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Hot corrosion behavior of powder metallurgy Rene95 nickel-based superalloy in molten NaCl–Na_2SO_4 salts

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ABSTRACT

Hot corrosion behavior of powder metallurgy (PM) Rene95 Ni-based superalloy in molten 25%NaCl + 75%Na_2SO_4 salts at 650 °C, 700 °C and 750 °C are investigated by weight loss measurements, X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDS). Experimental results show that hot corrosion kinetics follow a square power law at 650 °C and linear power laws at 700 °C and 750 °C. The corrosion layers on the surface of PM Rene95 superalloy are detected to be mainly composed of Cr_2O_3, NiO, and Ni_3S_2 at each temperature. Besides, small amounts of $NiCr_2O_4$ at 700 °C and NaCl at 750 °C are observed respectively. Cross-sectional morphologies and corresponding elemental maps indicate that corrosion layers near scale/alloy interface are composed of oxides at 650 °C while duplex oxides and sulfides at 700 °C and 750 °C. According to these results, a cooperating mechanism of oxidation and sulfuration for hot corrosion of PM Rene95 Ni-based superalloy is confirmed.

1. Introduction

Nickel-base superalloys are advanced structural materials that are mainly used in aircraft engines and also extensively used in chemical, petrolic and electrical industries [1–4]. They are very often exposed to mechanical stresses and aggressive environments simultaneously. Several studies [5–8] had shown that interaction between creep or fatigue and the environment have to be considered in determining the useful life of superalloy used at high temperatures. It had been shown that a condensation layer of alkali metal sulphate which was generally considered to be a mixture of the salts Na_2SO_4 and NaCl was often observed on the turbine blade surface of superalloys in gas turbine engines. The existence of such a corrosive condensation layer on the superalloy surface could produce severe hot corrosion which considerably reduced the service life of high temperature components. Hot corrosion became a topic of important and popular interest in the late 1960s as gas turbine engines of military aircraft suffered severe corrosion during operation over seawater [9]. This phenomenon had been observed even more frequently on the high temperature components of marine and industrial gas turbines and coal conversion systems. The results of much work with respect to the effects of hot corrosion on creep and stress rupture had been published in the literature [6–9]. The reviews by Tien and Davidson [10] in 1980 contained accounts of the generalized understanding of corrosion creep and stress rupture. With the development of aeroengine, new nickel-based superalloys appeared, such as Alloy 706 [6], Udimet 500 [7], IN-738LC [7,11], Inconel 713LC [12], Inconel MA 754 [12], Haynes 214 [12] Haynes HR-160 [12], MAR-M247 [13], M38G [14], and K44 [15,16]. And many efforts had been paid on hot corrosion behavior of these superalloys. Besides, as gas turbine firing temperatures are increased and as less-refined fuels are used, there is an ever-intensifying need that the coatings of superalloy components should provide them with a long-time surface stability. At present, MCrAlY coating is the most-widely used one [17–19].

Nickel-base superalloys can be classified into wrought, cast and powder metallurgy (PM) alloys according to the manufacturing routes [20]. For wrought and cast superalloys, many attentions have been paid on their hot corrosion behaviors [6,7,11–16]. However, there is no such investigation of PM superalloy has been carried out at present. The PM Rene95 Ni-based superalloy is an advanced structural material used in components of modern turbine engines, particularly as a high temperature alloy for turbine disk applications. At present, investigations of PM Rene95 alloy are concentrated into tensile and creep properties, high temperature strength, resistance to fatigue crack growth, and oxidation resistance in air [21–26]. It is noteworthy that hot corrosion resistance property is one of important aspects for Ni-based superalloy systems since corrosion can result in dealloying, loss of surface strength, crack initiation and ultimately failure [9,12,25–30]. Poor hot corrosion resistance will constitute severe degradation to the

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