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Influence of composition and heating schedules on compatibility of FeCrAl alloys with high-temperature steam

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Abstract: FeCrAl alloys are proposed and being intensively investigated as alternative accident tolerant fuel (ATF) cladding for nuclear fission application. Herein, the influence of major alloy elements (Cr and Al), reactive element effect and heating schedules on the oxidation behavior of FeCrAl alloys in steam up to 1500°C was examined. In case of transient ramp tests, catastrophic oxidation, i.e. rapid and complete consumption of the alloy, occurred during temperature ramp up to above 1200°C for specific alloys. The maximum compatible temperature of FeCrAl alloys in steam increases with raising Cr and Al content, decreasing heating rates during ramp period and doping of yttrium. Isothermal oxidation resulted in catastrophic oxidation at 1400°C for all examined alloys. However, formation of a protective alumina scale at 1500°C was ascertained despite partial melting. The occurrence of catastrophic oxidation seems to be controlled by dynamic competitive mechanisms between mass transfer of Al from the substrate and transport of oxidizing gas through the scale both toward the metal/oxide scale interface.

Key words: FeCrAl alloys; ATF; high-temperature oxidation; transient condition; steam

1. Introduction

Zirconium-based alloys possess low neutron absorption cross section, good corrosion and irradiation resistance as well as high mechanical strength. These outstanding properties guarantee them being well qualified for utilization as state-of-the-art cladding and structural components in water-cooled nuclear reactors with respect to normal operation [1]. However, an undesirable limitation is their fast self-catalytic exothermic reaction with high-temperature steam in case of off-normal conditions. Once the environment inside the core changes from normal operating conditions to accident scenarios, e.g. loss of coolant accidents (LOCA), the Zr-based claddings