Mitigation of Localized Corrosion in Sensitized SS304 via SS304L Cold Spray Coating for Dry Storage Canisters

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1. Introduction

In ROK, 304L stainless steel (SS304L) is being considered as a candidate material for spent nuclear fuel dry storage canisters [1]. However, austenitic stainless steels are highly susceptible to chloride-induced stress corrosion cracking (CISCC) at the heat-affected zone (HAZ). To mitigate this vulnerability, this study applied cold spray coatings of SS304L to provide a protective layer without inducing any thermal input. Specifically, the impact of coating thickness on pitting and intergranular corrosion resistance was evaluated.

2. Methods and Results

2.1 Specimen preparation

In this study, SS304 stainless steel substrates (150 mm × 30 mm) were used for all specimens. Substrates with a thickness of 2 mm were used for the thin-coated condition, whereas those with a thickness of 3 mm were used for the thick-coated condition. To simulate sensitization, all substrates were heat-treated at 650 °C for 48 h, followed by cold-spray coating and subsequent corrosion testing. Prior to testing, the uncoated specimens were ground to 320-grit to remove the surface oxide layer. In contrast, the coated specimens were not ground to better reflect practical application conditions.

Table 1. Chemical composition of 304 stainless steel

	SS304 2T (Thin-coated)	SS304 3T (Thick-coated)	SS304L powder
Fe (%)	Bal.	Bal.	Bal.
C (%)	0.0530	0.0526	0.007
Si (%)	0.402	0.412	0.38
Mn (%)	1.053	1.074	0.92
P (%)	0.0340	0.0338	0.009
S (%)	0.0032	0.0035	0.002
Cr (%)	18.409	18.075	19.32
Ni (%)	8.106	8.054	9.38
N (ppm)	400	371	-
Note	650℃ 48 h heat-treated		15-45 µm size

2.2 Cold spray deposition

SS304L powder was deposited onto each substrate using a cold-spray coating system (Impact Spray System EvoCSII, Germany). The coating thickness was measured on carbon-mounted cross-sectional specimens using optical microscopy. The average coating thickness was approximately 120 µm for the thin-coated specimens and 350 µm for the thick-coated specimens.

Table 2. Parameters of cold spray coating

	SS304 2T (Thin-coated)	SS304 3T (Thick-coated)
Pre-treatment	Polished using 240-grit SiC paper	
Pressure (bar)	50	
Temperature (℃)	1,000	
Pre-heating	-	
Stand-off distance (mm)	30	
Step distance (mm)	1	
Powder feed rate (RPM)	3	4
Traverse speed (mm/s)	500	300
Pass number (layer)	1	
Coating thickness (µm)	~ 120	~ 350

2.3 Corrosion test and results

All samples were cut into 15 mm diameter circular discs using Electrical Discharge Machining (EDM). To evaluate pitting corrosion resistance, each sample was immersed in a 6 wt.% $FeCl_3$ solution for 72 hours, in accordance with ASTM G48.

Following the 72-hour immersion test, the uncoated sample exhibited intergranular corrosion. In contrast, the cold-sprayed samples only exhibited localized surface pitting and minor coating defects, without evidence of intergranular corrosion.

Cross-sectional analysis of the uncoated sample revealed severe internal intergranular corrosion, leading to the formation of internal voids (Fig. 1). The thin-coated sample (deposited on SS304 2T) similarly showed severe internal intergranular corrosion of the substrate, indicating that the coating layer failed to provide sufficient protection to the underlying substrate. Nevertheless, the coating layer itself remained structurally intact, which prevented the formation of internal defects (Fig. 2a).

Conversely, the depth of internal corrosion was significantly reduced in the thick-coated sample (Fig. 2b). Furthermore, in both coated samples, the corroded coating displayed a distinct mesh-like corrosion morphology rather than typical intergranular attack. The corrosion morphology is related to the interparticle boundaries of the feedstock powder.

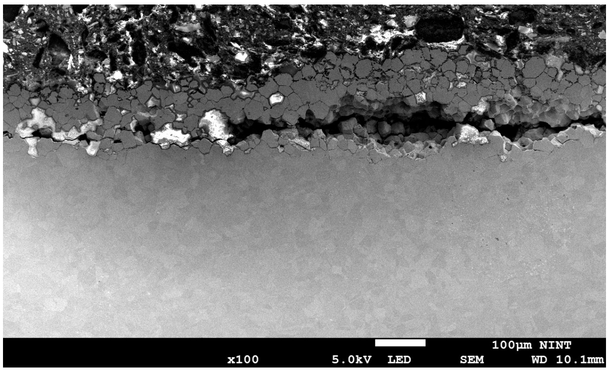

Fig. 1. Cross-sectional scanning electron microscope (SEM) image of the uncoated sample after the 72 h ASTM G48 $FeCl_3$ immersion test at ×100 magnification.

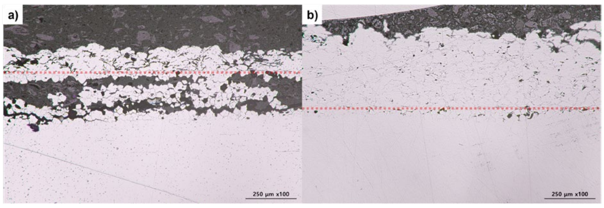

Fig. 2. Cross-sectional optical microscopy (OM) images of the coated samples after the 72 h ASTM G48 $FeCl_3$ immersion test at ×100 magnification. (a) the thin-coated sample (on 2 mm SS304) and (b) the thick-coated sample (on 3 mm SS304). The red dotted lines indicate the interface between the SS304L coating and the SS304 substrate.

3. Conclusions

Applying a 304L stainless steel cold spray coatings to sensitized 304 stainless steel substrates substantially enhances surface corrosion resistance. It is noted that the coating thickness is a determining factor in protecting substrate and mitigating the depth of internal corrosion.

These results suggest that the structural integrity of the coating layer and the characteristics of the interparticle boundaries are critical for overall corrosion resistance. Further investigations will be performed to reduce interparticle oxide inclusions and improve protection against internal corrosion.

REFERENCES

[1] Seo, K., Seo, J. S., Lee, J. C., and others, & Korea Atomic Energy Research Institute, Daejeon (Korea, Republic of). (2012). Technology Development for Integrated Safety Test of Spent Nuclear Fuel Transportation and Storage System.

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