E. Microstructural Characterization and Hot Ductility of Ni Based Weldments

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Introduction

A690 is a Ni based alloy with superior resistance to Stress Corrosion Cracking (SCC) in chloride containing environments than the current A600, which has found wide-spread use in the primary and secondary water loops of nuclear pressurized water reactors (PWRs). EN52 is the filler metal designed for use with A690, which has a higher corrosion resistance than EN82H, the standard filler metal for A600. EN52 has been shown by several researchers to be susceptible to ductility dip cracking (DDC). DDC is a form of solid state cracking that occurs upon reheating a previously deposited weld pass. DDC occurs over an elevated temperature range in the solid state. It is most often observed in multi-pass welds with high restraint. Fracture most often occurs intergranularly. The DDC of EN52 limits the wide scale use of A690. Despite the significant amount of research effort by several researchers, the fundamental mechanism(s) that cause(s) DDC in EN52 is still not completely understood . A more thorough understanding of microstructural evolution of EN52 will aid in understanding the mechanism(s) that cause DDC and, ultimately, improving the filler metal to reduce DDC susceptibility. The objective of this research is to characterize the microstructural evolution and ductility of the aforementioned alloys with heat treatment.

Procedure

Test specimens were machined from plates of A690 and A600 as well as from multi-pass weldments of EN52 and EN82H. Gleeble hot ductility tests were performed using the specimens, which underwent a simulated thermal cycle and were then held at various times at the ductility minimum temperature on the on-cooling portion of the thermal cycle. Samples were then either strained to fracture or allowed to cool in the Gleeble without application of strain. The ductility was measured by reduction of area in samples that were fractured. Microstructural characterization was carried out on the hot ductility samples and on V-groove mock-ups by use of various techniques, to include: light optical microscopy (LOM), scanning electron microscopy (SEM), X-ray energy dispersive spectroscopy (EDS), transmission electron microscopy (TEM) and analytical electron microscopy (AEM). Time Temperature Transformation (TTT) diagrams and Continuous Cooling Transformation (CCT) diagrams were also calculated for each alloy composition to aid in interpreting the microstructural evolution with alloy and hold time.

Results and Discussion

The microstructure and ductility was found to change with hold time at the ductility minimum temperature for all alloys. In general, the ductility increased with hold time, with the most significant increases observed in EN52 and A690. SEM images verified that the hold time at temperature significantly increased precipitation along grain boundaries. EDS identified the precipitates to be Cr rich and TEM was utilized to identify them as $M_{23}C_6$ type. SEM imaging also revealed void formation along grain boundaries and adjacent to precipitates in specimens that were fractured after being held at temperature. It is believed that these voids coalesce along the grain boundary to form intergranular cracks and subsequent fracture. AEM was utilized to examine the grain boundary composition profiles. Calculated CCT and TTT diagrams were used to better understand the microstructural evolution with alloy composition and hold time, along with making comparisons between the four alloy systems evaluated.

Conclusions

Ductility increases significantly in EN52 and A690 when isothermally heat treated at the ductility minimum temperature. Grain boundary precipitation also increased with hold time and may contribute to the increase in ductility with hold time.