Laser Welding of Superaustenitic Stainless Steels

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Introduction

Laser processing provides a unique opportunity to improve the corrosion performance of superaustenitic stainless steel (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. Furthermore, laser welding simplifies fume control and reduces thermal distortion. The overall objective of this research is to develop a complete solidification model of the laser welding process on SASS alloys in order to optimize the mechanical and corrosive properties of the weld material, thereby providing a multi-faceted perspective on the performance of SASS alloys in engineering applications.

Experimental Procedure

The ability to reduce microsegregation hinges on the ability to control the solidification velocity in the weld pool, making the development of a predictive model of the solidification velocity as a function of the laser parameters of prime importance. However, most engineering alloys have complex chemical compositions and SASS alloys are no exception. In order to fully understand the behavior of these materials, simpler systems must first be understood and modeled. Therefore, Ni-Cr-Mo and Fe-Ni-Cr-Mo alloys developed for this purpose were welded alongside a commercially available industrial SASS alloy, AL-6XN, at a range of laser powers and travel speeds to simulate the entire range of behavior expected for the SASS class of materials. The chemical compositions of these materials are displayed in Table 1.

Table 1. Alloy Composition (wt%) for Laser Weld Sample Array

Material	Elemental Composition				
	Fe	**Ni**	**Cr**	**Mo**	**Rest**
Al-6XN	46	25	21	6	2
Experimental 1	0	68	20	12	0
Experimental 2	0	55	20	25	0
Experimental 3	45	23	20	12	0

Results and Discussion

Another thrust of this research is to characterize the resultant weld pool shape of laser welds as a function of the laser welding parameters. Manipulation of the Rosenthal heat-flow equations results in a quantitative model of the growth angle as a function of the power and travel speed. From the growth angle, θ, the solidification velocity, V, can be determined as a function of the travel speed of the heat source. The growth angle has been experimentally determined in many of the laser-welded samples described above and from this the solidification velocity was determined as a function of travel speed of the laser. Analysis of this preliminary data exhibits reasonable agreement between experiment and the predicted solidification velocity based on calculations using the manipulation of the Rosenthal heat flow equations.

Microstructural characterization was also completed on several samples using light optical and scanning electron microscopy techniques. Phase identification of autogenously welded AL-6XN was conducted using Backscattered Electron Kikuchi Pattern (BEKP) analysis. These results were used to confirm the solidification sequence of AL-6XN, as predicted by thermodynamic calculations using CALPHAD algorithms. This microstructural characterization, coupled with the collected weld pool shape information provides fresh insight into the solidification behavior of SASS alloys under laser welding conditions.

Conclusion

A series of laser welds have been conducted a range of laser powers and travel speeds on AL-6XN superaustenitic stainless steel, along with three experimental compositions that simulate the solidification of SASS alloys. Data collected from preliminary microstructural analysis of these welds has demonstrated a distinct relationship between the solidification velocity and the travel speed. Further work will be done to quantify the contribution of each alloying element (Fe, Ni, Cr, Mo) on the shape of the weld pool and the solidification behavior of the material as a whole, providing a detailed model of the expected behavior of high alloy superaustenitic stainless steels in engineering applications.