Sludge Removal of a Nuclear Steam Generator by an Ultrasonic Means

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1. Introduction

Blockage of crevices such as the quarter-foil of the support plate of nuclear steam generator (S/G) is often observed in Korean nuclear power plants. Blockage of the quarter-foil often causes oscillation of S/G water level. By chemical cleaning, the scale or sludge could be effectively removed. However, it is very expensive and time consuming especially to remove scale deposited in crevices. Therefore, a new method of using ultrasonic means to remove scale accumulated in the crevices is being developed. In this paper, we suggested a new method of applying ultrasonic energy directly to the tube sheet of nuclear S/G to remove scale in the quarter-foil.

2. Ultrasonic Cleaning Tests and Transducer Setup

In this section, an idea to transmit ultrasonic energy to the quarter-foil (or broach hole) of the tube support plate is presented.

2.1 Ultrasonic Cleaning Test

We made a test setup as shown in Figure 1 to evaluate feasibility of ultrasonic cleaning method for removing sludge or scale generated in nuclear S/G. Twelve piezoelectric transducers, we call it transducer assembly, are attached to a stainless steel plate of a rectangular box. To make simulated sludge, we added magnetite powder to water. After submerging and applying power to the transducer assembly in magnetite added water, we observed the simulated sludge. It was disintegrated and dissolved in water in 20 minutes. However, the ultrasonic cleaning effect could only be observed at distance of less than 30 centimeter away from the transducer. Therefore, we concluded that submerging transducer assembly into a S/G cavity is not a good way to clean large component such as nuclear steam generator.

2.2 Ultrasonic Transducer Setup for S/G Cleaning

Broach holes of the tube support plate of Westinghouse model-F S/Gs at Kori NPP #3 and #4 have been observed to be blocked. Therefore, we suggested an idea to transmit ultrasonic energy to the broach holes as shown in Figure 2. We assumed that ultrasonic energy could easily be transmitted through the tube sheet which is about 50 centimeters thick. We also assumed that energy transmitted to the tube sheet could easily be transmitted to the broach hole through S/G tubes. If the assumptions are correct, we expected the whole S/G could be cleaned by the ultrasonic transducers which are attached to the tube sheet.

Fig. 1. Piezoelectric Transducers and Power Supply

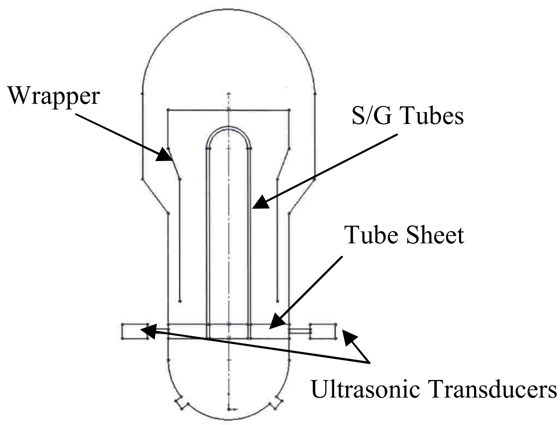

Fig. 2. Ultrasonic Transducer Setup for Ultrasonic S/G Cleaning

3. Test Setup and Experiments

3.1 Test Setup for Ultrasonic Cleaning of S/G

We developed a test setup for testing ultrasonic cleaning of S/G as shown in Figure 3. The tube sheet is manufactured with 50 centimeters thick carbon steel. Two magnetostrictive ultrasonic transducer of 4kW and 1kW capacity was used. S/G tubes are installed on the tube sheet. The simulated tube sheet area is sealed, and a exhaust hose is installed to remove toxic airborne chemicals in the test setup. A pump is used to circulate water and sludge.

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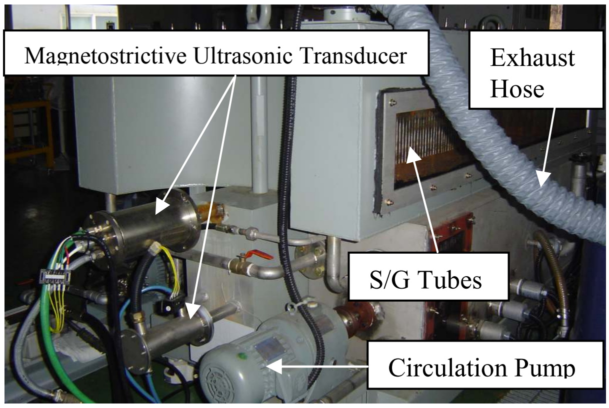

Fig. 3. Test Setup for Ultrasonic Cleaning of S/G

3.2 Experiments

We made a simulated sludge using magnetite and phosphoric acid which is similar in composition to sludge of nuclear S/G. Before testing with the simulated sludge, we put aluminum cooking foil into the test setup and applied ultrasonic energy for 10 hours. We observed cavitation on the tube sheet of the test setup. Therefore, we concluded that cleaning of S/G is possible by using ultrasonic means. Thus, we put the simulated sludge on the tube sheet among S/G tubes and applied energy to the ultrasonic transducers.

Firstly, we used pure water as a medium. After several hours, we could observe some sludge is removed. However, we decided that we could not have a satisfactory cleaning result when we use pure water and ultrasonic transducer. Even though cavitation on the tube sheet and S/G tube occurs, it was not strong enough to remove all the simulated sludge. We further decided that more transducers are necessary to get satisfactory cleaning because the tube sheet is too big to make sufficient cavitation.

Secondly, we put chemicals such as EDTA in water. We observed that sludge could be removed using water containing EDTA. When we apply ultrasonic energy to EDTA water, sludge was removed more quickly. Therefore we concluded that ultrasonic transducer could be used successfully for chemical cleaning of S/G to improve cleaning efficiency.

However, we expect that ultrasonic energy could enhance reactivity of the chemicals with the sludge accumulated in the broach holes. We tried test using a small scale mock-up to evaluate our assumption that ultrasonic energy could be transmitted to the end of S/G tubes when we apply energy to the tube sheet. Strong ultrasonic signal was detected at S/G tubes where the measurement position is 3 meters away.

3.3 Further Work

We would like to develop an ultrasonic means to remove scale deposit in broach holes as shown in Figure 4. Some broach holes are 6.5 meters away from the tube sheet. A S/G mock-up, which is longer than 6.5 meters, with broach holes coated with simulated scale is necessary to evaluate our ultrasonic cleaning method. Acoustic analysis to define location and direction of attaching ultrasonic transducers also should be made.

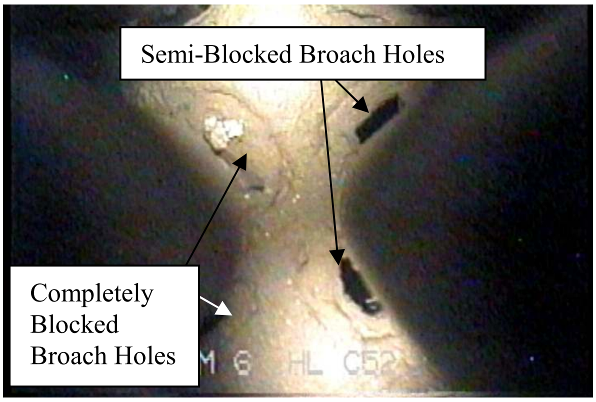

Fig. 4. Scale Deposit in Broach Holes

4. Conclusions

We suggested a methodology to clean the broach holes of nuclear S/G using ultrasonic means. It was observed that ultrasonic energy could be transmitted to the S/G tubes which are 3 meters away. Cleaning of the tube sheet using cavitation of ultrasonic transducers was observed to be possible. It was also observed that ultrasonic cavitation was helpful to reduce time necessary to remove sludge when EDTA was added to water.

REFERENCES

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