A Visual Inspection System for the Flow Distribution Plates of the OPR1000 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, a39leb@kepco.co.kr*
[b] *Sae-An Engineering Corporation, Rm910, Byucksan Digital Valley II, 481-10, Gasan-dong, Geumcheon-gu, Seoul, Korea 153-803, kangsc@sae-an.co.kr*

1. Introduction

The OPR1000 steam generators(S/G) of Ulchin Nuclear Power Plant #3 have the flow distribution plates (FDP) attached to the egg-crates by the joining bolts (FDP bolts). The newly designed FDP has to be visually inspected to check the possible damage or loss of the joining bolts. After reviewing the relevant drawings and checking the actual location of the bolts using the similar S/Gs which were being built at Doo-san Heavy Industries, we decided that the FDP bolts could be visually inspected by using a specially designed guide and a video probe. Therefore, we developed a visual inspection system for inspecting the FDP bolts using a guide and a video probe. Finally, we evaluated the feasibility of hot application using the S/G mock-up at Korea Electric Power Research Institute (KEPRI).

2. Design and Test

In this section, a description of the FDP was made to introduce the reason why we started this project. The developed inspection system was reviewed and feasibility test was summarized.

2.1 Flow Distribution Plate

It's empty in the central cavity region of the OPR1000 S/G. High speed upward flow of the secondary coolants often caused vibration of the U-shaped tubes which is called flow induced vibration (FIV). FIV often causes wear of the S/G tubes or the egg-crates. To minimize FIV, the FDP was designed and installed in the central cavity area. The FDP is a circular plate with many holes on it. It is fixed to an inner rim of the egg-crate by the joining bolts. The Korean Institute of Nuclear Safety (KINS) was worried about the possible failure of the bolts, and recommended to inspect it regularly during plant outage. Therefore, we started a study to develop a special tool or system to visually inspect the FDP bolts.

2.2 Probe Guider

A probe guider is designed to enable visual inspection of the FDP bolts. It's 10 meters long, 10cm wide, and 10mm thick Teflon strip. Teflon is selected because it is flexible and easy to make the shape we want. A probe guider is inserted through the man-way of nuclear S/G. The probe guider is bent toward the bottom of the S/G as shown in fig.1. When the tip of the probe guider reaches at the level of the FDP, tensioning on the stainless wire makes the direction of the tip toward the FDP. After the installation of the probe guider, a video-probe is inserted through the hole on the probe guider to the FDP. The probe guider is made up of 6 separate segments. Therefore, we should assemble those segments when we install it into the S/G. Assembling each segments using screw driver was not easy and time consuming. Modification should be considered for easier installation.

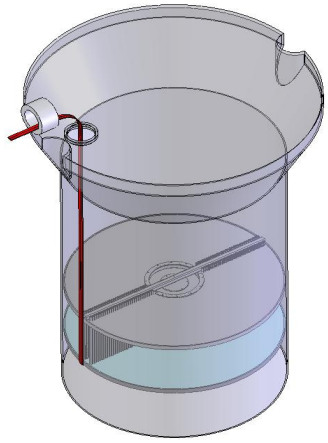

Fig. 1. The probe guider inserted through the man-way and a hole on the wrapper of the S/G

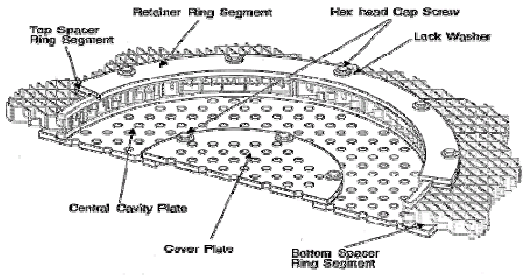

Fig. 2. FDP attached to the egg-crate by joining bolts (we called it FDP bolts and designated as Hex Head Cap Screw above)

2.3 Video Probe

A quartz video-probe of Olympus IPLEX-SXII-R is selected to maintain its performance in gamma-ray

environment during hot application for more than 10 times. Based on our measurement of radiation level at the FDP, we decided that the ordinary video-probe is too weak to be used in the S/G. The brightness at the probe tip may be reduced to almost a half after several hot applications. We also considered of using a video-probe which uses LED as a light source. However, after several test, we decided that it was not bright enough to be used for our application.

2.4 Steam Generator Mock-up

The S/G mock-up is manufactured to check feasibility of our inspection system. Secondary man-way and other important structures are designed exactly the same as the actual OPR1000 S/Gs. However, the egg-crate and the FDP are simplified in their design to minimize manufacturing cost as shown in fig. 3. The whole S/G mock-up is wrapped with a thick cover to make inside dark as the actual 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.

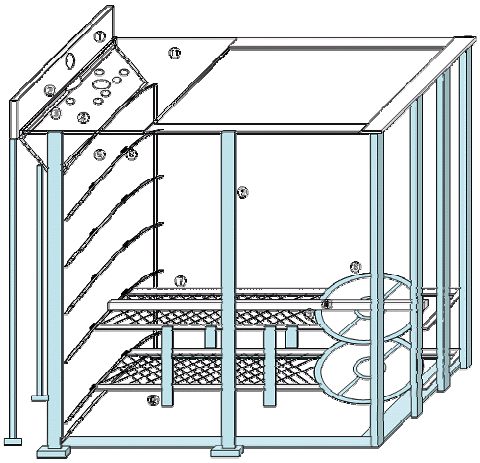

Fig. 3. S/G mock-up to check feasibility of the inspection system

2.5 Feasibility Test

Using the probe guider, the video-probe and the S/G mock-up, we tried visual inspection of the FDP bolts. As the diameter of the FDP is about 90 cm, we inspected FDP bolts at the location of 90 cm away from the video probe tip. From this experiment, we could visually inspect the bolts even though it is completely dark.

As is shown in fig. 3, we have two FDPs to be inspected. Upper FDP was easier to inspect than the lower FDP, because the narrow gap between the rectangular pipe on the egg-crate and the S/G tubes becomes a guide for the video-probe.

The rectangular structure of the egg-crate often made it difficult for the video-probe to proceed toward the FDP. The operator is 10 meters away from the FDPs, therefore, it was not easy to make the probe tip direct upward.

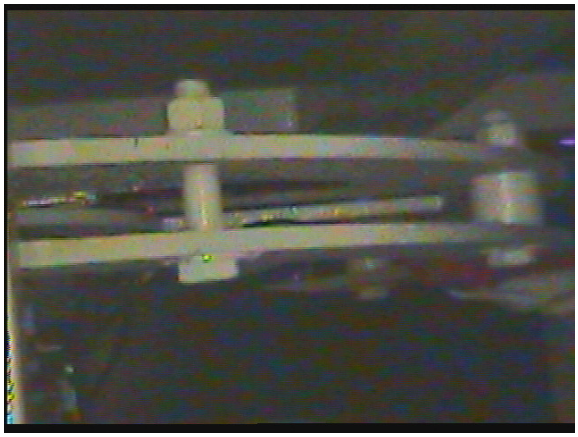

Fig. 4. An image by the video-probe showing the S/G bolts

2.6 Future Work

Installing the probe guider through the S/G man-way was time consuming. Modification of the probe guider design should be considered to minimize installation time. Probe guider is made of 6 segments of 1.5 meters long, and each segment is joined together when it is installed. Making the segmented probe guider as a single body should be considered to minimize installation time and make it easier to handle.

3. Conclusions

The visual inspection system we developed had shown that it could be used for S/G bolt inspection. However, several modifications in its design should be considered for easier handling and inspection.

REFERENCES

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