International Round-Robin Test Results for Dissimilar Metal Weld (DMW)

Sung-Sik Kang, Kyung-Jo Kim, Hae-Dong Jung
Korea Institute of Nuclear Safety, P.O. Box 114, Yuseong, Daejeon, Korea , sskang@kins.re.kr

1. Introduction

In nuclear power plant, there are many joints to connect pipes, nozzles and structural components. Most of them are welding joint, and it may be a weak point for leakage and cracks. Some cracks were found in dissimilar metal welds (DMW), which are connected with major components of nuclear power plants. Usually, the dissimilar metal welds are consisted of Alloy 600, carbon steel and stainless steel. Since 2000s, most of the cracks are found in welds, especially dissimilar metal welds such as pressurizer safety relief nozzle, reactor head penetration, reactor bottom mounted instrumentation (BMI), and reactor nozzles. Since the cracks are revealed as a primary water stress corrosion cracking (PWSCC), the reliability of non destructive evaluation (NDE) technique becomes more important.

To cope with the NDE reliability, PINC (program for inspection of nickel alloy components) international cooperation was organized. The aim of the project was 1) to fabricate representative NDE mock-ups with flaws to simulate PWSCCs, 2) to identify and quantitatively assess NDE methods for accurately detecting, sizing and characterizing PWSCCs, 3) to document the range of locations and morphologies of PWSCCs and 4) to incorporate results with other results of ongoing PWSCC research programs, as appropriate.

In this study, as part of the PINC project, international RRT (round robin test) results for DMW will be introduced.

2. PINC project

PINC group was organized by three task groups. Task group 1 is Morphology Atlas (TG-Atlas) group. Task group 2 is NDE Technology Assessment (TG-NDE) group. Task group 3 is Data Analysis group (DAG).

Morphology Atlas (TG-Atlas) group aims 1) to compile existing work on crack morphology of PWSCC, 2) to correlate with NDE data, when available, 3) to develop an electronic Atlas (database) of NDE and metallographic information and 4) to perform new NDE, fractography, and metallography.

NDE Technology Assessment (TG-NDE) group aims 1) to perform Round Robin Test (RRT) of NDE techniques on PWSCC and simulated cracks, 2) to apply techniques to detect and size cracks, 3) to assess techniques to manufacture test blocks, 4) to survey relevant materials and geometries, and 5) to integrate findings of regulatory application and process qualification.

Data Analysis group (DAG) aims 1) to analyze the procedures, 2) to analyze and characterize the flaws and 3) perform the regression analysis. All organizations were involved in DAG.

In the PINC program, KINS is a main contractor and participant organizations of Korea are KAERI (Korea Atomic Energy Research Institute), SNU (Seoul National University), SKKU (SungKyunKwan University) and 5 inspection companies including KPS (Korea Plant Service and Engineering) and Doosan Heavy Industries. We have already presented the status of PINC program at the KNS 2008 autumn meeting. Recent status of PINC program will be also introduced in this study.

3. Round Robin Test

For the international NDE round robin test, we used 8 test blocks (6 from JNES – Japan Nuclear Energy Safety Organization, and 2 from SKi – Swedish Radiation Safety Authority). The test blocks have mid thickness DMW, wall thickness range 4.1 to 4.7 cm. Totally 25 flaws are in 8 test blocks, and total length of weld to be inspected is about 4 meters.

Sixteen teams participated in the PINC dissimilar metal weld round robin. The team asked for 2 weeks to conduct the inspections. So, in a 3-month period it is possible to have 5 teams inspect the test block and still allow 2 weeks for shipping the test blocks to the next country. The RRT began with the Japanese teams conducting their inspections followed by one European team. Next, the Korean teams conducted their inspections, followed by three more European teams.

Fig. 1 shows one of the test blocks and coordinate system.

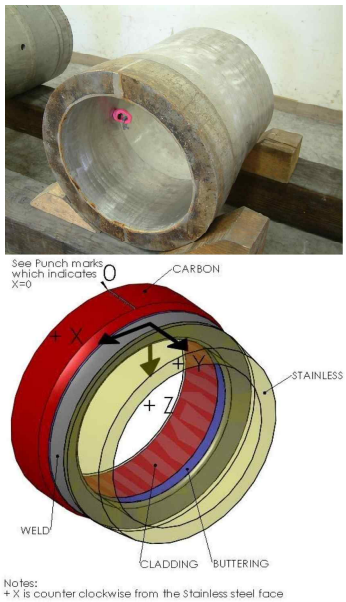


Fig. 1. One of the test blocks and coodinate system

The teams conducting the DMW examinations used a wide mix of nondestructive techniques, ranging from standard methods such as conventional ultrasonic inspection to experimental techniques such as potential drop. As there was a wide variety in techniques and the application of those techniques, comparing the effectiveness of the individual techniques would result in a very complex matrix. In this study, we will discuss the effectiveness and difficulties.

Through a scoring procedure, detection and sizing results table and false call table was made and POD (probability of detection) also. Fig. 2 shows the indication associated with the detection as an example. The test block contains 12 flaws used for scoring (shown in red) and 2 poorly documented flaws that were not intentionally placed in the test block for the PINC studies but still are detectable (shown in blue). When the intersections between the called indications and the actual flaw locations are compared, one can determine how well the team performed.

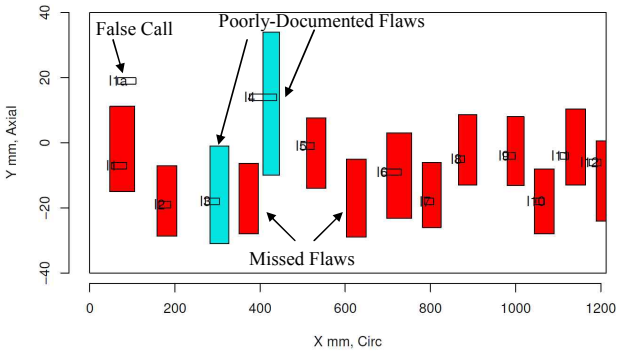


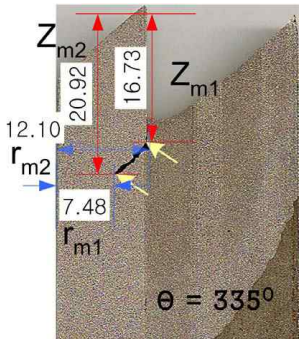
Fig. 2. Example of scoring inspection results

Now the USNRC is processing to issue a NUREG report for PINC results. Since the final report does not published yet, we are going to present the result of Korea side as soon as possible in this meeting.

4. Destructive Analysis

To see the crack morphology and check the NDE reliability, destructive analysis was conducted for some of the test blocks. In case of Korea, KAERI has done the destructive analysis for BMI (bottom mounted instrumentation) block.

Fig. 3 shows one of fractography and depth profile results.



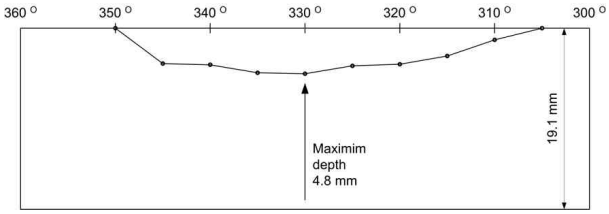


Fig. 3. Examples for destructive analysis of BMI block

In this KNS meeting, we are going to compare the results for the NDE indication and destructive analysis.

5. Results and discussion

The DMW RRT is an important part of the process in assessing nondestructive testing methods because the data that is developed in the round robin testing offers insight into capabilities of "current" nondestructive methods used to detect PWSCC and insight into the capabilities of more "experimental" nondestructive methods. These insights may then be used in developing regulatory positions and help direct additional research plans.

Even though there are some of mitigation methods for PWSCC, detection by NDE is an important part practically. Especially, for significant improvements in safety for components susceptible to PWSCC, effective NDE techniques may need to be combined with inspection intervals selected based on the crack growth rates. Therefore, the analysis should be refined using PWSCC crack growth rates in nickel-based alloys.

For the discussion, we are going to present the RRT results, including the POD performance, flaw sizing performance and effectiveness of ISI (in-service inspection) in DMW. On the other hand, since the Korea teams have experienced first time for real DMW specimens, it was good opportunity to improve their detection ability. We can also discuss the performance demonstration for DMW.

Acknowledgements

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