INTERNATIONAL NUCLEAR ENERGY RESEARCH INITIATIVE

High-Temperature Nickel-Based Alloys for VHTR Applications: Mechanical and Corrosion Testing

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Abstract

The Very High Temperature Reactor (VHTR) is a helium-cooled reactor operating with outlet temperatures exceeding 950°C. There are two main advantages of this concept—high yields for energy generation and the ability to supply high-temperature process heat for hydrogen production. However, the high temperatures impose challenging design requirements on structural materials, particularly for the intermediate heat exchangers.

Nickel-based alloys are the most suitable materials for high temperatures, particularly Inconel Alloy 617 and Haynes 230. However, these alloys are not fully ASME code-qualified for nuclear applications. Basic data are needed to achieve a complete understanding of their behavior at high temperatures. Researchers must investigate the mechanical properties of these alloys and study surface/subsurface corrosion effects caused by helium impurities. As component integrity must be demonstrated over the entire operational lifetime (on the order of 100,000 hours), the evolution of properties over time must be taken into account, specifically the effects of thermal aging.

In this work, researchers will conduct experimental thermal aging studies of Alloy 617 and Haynes 230 through short-duration (500 hours) and medium-duration (5,000 hours) exposure tests of material coupons and specimens. Through these experiments, they will evaluate the microstructural evolution under thermal aging conditions and determine the effect of thermal aging on Charpy and tensile test data. They will use the results of these studies to develop a model capable of extrapolating the effects of thermal aging on materials properties over a very long duration in order to predict component lifetimes. Finally, they will validate the model by conducting long-exposure testing on material specimens to 15,000 hours.