Experiments on Steam Generator Cleaning by Ultrasonic Means

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1. Introduction

In this paper, we studies ultrasonic energy transmission for three cases for application to SG ultrasonic cleaning. Firstly, we submerged a steel strip in water and attached a magneto-strictive transducer at the end of the strip. Secondly, we attached a transducer on a small, model tube sheet, and a tube is rigidly fixed on the tube sheet. Thirdly, we measured ultrasonic energy on a SG mockup which is designed and manufactured similarly with the actual SGs. Through the experiments, we tried to find a trend for ultrasonic energy transmission

2. Ultrasonic Cleaning of SG

2.1 Transmission of Ultrasonic Energy to Steel Plate

Ultrasonic energy is transferred through a thin steel plate as shown in figure 1. In all the experiments below, we used magneto-strictive transducers. In the first experiments, we tried to evaluate a possibility of using a thin steel plate to submerge it in a nuclear steam generator which is very limited in space for transducer positioning. The figure 2 shows pressure distribution in a water box. In this figure, we could see that ultrasonic energy does not change rapidly depending on X coordinates. Therefore, we could transfer energy deep into the SG tube bundle without much energy loss through a thin steel plate.

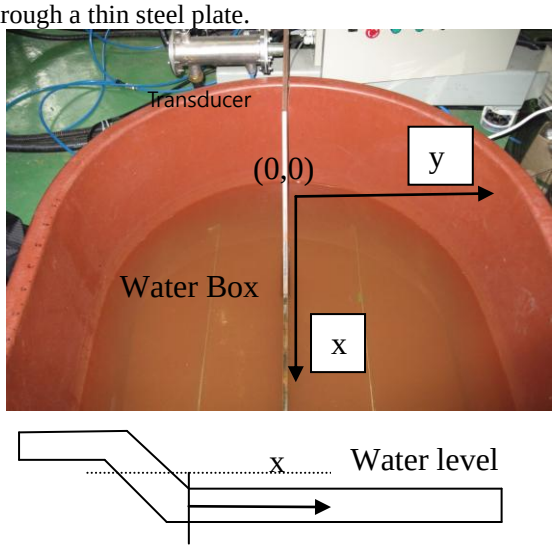


Fig.1 Transmission of Ultrasonic Energy Through Thin Steel Plate

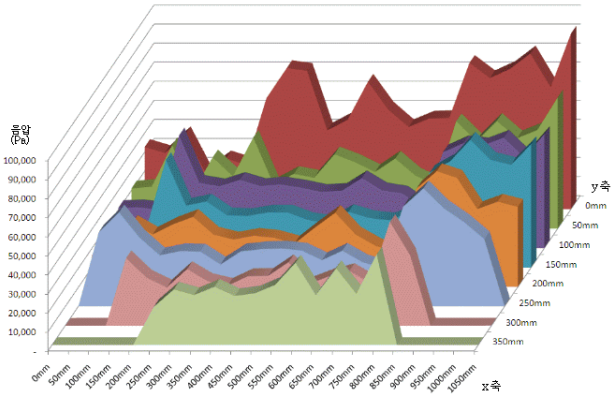
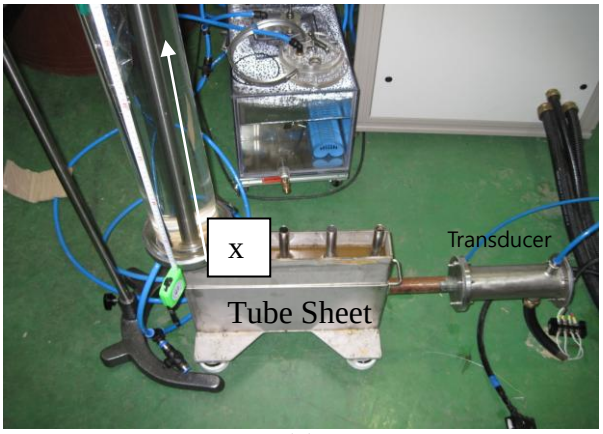


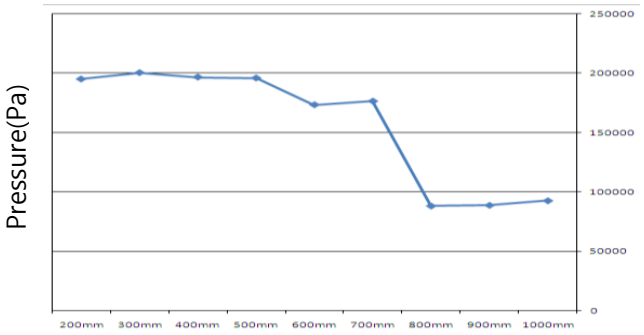
Fig.2 Pressure Distribution in Water Box

2.2 Transmission of Ultrasonic Energy to Upper Bundle

We tried to examine a possibility of transferring energy through SG tubes to upper bundle. As we explained in our previous paper[1], quatrefoil blockage could be easily removed by cabitation if sufficient ultrasonic energy could be transferred to the quatrefoil through SG tube. In the test mockup shown in figure 3(a), a SG tube is rigidly fixed to a simulated tube sheet, and a circular acrylic pipe surrounds the SG tube. Ultrasonic energy was measured in water of the acryl pipe. The energy level at 1,000mm high from the tube sheet is approximately a half of the level at the tube sheet. From the figure 3(b), we could find that ultrasonic energy transferred to the tube decreases rapidly depending on the height of SG tube from the tube sheet.



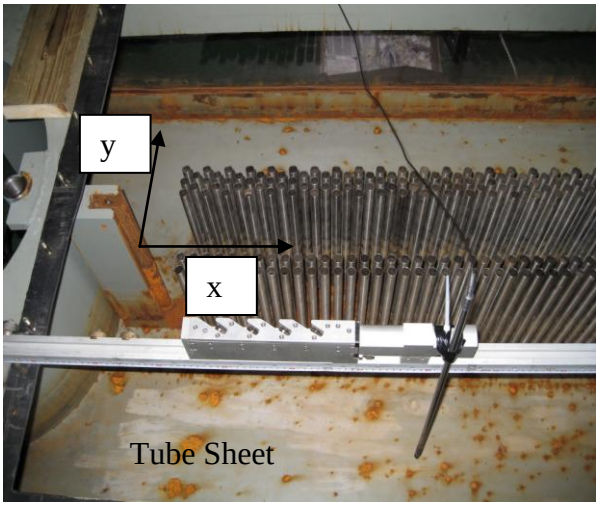
(a)



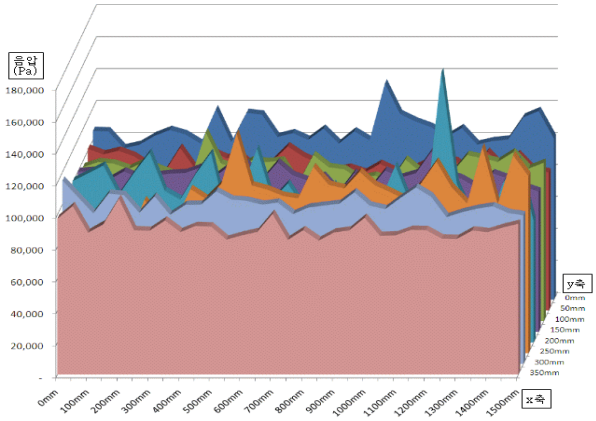
(b)

Fig.3 Transmission of Ultrasonic Energy to Upper Bundle

2.3 Transmission of Ultrasonic Energy to Tube Sheet



(a)



(b)

Fig. 4 Transmission of Ultrasonic Energy to Tube Sheet

Figure 4(a) shows a SG mockup with tube sheet of 500mm thick. We measured ultrasonic energy at various locations above the tube sheet. We used hydrophone of TC4013 which is attached to a linear guide. Water depth was 150mm above the tube sheet. Power output of the magneto-strictive transducer was 1kW.

Figure 4(b) shows ultrasonic energy distribution above the tube sheet. We expected, before the experiments, that the energy may exponentially decrease as the distance from the transducer increases. However, from the figure 4(b), we can say that the energy distribution is not relevant to the distance from the transducer. The tube sheet is made of carbon steel with the same thickness of 500mm as the APR1400 or OPR1000 SGs. Ultrasonic energy applied to the tube sheet does not have any exit for dissipation. Therefore, we assume that encapsulation of the energy made the energy distribution rather uniform in every location. We also can say that the amount of energy is more important than the location and orientation of the ultrasonic transducer.

3. Conclusions

From above 3 experiments on ultrasonic energy transmission, the following conclusions may be made:

Ultrasonic energy could be easily transferred deep into SG bundle through steel plate. Energy level measured at one end near to the transducer and at another end far from the transducer does not show much difference.

Ultrasonic energy measured at the tube sheet is stronger twice than the energy near the tube at 1,000mm away. Energy transfer through the SG tube is possible, but it may not be a good idea because the tube is much longer than 1,000mm.

Energy measurement above SG mockup shows that the profile is rather uniform. We assume it's because energy encapsulation in the tube sheet. For a larger tube sheet, the amount of energy input through the tube sheet is more important than the other factors such as position and direction of each transducer.

REFERENCES

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[2] Woo-tae Jeong, Seok-tae Kim, Dong-ho Shin and Hyun-chul Back, "A Study on Sludge Cleaning of a Nuclear Steam Generator by an Ultrasonic Transducer," Transactions of the Korean Nuclear Society Spring Meeting, Kyeongju, Korea, May 29-30, 2008.

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