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The Role of Nickel on the High-Temperature Corrosion of Modell Alloys (Stainless Steels) before and after Breakaway Corrosion at 600°C: A Microstructural Investigation

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Abstract : Renewable fuels such as biomass/waste for power production is an attractive alternative to fossil fuels in order to achieve a CO_2 -neutral power generation. However, the combustion results in the release of corrosive species. This puts high demands on the corrosion resistance of the alloys used in the boiler. Stainless steels containing nickel and/or nickel containing coatings are regarded as suitable corrosion resistance material especially in the superheater regions. However, the corrosive environment in the boiler caused by the presence of water vapour and reactive alkali very rapidly breaks down the primary protection, i.e., the Cr-rich oxide scale formed on stainless steels. The lifetime of the components, therefore, relies on the properties of the oxide scale formed after breakaway, i.e., the secondary protection. The aim of the current study is to investigate the role of varying nickel content (0–82%) on the high-temperature corrosion of model alloys with 18% Cr (Fe in balance) in the laboratory mimicking industrial conditions at 600°C. The influence of nickel is investigated on both the primary protection and especially the secondary protection, i.e., the scale formed after breakaway, during the oxidation/corrosion process in the dry O_2 (primary protection) and more aggressive environment such as H_2O, K_2CO_3 and KCl (secondary protection). All investigated alloys experience a very rapid loss of the primary protection, i.e., the Cr-rich $(Cr, Fe)_2O_3$, and the formation of secondary protection in the aggressive environments. The microstructural investigation showed that secondary protection of all alloys has a very similar microstructure in all more aggressive environments consisting of an outward growing iron oxide and inward growing spinel-oxide $(Fe, Cr, Ni)_3O_4$. The oxidation kinetics revealed that it is possible to influence the protectiveness of the scale formed after breakaway (secondary protection) through the amount of nickel in the alloy. The difference in oxidation kinetics of the secondary protection is linked to the microstructure and chemical composition of the complex spinel-oxide. The detailed microstructural investigations were carried out using the extensive analytical techniques such as electron back scattered diffraction (EBSD), energy dispersive X-rays spectroscopy (EDS) via the scanning and transmission electron microscopy techniques and results are compared with the thermodynamic calculations using the Thermo-Calc software.

Keywords : breakaway corrosion, EBSD, high-temperature oxidation, SEM, TEM
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