Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Development and Application of Ultrasonic Cleaning System in Nuclear Power Industry

Woo-Tae Jeong*, Sang-Guk Lee
KHNP-CRI, 70 1312-gil Yuseongdaero, Yusung-gu, Daejeon, Korea 305-343
**Corresponding author: wtjeong@khnp.co.kr*

1. Introduction

Development of sludge cleaning system for steam generator was completed on December 2013. Initially, the project was started to develop an ultrasonic means for removing sludge deposit in steam generators. However, more steam generators is being replaced or planned to be replaced soon. Increasing cleaning efficiency has become not very important at this stage. Therefore, we studied various fields in nuclear industry where ultrasonic cleaning technology is applicable.

2. Development of Ultrasonic Cleaning System

2.1 Transducer Modification

The ultrasonic transducers, as shown in Fig. 1 (left), were modified to be inserted smoothly on the annulus of SG. Sharp edges of the transducers may cause damage of the tubes of SG. Circular protection caps are attached to both ends of the transducer. Eight wheels were attached to both ends of the transducers. These wheels were made to reduce friction between the transducer and surface of the annulus.

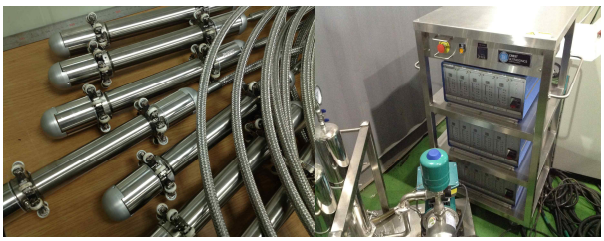

Fig.1 Ultrasonic Transducers (left) and Generators (right)

2.2 Generator Rack Design

One generator module supplies electrical power of 500 watt to each transducer. For removing sludge deposit in PWR steam generators (SG), 12 transducers are recommended. In this case, 6 kilowatts of electrical power are consumed.

We designed a generator rack with three cabinets as shown in Fig. 1 (right). Each cabinet has five generators. Therefore, 15 generators are could supply electrical power to 15 transducers. Generally, only 12 generators are connected to the transducers. Remaining 3 generators are used as a back-up for failure of generators.

24 hour timer is attached to control 15 generators. By adjusting timer, operators can adjust cleaning time. Emergency power off button may be used for immediate power off of all the generators.

2.3 Sludge Processing System

Sludge deposit removed from tube-sheet area of SG is filtered in the sludge processing system. Sludge is separated by ultrasonic transducers on the tube-sheet of SG. Air operated diaphragm pump sends sludge to the 1st tank in sludge processing system. Transfer pump connected to the 1st tank sends sludge to the 2nd tank by way of filtering system. Filtering system is composed of a bag filter and a cartridge filter system. Bag filter system removes 10 microns or larger impurities in sludge. Cartridge filter system removes 1 micron or larger solid particles in sludge.

Pressure gauges are installed at the inlet and the outlet of the bag and the cartridge filtering system. As solid particles accumulates more in filters, pressure drop increases. By calculating pressure drop between the inlet and the outlet, operators can decide whether filters should be replaced or not.

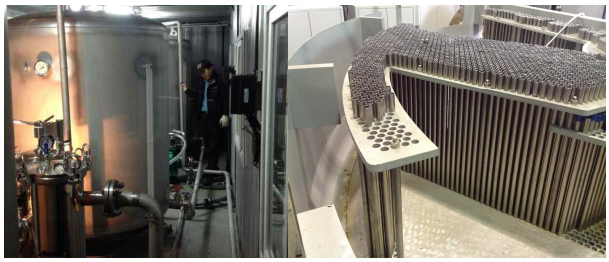

Fig.2 Sludge Processing System (left) and SG Mock-up (right)

Clean water accumulated in the 2nd tank is fed to the 3rd tank by way of a micro-bubble generator. Micro-bubble generator creates numerous micro-bubbles in water. Therefore, the 3rd tank becomes a micro-bubble water reservoir.

Clean water with micro-bubbles in the 3rd tank is transferred to SG by way of transfer pump. When depth of water on SG tube-sheet reaches 100 millimeter or more, we stop water transfer. By switching on the generator rack, we supply energy to the transducers which are already installed on annulus of SG.

Figure 2 (right) shows full scale SG mock-up. Size of mock-up is the same as OPR1000 SG. However, only half of tube-sheet area was designed, and tubes are partly installed to see the effects of ultrasonic cleaning. Six transducers are installed along the annulus area through the hand-hole. We adjusted the location of the transducers by pushing the braided cable attached to the transducers.

3. Application of Ultrasonic Cleaning in Nuclear Industry

3.1 Nuclear Fuel Cleaning

Nuclear fuels in commercial power generating stations are often coated with zinc or other impurities. Zinc ion is added to the coolants in some plants to get uniform axial power generating level. Zinc may be coated on the surface of nuclear fuel. To remove zinc cladding, ultrasonic cleaning system for nuclear fuel was developed in the USA and in Korea.

We developed fuel cleaning system as shown in Figure 3. Ultrasonic transducers are inserted in a vacant cell of a fuel rack. Cavitation generated by the transducers removes cladding on the surface of the surrounding nuclear fuels. Solid particles are filtered by the filtering system as shown. All the procedure is done in water of a spent fuel pool.

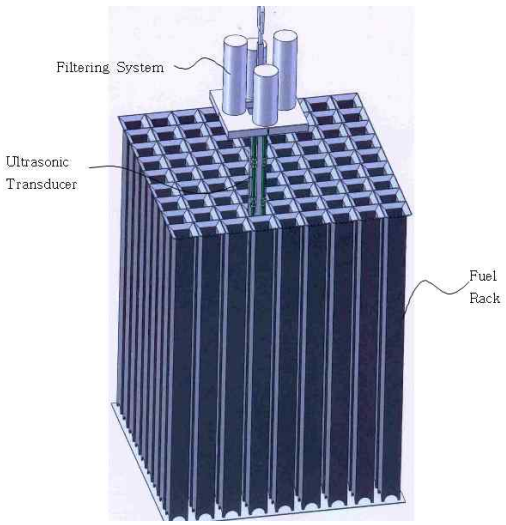

Fig.3 Fuel Cleaning System Developed by KHNP-CRI

3.2 Decommissioning of Power Plant

KHNP-CRI started several projects on 2014 for decommissioning of nuclear power plants in Korea. Highly activated material such as a power reactor is going to be segmented and sent to the disposal site. However, various material which is contaminated only on surface could be cleaned by ultrasonic cleaner similar to the system shown in chapter 2 of this paper. Cleaning chambers in various sizes may be prepared for cleaning of radioactively contaminated parts and assemblies.

Surfaces of the metal parts which are very complex in shape may be effectively cleaned by ultrasonic cavitation in water bath. Contaminated water may be circulated and cleaned by a system similar to the sludge processing system as shown in this paper. Radioactively contaminated solid particles may be removed by the filtering system.

3.3 Decontamination of Equipments

Equipments used in containment vessel (CV) may be radioactively contaminated. These equipments are complicated in shape. Decontamination of the surface is not easy. KHNP is developing an IRWST (Irradiated Water Storage Tank) robot as shown in Figure 4. The IRWST robot visually inspects water filtering system in water. It has several underwater camera and four robotic legs and one arm for visual inspection. Water in IRWST is radioactively contaminated. Therefore, after inspection of the filtering system by the robot, it should be thoroughly cleaned for removing possible radioactive particles in robot arms and body. Cleaning of the robot is not easy because of its complex shape.

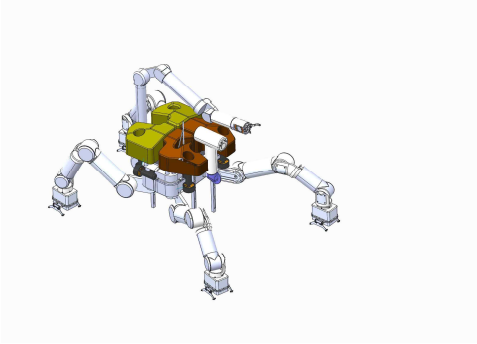

Fig.4 IRWST Robot

We could submerge the robot in water with ultrasonic transducers. By supplying electrical energy to the transducers, we could generate cavation in water. The robot is cleaned by cavition in water. Contaminated water is sent to filtering system of the sludge processing system. Radioactively contaminated particles in water are removed by filters.

4. Conclusions

Development of ultrasonic cleaning system for removing sludge deposit on tube-sheet of SG is completed. Transducers are modified to protect tubes from damage. Sludge processing system is designed to remove solid particles in removed sludge deposit.

Application of ultrasonic cleaning system in three areas including fuel cleaning system, decommissioning system, and decontamination system is suggested. Ultrasonic fuel cleaning system is designed and applied for patent. Application of ultrasonic cleaning system for decommissioning and decontamination of contaminated equipments is under consideration.

REFERENCES

[1] Woo-tae Jeong, KHNP-CRI Internal Report, Development of Ultrasonic Cleaning Technology(II), March 2013.