D. Modeling Of Fe-C-Al-Mn Steel Weld Microstructure

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Introduction

In self-shielded flux cored arc welds containing greater than 1 wt.% aluminum, the final weld microstructures contains a large fraction of delta-ferrite. This microstructure evolution is related to increased phase stability of delta-ferrite. Previous, in-situ time-resolved X-ray diffraction investigations showed that, in the same weld, austenite solidification might occur at high cooling rates. In this research, a coupled thermal, geometrical, solidification and microstructure model was developed to rationalize previously published microstructure evolution results.

Technical Approach

Both moving (1 in/min to 100 in/min speed) laser (Nd-Yag) and stationary arc welds were made on a steel cylinder of composition Fe – 0.28C – 0.45 Mn – 3.70 Al – 0.39 Si – 0.01 Ni – 0.004 Ti – 0.003 O – 0.035 N (wt.%). The microstructure evolution was studied with optical microscopy. The phase evolution was predicted using ThermoCalc® software and diffusion controlled transformation models. Thermal cycles were modeled using finite different method. Interface response function models were used to describe the solidification modes.

Results/Discussion

The moving laser welds did not show a change in solidification mode from equilibrium ferrite to nonequilibrium austentic solidification. With an increase in welding speed, only a change in dendrite arm spacing was observed. Similar observations were made even in stationary welds with no imposed change in liquid-solid interface velocity. However, stationary welds with an imposed rapid increase in liquid-solid interface velocity led to a transition from equilibrium delta-ferrite to austenite mode of solidification. The above result suggests that the liquid-solid interface velocity in laser welds did not increase above a critical velocity to induce a change in solidification mode. A geometric model for single crystal weld growth was used to evaluate the interface velocities as a function of weld pool geometry. The above analysis was coupled with multicomponent dendrite growth theories to rationalize the observed phase selection phenomena. Additional experiments showed that the above changes in solidification mode were also associated with weld ripples.

Conclusions

The solidification microstructure evolution in Fe-C-Al-Mn steel welds was described by coupling geometrical model for crystal growth with multicomponent dendrite growth. The analysis shows a complex relation between liquid-solid interface velocities, phase selection phenomena, aluminum and carbon concentrations in these welds. The approaches to use these models will be highlighted.

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