Development of Regulatory PWSCC (Primary Water Stress Corrosion Cracking) Management System

Jeong Soon Park [a], Young Hwan Choi [a*], Yeon-Ki Chung [a], Jin Su Kim [a], Kyungcho Kim [b]
[a]*Korea Institute of Nuclear Safety, 19 Gu-sung, Yusung, Daejeon*
[*]*Corresponding author: young@kins.re.kr*

1. Introduction

Primary water stress corrosion cracking (PWSCC) is one of the important safety issues in operating nuclear power plants (NPPs). The PWSCC can significantly affect on the integrity of reactor coolant pressure boundary[1]. The PWSCC is also related to the some regulatory safety issues such as leak before break (LBB) and power uprate, and re-definition of LB-LOCA based on Risk-Informed Regulation (RIR) option 3. In this study, regulatory PWSCC management system (R-PWSCC) is developed to support PWSCC regulatory activities such as identification of current status of PWSCC, mitigation, corrective action for failure, enhanced inspection, and regulatory safety issues.

2. Structure of R-PWSCC system

The R-PWSCC system is developed by web-based program to support regulatory activities related to PWSCC. Fig. 1 shows the web page of R-PWSCC. The R-PWSCC system consists of 4 modules including PWSCC database, regulatory audit calculation program, PWSCC regulatory guides, and regulatory application.

Fig 1. R-PWSCC Web page

3. Development of R-PWSCC system

3.1 PWSCC Database

The PWSCC database (DB) module has four (4) kinds of database as dissimilar metal weld DB in domestic NPPs, PWSCC failure event DB, international research program DB, and document DB.

5,652 dissimilar metal welds are identified in all domestic NPPs. Among them, detailed information such as position, materials, geometries and dimension is collected for the 446 dissimilar metal welds. Some of PWSCC failure events data are collected in this module. Both 4 domestic PWSCC events and some foreign PWSCC events are analyzed in detail.

Some international research programs for PWSCC such as OPDE (OECD piping Failure Data Exchange), SCAP (OECD/NEA Stress Corrosion Cracking and Cable Ageing Project), PINC (Program for the Inspection of Nickel Alloy Components), and PMMD (Proactive Management of Materials Degradation) give lot of information and data on PWSCC. The data is summarized and analyzed in this module.

Document DB includes regulatory guides, research reports and industrial Codes & Standards related to PWSCC issues.

3.2 Regulatory Audit Calculation Program

Some regulatory audit calculation programs are required during the regulatory activities. The following Seven (7) regulatory audit calculation codes about PWSCC evaluation are given in this module.

1) RES-WO (Residual Stress Evaluation System in Weld Overlay) Code
2) W-SCAS (Web-based Stress Corrosion Cracking Analysis System) Code
3) SUCEP (Susceptibility Category Evaluation Program) Code
4) SQUIRT (Seepage Quantification of Upsets in Reactor Tubes) Code
5) LBB-ESP (Leak Before Break Evaluation System for PWSCC) Code
6) P-PIE (Probabilistic Piping Integrity Evaluation)
7) PRO-LOCA (Probabilistic Fracture Mechanics Code for LOCA) Code

The SQUIRT and PRO-LOCA codes were developed by MERIT international research program, while the other programs are developed in this study.

3.3 PWSCC Regulatory Guides

PWSCC regulatory guides are required in both regulatory activities and industrial applications for PWSCC issues. Five (5) regulatory guides for identification of current status of PWSCC, mitigation, corrective action for failure, enhanced inspection, and

regulatory safety issues are developed in this study. The regulatory guides include regulatory requirements, procedure, and references related to PWSCC.

3.4 Regulatory Application

The regulatory application module provides review procedures for regulatory activities based on data and information from the modules of PWSCC database, regulatory guides, and regulatory audit calculation program in R-PWSCC system. Five (5) regulatory activities related to PWSCC are considered in this module including identification, mitigation, corrective action for failure, enhanced inspection, and regulatory safety issues.

The PWSCC data identified from domestic and foreign NPPs is a basic element of R-PWSCC system. In special, the failure data due to PWSCC is very important to set up mitigation strategy against PWSCC.

Both advantage and disadvantage of mitigation methods against PWSCC including weld overlay[2], inlay, onlay, mechanical stress improvement process (MSIP), and other methods are estimated in this module. In special, the regulatory guide for weld overlay, which is widely used as mitigation method, is provided. In the guide, regulatory requirements on design of weld overlay, non-destructive examination, and plant-specific consideration are proposed. The regulatory audit calculation code to evaluate residual stress by weld overlay is provided in this module.

To regulate applicant's corrective action for the failure due to PWSCC, regulatory guide for inspection, crack stability evaluation, and repair and/or replacement are provided. For the detected crack due to PWSCC, audit calculation program to evaluate the crack stability is developed in this study. Because mitigation may be considered as a corrective action after repair or replacement for the failed components, mitigation procedure is proposed in this module.

Because the current inspection program by ASME code[3] has limitation to detect the failure due to PWSCC, enhanced inspection of the components susceptible to PWSCC is required[4]. The procedure for inspection methods, inspection scope and period, and performance demonstration (PD) for ultrasonic testing (UT) [5]are given in this module.

Four (4) regulatory safety issues related to PWSCC is considered including leak before break (LBB) & power uprate, re-definition of LB-LOCA based on RIR option 3, risk-informed in-service inspection (RI-ISI), and feedback to the newly constructed NPPs. In LBB analysis, PWSCC is related to screening criteria for LBB application and determination of leakage crack size[6]. The current LBB evaluation may be failed by considering PWSCC effect. 10CFR 50.46 'Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors'[7] requires the LB-LOCA in reactor coolant piping. Based on RIR, re-definition of LB-LOCA is discussed in USA. Proposed rule of 10CFR 50.46 requires PWSCC management. This implies that the PWSCC can be controlled by management. For the RI-ISI evaluation, piping failure mechanism should be defined. The PWSCC failure did not considered in the current RI-ISI evaluation. The feedback of PWSCC to the newly constructed NPPs is important to nuclear safety. The procedures and guides for the regulatory issues are provided in the module.

4. Conclusions

In this study, regulatory PWSCC management system (R-PWSCC) is developed to support regulatory activities related to PWSCC such as identification, mitigation, corrective action for failure, enhanced inspection, and regulatory safety issues.

The R-PWSCC system provides PWSCC database, regulatory audit calculation programs, PWSCC regulatory guides, and procedure for regulatory applications. The R-PWSCC system can be applied to regulatory safety issues including as LBB & power uprate, re-definition of LB-LOCA based on RIR option 3, RI-ISI, and feedback to the newly constructed NPPs.

REFERENCES

[1] USNRC, Regulatory Approach for Primary Water Stress Corrosion Cracking of Dissimilar Metal Butt Welds in Pressurized Water Reactor Primary Coolant System Piping, NRC Regulatory Issue Summary 2008-25, 2008.
[2] EPRI, Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs, MRP-169, 2008
[3] ASME, Rules for Inservice Inspection of Nuclear Power Plant Components, ASME Boiler and Pressure Vessel Code Section XI, 2004
[4] EPRI, Primary System Piping Butt Weld Inspection and Evaluation Guideline, MRP-139, Revision 1, 2008.
[5] ASME, Performance Demonstration for Ultrasonic Examination System, ASME B&PV Code Section XI Mandatory Appendix VIII, 2004
[6] USNRC, Leak-Before-Break Evaluation Procedures, NRC Standard Review Plan 3.6.3, Revision 1, 2007
[7] USNRC, Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors, 10 CFR 50.46, 2010