Visual Inspection of the Flow Distribution Plate of a Steam Generator

Woo-tae Jeong [a*], Seok-tae Kim [a], Seok-chul Kang [b], Young-kug Kim [b]
[a] *Korea Electric Power Research Institute, Nuclear Power Lab., 103-16 Munji-dong, Yusung-gu, Daejeon, Korea 305-380*
[b] *Sae-An Engineering Corporation, Rm910, Byucksan Digital Valley II, 481-10, Gasan-dong, Geumcheon-gu, Seoul, Korea 153-803*
[*] *Corresponding author: a39leb@kepco.co.kr*

1. Introduction

An equipment for visually inspecting the joining bolts of the flow distribution plates (FDP) of the OPR1000 steam generators(S/G) has been developed and tested at S/G Lancing Test Center of KEPRI (Korea Electric Power Research Institute). The positioning subassembly is designed to be attached to the flange of man-way by two 1.5 inch diameter bolts as shown in Fig 1. The probe guide subassembly is inserted through the man-way on the positioning subassembly. Finally, a quartz video-probe is inserted through the guide subassembly for visual inspection of the FDP bolts.

2. System Design and Application

2.1 Visual Inspection of Flow Distribution Plate

High speed upward flow at the central cavity region of the OPR1000 S/Gs often caused flow induced vibration (FIV). Wear of the S/G tubes or the egg-crates was observed at several S/Gs. The FDP was designed and installed in the central cavity area to minimize FIV. The FDP, which is a circular plate with many holes on it, is fixed to a rim of the egg-crate by the joining bolts. The Korean Institute of Nuclear Safety (KINS) recommended regular inspection of FDP joining bolts during plant outage. Therefore, we started a project for developing a system for visual inspection of the FDP bolts.

The visual inspection system we developed is composed of two separate subassemblies. The positioning subassembly, as shown in Fig. 1, moves probe guide subassembly from left to right or from right to left. The probe guide subassembly, which is not shown in Fig 1, is composed of rectangular plates having five through holes.

2.2 Positioning Subassembly

The Positioning Subassembly is similar to X-Y table. Four horizontal LM guides are used for X and Y locomotion. A ball screw is used for X position adjustment. Two mechanical breaks are installed for locking Y locomotion and setting the probe guide subassembly to appropriate position. A device for Y locomotion enables easy installation of the probe guide subassembly. The positioning subassembly is designed to be fixed to the S/G by two 1.5 inch aluminum bolts.

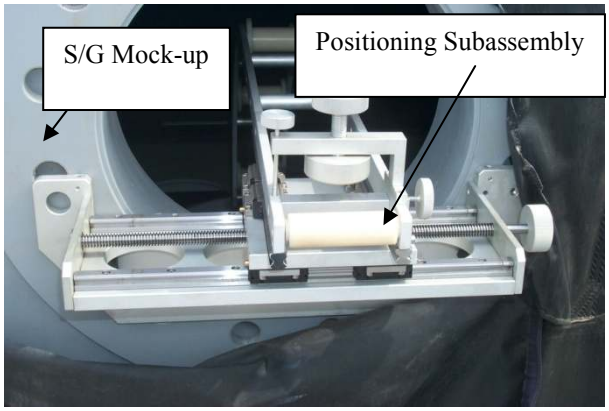

Fig. 1. Positioning Subassembly Installed to S/G Mock-up

2.3 Probe Guide Subassembly

A probe guide subassembly provides a means to guide a video-probe of endoscope to the FDP bolts to be inspected. It is composed of 65 ABS polymer plates of 100mm long, 42mm wide, and 14mm thick. Each ABS polymer plate is linked together making a 6.5meters long flexible bar. ABS polymer is selected because it is resistant to impact at low temperature.

The probe guide subassembly, which is attached to the positioning subassembly, is inserted through the man-way of nuclear S/G. After the insertion, the probe guide subassembly is bent 90 degrees downward the S/G.

When the tip of the probe guide subassembly reaches to the level of the FDP to be inspected, we apply tension on the stainless wire to change the direction of the tip. The tip is made up of nine segments having hinge mechanism. Nine segments are linked by hinges and pins. Assembled nine segments could be controlled by two stainless steel wires. Tension on the steel wires makes the assembled segments bent 90 degrees toward the FDP.

2.4 Video Probe

Several industrial endoscopes are tested for the application to the visual inspection. Quartz video-probes of Olympus IPLEX-SXII-R and Everest XLG3 are tested. Both endoscopes satisfies our requirements, however, we selected Everest XLG3. It gives us brighter and more detailed image of the bolts to be inspected. Another factor we considered was

performance of articulation of the probe tip. Response of the XLG3 was faster, and it was easier to operate for our application.

2.5 Visual Inspection of FDP Bolts

We tried simulated visual inspection using the S/G mock-up which we developed in 2008 and the newly developed equipment. S/G mockup was designed exactly the same as the actual OPR1000 S/Gs. However, the egg-crate is simplified in its design to minimize manufacturing cost. The FDP was newly designed and installed. Dimension and shape is the same as the actual FDP.

Figure 2 shows the probe guide subassembly installed in S/G mock-up. The probe guide subassembly was inserted through the gap of 19 mm between the egg-crate rim and the wrapper of the S/G. As actual visual inspection is made in completely dark environment, it is very important to prove that inspection is possible in complete darkness.

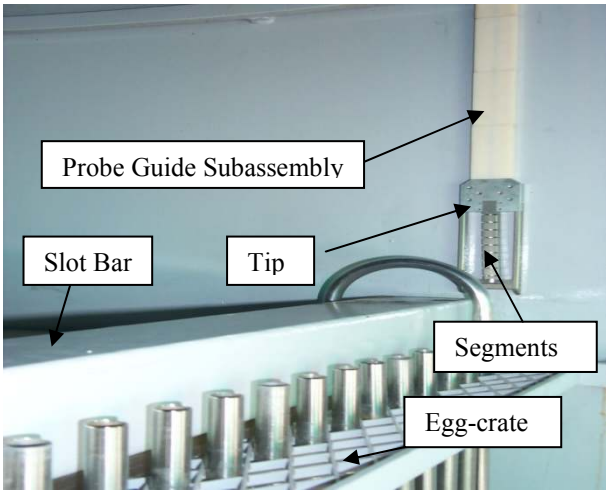

Fig. 2. A Probe Guide Subassembly Installed in S/G Mock-up

When the tip of the probe guide subassembly reaches the level of the egg-crate, we pull stainless wires connected to the segments to change its direction from its initial position as shown in Figure 2 to the center of FDP. The end of the segments are inserted between the slot bar and S/G tubes. At this position, we inserted the video-probe through the hole in the probe guide subassembly. The probe moves along the hole of probe guide subassembly, and reaches the egg-crate. Further pushing the video-probe makes it reach the FDP. However, before the video-probe moves to the FDP, it should go over an elevated place of 19 mm in height as shown in Figure 3. By using the articulation of the endoscope, we move the tip of the video probe to direct upward and push the video-probe to climb the place. Finally, the probe reaches the FDP. We use the articulation again to visually inspect FDP bolts. After inspecting left or right half of the FDP bolts, we remove the video-probe and change the location of the probe guide subassembly for inspection of the remaining half.

Upper FDP bolts are could be inspected by the above mentioned procedure. However, we should inspect lower FDP bolts by inserting the video-probe into the FDP holes as shown in Figure 3. We insert the video-probe to the center of the FDP, and let the video-probe direct downward. By pulling the video-probe slowly, we could see whether the probe tip is in the FDP hole or not. When the tip is located in the FDP hole, pushing the video-probe slowly makes it enter the hole. Therefore the lower FDP bolts could be inspected from the upper FDP holes.

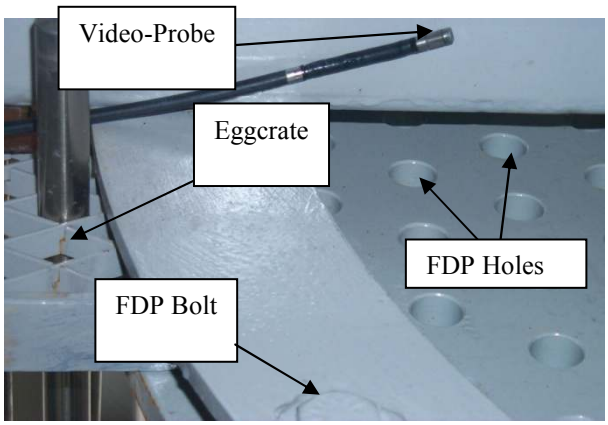

Fig. 3. A Probe Guide Approaching the FDP

3. Conclusions

We successfully developed and tested a visual inspection system for FDP bolts of OPR1000 S/G. After several months of optimization, the finalized inspection system is going to be delivered to KHNP Ulchin NPP#3 in this year. The developed system could be used for inspecting not only FDP bolts but also other various internal components of S/G.

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