Identifying and Understanding Environment-Induced Crack Propagation Behavior in Ni-Based Superalloy INCONEL 617

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Abstract

The nickel-based superalloy INCONEL 617 is a candidate material for heat exchanger applications in the next-generation nuclear plant (NGNP) system. This project will study the crack propagation process of alloy 617 at temperatures of 650°C-950°C in air under static/cyclic loading conditions. The goal is to identify the environmental and mechanical damage components and to understand in-depth the failure mechanism.

Researchers will measure the fatigue crack propagation (FCP) rate (da/dn) under cyclic and hold-time fatigue conditions, and sustained crack growth rates (da/dt) at elevated temperatures. The independent FCP process will be identified and the rate-controlled sustained loading crack process will be correlated with the thermal activation equation to estimate the oxygen thermal activation energy. The FCP-dependent model indicates that if the sustained loading crack growth rate, da/dt, can be correlated with the FCP rate, da/dn, at the full time dependent stage, researchers can confirm stress-accelerated grain-boundary oxygen embrittlement (SAGBOE) as a predominate effect. Following the crack propagation tests, the research team will examine the fracture surface of materials in various cracking stages using a scanning electron microscope (SEM) and an optical microscope. In particular, the microstructure of the crack tip region will be analyzed in depth using high resolution transmission electron microscopy (TEM) and electron energy loss spectrum (EELS) mapping techniques to identify oxygen penetration along the grain boundary and to examine the diffused oxygen distribution profile around the crack tip. The cracked sample will be prepared by focused ion beam nanofabrication technology, allowing researchers to accurately fabricate the TEM samples from the crack tip while minimizing artifacts. Researchers will use these microscopic and spectroscopic results to interpret the crack propagation process, as well as distinguish and understand the environment or SAGBOE damage process under hold-time fatigue and sustained loading conditions.