Performance Demonstration Examination of IGSCC Depth Sizing by UT in Japan
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ABSTRACT
The PD Center at the Central Research Institute of Electric Power Industry (CRIEPI) commenced Performance Demonstration examinations for flaw depth sizing of austenitic stainless steel pipes in March 2006. As of March, 2009, 23 examination courses have been completed and 27 out of 38 candidates passed the examination. The test results show that candidate’s UT skill could be advanced for SCC depth sizing.

INTRODUCTION
In June 2005, the Japanese Performance Demonstration standard NDIS 0603 “Qualification and certification of personnel for performance demonstration of ultrasonic test systems” was issued by the Japanese Society for Non-destructive Inspection (JSNDI). The Central Research Institute of Electric Power Industry (CRIEPI) established a “PD Center” to fill the role of the authorized PD qualifying body and PD examination center for the Japanese PD system on November 1, 2005 [1]. March 2006 saw the start of PD examinations for depth sizing of austenitic stainless steel pipes in Japan.

This paper describes the current status of PD for intergranular stress corrosion cracking (IGSCC) depth sizing by ultrasonic testing (UT) in Japan and the performance of candidates in the examination.

PD QUALIFICATION EXAMINATION
Although the Japanese PD standard NDIS 0603 is basically similar to the ASME Code Section XI, Appendix VIII, certain adaptations have been made to reflect our findings on IGSCC in the 316L stainless steel piping weld. The following is an outline of the Japanese PD qualification examination. The qualification test specimens are butt welded austenitic pipes with artificially introduced IGSCC. The minimum number of IGSCC must be ten. Table 1 shows the nominal diameter and wall thickness of the test specimens. 10 IGSCCs, with the three different pipe sizes as shown in Table 1, must be tested.

<table>
<thead>
<tr>
<th>Nominal diameter (mm)</th>
<th>Wall thickness (mm)</th>
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<tbody>
<tr>
<td>600</td>
<td>35</td>
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<tr>
<td>350</td>
<td>25</td>
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<td>150</td>
<td>10</td>
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Table 1 - Nominal diameter and wall thickness of the test specimens

Cracks in the depth sizing sample set are to be distributed according to the specifications in Table 2. The remaining IGSCCs can be in any of the categories. Moreover, at least one IGSCC should be deeper than 15mm, and the tip of one IGSCC should penetrate into the weld material.
Flaw depth $h$ (% wall thickness) & Minimum number of flaws \\
0 < $h$ ≤ 30 & 2 \\
30 < $h$ ≤ 60 & 2 \\
60 < $h$ < 100 & 2 \\

Table 2 - Specification for distribution of the flaw depth

The acceptance criteria are as follows:
1) The RMS (Root Mean Square) error of the flaw depths estimated by UT shall not exceed 3.2mm as compared with the true depth.
2) No flaw depth estimated by UT shall be underestimated by more than 4.4mm, compared with the true depth.

When a candidate fails in the PD examination, he/she must wait 30 days before taking a re-test unless having been able to pass training at the PD training center.

TEST RESULTS

The 1st PD qualification examination was held in March 2006, and operated by the CRIEPI PD Center. As of March 2009, 23 examination courses have been completed and 27 out of 38 candidates passed the examination as shown in Table 3. The total number of candidates including re-tests is 63.

Figure 1 shows the relationship between the RMSE and the average scan time per sample of all candidates. The RMSEs for passed candidates after the 5th period range between 1.5 to 2.5mm, with only one candidate achieving RMSE of more than 5 mm, despite the large number of candidates during the 1st and 4th period. This result suggests that the UT skill could be advanced for SCC depth sizing.

![Figure 1 - Plot of RMSE as a function of the averaged examination time per sample for all candidates.](chart1)

○ and × indicate the RMSE values for candidates having passed and failed, respectively.

Figure 2 shows a plot of RMSE as a function of the average measurement error for all candidates. The average measurement errors are within a band of plus or minus 1 mm for candidates having passed the examination. This result suggests that the personnel who were qualified at the PD examination measured the IGSCC depth accurately by UT. In addition, the average measurement errors are also within a band of plus or minus 1 mm for almost all candidates having failed the examination after the
5th period. Figure 2 also indicates that many candidates failed with RMSE exceeding 3.2 mm and averaged errors exceeding 2 mm during the 1st and 4th period. These candidates were unable to distinguish the crack tip echo from the echo of the weld to the base-metal interface [2]. Conversely, none of the average error for the candidates after the 5th period is exceeding 2 mm. These results suggest that candidates could distinguish the crack tip echo from the weld to base-metal interface echo and that the UT skill for SCC depth sizing could be improved overall after the 5th period.

Figure 3 shows the UT methods used by the candidates. As for the technique, almost all candidates applied the tip diffraction technique. As shown, more than half the candidates used a combination of the conventional UT method and an encoder-equipped phased array (PA) system; a combination which achieved the best examination pass ratio. Since they consider the test results from the combination conventional UT and PA together, it seems that they capitalize on the strengths of each method for SCC depth sizing.

![Figure 2 - Plot of RMSE as a function of the average measurement error for all candidates. ○ indicates candidates having passed and ×those having failed.](image)

![Figure 3 - UT methods used by candidates. (■:conventional UT and PA, ■:conventional UT, ■:PA and ■:other)](image)

Figure 4 shows the RMSE ratio between first try and re-try of candidate having passed and failed in the Re-test. As shown in Fig. 4, their RMSEs of candidates having passed the re-test drastically improve. It seems that they had effective training and adjusted their UT skills better at the PD training centers or the companies to which they belonged.

Figure 5 shows the candidate age distribution counting on April 1st, 2009. The decreasing NDE workforce is a major issue on a worldwide scale [3]. However, there are many personnel who are of the younger generation as seen in Fig. 6, contrary to our expectations.
In 2006, an IGSCC was detected in the PLR piping at the Kashiwazaki-Kariwa Unit 3 operated by the Tokyo Electric Power Company (TEPCO) [4]. The IGSCC depth was determined by the PD certified personnel and the crack growth behavior was assessed based on the fitness-for-service (FFS) code. In July 2006, the Japanese regulatory agency reviewed the flaw evaluation report and accepted it as the first application of the FFS code for plant operation renewal. After one year of continuous operation, TEPCO removed that weld part and carried out a destructive test, with the results shown in Table 4. The UT results measured by a PD certified inspector is very close to the depth of destructive test. This result shows that the accuracy of UT depth measurement achieved by a PD certified inspector is high. In addition, this result indicates that our SCC specimens can simulate the actual SCC observed in piping of nuclear power plants.
SUMMARY

As of March 2009, 27 personnel were qualified for the crack depth sizing of austenitic stainless steel piping welds of Japanese PD.

The test results show that the candidate’s UT skill could be advanced for SCC depth sizing. More than half the candidates used a combination of the conventional UT method and encoder-equipped Phased array (PA) system; combination, which was seen to achieve the best examination pass ratio.

REFERENCES

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