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Evaluation of Residual Stress Resistance of Spent Fuel Dry Storage Canister Using Air Laser Peening

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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 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, this study was conducted to develop the CISCC reduction effect by removing the residual stress (tensile stress) of the canister welding part based on the Air Laser Peening technology.

3. Preparation of the Specimens

3.1 Layout & Plan

Three curved specimens of Spent Fuel dry storage canister material were provided by EPRI. One piece of specimen not welded is not used, and two pieces of specimen welded are used according to table 3-1. Welded specimens are too large to set up on the ALP machine, so cut according to Figure 3-1.

Table 3-1 Plan to Use Curved Specimens

Name	Purpose	Details
CA1	**Peening Specimen**	**Official Specimen for Peening**
CA2	**None-Peening Specimen**	**Official Specimen for Non-Peening**
CB1	Test Specimen 1	Test Specimen for ALP Non-Coating
CB2	Test Specimen 2	Test Specimen for ALP Non-Coating
CB3	Spare Specimen	Not Used
-	No Welded Specimen	Not Used

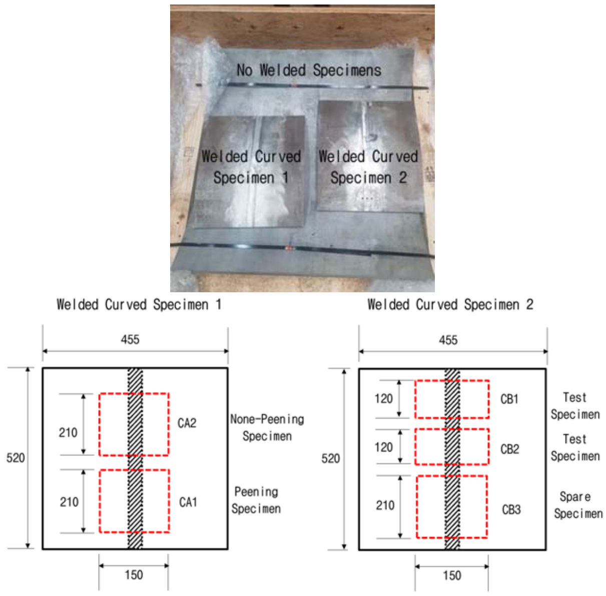


Fig. 3-1. Layout of the Specimens

3.2 Fabrication

The curved specimens are fabricated in accordance with figure 3-2. The Air Laser Peening (ALP) is performed as laser beam with a high-energy pulse generated by the ALP generator, which has an impact on the specimen mounted on the jig. detailed parameters of ALP are shown in Table 3-2.

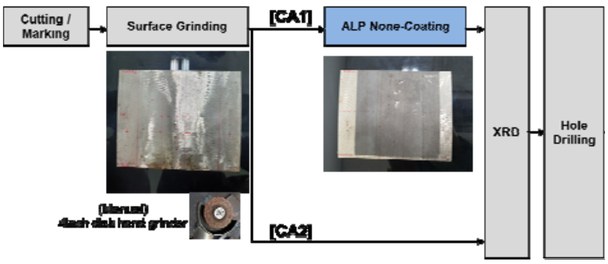


Fig. 3-2. Curved Specimens Fabrication Flow Chart

Table 3-2 ALP Peening Parameters

Laser Type	Laser Energy (J)	Laser Beam Diameter (mm)	Overlapping (%)	Confinement Layer
Nd-YAG (1064 nm, IR)	4.4	3	50	Water

3.3 Residual Stress Measurement Location

Residual stresses were measured at 4 points on the base material, two points on the weld area, and four points on the heat affected zones (HAZ). 2 points (PB1, PB2) are added to compare before and after peening of the base material.

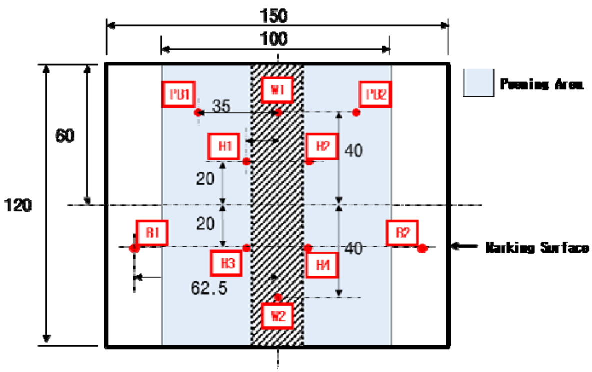


Fig. 3-3. Residual Stress Measurement Locations

4. Results & Observation

4.1 XRD Results

In the XRD residual stress measurement of ALP non-coating, compressive stress does not appear even after peening.

Table 4-1 XRD Measurement Results

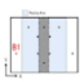
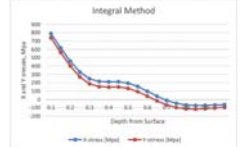
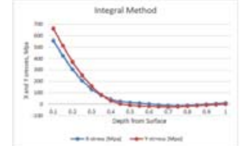
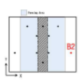
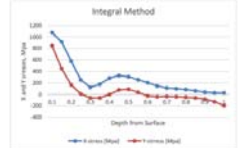
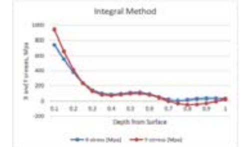
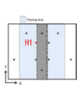
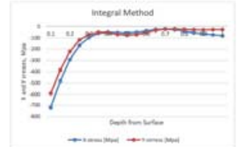
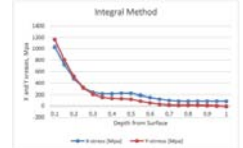
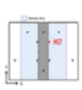
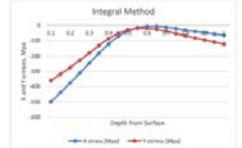
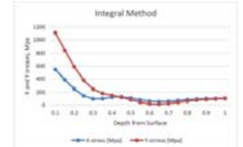
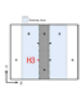
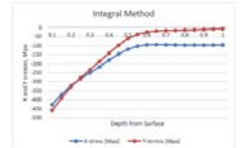
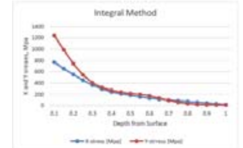
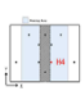
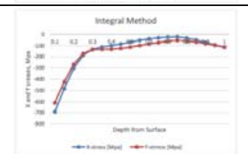
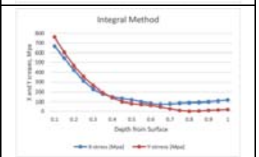
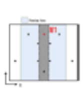
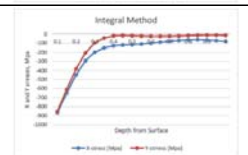
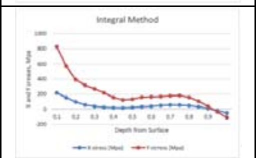
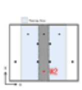
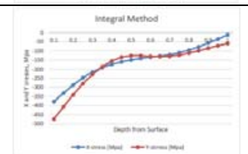
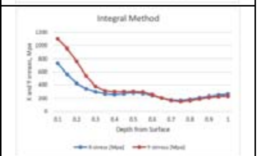
Name	Direction	Measurement Location				
		B1	**PB1**	**H1**	**H3**	**W1**
CA1 Before Peening	*0°*	846.2	926.0	848.3	527.4	1036.7
	90°	452.7	409.9	968.3	386.2	763.1
CA1 After Peening	*0°*	847.1	539.4	456.1	420.1	513.6
	90°	581.2	400.0	538.8	491.3	453.6
CA2 None Peening	*0°*	990.4	805.3	478.8	672.1	1064.3
	90°	679.7	414.3	-32.2	51.2	824.3

Name	Direction	Measurement Location				
		W2	**H2**	**H4**	**PB2**	**B2**
CA1 Before Peening	*0°*	688.3	499.1	429.2	870.0	800.4
	90°	234.7	51.8	76.6	506.5	347.1
CA1 After Peening	*0°*	424.9	453.8	448.4	500.0	763.2
	90°	435.0	405.6	415.9	404.4	445.3
CA2 None Peening	*0°*	841.6	254.1	797.5	811.5	820.4
	90°	449.3	-201.6	273.6	373.8	482.1

4.2 Hole Drilling Results

Table 4-2 below compares the hole drilling results. Both specimens showed tensile stress in the base without peening, but in HAZ and Weld point, compressive stress were derived at the CA1 specimen.

Table 4-2 Compare of Hole Drilling Result (CA1 vs CA2)

Location	CA1	CA2
Base 1 		
Base 2 		
HAZ 1 		
HAZ 2 		
HAZ 3 		
HAZ 4 		
Weld 1 		
Weld 2 		

5. Conclusion

This study focused on the effects of laser peening in canister (304 stainless steel). The specimen obtained by laser peening had a very deep compressive residual stressed depth over 1mm and was evaluated based on XRD and hole drilling measurement. In the results of the XRD residual stress measurement of ALP non-coating, compressive stress does not appear even after peening. Results of residual stress measurement by hole drilling are summarized in Tables 4-2. Measurement locations of the residual stresses are according to Figure 3-3, as in the case of XRD (B1 and B2 are in non-peened base material; H1, H2, H3, and H4 are in peened heat affected zone; W1 and W2 are in the center peened weld area; PB1 and PB2 are in peened area). For the curved material, the residual stresses are measured in X and Y directions and 1 mm in depth from the surface. When the residual stress is greater than 0, the tensile stress is indicated, and when the residual stress is less than 0, the compressive stress is indicated. The non-peened areas (B1 and B2 in Figure 3-3) tend to have stresses below +800 MPa (tensile stress) due to grinding forces and had various conditions, such as compression depending on degrees of grinding force or overlapping. Compressive stresses were observed in the peened curved canister materials.

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