Search and Retrieval of Foreign Objects for the Steam Generator of Wolsung NPP Unit 1

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1. Introduction

We developed a foreign object search and retrieval (FOSAR) system for Wolsung NPP unit 1 steam generators. The steam generators of Wolsung NPP unit 1 have one 2.5 inch hand hole and two 4 inch hand holes. The FOSAR system was designed to be installed through 4 inch hand holes. Using permanent magnet, the FOSAR system was firmly attached to the vertical annulus wall of the steam generator. However, it was also designed to smoothly move along the wall. In this paper, we will present the novel mechanism and test application of the FOSAR system.

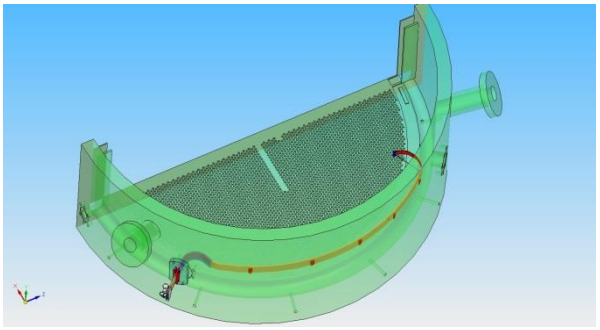

Fig. 1. Steam Generator of Wolsung NPP Unit 1

2. FOSAR system for Visual Inspection

2.1 Development of FOSAR system

Access of the tube sheet area through 2.5 inch hand hole is very limited. Therefore, we designed the FOSAR system to be inserted through the 4 inch hand holes as shown in figure 1.

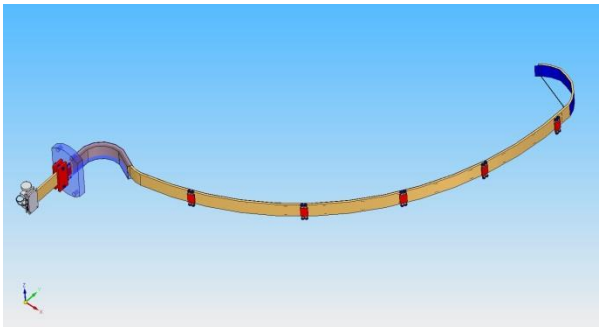

Fig. 2. The Developed FOSAR System

The developed FOSAR system is consisted of two flexible polycarbonate strips, five magnet carts, a wire for controlling the bending radius at the tip, a hand hole mount, and a wire fixture. The two polycarbonate strips are separated by about 6 millimeters for inserting the GE video probe called sword probe. The sword probe looks like a long strip with 2.95 millimeters thick and 3 meters long.

Polycarbonate strips were chosen for its flexibility and high resistance to impact compared to acryl and other plastics. Two polycarbonate strips were assembled by a stainless steel wire. Heating cables were inserted between the two polycarbonate strips. Heating cable was chosen because of its limited flexibility at temperature of about 80℃ in the steam generators.

Two polycarbonate strips were initially assembled using bolts and nuts. The assembled strips were difficult to bend when it is entering the hand hole. Furthermore bending the tip of the assembled strip was also difficult. Therefore we changed assembling method by applying stainless steel wire instead of bolts and nuts.

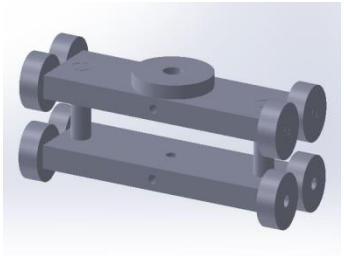

Fig. 3. Magnet Carts for Attaching the Strips to the Wall

Several magnet carts as shown in figure 3 were attached to the assembled polycarbonate strips. Several stainless steel bearings were used for smooth movement along the annulus wall. One permanent magnet was used to make each cart attached to the wall. The surface of the magnet is designed not to directly contact the annulus wall. Therefore the cart could move along the surface of the annulus wall while firmly attached to it. The assembled FOSAR guide is shown in figure 4.

Fig. 4. The Assembled FOSAR System

2.2 Application of FOSAR system

Test operations of the developed FOSAR system was made several times at Wolsung NPP during February and March. Ensco technicians participated in the test operation. The major objective of the test operation was to help the Ensco technicians to understand the developed FOSAR system. Simulated foreign object such as a stainless steel screw was intentionally placed deep into the tube bundle. Ensco technicians showed their ability to pick it up and remove it using an alligator tool.

Actual application of the developed FOSAR system was started on the 6th of March 2016. All four steam generators were visually inspected and foreign objects were successfully removed. Figure 5 shows mock-up test of the developed FOSAR system.

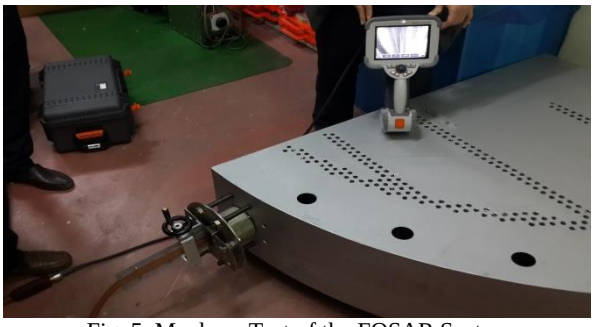

Fig. 5. Mock-up Test of the FOSAR System

Figure 6 shows 2.5 inch and 4 inch hand holes of unit #1 steam generator of Wolsung NPP. The hand-hole mount is designed to be firmly attached to the 4 inch hand hole using two bolts after removing hand-hole cover shown in the figure.

Fig. 6. Steam Generator Hand Holes

After installing the hand-hole mount, the assembled FOSAR system as shown in figure 4 is inserted through the rectangular opening of the hand-hole mount. When the permanent magnet of the assembled FOSAR system contacts the annulus wall of the steam generator, it becomes firmly attached to the wall. However the assembled FOSAR system could maneuver along the surface of the annulus wall as the surface of the magnet does not directly contact with the annulus wall.

The next stage is to insert the sword probe through the gap of the assembled FOSAR system. As the surface of the sword probe is made of urethane, it was easily inserted through the gap of the assembled FOSAR system and the tube bundle of the steam generator.

We attached stainless steel spring to the top surface of the sword probe. The spring is 3 meters long, and 3 millimeters in inside diameter. Through the 3 millimeter hole of the spring, commercially available FOSAR tools could be deployed.

Some of the in-bundle area on the top of tube-sheet was not accessible by the developed FOSAR system. It is because of the wrapper located between the tube bundle and the annulus wall.

Magnet tool was the most useful means for removing metal sheets. Just by approaching the metallic objects, the objects were automatically attached to the tool without any further gripping action. Furthermore it was not necessary to maintain gripped status. Alligator tool was the second useful tool. However it was a little more time consuming to grip the foreign objects.

Figure 7 shows monitor screen displayed during the FOSAR service at Wolsung. Most of the in-bundle area was relatively clean considering no cleaning of the tube-sheet area was made before the inspection. However, insertion of the sword probe was sometimes impossible because of sludge and scale. Generally FOSAR activities are followed by lancing. Most sludge and scales are removed by lancing.

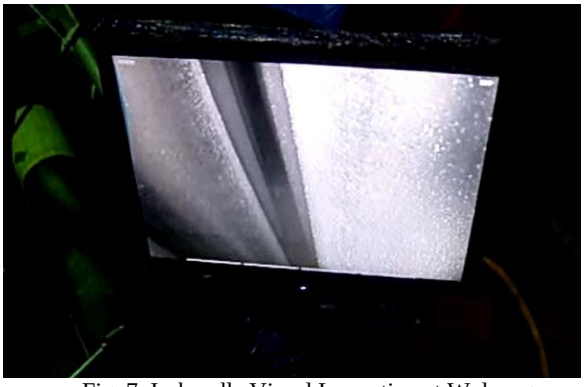

Fig. 7. In-bundle Visual Inspection at Wolsong

3. Conclusions

We successfully developed the FOSAR system for Wolsung NPP unit 1. Using the developed FOSAR system, technicians successfully found and removed various foreign objects. Most of the foreign objects, we found, were made of carbon steel sheet, therefore magnet tool was the most useful to remove it. Alligator tool was sometimes used.

Based on the experience during the FOSAR activities, we are developing a lancing system for Wolsung NPP unit 1. It will be designed and manufactured until November 2016. After several months of test and modification, it will be applied for lancing and FOSAR on June 2017.

REFERENCES

[1] Woo-tae Jeong et al, Development of Robot System for Removal and Inspection of Hard Deposit in Steam Generator, KHNP internal report, 2016