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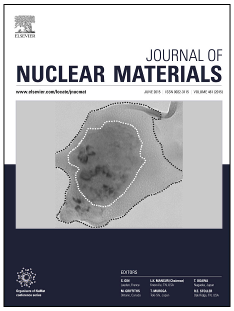

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A Novel In-Situ, Lift-Out, Three-Point Bend Technique to Quantify the Mechanical Properties of an Ex-Service Neutron Irradiated Inconel X-750 Component

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Abstract

A first of its kind small scale mechanical testing technique involving micro- three-point bending was invented, developed, and implemented on reactor irradiated, active Inconel X-750 components removed from service after approximately 53 and 67 dpa. These tests were performed at ambient room temperature in-situ using a scanning electron microscope in order to obtain live recordings of sample deformation and loading curves. Sample and testing apparatus preparation required novel lift-out and fabrication processes. Materials from two irradiation temperature regimes, low temperature (120-280 ^{o}C) and high temperature (300 ± 15 ^{o}C) were examined. Manufacturing and finishing (grinding) of this component create differences between its edge and center, so micro-specimens from both areas were extracted in order to study these differences. According to three-point beam bending theory, a 0.2% offset yield stress parameter is introduced and calculated for all specimens. Differences in mechanical properties due to irradiation temperature and dose effects were observed. Material irradiated at the higher temperature exhibited yield strength increases of ~540 MPa after 53 dpa and ~1000 MPa after 67 dpa. There was little difference (≤ 310 MPa) in yield strength between materials irradiated at the lower temperature at 53 dpa and 67 dpa compared with non-irradiated material. Differences in yield strengths between the edge and center of the component are retained after irradiation. The difference in yield strengths for the edge and center regions was ~740 MPa for non-irradiated material. After irradiation to a dose of 67 dpa these differences were ~570 MPa for the lower irradiation temperature and ~710 MPa for higher irradiation temperature. There were no indications of grain boundary failures via cracking except for material irradiated to 67 dpa at low temperature.

Keywords: Small scale mechanical testing (SSMT), neutron irradiation, high dose, nickel superalloys, mechanical properties

1. Introduction

Face-centered cubic (fcc), age-hardenable, nickel-based superalloys, including Inconel X-750, provide high mechanical strength and ductility [1,2], good creep properties [3], and excellent corrosion resistance at elevated temperatures [1,2]. This combination of superior properties has made them suitable for use in nuclear reactors, specifically as fasteners (bolts) [4], centering pins [5], jet pump restraints [6], tie-rods and cladding for absorber rods in light water reactors (LWRs) [7,8] as well as cable sheathing and core wires in flux detector assemblies, fuel channel garter springs, and tensioning springs in CANDU reactors [2].