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Corrosion Resistance of Pure Ni and Inconel 625 Thermal Spray Claddings for Type 316H Stainless Steel in High-Temperature Molten Salt Environments

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1. Introduction

The research is being conducted domestically and internationally on coating the substrate surface with corrosion-resistant materials to address the corrosion issues of Type 316H stainless steel, a key structural material for molten salt reactors (MSRs) that use high-temperature molten salt coolant up to 650°C Nickel-based alloys such as nickel (Ni) and Inconel 625 have been evaluated as suitable coating materials [1]. Various chemical and physical techniques exist for corrosion-resistant metal coatings, but from the perspective of technological maturity, overlay welding and laser cladding—where corrosion-resistant metals are deposited onto the substrate using thermal energy—are the most representative methods. However, both overlay welding and laser cladding involve the melting of corrosion-resistant metals and their deposition onto the structural metal, inevitably causing thermal effects such as partial melting, resolidification, and microstructural changes in the base material [2]. Additionally, welding and laser cladding require depositing metal layers of several hundred micrometers, making them less suitable for corrosion-resistant coatings inside inner vessels or small-diameter pipes. In contrast, thermal spray coating, which allows for thinner coatings (below tens of micrometers), presents a viable alternative [3].

Therefore, in this study, a high-velocity oxy fuel (HVOF) spraying process—capable of minimizing the effects on the base material and enabling thin coatings—was used to clad Ni-201 and Inconel 625 onto all surfaces of Type 316H stainless steel specimens [4]. The specimens were then subjected to immersion testing in $NaCl + MgCl_2$ molten salt for 100 hours. The corrosion rates before and after cladding were compared, and the microstructures were analyzed.

2. Experimental

2.1 Materials

Thermal spraying was performed on rectangular Type 316H stainless steel specimens with holes using Ni-201 grade power and Inconel 625 powder. Ni-powder was produced by Hoganas AB in Sweden, with a carbon content of 0.02 wt% and oxygen content of 0.11 wt%. The particle size of Ni-201 powder and Inconel 625 powder was 50-150 um.

2.2 Deposition Process

The corrosion test specimens were produced by spraying pure Ni and Inconel 625 powder to a thickness of approximately 300 um onto the entire surface of Type 316H stainless steel rectangular solids measuring 4 mm (t) x 20 mm(l) x 10 mm(w) using HVOF (High Velocity Oxygen Fuel) method. Here, the power supply speed was 70-80 g/min, and oxygen and kerosene was used as fuels and argon as the powder carrier gas, respectively.

The cladded specimens are shown in Fig. 1.

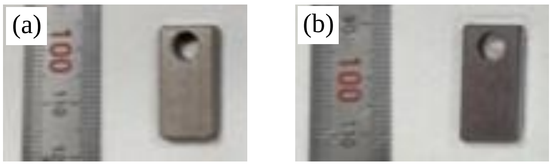

Fig. 1. Cladded Type 316H stainless steel specimen; (a) Ni cladding, (b) Inconel 625 cladding.

2.3 Immersion Corrosion Testing

The specimens were subjected to immersion corrosion tests in 57 mol% NaCl–43 mol% $MgCl_2$ at 650ºC for 100 hours. Prior to the test, a mixed salt was heated at 300ºC for 24 hours, followed by a descaling process at 600ºC using Mg for 48 hours to eliminate O_2 and H_2O. During the test, O_2 levels was maintained with below 20 ppm and H_2O levels below 2 ppm.

The specimens were placed in an alumina crucible while being threaded onto an alumina rod as shown in Fig. 2. A sufficient amount of mixed salt powder was filled into alumina crucible so that the specimen was fully immersed in the molten salt even as the mixed salt melted and some of it evaporated.

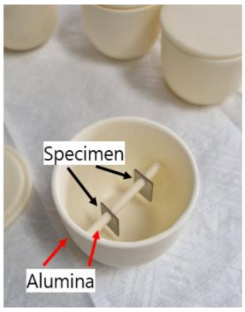

Fig. 2. Specimen placed in a crucible for immersion corrosion testing in molten salt.

3. Results and Discussion

Fig 3 is a bar chart showing the weight change of the specimens after immersion in molten salt at 650°C for 100 hours. When this result is converted into a corrosion rate, the corrosion rates of the Inconel 625-clad specimen and the unclad specimen were approximately 1 mm/year and 0.17 mm/year, respectively. However, in the case of pure Ni-clad specimen, the weight increased after the test, making it impossible to measure the corrosion rate. The reason for the weight gain is presumed to be that the weight of some of the molten salt attached to the specimen was greater than the small amount of corrosion.

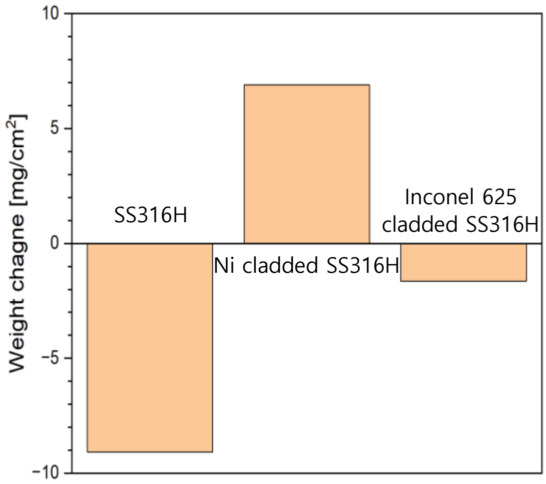

Fig. 3. Comparison of weight changes after immersion tests on specimens before and after cladding with Ni and Inconel 625.

These facts means that corrosion rate of Type 316H stainless steel was reduced by less than 1/5 by Inconel 625 cladding, and even more so by pure nickel cladding.

4. Summary

A high-velocity oxygen fuel spraying process was used to clad Ni-201 and Inconel 625 onto all surfaces of Type 316H stainless steel specimens. The specimens were then subjected to immersion testing in NaCl + $MgCl_2$ molten salt for 100 hours. The corrosion rates before and after cladding were compared. It was found that corrosion rate of Type 316H stainless steel was reduced by less than 1/5 by Inconel 625 cladding, and even more so by pure nickel cladding.

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