Interdependent and nonuniform microstructural evolution pathways of thermal aging degradation of cast austenitic stainless steels

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Complex, multicomponent alloys like cast austenitic stainless steels (CASSs) allow for the investigation of interdependent microstructural evolution mechanisms during thermal aging or irradiation, where simpler model systems may not show the co-dependency of different evolution pathways. These CASS alloys are used for many large components of nuclear light water reactor coolant systems. In this ongoing study, we aim to provide a comprehensive knowledge base for the integrity assessment of CASS components for extended operations, with a focus on thermal aging degradation mechanisms in the cast CF3, CF3M, CF8, and CF8M stainless steel alloys at reactor-relevant accelerated aging temperatures of 290-400°C up to 10,000 hours. A comprehensive evaluation of the microstructural evolution of the ferrite phase and austenite/ferrite interphase boundary after aging was conducted using atom probe tomography and electron microscopy, and further interpreted by kinetic Monte Carlo simulation. Within the ferrite phase of these duplex stainless steels, we have found a large dependence of precipitation of the Ni-Si-Mn-rich G-phase on the concentration of Cu, Mo, and C. In particular, Cu clusters that form at early stages of aging act as seeds for further precipitation of other phases. This same effect of Cu is found to influence the nonuniform nature of precipitation at the austenite-ferrite phase boundary, where the size of the precipitate denuded zone is reduced with the addition of Cu. This precipitate denuded zone also affects the extent of spinodal decomposition of the ferrite within this region. The mechanical behavior changes were assessed using Charpy impact testing, tensile testing, and fracture testing. We will provide a thorough analysis and comparison of the co-dependent microstructural evolution mechanisms and their relationship with mechanical property changes. The influence of composition and aging conditions will be evaluated to produce predictive models for behavior of components after long-term service.