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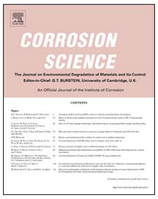

Investigation on hot corrosion behaviour of Aluminum Rare Earth coating in mixed sulphate at 1050 °C

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ABSTRACT

In this paper, hot corrosion behaviour of the Aluminum Rare Earth coating in mixed sulphate at 1050 °C was investigated. Results demonstrated that during the first 20 h of hot corrosion, it was difficult to form a protective oxide scale on the coating surface, and the antioxidant element Al was consumed significantly. Meanwhile, it took more than 50 h to reach to the steady-state oxidation which lasted only for 10 h. It is clearly demonstrated that, the molten salt at temperature more than 1000 °C, not only acts as hot corrosion media, but also will chemically attack the coating surface.

1. Introduction

There is a continues quest for increasing the working temperature of aero engine turbines [1] and thermal barrier coating (TBC) is one of the most effective ways to achieve this [2,3]. TBCs consist of a ceramic top-coat and a metallic bond coat [4] to bond the ceramic top-coat to the base material. In most of the cases, the oxidation corrosion of the metallic bond coat is the main reason of TBCs failure. In the recently developed TBCs, by considering the adiabatic effect of the ceramic top-coat and cooling system, the working temperature of the metallic bond coat can be assumed to be more than 1000 °C [5]. Therefore, it is of great significance to investigate the oxidation corrosion resistance behaviour of the metallic bond coat at extreme temperature, more than 1000 °C.

Oxidation corrosion consists of two oxidation, hot oxidation and hot corrosion. Hot corrosion is defined as an accelerated corrosion in the salts environment, such as sulphate, chloride and vanadium [6]. Recent studies have used more than 1000 °C even to 1200 °C as hot oxidation temperature for investigating the bond coat resistance against oxidation corrosion [7–11]. Haizhong Zheng et al. [9] have investigated the oxidation behaviour of Al-Si coating at 1200 °C. However, most studies have used temperature below 1000 °C [12–18] for investigating the hot corrosion of the metallic bond coat. Xin Peng et al. [14] investigated the hot corrosion of NiCrAlY coating in mixed sulphate at 700 °C and demonstrated that numerous internal oxidized voids generated in the surface layer at the initial period. Jintao Lu et al. [16] showed NiCoCrAlY coating was completely failed after 80 h of hot corrosion in mixed sulphate at 900 °C. Thus visible, the metallic bond coat serviced in temperature below 1000 °C has been faced with extremely severe hot corrosion challenge. Hence, increasing number of studies have focused on how to improve the high-temperature corrosion resistance of the metallic bond coat [19–22]. However, studies of hot corrosion at temperature more than 1000 °C of the metallic bond coat are rarely reported. Hongyu Wang et al. [23] investigated the hot corrosion of the low Al NiCoCrAlY laser cladded coating in mixed sulphate at 1050 °C. Results demonstrated the mass of the coating was lower than starting mass and the coating has tended to fail completely after 50 h of hot corrosion. It is clearly demonstrated that the hot corrosion of the metallic bond coat at temperature more than 1000 °C is more serious.

Aluminum Rare Earth (Al-R.E.) coating attracts much attention because of its relatively easy preparation process and it can form stable and protective Al_2O_3 scale at high temperature [24,25]. At the same time, rare earth elements can play “active effect” during hot corrosion [26,27], which can enhance the resistance of the coating. In the current study, the hot corrosion behaviour of the Al-R.E. coating in mixed sulphate (75 wt.% Na_2SO_4 + 25 wt.%K_2SO_4) at 1050 °C was investigated. To understand the hot corrosion behaviour of this coating, hot corrosion kinetics, corrosion morphology, elements distribution and surface phases were studied and hot corrosion mechanism was discussed in detail.

2. Experimental

2.1. Coating process

Nickel-based superalloy GH4033 with nominal composition as listed in Table 1 [23] was used as the substrate. The alloy rod was sliced into substrate specimens with the size of 6 mm × 4 mm × 4 mm by a wire-

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Table 1
Nominal chemical composition of GH4033 alloy.

Element	Mass fraction (wt.%)
Cr	19–22
Al	0.60–1.00
Ti	2.40–2.80
Fe	4.00 (max)
B	0.01 (max)
Si	0.35 (max)
Ni	Balance

electrode cuter (Model MSC-M332, China). All surfaces of the substrate specimen were polished using 400 grit silicon based abrasive paper. Then, substrate specimens were cleaned with submerging in acetone solution in the ultrasonic in order to remove any contamination. The Al-R.E. coating was prepared by the pack cementation process with a pack composition of 44 Al (100–200 mesh) – 9 CeO_2 (30–50 nm) – 44 Al_2O_3 (100–200 mesh) – 3 NH_4Cl (wt.%) [28]. The Al and Al_2O_3 powders were used as donor and filler, respectively. The halide salts NH_4Cl were used as activator, which would react with the depositing elements to form a series of halide vapors. Subsequently, the substrate specimens were buried in the well-mixed pack powders in a sealed 45 steel container with a dimension of 60 mm in diameter, 5 mm in thickness and 65 mm in height, which was placed in a muffle furnace. The deposition temperature was chosen as 850 °C holding for 8 h then 1050 °C holding for 4 h. The heating rate was 10 °C min^{-1} from room temperature to 850 °C and 20 °C min^{-1} from 850 °C to 1050 °C. Finally, the steel container was furnace cooled to room temperature.

2.2. Hot corrosion test

A reported salt deposition method was used for the hot corrosion test [29]. Before hot corrosion tests, surfaces of the coating samples were ground with 400 grit metallographic sandpapers to remove any surface impurity or remaining powder from coating process. The weight of samples was recorded before the single hot corrosion test. Then, one surface with 6 mm × 4 mm dimension was brushed with the saturated salt solution of 75 wt.% Na_2SO_4 + 25 wt.% K_2SO_4. During brushing of salt solution, the samples with coating were placed on the electric stove to ensure drying of salts solution and having 2 mg cm^{-2} of salts on samples surface after drying. One sample without brushed salt as control sample was placed in alumina crucible along with three other samples with coating salts. Subsequently, the alumina crucible was placed in a muffle furnace at 1050 °C with still air atmosphere to carry out the hot corrosion test. The whole test contained 10 cycles of 10 h at 1050 °C followed by cooling to room temperature and boiling in deionized water for 30 min to remove any residual salts from the surface. After being dried, the electronic balance with an accuracy of 0.1 mg was used to measure the mass of samples after each cycle, the obtained

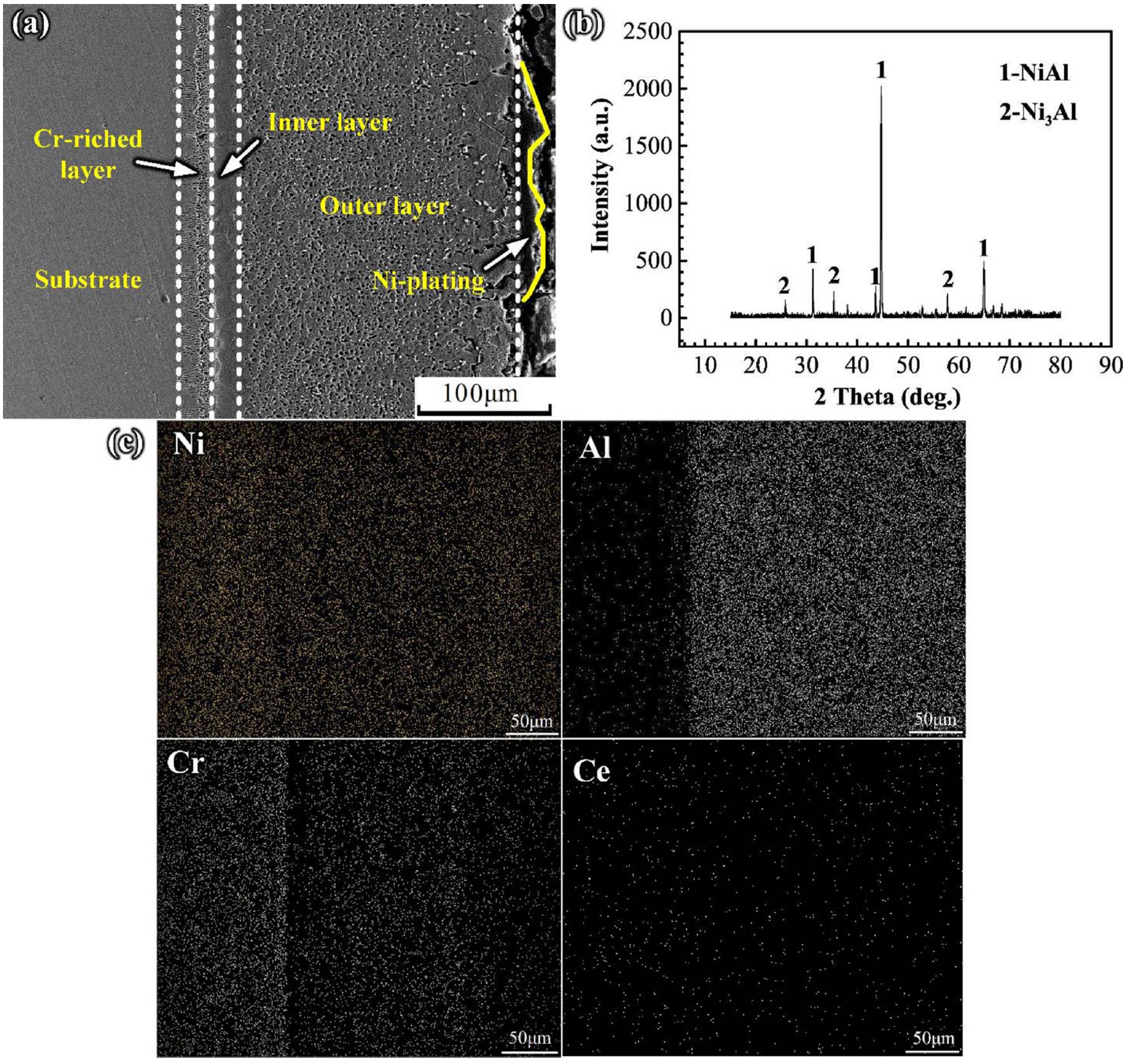

Fig. 1. Cross-sectional SEM morphology (a), XRD pattern (b) and element mapping (c) of the Al-R.E. coating.