C. Characterization of Microconstituents in Welds Produced Using Self-Shielded Flux Cored Arc Welding Consumables

Jeff A. Major and Stephen Liu, Center for Welding, Joining and Coatings Research, Colorado School of Mines, Golden, Colorado 80401

Introduction

The presence of microconstituents (MC's) in weld metals produced with self-shielded flux cored arc welding (FCAW-S) consumables is common. It is accepted that microconstituents are the last microstructural feature to transform from austenite. Microconstituents are a mixture of martensite, austenite, pearlite and carbides found at grain boundaries, triple junctions, and interlath regions. The presence of MC's, namely martensite-austenite (M-A), has been shown to greatly reduce the toughness of welds. A major problem with MC's is their characterization using traditional techniques. The presentation will focus on improved characterization techniques of MC's in FCAW-S weld microstructures.

Procedures

Light microscopy, scanning electron microscopy (SEM), and scanning transmission electron microscopy (STEM) were used to characterize MC's. The visual characterization also includes a 3-D model of the MC's in the welds, enhancing the ability to characterize the phases. Tint etching was employed for phase identification using light microscopy. Characterization includes localized chemical distributions, bulk compositions, X-ray diffraction, distribution and size, hardness (micro- and nano-indentions), and formation/decomposition as a function of cooling rates.

Results and Discussion

Two etching techniques were used for examination with light microscopy: nital and tint etching. Nital etching resulted in the MC's to appear dark (black) and the features couldn't be resolved. Because of today's color photographic digital ability, the use of tint etching was employed to differentiate between carbide, martensite, austenite, and ferrite. The techniques employed result in martensite etching brown, austenite etching white, carbides etching black, and ferrite etching an off white. Correlating the tint etch findings with the high resolution of the SEM, surface features of the phases could be resolved. To further improve SEM's MC characterization ability, a 3-D model was developed to examine the geometry of the MC's. The model verified observations of the morphological descriptions of the MC's. The model also enhanced characterization of specific MC's by revealing regions where certain phases of the MC's are more likely to reside. For instance, it is more common for the blocky MC to be MA constituent then carbide. These findings were later correlated to 2-D characterization of the MC's. The model was useful when determining critical sizes of MC's on mechanical properties, specifically toughness. The use of STEM allowed for orientation relationships to be determined between the MC's and the matrix microstructure. In some cases, the Kurdjumov-Sachs (K-S) relationship was found between MC and matrix.

Formation of MC's depends mainly on alloy content and cooling rates. The alloy contents were determined using surface analysis tools; such as energy dispersive spectroscopy (EDS) and electron probe microanalysis (EPMA). Cooling rates were examined in both the as-solidified and reheated conditions.

Conclusion

It is observed that characterization of MC's using traditional techniques is difficult, especially when using light microscopy and SEM. The use of tint etching enhanced light microscopy and SEM as characterization tools. Three-dimensional models allowed the geometrical aspect of the MC's to be verified. Critical sizes for correlation to toughness values were also determined using the models. The techniques used in the current study allowed for increased resolution of MC phases.