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# Evaluation of Residual Stress on Welds of Spent Fuel Dry Storage Canisters by Peening Technology

Donghee Lee[a]*, Yongdeog Kim[a], Sungwoo Cho[b]

[a] Central Research Institute Korea Hydro and Nuclear Power Co. LTD,
1312-70 Yuseon-daero, Yuseong-gu Deajeon, 34101, Korea
[b] 22, Doosan volvo-ro, Seongsan-gu, Changwon-si, Gyeongsangnam-do, 51711, Korea
*Corresponding author: donghee.lee@khnp.co.kr

## 1. Introduction

Chloride-induced Stress Corrosion Cracking (CISCC) is known as one of the major material deterioration of dry storage canisters made of stainless steels. Particularly, dry storage canisters installed in coastal regions where salt content in the atmosphere are high are known to be more susceptible to CISCC. Recently, surface stress improvement technologies such as laser peening, water jet peening, ultrasonic peening, and low plasticity burnishing (LPB) have been proven to be effective in preventing stress corrosion cracking (SCC) of welded and thermally affected parts under operating environment. As a result, Surface Stress Improvement (SSI) Technologies are more widely applied in production of new dry storage canisters in many countries including the U.S. and utilization of other technologies such as cold spraying is also being explored to prevent CISCC even in dry storage canisters that are already in operation. Therefore, residual stress analysis was conducted in this study to examine efficacy in preventing CISCC as well as applicability in dry storage canisters of most widely utilized SSI technologies - laser peening and ultrasonic peening.

## 2. Objective

This study is a feasibility study which is aimed to analyze and evaluate CISCC reduction effects of 4 technologies. ALP (air laser peening) ALP non-coating / coating, UNSM (ultrasonic nano-crystal surface modification), and USP (ultrasonic shot peening) are the technologies included in the study. The purpose is to analyze which of the four technologies is most effective in reducing CISCC in welded stainless steels dry storage canisters.

## 3. Surface Stress Improvement Technology

### *3.1 Air Laser Peening*

ALP process typically uses laser beams with energy of 5 to 25J per pulse and duration of 5 to 25 nsec, resulting in uses of peak power that range from several tens of MW to several GW. A method of protecting product surface with black paint or metal tape for laser peening is commonly referred to as laser peening coating, and a method of not applying any protective coating on product surface is commonly referred to as laser peening non-coating

### *3.2 Ultrasonic Nanocrystal Surface Modification*

UNSM technology is utilized ultrasonic vibration energy to strike metal surfaces with a ball, on which a large amount of static and dynamic force are added, more than 20,000 times per second (about 1,000 to 100,000 times/mm2) and cause severe plastic deformation (SPD) and elastic deformation, thereby transforming structures of the surface layer into nano-crystal and adding very large and deep compressive residual stresses

### *3.3 Ultrasonic Shot Peening*

Ultrasonic shot peening is a process used to induce superficial compressive stress and lead to modify the mechanical properties of metals. USP method converts tensile stress present on material surface into compressive stress by striking like mini-hammer the material surface with small projectiles such as metals, glasses, and ceramics high speed with sufficient force by using ultrasonic waves and causing plastic deformation.

## 4. Research Scope

Specimens have been fabricated by using gas tungsten arc welding (GTAW) widely used in general industries including nuclear engineering field. Residual stress will be measured by using hole drilling method and X-ray diffraction method.

| Classification | Description |
|---|---|
| Materials | • 304 and 316LN Stainless Steels |
| Weld Process | • Gas Tungsten Arc Welding (GTAW) |
| Peening Technologies | • Air Laser Peening Non-Coating<br>• Air Laser Peening Coating<br>• UNSM<br>• USP |
| Residual Stress Measurement | • Destructive Measurement<br>- Hole Drilling Method: Verification of residual stress depth<br>• Non-destructive Measurement<br>- XRD Method: Verification of surface residual stress |

### *4.1 Specimens*

Residual stresses were measured at 2 points on the base material, 2 points on the weld area, and 4 points on the heat affected zones (HAZ) for each specimens to minimize measurement errors that may occur depending on equipment and other environment related factors. Since CISCC occurs most frequently in the heat affected zones, more measurements have been taken at such area. Because all measurements should be taken at similar location in each specimens, the residual stresses have been measured at 8 points shown in the figure 4-1.

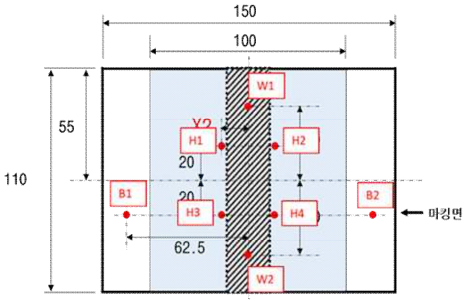

Figure 4-1. Residual Stress Measurement Locations

## 5. Results & Observation

### *5.1 XRD Results*

The residual stress measurement results using XRD are as follows.

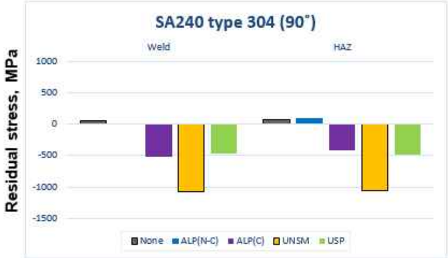

Figure 5-1. XRD Measurement Results (Avg. Value) Comparison Table (Type 304, 90° direction)

Figure 5-2. XRD Measurement Results (Avg. Value) Comparison Table (Type 316LN, 90° direction)

### *5.2 Hole-Drilling Results*

The residual stress measurement results using Hole-Drilling are as follows.

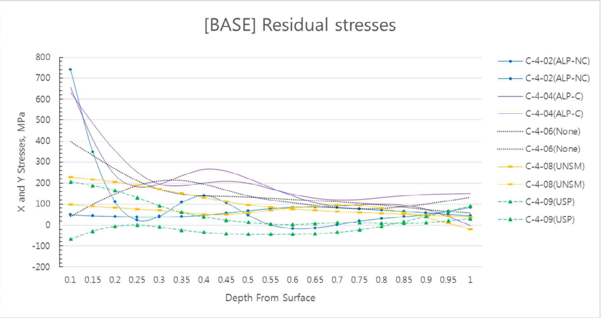

Figure 5-3. H/D Measurement Results Comparison (Base (Type 304), X-Direction)

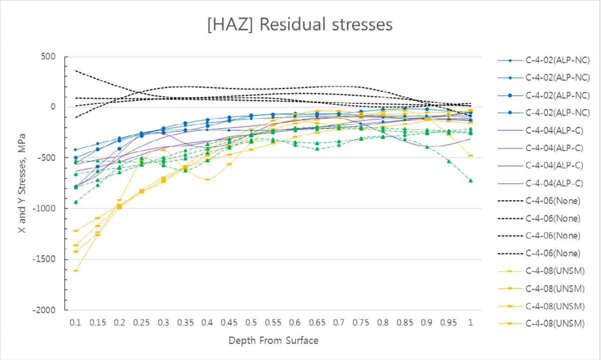

Figure 5-4. H/D Measurement Results Comparison (HAZ (Type 304), X-Direction)

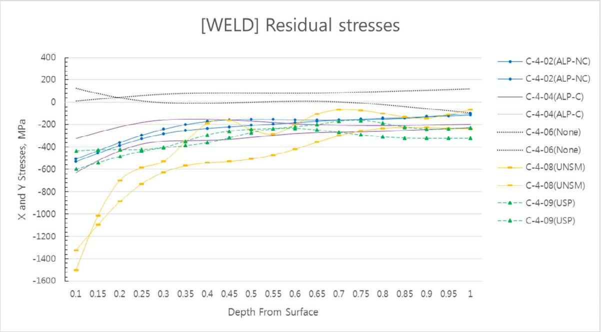

Figure 5-5. H/D Measurement Results Comparison (Weld (Type 304), X-Direction)

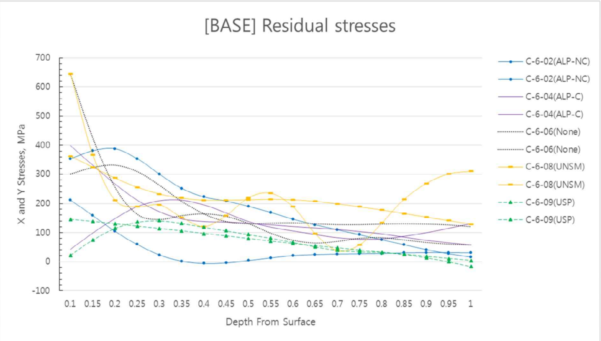

Figure 5-6. H/D Measurement Results Comparison (Base (Type 316LN), X-Direction)

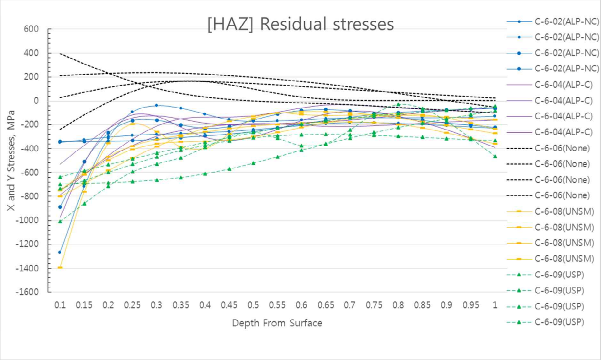

Figure 5-7. H/D Measurement Results Comparison (HAZ (Type 316LN), X-Direction)

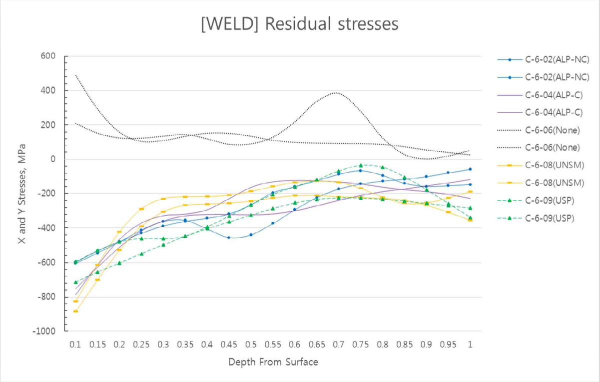

Figure 5-8. H/D Measurement Results Comparison (Weld (Type 316LN), X-Direction)

### *5.3 Observation*

- Base: The base material area did not display any clear tendency for all specimens, residual stresses were generally measured in a range of 0 to +800 MPa in both 304 and 316LN base materials.

- HAZ: HAZ had stress distributions of -300 to +500 MPa, but both 304 and 316LN base materials had compressive stress distributions surface to 1mm depth after application of the peening technologies.

- Weld: It was confirmed that the untreated weld areas had stress distributions of -120 to +580 MPa, but both 304 and 316LN base materials had compressive stress distributions surface to 1mm depth after application of the surface stress improvement technologies.

As results of application of four different surface stress improvement technologies, it was able to confirm that compressive stresses were distributed to a depth of 1mm in all treated specimens. These results are considered to be the basis technology for the aging management of spent fuel dry storage containers in the future.

## REFERENCES

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