Effect of Thermal Aging on Static and Impact Fracture Properties of Cast Duplex Stainless Steels

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Abstract

The thermal aging degradation of cast austenitic stainless steel (CASS) components has been of serious concern because any component failure in the primary reactor coolant system will affect the performance of the entire power plant. Understanding of the thermally-induced fracture toughness degradation is essential to assess the integrity of those components during an extended-term (≥ 60 years) operation. A long-term, systematic research has been performed to provide scientific understanding of thermal aging degradation and predictive models and conclusions on the long-term integrity of the CASS components. Eight CASS materials with a wide range of δ-ferrite contents (3–34%) and two reference alloys, 304L and 316L, were thermally-aged at 290–400°C up to 30000 hours and characterized using various mechanical testing and high-resolution microscopy capabilities. Both static and impact fracture properties have been evaluated systematically for the ten stainless steels in various thermal aging conditions. This presentation focuses on the large database for static fracture toughness and impact toughness properties in a variety of thermal aging conditions. Further, degradation of static and dynamic fracture toughness is explained with the detailed results of STEM and APT analyses. The primary microstructural evolution features that cause fracture property degradation take place within the δ-ferrite and at ferrite-austenite phase boundaries. These include spinodal decomposition of the δ-ferrite, precipitation of G-phase and Cu-rich phases in the δ-ferrite, carbide precipitation at ferrite-austenite phase boundaries, and elemental segregation at boundaries. The test results also indicate that property degradation behavior is not monotonic: with the highest degrees of thermal aging some mechanical properties, such as the ductile-brittle transition temperature of impact energy and static fracture toughness, often show obvious recovery after steep degradation. Thermally-induced mechanisms are proposed to explain such a complex degradation behavior in the CASS materials. Finally, predictive models were proposed to express the thermal degradations of properties as functions of microstructural data and newly-defined aging parameter; which can be used for assessing the integrity of stainless steel components in extended-term services.