Study on abnormal weight gain of lean-Cr FeCrAl alloys for accident resistant cladding during uniform corrosion

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Abstract Since Fukushima nuclear accident, FeCrAl alloys have been considered promising to replace existing used Zr-based alloys as a cladding material for light water reactors due to its excellent corrosion resistance and mechanical properties [1]. Under normal operating conditions of pressurized water reactors, the outer chromium rich protective oxide layer acts as a barrier to prevent the inward diffusion of oxygen elements and the outward diffusion of metal atoms to inhibit oxidation [2].

This study systematically investigated the uniform corrosion behavior of Fe-13Cr-4.5Al (wt%) and lean-Cr (7-10 wt%) with 5Al (wt%) FeCrAl alloys under simulated pressurized water reactor conditions (20.0 MPa and 360° C) with a time scale of 6000 hours in an autoclave system. Comparing the weight gain curves of sample groups, it was found that in the early stage of uniform corrosion, the lower Cr content had a weaker inhibitory effect on the outward diffusion of Fe elements, resulting in a significantly higher weight gain rate. However, in the later stage, the corrosion rate of the 7Cr group samples was abnormally low. Based on the surface and cross-sectional characterization, a double-layer structure containing external oxide particles and internal chromium rich spinel was observed. When the Cr content was higher than 8wt%, a sharp-edged iron oxide was detected on the surface. While the Cr content was 7wt%, the surface oxide layer was amorphous and uniformly covered the inner spinel layer. As the uniform corrosion time prolongs, the external oxide particles show significant size growth. When the external oxide particles have edges, the O element easily diffused inward through the gaps between the peroxide particles, leading to further oxidation of the internal matrix. While the external oxide particles were in an amorphous state, the outer coated oxide particles reduced the fast channel, resulting in better resistance to uniform corrosion.

Keywords: FeCrAl alloy; Accident-tolerant fuel; Simulated PWR environment; Oxidation

Reference

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