MICROSTRUCTURAL FEATURES RELATED TO RIPPLING PHENOMENON IN 304 STAINLESS STEEL GTA WELDS

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EXTENDED ABSTRACT

Introduction

A high-speed, high-magnification video microscopy technique has been developed to investigate solidification phenomenon that occur during welding. This technique uses a high quality zoom lens system and a high-speed CCD camera to image the edge of a weld pool (solid-liquid interface) during the welding process. Rippling phenomenon are common to many welding processes and are not completely understood. A better understanding of gas tungsten arc (GTA) welds is critical for their use in high-consequence safety and security applications. Understanding rippling phenomenon and their effects on the microstructure of GTA welds is a first step towards better understanding this welding process.

Procedure

High-speed, high-magnification video microscopy was used to image the solid-liquid interface in a 304 stainless steel GTA weld. The high-speed camera, welding torch, and sample were arranged so that the weld pool remained stationary with respect to the camera. This allows the solid-liquid interface to be successfully filmed at a variety of welding speeds. The camera, lens system, welding torch, and sample were contained in an inert atmosphere glove box in order to prevent oxide formation on the weld pool. Quantitative data was extracted from the video clips using commercial image analysis software. The microstructure of the welds was examined

using optical metallography, Electron Beam Kikutchi Pattern imaging, and Energy Dispersive X-Ray Spectroscopy.

Results and Discussion

The visualization technique described above was used to investigate solid-liquid interface motion in 304 stainless steel DC GTA welds. Weld rippling formation was observed and the associated solid-liquid interface velocity was measured. High-speed, high-magnification images of ripple formation show that a distinct sequence of events occurs each time a ripple forms. This sequence of events involves changes in the solid-liquid interface velocity, changes in dendrite morphology, and changes in growth direction. Computer image analysis was used to measure solid-liquid interface velocity changes during ripple formation. It was found that during ripple formation the solid-liquid interface can travel at velocities that are significantly faster and significantly slower than the nominal welding speed. These velocity variations are cyclic.

The microstructures of a group of rippled welds were examined and a number of features associated with the rippling phenomenon were identified. These features included: a pattern change in the interdendritic material, an orientation change in the grains associated with the ripple, and a chemical change associated with the ripple. The pattern change can be seen using the optical microscope. It appears as light or dark features that extend across the weld bead and are shaped like the prior solid-liquid interface. The scale of these features is larger than the dendrite length scale. SEM based techniques were used for orientation imaging and chemical analysis. Electron Beam Kikutchi Pattern analysis indicated that a crystallographic orientation change is associated with the ripple features seen in the optical microscope. Energy Dispersive X-ray Spectrosocpy was used to detect a change in Cr and Ni content at the ripple feature. This change in solute content is consistent with a change in the solid-liquid interface velocity.

Conclusion

In summary, a detailed description of weld rippling phenomenon in 304 stainless steel DC GTA welds will be presented. This description includes high-speed, high-magnification imaging of ripple formation and metallurgical examination of the finished weld. A distinct sequence of events has been observed during ripple formation. The velocity of the solid-liquid interface associated with the rippling phenomenon has been measured. Microstructural examination of rippled welds showed that crystallographic orientation changes and chemical changes are associated with the ripple features.

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