Weld Solidification Behavior of Superaustenitic Stainless Steel and Ni-Base Alloys for Marine Environment Applications

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Introduction

Superaustenitic stainless steels (SASS) exhibit superior corrosion resistance and toughness compared to the low alloy steels that are currently used in marine applications. However, conventional welding processes destroy the chemical homogeneity of the material, leaving solute depleted regions of the microstructure susceptible to preferential corrosive attack. Laser processing provides a unique opportunity to improve the corrosion performance of SASS welds by potentially producing segregation-free microstructures with extended solubilities through the imposition of rapid solidification conditions within the weld pool. In addition, these laser welds can be produced without the need for Ni-base filler metals, thereby providing a cost benefit. The overall objective of this research is to develop a multifaceted solidification model of the laser welding process on SASS alloys in order to optimize the mechanical and corrosive properties of the weld material for use in engineering applications. Preliminary research completed on the solidification behavior of the alloys examined in this study under casting and conventional arc welding processes is presented in detail.

Experimental Procedure

The unique properties of the superaustenitic class of stainless steels are afforded by complicated chemical compositions, making variations in material behavior extremely difficult to attribute to the presence or absence of a single alloying element. Consequently, a material matrix of three experimental alloys with simple chemical compositions were chosen along with a commercial superaustenitic stainless steel (AL-6XN) in an effort to isolate the contribution of individual alloying elements on the overall solidification behavior of the material. Microstructural characterization has been completed on each of the four alloys being examined in this study using light optical and scanning electron microscopy techniques. Phase identification was conducted using Backscattered Electron Kikuchi Pattern (BEKP) analysis in order to confirm the solidification sequence of each alloy, as predicted by thermodynamic calculations using CALPHAD algorithms. The segregation behavior of each material under casting and conventional arc welding conditions was measured and the results compared to models created to predict the microstructural development of these alloys, and ultimately alloy performance in corrosive environments.

Results and Discussion

The predictive model used to describe the solidification behavior of the SASS class of alloys shows good agreement with the microstructural analysis data presented. Solidification path calculations, when combined with multi-component liquidus projections created for each alloy in this study, provide an accurate prediction of the microstructural development of SASS and Ni-base alloys within the range of cooling rates associated with casting and conventional arc welding processes. Predicted microsegregation behavior of individual alloying elements within each material correlates closely with the solute redistribution observed in the solidified microstructures. The segregation of Mo during solidification drives the microstructural development of the materials in this study, and the models presented provide a good description this phenomenon under conventional arc welding conditions. This set of data is therefore an extremely useful reference point in the continuing research efforts to reduce the severity of microsegregation of strategic alloying elements by promoting extended solid solubilities through laser welding and high energy density welding processes.

Conclusions

The analysis presented validates the predictive model used to describe the SASS material system and serves as an important first step to understanding how microstructural development and solute redistribution in SASS and Ni-base alloys can be controlled during welding processes.