Development of Surface Stress Improvement System for Preventing Defects in Grade 1 Nuclear Power Plant Equipment and Standardization by KEPIC

CHULHEE CHOI, TAEJUN CHUNG, MYOUNGSUNG SOHN
113, Jungdae-ro, Songpa-gu, Seoul, Republic of Korea
E-mai : : cch@kea.kr

***Keywords : KEPIC, PWSCC, Code&Standard**

1. Introduction

Nuclear power plants heavily rely on defect prevention and management of key equipment to maintain safety and reliability. Particularly, Primary Water Stress Corrosion Cracking (PWSCC) in the pressure boundary, one of the Grade 1 safety-related components, poses a significant safety concern during nuclear power plant operation. This issue is prevalent not only domestically but also in international nuclear power plants, leading to substantial costs and time consumption due to plant shutdowns and maintenance.

This paper analyzes the importance and ripple effects of surface stress improvement technology for enhancing nuclear safety and proposes the need for developing suitable technical standards for the domestic nuclear industry. Specifically, it investigates the standardization status and feasibility of applying related technologies along with the development of surface stress improvement technology for PWSCC prevention. Through the establishment of standards tailored to the domestic nuclear environment, the paper aims to discuss the anticipated benefits for the future nuclear industry.

2. Standardization Status

In the nuclear industry, ensuring product quality and safety requires applying internationally recognized standards and conducting tests to obtain consistent results and improved quality. ASME (American Society of Mechanical Engineers) and KEPIC (Korean Electric Power Industry Code) are prominent organizations that develop and provide such standards.

ASME possesses advanced technology in existing surface stress improvement techniques. The ASME Code Committee actively discusses establishing technical standards for applying peening methods in pressure vessel manufacturing, including issuing Code Cases for operational plants and future reactor designs.

While KEPIC promotes standardization in Korea's nuclear industry, its application to surface stress improvement technology is currently at the laboratory evaluation stage. Practical implementation in nuclear power plants necessitates further development of equipment, process optimization, validation, and standardization.

3. Standardization Status Plan

This paper investigates the research and development status of surface stress improvement technology for enhancing the safety and reliability of the nuclear power industry, along with discussing domestic standardization plans for preventing PWSCC (Primary Water Stress Corrosion Cracking). Initially, over the course of four years, the following research was conducted as part of a system to improve surface stress on Grade 1 nuclear plant equipment, utilizing laser peening and ultrasonic nano-surface modification technology:

1. Development and process optimization of laser peening systems for surface stress improvement in operational nuclear plant BMI (Bottom Mounted Instrumentation) Nozzle, and ultrasonic nano-surface modification systems for surface stress improvement in new reactor inlet and outlet nozzles.
2. Performance and validation testing of laser peening and ultrasonic nano-surface modification devices.
3. Development of surface stress improvement work procedures.
4. Development of residual stress and surface stress improvement effect analysis and evaluation techniques.
5. Empirical testing and analytical evaluation techniques for PWSCC crack resistance under primary water environment before and after surface stress improvement.
6. Development of the final draft of KEPIC technical standards for applying surface stress improvement technology to domestic nuclear plants.

To achieve these goals, specific quantitative evaluation criteria and methods were detailed. Evaluation involved the formation of committees comprising experts in the relevant fields. Methods such as XRD (X-ray Diffraction) or Hole-drilling using specimens and empirical mock-ups were used to assess parameters such as residual stress, surface compressive residual stress depth, surface roughness, and surface hardness. Additionally, residual stress and crack resistance evaluations were conducted considering the primary water environment conditions of domestic nuclear plants. Evaluation results were validated

through expert committee assessments, ultimately leading to the development of the final draft of technical standards and certification evaluations through KEPIC.

4. Standardization Development status

KEPIC is currently developing two Code Cases, MI-C-172-4 and MI-C-178-3, based on the validated laser peening and ultrasonic nano-surface modification technologies, following the standardization plan. These Code Cases are being developed in accordance with the ASME standards N-729-4 and N-770-1, aiming to be applicable to the domestic industry. The main revisions for each Code Case are outlined in Table 1.

Table 1. Main Revisions

N-729-4 (MI-C-172-4)	N-770-1 (MI-C-178-3)
SCOPE	SCOPE
INSPECTION SCHEDULE	EXAMINATION REQUIREMENTS
EXAMINATION REQUIREMENTS	EXAMINATION CATEGORIES
ACCEPTANCE STANDARDS	EXTENT AND FREQUENCY OF EXAMINATION
PERFORMANCE CRITERIA AND MEASUREMENT OR QUANTIFICATION CRITERIA FOR MITIGATION BY SURFACE STRESS IMPROVEMENT (PEENING) OF THE REACTOR VESSEL UPPER HEAD PENETRATIONS AND ATTACHMENT WELDS	SUCCESSIVE EXAMINATIONS & ADDITIONAL EXAMINATIONS
	ACCEPTANCE STANDARDS
	PERFORMANCE CRITERIA AND MEASUREMENT OR QUANTIFICATION CRITERIA FOR MITIGATION BY STRESS IMPROVEMENT OR PEENING

5. CONCLUSION

Through this study, the surface stress improvement technology for major nuclear power plant components that we aim to develop is already possessed by institutions and companies in the United States and Japan, which have advanced expertise in this area. In the United States, ASME has revised technical standards and developed Code Cases to apply surface stress improvement to operating and new nuclear power plants. However, it is estimated that standardization activities tailored to the domestic nuclear power plant situation have not been conducted abroad. Therefore, recognizing the high necessity of this research, a consortium was formed to perform tasks by institution, and two application cases of surface stress improvement technology suitable for the domestic nuclear power industry were developed. Additionally, KEPIC technical standards (draft) were established.

6. Expected effect

The surface stress improvement technology developed in this study, particularly pinning, presents the potential to reduce dependence on foreign nuclear power industries and substitute imports. Moreover, the application of this new technology is expected to generate employment opportunities and enhance public value by ensuring the safety of nuclear power plants. This contributes to the enhancement of expertise in the nuclear maintenance industry through technological development, leading to positive prospects of import substitution and cost reduction.

Acknowledgements

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE)
(No.2021M2D4A2046777)

REFERENCES

[1] Determination of Peening Area for Finite Element Residual Stress Analysis of Ultrasonic Nanocrystal Surface Modification under Multiple Impact Conditions, HNS.