Development of Advanced Defect Sizing Technique using Ultrasonic Testing for Nozzle Welding

ABSTRACT

In Japan, the preventive maintenance task of the 600 series nickel basis alloy weld of the reactor vessel (RV) and the steam generator (S/G) safe end weld are pushed forward sequentially, and a defect sizing using the ultrasonic testing (UT) from the inside of the safe end is carried out when the defect was detected by surface inspection prior to the work. Some defects are recognized on the S/G safe end and the RV safe end in Japan, and these defects have occurred in the axial direction of the safe end weld. Therefore the defect sizing by UT arranges a probe on the direct top of the welding and inspects it, and the attenuation of the ultrasonic wave by the welding and influence of being scattered are big, so advanced defect sizing technique for these area is required.

This report shows the development status that aimed at the advancement of the sizing technique from the inside for the safe end weld. We have developed the advanced technique using phased array UT and planned improvement of the sizing accuracy. The UT simulation technology also applied to probe development, and the optimization of the design parameter has been performed. We will apply the developed technology and carry forward safe end maintenance work in future.”

BACKGROUND

In Japan, inspections of nickel alloy components (Ally 600) such as a safe-end of S/G and R/V are enforced from 2007. Some axial defects were detected in the dissimilar metal welding (DMW) of S/G safe-end by ECT. Depth sizing by a conventional UT have been conducted for these defects, and the good accuracy of defect sizing are achieved.

In 2008, a defect was detected by ECT in DMW of R/V safe-end at KEPCO Ohi unit3. We tried the depth sizing by a conventional UT, but we could not detect the tip echo, so depth sizing of the defect was not carried out. By consecutive surface grindings in order to remove the defect, it has become clear that the depth of the defect is about 20mm. The profile of the defect is so different from defects in S/G safe end. The length of the defect and the tip is shorter than other defects. We consider that that is the reason why we could not detect the tip echo. Therefore, it is necessary to develop the advanced sizing technique with high detectability of the tip echo.
Sizing Technique

We have introduced the following targets as a sizing technique to the surface breaking defects in DMW of safe-end.

- For the general profile SCC detected at S/G safe-end, the target is Improvement of the sizing accuracy.
- For the special profile SCC at R/V safe-end such as the length of the defect and the tip is short, the target is the achieving the defect sizing with detection of tip echo.

Sizing technique have been developed based on the Phased-array UT. For covering 40mm depth area, following two kinds of the probes are developed for different depth areas.

- For shallow area: The small TRL PA has been applied for the defect sizing from the surface to a shallow area (up to 10mm).
- For deep area: The TRL Matrix PA has been applied for the improvement of the beam focusing (point focus beam) and 3D beam scanning to correspond to the influence of the ultrasonic refraction in the welding.

Figure 4 shows the image of two kinds of PA technique. Table 1 shows the probe specification of these PA techniques, and Figure 5 also shows these probes overview.
We have prepared the two kings of test blocks including a mock-up and planar test blocks. Some notches have been inserted in the DMW of the mock-up. Some SCC has been inserted in the welding area of plane test blocks. SCC profile of planar test blocks is general shape and is not special that D/L is less than 1.
Sizing test

Test results for shallow notches and SCCs are shown in figure 7. The sizing of the notch with 5mm depth was overestimated by the conventional probe, but the small TRL PA probe achieved sizing precision less than 1mm. There was not the significant difference in sizing precision between the conventional probe and the small TRL PA probe for the SCC with 2.6mm depth, but the small PA probe was 2 times higher than the conventional probe in the S/N ratio for the tip echo.

Test results for deep notches are shown in figure 8. The conventional prove had good sizing precision to 20mm depth, and sizing was difficult at 40mm depth. But TRL matrix PA probe achieved sizing precision less than 1mm even at 40mm depth.

Test results for deep SCC are shown in figure 9. The sizing precision of the conventional probe was less than 5mm, but that of the TRL matrix PA was less than 1mm.

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<th>Conventional UT</th>
<th>Small TRL PA-UT</th>
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<tr>
<td><strong>Notch 5mm depth</strong></td>
<td><img src="image" alt="Evaluation: 6.5mm" /></td>
<td><img src="image" alt="Evaluation: 4.3mm" /></td>
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<tr>
<td><strong>SCC 2.6mm depth</strong> (planned value)</td>
<td><img src="image" alt="Evaluation: 2.8mm S/N ratio: 3.6" /></td>
<td><img src="image" alt="Evaluation: 2.7mm S/N ratio: 6.8" /></td>
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Figure 7 - Test result for shallow notch and SCC
We have evaluated effectiveness of the developed technique for the special defect with short length of the tip such as the defect in Ohi unit 3 by using UT simulation technique. It is confirmed that clear tip echo is detected with the matrix PA compared to the conventional probe, and sizing will be realized with the TRL matrix PA. It seems that the ultrasonic beam is focused by the matrix PA, so the identification of the tip echo from other noise signals becomes possible.
CONCLUSION

We have developed the UT techniques for the depth sizing of the axial defect detected in DMW of both S/G and R/V safe-end. We have developed two kinds of the probes for different depth areas. One is the small TRL PA probe for shallow defects about up to 10 mm, and another is TRL matrix PA probe for deep defects about up to 40 mm. It is confirmed that the developed technique has the higher sizing precision than the conventional technique for defects with general profile detected at S/G safe-end. It is also confirmed that the developed technique will be effective for the special defect at R/V safe-end in Ohi unit 3 by UT simulation. We are trying to make SCCs simulating the special defect at R/V safe-end in Ohi unit 3 and we will verify the developed UT technique experimentally. We consider that the developed UT technique contributes to the safety and reliability of nuclear power plants.

Figure 10 - UT simulation results

Figure 11 - Beam focusing image
REFERENCE

1) K. Kono, M. Otaka, H. Miharada, “Proceedings of the Fifth International Conference on NDE in Relation to structural Integrity for Nuclear and Pressurised Components”, Detectability and Sizing Capability of UT to SCC in Nickel Based Alloy Welded Joint, Budapest, 2007