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Mechanical Property Degradation and Microstructural Evolution of Cast Austenitic Stainless Steels under Short-term Thermal Aging

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Abstract

Mechanical testing and microstructural characterization were performed on short-term thermally aged cast austenitic stainless steels (CASS) to understand the severity and mechanisms of thermal-aging degradation experienced during extended operation of light water reactor (LWR) coolant systems. Four CASS materials – CF3, CF3M, CF8, and CF8M – were thermally aged for 1500 hours at 290 °C, 330 °C, 360 °C, and 400 °C. All four alloys experienced insignificant change in strength and ductility properties but a significant reduction in absorbed impact energy. The primary microstructural and compositional changes during thermal aging were spinodal decomposition of the δ-ferrite into α/ α`, precipitation of G-phase in the δ-ferrite, segregation of solute to the austenite/ ferrite interphase boundary, and growth of $M_{23}C_6$ carbides on the austenite/ferrite interphase boundary. These changes were shown to be highly dependent on chemical composition, particularly the concentration of C and Mo, and aging temperature. The low C, high Mo CF3M alloys experienced the most spinodal decomposition and G-phase precipitation coinciding the largest reduction in impact properties.

1. Introduction

Cast austenitic stainless steels (CASS) are Fe-Cr-Ni steels with 300 series stainless steel chemistries that have a duplex austenite (γ)–ferrite (δ) phase structure due to the various casting processes, and are often used in structural applications due to their high corrosion resistance combined with relatively high strength, ductility, and toughness [1-4]. Thus, they are widely used for various large components within light water reactor (LWR) primary coolant systems, such as piping and pump casings [5-7]. These components are used in persistently extreme and damaging environments including high temperature and high pressure coolant water and low dose radiation for extended periods of time. The principal susceptibility of these materials under these conditions is reduced mechanical integrity through microstructural changes associated with long term thermal aging that can lead to, in some cases, embrittlement. For LWR applications, the degree and mechanisms of thermal aging degradation must be understood to make conclusive predictions about the lifetime of LWRs and these components during service conditions [8].