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Low temperature crack propagation in nuclear shut-down water chemistry of Alloy 52 with potential effects of hydrogen

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Abstract

Constant-displacement bolt-loaded compact tension specimens of Nickel-based Alloy 52 were exposed to boiling water reactor environment for 12 years and then in cold shutdown water environment for a further 3 years in a Swedish nuclear power plant at a stress intensity factor of 20 MPa√m. Follow decontamination and specimen opening, unexpected crack extensions of 3–4.5 mm were observed. The fracture surface and the cross-sectional deformation microstructure were examined by electron microscopies techniques up to nanoscale. The dominant fracture mode is transgranular along the close-packed {111} planes. Extensive shear bands were observed in vicinity of the crack tips, revealing localized plasticity. Hydrogen reduces stacking fault energy, results in localized plasticity and enhances shear bands formation. Low temperature crack propagation with evident effects of hydrogen was considered as the potential cause of the crack propagation in Alloy 52 without external dynamic loading in cold shut down water chemistry. The project promotes knowledge transfer, improves nuclear materials and fracture mechanics competence and strengthens the connections and experience exchange between the Nordic research organizations, universities, industries, authorities, and especially the young generation. The project deals with structural integrity, long-term operation, and ageing management, which are relevant for both present and future nuclear power plants. The technical results provide a basis for assessment of long-term operation for the Finnish and Swedish nuclear power plants for both the operators and the regulatory perspectives. Dissemination through the peer reviewed publications and the oral presentations at the international conferences ensured the knowledge exchange in international and Nordic networks.

Key words

Dissimilar metal weld, Alloy 52, fusion boundary, characterization, fracture mechanical test, hydrogen embrittlement; low temperature crack propagation

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