

Public Abstract

First Name:Hakan

Middle Name:

Last Name:Us

Adviser's First Name:Tushar K.

Adviser's Last Name:Ghosh

Co-Adviser's First Name:Sudarshan K

Co-Adviser's Last Name:Loyalka

Graduation Term:FS 2016

Department:Nuclear Engineering

Degree:PhD

Title:OXIDATION BEHAVIOR OF VERY HIGH TEMPERATURE REACTOR (VHTR) CANDIDATE MATERIALS: 316L STAINLESS STEEL,ALLOY 617, AND INCOLOY-800H

High temperature nuclear reactors require alloys to perform well at temperatures around 1000 to 1400 K. The oxidation behavior of three high temperature reactor candidate materials, 316 L stainless steel, alloy 617, and Incoloy 800-H under different conditions were investigated in the present work. For molybdenum-based 316 L stainless steel, the tests were performed isothermally at temperatures between 773 K and 1,273 K (in steps of 100 K) for 24 hours in controlled air environments. The oxidation behavior followed the parabolic oxidation kinetic rate law. The activation energy was 149.21 kJ/mol at 873 K to 1273 K. At 773 K, a thin external oxide layer was observed, while at higher temperatures a continuous and relatively irregular and inwardly protruded external oxide layer was observed. The external layer width and composition depended on increasing temperatures. At 1073 K a Cr₂O₃ layer was detected. After 1273 K, a Fe₂O₃ sub-layer formed in addition to the Cr₂O₃ layer. Continuous larger external oxide scales and grain boundary ridges were also observed with increasing temperatures. The oxide morphology and structure of 316L stainless steel were strongly affected by the controlled air environments. The best oxidation resistance of 316L stainless steel was observed at 1073 K with the highest Cr content value. At 1273 K, mass gain was related to iron oxidation. Increasing oxidation temperatures were attributed to the formation of pores, voids, and grain boundaries.

Alloy 617 tests were performed isothermally at temperatures between 1073 K to 1473 K (in steps of 100 K) for 24 hours in controlled air environments. The oxidation behavior followed the parabolic oxidation kinetic rate law. The activation energy was found to be 233.46 kJ/mol for 1073 K to 1473 K. At 1073 K to 1473 K, a thin external oxide layer was identified as an NiO Cr₂O₃ double layer. The external layer had Cr₂O₃, and the inner layer was a NiO layer. Meanwhile, a continuous and relatively irregular and inwardly protruded external oxide layer was observed with an external layer width dependent on increasing temperatures. Besides the NiO-Cr₂O₃ layer, Al₂O₃ areas were also detected. Figures sequentially showed a continuous growth of external oxide scales and grain boundary ridges with temperatures. The oxide morphology and structure of alloy 617 were strongly affected by environments. At 1473 K, the increasing mass gain was related to Ti oxidation. The oxidation depth increased as the temperature increased. Increasing oxidation temperatures is attributed to the formation of pores, voids, and grain boundaries.

Incoloy 800H tests were performed isothermally at temperatures between 1073 K to 1473 K (in steps of 100 K) for 24 hours in controlled air environments. The activation energy was found to be 266.8 kJ/mol for 1073 K to 1473 K Results showed that the oxidation followed a parabolic oxidation kinetic law. Spallation occurred as a result of oxidation after 1373 K. At 1473 K, the increasing mass gain was related to Ti oxidation. As revealed by SEM, a triple layered external oxide scale was formed.

A thermogravimetric analyzer, scanning electron microscopy/energy dispersive X-ray spectroscopy, and X-Ray diffraction were among the analytical techniques used.