INTERNATIONAL NUCLEAR ENERGY RESEARCH INITIATIVE

Atomic Ordering in Alloy 690 and Its Effect on Long-Term Structural Stability and Stress–Corrosion Cracking Susceptibility

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Project Number: 2011-001-K

Program Area: Reactor Concepts RD&D

Project Start Date: October 2011

Project End Date: September 2014

The objective of this project is to determine the effects of atomic ordering in Alloy 690 under pressurized water reactor (PWR) operating conditions on mechanical integrity and susceptibility to intergranular stress–corrosion cracking (SCC). Nickel-based Alloy 690 is being considered as a possible replacement for Alloy 600 in reactor structural components due to its improved resistance to primary water SCC. However, thermally treated Alloy 690 subjected to 20% to 30% cold working has demonstrated crack growth rates as high as those of Alloy 600 during testing in high-temperature deaerated primary water. Alloy 690 is prone to multiple atomic ordering, including Ni_2Cr type ordering at 420°C and Fe_3Ni and Ni_3Fe type ordering at lower temperatures. Such ordering is likely under light water reactor operating conditions and would adversely affect the long-term structural stability and mechanical properties of this alloy.

To obtain a fundamental understanding of the SCC mechanisms, the project team will prepare eight samples of Alloy 690, four at each allowable extreme of iron content. Each set of samples will be subjected to either solution annealing or thermal treatment at 700°C, with and without 20% cold working. The eight samples will then be aged at 360°C to 550°C for up to 14,000 hours and characterized to investigate the degree of atomic ordering and its effect on mechanical properties. PWR primary water SCC tests will also be conducted as a function of aging. To evaluate the correspondence between atomic ordering and aging temperature and time, the team will analyze materials in the nanoscale ordered phase using electron microscopy and neutron analytical techniques. Key activities are as follows:

- Year 1: Prepare eight kinds of Alloy 690 samples, age at 360°C–550°C, and characterize.
- Year 2: Analyze nano-scale ordered phases to understand the effects of short-range ordering (SRO) and long-range ordering (LRO) phases on mechanical properties.
- Year 3: Evaluate SCC resistance of aged Alloy 690 to understand the effects of cold working, iron content, and thermal treatment.