

Ni segregation in the oxide film of 15-15Ti austenitic steel at high-temperature CO₂

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Abstract The supercritical CO₂ Brayton cycle has great application prospects in advanced nuclear energy systems due to higher thermal efficiency and desirable compactness [1-3]. The implementation of the Brayton cycle requires materials with excellent performance in high-temperature and high-pressure CO₂ environments, which is a great challenge for structural materials. Austenitic steel is expected to be used in CO₂ Brayton cycle because of its good corrosion and irradiation resistance [4, 5]. Currently, most studies on austenitic steels have tended to explore the composition and structure of the oxide films in different exposure conditions, and the results have shown that the typical oxides formed in CO₂ include a thin Cr₂O₃ film or a double-layer Fe-rich oxide film [6, 7]. However, the oxidation and segregation of the stabilizing element Ni in the oxide film is also a non-negligible issue for austenitic steels. Although a complex and irregular distribution of Ni has been observed in the available literature, authors have not focused on it due to the lack of a clear regularity [8-10].

In this work, 15-15Ti austenitic stainless steel was selected to investigate the microstructure and composition of the oxide film formed by exposure to CO₂ at 550-650 °C for 20-200 h. A double-layer oxide film was formed on 15-15Ti exposed to high-temperature CO₂, with outer Fe-rich layer and Cr/Ni-rich inner layer comprising Ni-poor and Ni-rich zones. The Ni-poor zone contained Fe-Cr spinel oxides and numerous nanopores, whereas the Ni-rich zone consisted of Fe-Cr spinel oxides and Ni-rich phases with austenite structure. The Ni segregation showed a specific evolution with exposure time and temperature: Ni-poor zones grew up and evolved into a laminar structure as the oxide film thickened. The analysis showed that the oxidation and migration behavior characteristics of Ni was the main reasons for the formation of the laminar structure.

Keywords: Austenitic steel, TEM, High-Temperature CO₂, Oxidation, Oxide film, Ni segregation.

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