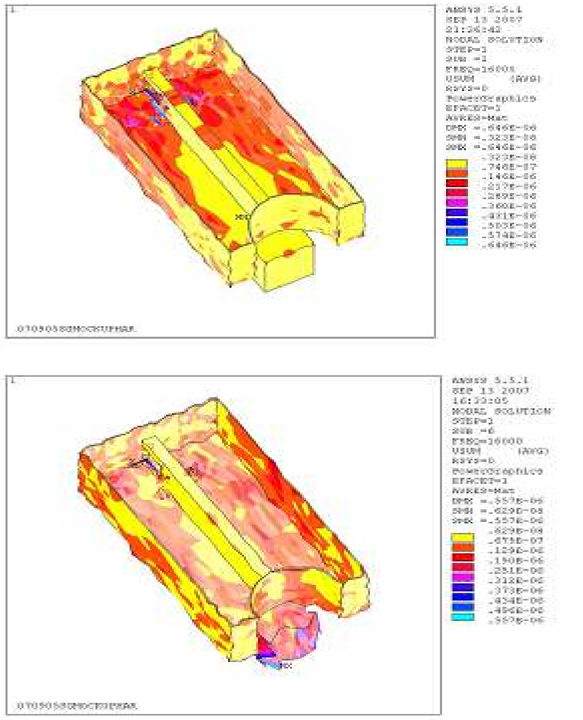

Fig. 4. Distribution Profile of Acoustic Energy over the S/G Mock-up: above(a) below(b)

3. Conclusions

Cavitation was observed on the tube-sheet which is a plate of 50cm thick carbon steel. Therefore, it could be concluded that sludge removal using the ultrasonic transducers for the nuclear steam generator is possible. Furthermore, the simulation result shows that bidirectional positioning of the transducers is more effective to clean wide area of the S/G. However, it further could be concluded that unidirectional transducer positioning could be used for removing sludge effectively in restricted area.

REFERENCES

[1] Woo-tae Jeong, Seok-tae Kim, "An Experiment for Ultrasonic Cleaning and Acoustic Pressure Distribution of S/G Mock-up Using Continuous Type Magneto-strictive Transducer," Internal Technical Memo, KEPRI, 2007.