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# Characteristics of the Heat-Affected Zone of Metal-Clad Structural Materials for Molten Salt Reactor

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## 1. Introduction

The structural materials of the molten salt reactor (MSR) are used for long periods of time in a harsh environment of high temperature, corrosive molten salt up to 650$^{o}$C, hence corrosion resistance against molten salt is considered as top priority. In order to solve the problems caused by corrosive molten salt, research is being conducted at advanced research institutes abroad to improve corrosion, wear, and high temperature oxidation by coating the surface of the base material with excellent corrosion resistance as an effective method. There are various chemical and physical methods for corrosion-resistant metal coating technology, but in terms of technological maturity, the representative methods are overlay by welding and laser cladding, which deposits corrosion-resistant metal on the surface of the base material using a laser. Currently, the most promising candidate material for MSR is Type 316H stainless steel, and nickel (Ni) is considered to be a suitable coating material for it [1-2].

Metal coating processes such as welding overlay and laser cladding are both processes that melt corrosion-resistant metal by applying thermal energy and deposits it on the main structural materials, therefore the structural materials are inevitably affected by heat such as partial melting, re-solidification, and microstructural changes due to high heat [3]. Therefore, it is essential to verify that not only corrosion resistance but also mechanical properties and microstructural stability required as structural components are maintained at an appropriate level or higher after the coating process. However, there are almost no systematic research results on the thermal effects of the substrate during overlay welding or laser cladding of corrosion-resistant metals.

In this study, Ni was coated on Type 316H stainless steel using gas tungsten arc (GTA) overlay welding and direct energy deposition (DED) laser cladding methods, and the microstructural changes, hardness, and mechanical properties of the base material near the interface were observed to evaluate the thermal effects according to the metal cladding process.

## 2. Experimental

### *2.1 Materials*

GTA welding was performed using ERNi-1bare rods, which contain 0.15 wt% carbon and 2.5 wt% Ti. The powder used for DED laser cladding was Ni-201 grade Ni-power produced by Hoganas AB in Sweden, with a carbon content of 0.02 wt% and oxygen content of 0.11 wt%, and a particle size of 50-150 um.

### *2.2 Deposition Processes*

Figures 1(a) and (b) in Fig. 1 illustrate cross-sections of test blocks with nickel onto Type 316H stainless steel through GTA welding and laser cladding, respectively.

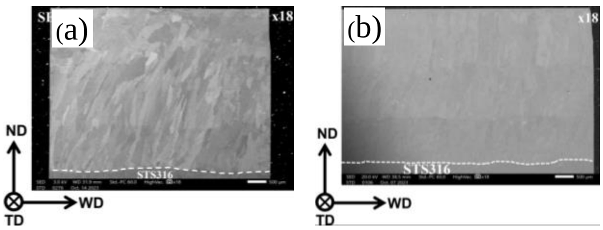


Fig. 1. Cross-section of Ni-cladded Type 316H stainless steel blocks; (a) GTA weld cladding, (b) DED laser cladding.

The welding rods were deposited on a Type 316H stainless steel plate to a thickness of about 6 mm as shown in Fig. 1(a). When welding in layers, an automated process using robot arms was applied, and the welding parameters were argon shielding gas: 20 l/min, current: 185 A, voltage: 16-17, speed: 160 mm/min, heat input: 1.5 kJ/min.

A direct energy deposition (DED) type laser cladding system produced by Korean domestic company was used for Ni cladding on Type 316H stainless steel substrate with a thickness of about 4mm, similar to Ni cladding by GTA welding depicted in Fig. 1(b).

The DED equipment uses Ytterbium fiber laser as a power source and has working envelope of 400 x 450 x 300 (mm). Under DED conditions, the output was 550 W, a laser beam size of 0.8 mm, the scan speed was 500 mm/min, a focal length of 9 mm, and the stacking was performed at a hatch interval of 400 μm under high purity argon gas atmosphere with a pressure of 10 mbar.

### *2.3 Hardness Measurements*

The hardness of the GTA welding and laser cladding layers and their underlying areas were measured using

Mitutoyo Model HM 201 micro-Vickers hardness tester. The hardness tests were performed with indentations at intervals of 0.25 mm under a load of 300gf and a dwell time of 15 seconds.

### 3. Results and Discussion

Fig 2. shows a comparison of the cross-sectional hardness profiles of the GTA welded clad and laser clad test blocks.

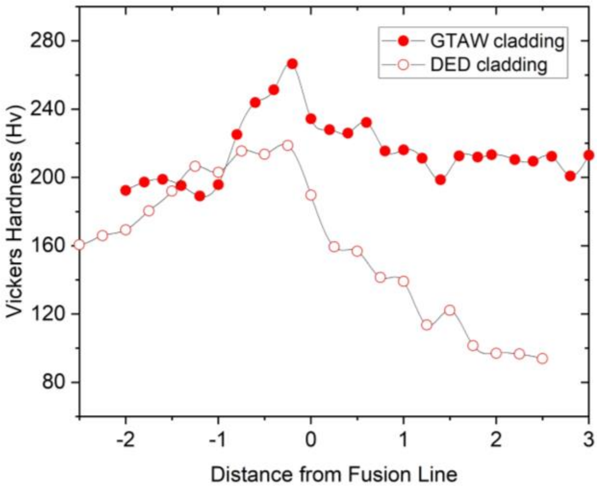


Fig. 2. Comparison of Vickers hardness profiles near clad layer formed by GTA welding and clad layer formed by laser deposition.

Overall, the hardness of the GTAW cladding block was higher than that of laser cladding block. The hardness of the substrate just below the interface between the cladding and the substrate was highest in both GTAW cladding block and laser cladding block, but that of the GTAW cladding block was about 20% higher. The noteworthy that the hardness of the cladding layer was significantly higher for GTAW cladding that for laser cladding, and the difference became increasingly larger up to distance of 3 mm.

It is presumed that this difference in hardness depending on the cladding method is attributed to the difference in heat input during cladding, the resulting difference in microstructure, and the difference in the degree of dilution of substrate alloy elements and diffusion into the cladding layer. That is, compared to GTAW, the lower heat input of laser cladding resulted in less thermal influence on the substrate, and the hardness increase region of the cladding layer was also much smaller that of GTAW. It is thought that the difference in the depth of the diffusion layer of solutes such as Fe and Cr from the substrate also caused the difference in the hardness of the two cladding layers.

### 4. Summary

The heat effects was evaluated by measuring the difference in hardness near the interface when Ni was cladded on Type 316H stainless steel by GTA welding and laser. The overall hardness of the GTAW cladding block was higher than that of laser cladding block. It is presumed that this difference in hardness depending on the cladding method is attributed to the difference in heat input during cladding, the resulting difference in microstructure, and the difference in the degree of dilution of substrate alloy elements and diffusion into the cladding layer.

### ACKNOWLEDGEMENT

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