# Ultrasonic Cleaning of Nuclear Steam Generator by Micro Bubble

Woo-Tae Jeong [a*], Sang-Tae Kim[b], Sang-Jung Yoon [b]
[a]*Korea Hydro & Nuclear Power Co., Ltd., Central Research Institute, 1312-70 Yuseongdaero, Yusung-gu, Daejeon, Korea 305-343*
[b] *Sae-An Engineering Corporation, Rm910, Byucksan Digital Valley II, 481-10, Gasan-dong, Geumcheon-gu, Seoul, Korea 153-803*
[*]*Corresponding author: wtjeong@khnp.co.kr*

## 1. Introduction

In this paper, we present ultrasonic cleaning technology for a nuclear steam generator using micro bubble. We could extend the boundary of ultrasonic cleaning by using micro bubbles in water. Ultrasonic energy measured was increased about 5 times after the generation of micro bubbles in water. Furthermore, ultrasound energy was measured to be strong enough to create cavitation even though the ultrasound sensor was about 2 meters away from the ultrasonic transducer.

## 2. Ultrasonic Cleaning of SG

### *2.1 Simulated Sludge*

Sludge pallets were made using 10 gram of magnetite powder, 1.4 ml of ethylene glycol and 10 ml of benzene. These were mixed and agitated until the weight of mixture reaches 12 gram, and were divided into 12 pieces thereafter. A metallic mold with a 13mm plunger in diameter and a press with 2 ton capacity were used to form solid pallets. The mold having 1 gram of mixture was pressed with 800Kg weight for 60 seconds forming a solid pallet. The pallets were heated in electrical furnace at 120 degrees Celsius for 2 hours.

Fig.1 Simulated Sludge Pallets

### *2.2 Sludge Removal without Micro Bubble*

A steam generator mockup was made to test whether the simulated sludge pallets could be dissolved in water by cavitation caused by ultrasonic transducer. A SG mockup with the same tube arrangement as OPR1000 SG was made. Ultrasonic transducers were attached to the left vertical circular bar, and an ultrasound sensor was installed to the right vertical circular bar on Fig. 2.

Fig.2 SG Mockup for Ultrasonic Cleaning

Fig. 3 shows weight ratio of remaining to initial sludge mass (vertical axis) after cleaning by ultrasonic transducers for several hours (horizontal axis). Sludge located in no tube region was removed faster than the sludge in tube bundle. Sludge nearest to the ultrasound transducer was completely removed in 5 hours. Sludge number 5 which is farthest from the transducer was not completely dismantled in 12 hours.

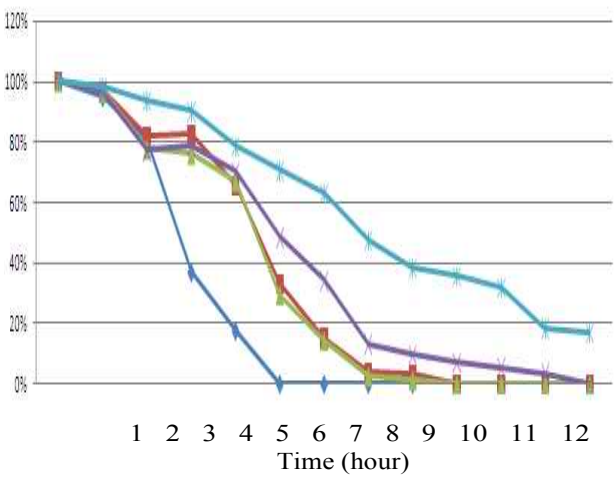


Fig.3 Weight Ratio of Remaining Sludge with Time (hour)

Fig. 4 shows change in ultrasound energy level in W/in$^2$ (vertical axis) with respect to measurement position in millimeters from the ultrasonic transducer (horizontal axis). Ultrasound energy level was a little higher in no tube area of upper line than in tube area of lower line. Energy level near ultrasonic transducer was relatively higher.

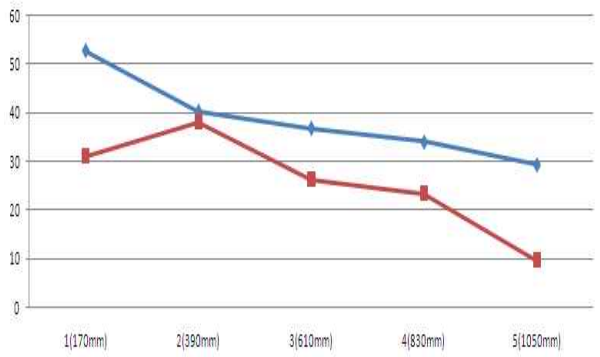


Fig.4 Ultrasound Energy (W/in$^2$**)** at Various Sensor Position

*2.3 Sludge Removal with Micro Bubble*

A similar experiment was made with the same ultrasonic transducer and SG mockup. Micro bubble generator was used to make bubbles of 50 micron or less in size. In previous experiments, some sludge was not removed after 12 hours of ultrasonic cleaning. However, in this experiment with micro bubble, all the sludge was removed just in an hour or less.

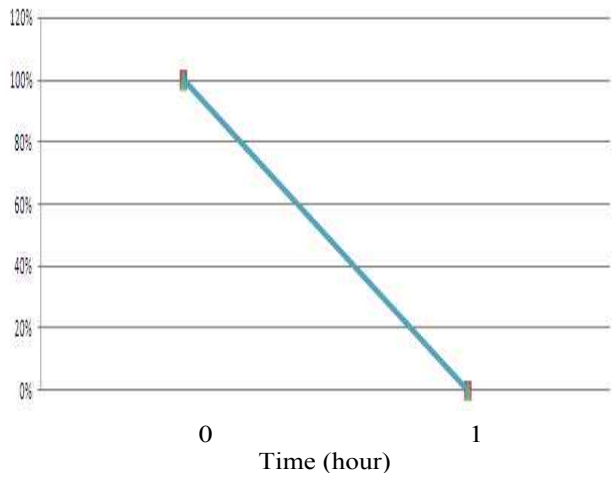


Fig.5 Weight Ratio of Remaining Sludge with Time (hour)

Ultrasound energy measured at the same position in section 2.2 is shown in Fig. 6. In most locations, the energy measured was more than 5 times than that of previous experimental result with no micro bubble.

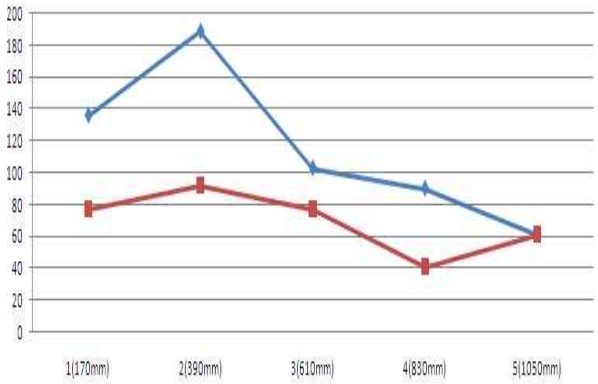


Fig.6 Ultrasound Energy Level (W/in$^2$**)** with Micro Bubble at Various Sensing Position from Transducer

## 3. Conclusions

Simulated sludge was made to evaluate the effectiveness of micro bubble for ultrasonic cleaning. Several experiments with and without micro bubble effect were made to compare the time necessary to remove sludge from SG mockup.

It took more than 12 hours to clean the simulated sludge in SG mockup by ultrasonic cleaning without micro bubble. Furthermore, ultrasound energy level was not sufficiently high to create enough cavitation for removing hardened sludge.

In a similar ultrasonic cleaning experiment with micro bubble, simulated sludge was completely removed in less than an hour. Ultrasound energy level in water with micro bubble was more than 5 times higher than that with no micro bubble.

We expect that ultrasonic cleaning technology using micro bubble could be effectively applied to clean nuclear SG of four meters in diameter.

## REFERENCES

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