Methodology of licensing for field applications of Weld Inlay and Ultrasonic Nanocrystal Surface Modification

Hong Seok Cho[a,*], Kwang Woon Jung[a], Ik Keun Park[b], Young Sik Pyun[c]
[a]Technology Research and Development Institute, KEPCO KPS, Naju 520-350, Korea
[b]*Dept. of Mech. and Automotive Engineering, Seoul National Univ. of Science & Technology, Seoul 139-743, Korea*
[c]*Dept. of Mechanical engineering, Sun Moon University, Asan, 336-708, Korea*
**Corresponding author: chs@kps.co.kr*

1. Introduction

PWSCC(Primary Water Stress Corrosion Cracking) generating in dissimilar metal welds of primary system components of NPP(nuclear power plant) has been caused to threat safety and economical management of NPPs. Weld Inlay [1] is one of the effective solutions for PWSCC of dissimilar metal welds of reactor vessel In/Outlet nozzles. However, high tensile residual stress on weld surface generated after Weld Inlay leads to the increase in PWSCC susceptibility. Therefore, there are many attempts to relieve or change high tensile residual stress to compressive residual stress for a mitigation of PWSCC. LSP(Laser Shot Peening) and WJP(Water Jet Peening) have been applied in several NPPs of Japan and technical and topical reports under Materials Reliability Program of EPRI(Electric Power Research Institute) USA have been developed.[2-4]
Weld Inlay technology and UNSM(Ultrasonic Nanocrystal Surface Modification)[5] technology using ultrasonic vibration energy as the method for a mitigation of tensile residual stress generated after Weld Inlay have been developing in Korea. So in this study, the methodology of licensing for field application of these technologies is suggested.

2. Regulations related to repair/replacement

The main ASME Code for a repair/replacement of the components of NPPs is KEPIC(Korea Electric Power Industry Code) MI(equally, ASME Code Section XI) that was suggested in long-term inservice inspection plan of owner, and its fundamental philosophy is to conduct a repair/replacement applying intactly the applied Codes when an original nuclear power plant was constructed. At this time, the applied Codes are the owner's requirement and the original construction Code. The Construction Code applying mostly in a repair/replacement of those domestic PWR(Pressurized Water Reactor) NPPs is ASME Code Section III, and this Code is applied only if KEPIC MI instructs to use a repair/replacement activity. Figure 1 shows a relationship between the Codes and the Standards applying in a repair/replacement activity.

3. Methodologies of licensing for field applications

3.1 Existence of Code Case for repair/replacement: Weld Inlay

In case of existing the Code Case for a generally repair/replacement, this Code Case for duration reduction and a simplification of licensing can apply to receive an approval from a regulatory agency. ASME Code Case N-766 [6] for Weld Inlay/Onlay technique as the method for a mitigation of PWSCC of dissimilar metal welds with Alloy 82/182 in safety Class 1 components of NPPs was approved from ASME Code

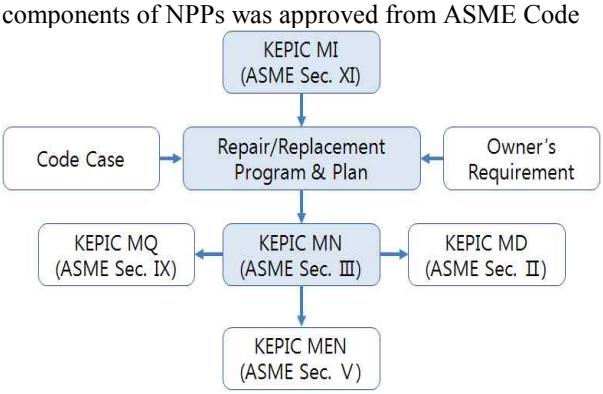

Fig. 1. Relations among the Code & Standards for repair/ replacement activity

Committee in December 20, 2010. And after, ASME Code Case N-766-1 by complementary request of NRC(Nuclear Regulatory Commission) to add crack growth evaluation of PWSCC verifiable, that a crack missed in surface inspection before next inspection period doesn't pass Inlay and Onlay ranges, was developed and accomplished the approval of ASME Code Committee in April 7, 2013. ASME Code Case N-803 [7] for ULBW(Underwater Laser Beam Welding) using temper bead method was made up of the approval of ASME Code Committee in February 25, 2011. Therefore, it is possible to field application if a licensing of a regulatory agency is approved through the development of Weld Inlay methodology to apply reactor vessel In/Out nozzles of domestic NPPs based on the methodology suggesting in the above ASME Code, and the preparation of TR(Topical Report) or RR(Relief Request). Figure 2 represents a procedure of field application for the existence of ASME Code(Weld Inlay) and the absence of ASME Code(UNSM) with regard to a repair/replacement activity.

3.2 Absence of Code Case for repair/replacement: UNSM

An ASME Code Case about the improvement of surface residual stress for a mitigation of PWSCC of dissimilar metal welds with Alloy 82/182 in safety Class 1 components has not been currently developed. However, in case of NPPs of Japan, there are many applications that be improved surface residual stress for a mitigation of PWSCC using LSP and WJP. In case of America, many researches for LSP and WJP under EPRI Materials Reliability Program have been carried out, and some of research results such as MRP-267 [2],

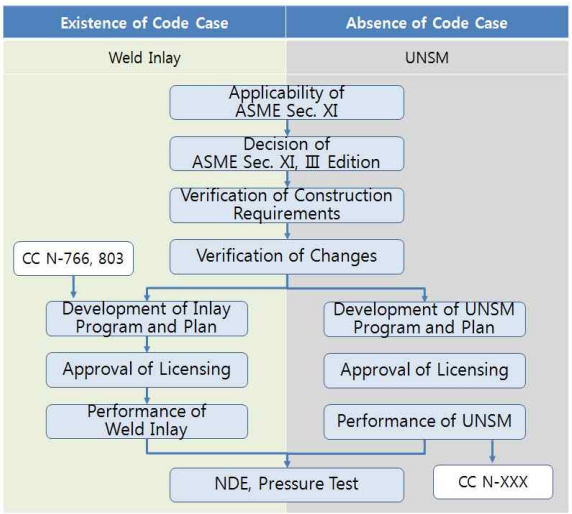

Fig. 2. Flow chart of the Weld Inlay and UNSM activities

MRP-335 [3] and MRP-336 [4] have been published. Besides, a research for a mitigation of PWSCC using UNSM technique is still in the beginning stage, and a fundamental and application research in Korea and USA is the progress [8]. In order to apply UNSM for a mitigation of residual stress in dissimilar metal welds of reactor vessel In/Outlet nozzles, it could be possible an approach by two kinds of methods. First, one is the preparation of a Code Case for UNSM application, and then to apply in a field through an approval of a regulatory agency after registering a Code Case over an approval procedure of Code Committee. Second, another is to apply in a field through an approval of licensing from a regulatory agency after developed a methodology for UNSM application and prepared TR or RR.

The methodologies for an approval of licensing regarding UNSM application should be considered to include a few contents same as below.

1) Evaluation of no unacceptable side effects of UNSM treatment
2) Analytical evaluation for mitigation effect of residual stress through UNSM
3) Verification test for mitigation effect of residual stress
4) Decision for non-destructive inspection method before and after UNSM treatment
5) Crack growth evaluation during operation after USNM treatment
6) Identification of geometric application limitations for geometrical application
7) Identification of surface condition limitations
8) Identification for coverage of UNSM
9) ASME Code considerations regarding limitations on peening and need for post-peening stress relief
10) Identification of control methods for the optimum process parameters and application parameters of UNSM

4. Conclusions

The residual stress generated after Weld Inlay was confirmed to exist on range of 450~500MPa through analytical evaluation, and a follow-up such as peening for a mitigation of tensile residual stress after Weld Inlay is certainly necessary. The results of residual stress measured before and after UNSM for Weld Inlay specimens using UNSM equipment of domestic source technology holdings to obtain an equivalent effect, which has the simplification of equipment and the flexibility of field application in comparison with LSP and WJP, indicated to obtain a mitigation effect of residual stress until 0.5 mm of surface depth. In order to accomplish field application of Weld Inlay that the Code Case was already developed, the approval of a regulation agency through the preparation of TR or RR based on ASME Code Case N-766, N-803 is necessary. Also, in order to apply UNSM technique that the Code Case was not currently developed, the approval of a regulation agency and the development of UNSM methodology are necessary.

REFERENCES

[1] H. S. Cho, K. W. Jung, M. H. Mo, K. H. Cho, D. C. Choi, J. W. Lee and S. B. Cho, “Process development of laser cladding for Weld Inlay repair of dissimilar metal weld in reactor vessel In/Outlet nozzles”, Transactions of the Korean Society of Pressure Vessels and Piping, Vol. 11, No.1, p. 53-60, 2015.
[2] Materials Reliability Program-267, 2010 “Technical basis for primary water stress corrosion cracking mitigation by surface treatment”, Electric Power Research Institute.
[3] Materials Reliability Program-335, 2013 “Topical report for primary water stress corrosion cracking mitigation by surface stress improvement”, Electric Power Research Institute.
[4] Materials Reliability Program-336, 2012 “Specification guideline for primary water stress corrosion cracking mitigation by surface stress improvement”, Electric Power Research Institute.
[5] Y.S.Pyun, Vijay K. Vasudevan, International Nuclear Energy Research Initiative, “An Investigation of Advanced Surface Treatments for Enhancing Stress Corrosion Cracking and Fatigue Resistance of Nickel-Base and Stainless Steel Structural Alloys and Inlay Welded Dissimilar Materials for PWRs.” 2014
[6] ASME Code Case N-766.
[7] ASME Code Case N-803.
[8] H. S. Cho, I. K. Park and K. W. Jung, “The effect of ultrasonic nano crystal surface modification for mitigation of the residual stress after weld inlay on the alloy 82/182 dissimilar metal welds of reactor vessel in/outlet nozzles”, Journal of Welding and Joining, Vol.33, No.2, p.40-46, 2015.