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Oxidation behaviour of the nickel-based superalloy DZ125 hot-dipped with Al coatings doped by Si

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ABSTRACT

A pure Al coating and Al-Si coating were prepared on the surface of the DZ125 superalloy by hot-dipping. The Al-Si coating provides better thermal oxidation resistance than that of the pure Al coating due to the formation of a more compact Al_2O_3 layer. The microstructure of the Al-Si coating shows a silicon-aluminium-based layer with Ta_5Si_3 and AlHfSi phase forms after heat treatment in argon at 850 °C. This layer is a barrier to the diffusion of oxygen and other metal elements during cyclic oxidation, which has a significant effect on the formation of the compact Al_2O_3 layer.

1. Introduction

The DZ125 nickel-based superalloy is widely used for gas turbines and boilers due to its good thermo-mechanical properties [1,2]. Unfortunately, poor high-temperature oxidation behaviour obviously restricts its application. Thus, a protective coating on the surface of DZ125 is necessary. Both the thermal barrier coating (TBC) and anti-oxidation coating systems are applied widely as protective coatings. Usually, MCrAlY or β-(Ni, Pt) Al acts as a bond coating for the TBC system [3–5], which is achieved by thermal spraying or EB-PVD [6,7]. Diffusion aluminide coatings are used in the anti-oxidation coating system [8], and several aluminizing methods have been developed, such as thermal spray [9], pack cementation [10] as well as hot-dipping [11,12].

The addition of silicon in diffusion aluminide coatings is an economic process because it has a lower cost for coating preparation than that for MCrAlY or β-(Ni, Pt) Al coatings, when applied to the protection of the superalloy at high temperature. As a result, many researchers have given attention to the diffusion aluminide coatings doped by silicon. Recently, the oxidation resistance of the alloys, such as low carbon steel, Cr-50Nb, TiAl. etc [13–15], were improved significantly with Al-Si coatings. Xiang et al. [16] performed the co-deposition of aluminium and silicon to form diffusion coatings by pack cementation and investigated the feasibility of co-depositing Al and Si to form multiple element diffusion coatings on nickel-based superalloys. Subsequently, other researchers found that Si could accelerate the formation of Al_2O_3 layer and improve the oxidation resistance of the coatings on nickel-based superalloys [17,18]. The silicon was also reported being existed in the form of solid solution, not crystalline phase, in the coating prepared via pack cementation [19]. However, some elements (Cr, Co, Y, Hf, Ta, Ti, etc) in superalloys could diffuse to the protective coatings and affect the oxidation resistance of the coatings. Thus, the influence of silicon and these elements on oxidation resistance is necessary to be explored. Wang et al. [20] reported that Y could refine the alloy grains, which promoted the rapid formation of protective SiO_2 and GeO_2 scale to improve the oxidation resistance. Guo et al. [21] investigated the Si contributed to enhancing oxide scale adherence through avoiding the segregation of Cr and Mo beneath the oxide scale. But understanding of the mechanism through which Si and substrate elements (Cr, Co, Y, Hf, Ta, Ti, etc) affect the microstructure and oxidation performance of the coatings on the superalloy is still poor. Moreover, the oxidation resistance of the Al-Si diffusion coating co-deposited by pack cementation [10,13–19,21] is not sufficient because the balance position of mass change in oxidation kinetics curves is still high. Among all aluminizing methods, the low cost and high efficiency of hot-dipping have made it widely adopted in industry [22]. Thus, a hot-dipped Al-Si coating is worth investigation to determine if it can exhibit better thermal oxidation resistance than that of other

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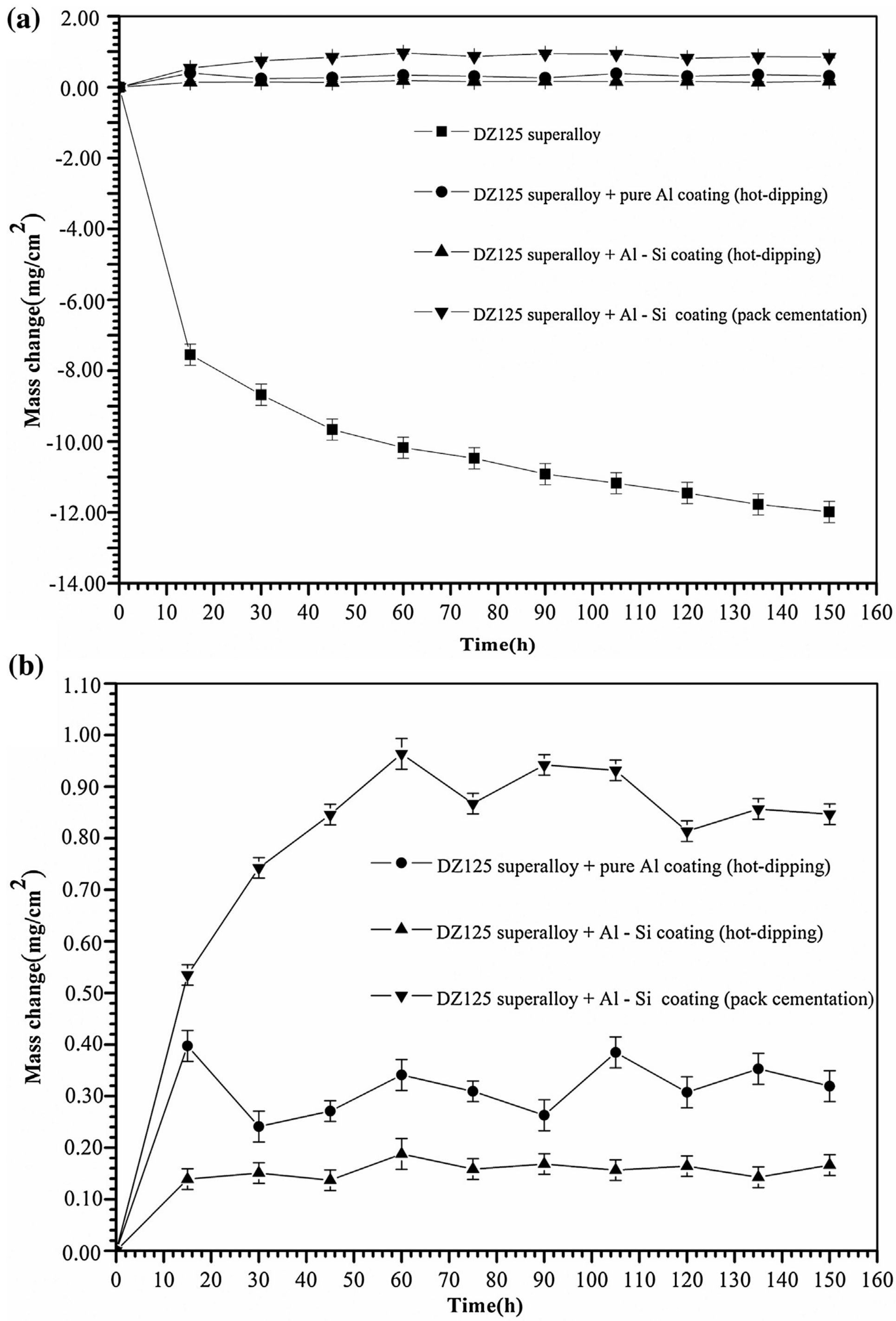

Fig. 1. Cyclic oxidation kinetics of DZ125 with different coatings over an initial 10 cycles, with 15 h per cycle: (a) hot-dipped pure Al and Al-Si coatings, pack cementation Al-Si coating and uncoated alloy and (b) enlarged drawing of the coatings curves.

aluminizing methods such as pack cementation. Interestingly, an Al-Si coating prepared by hot dipping on DZ125 improves oxidation resistance more than that prepared by pack cementation, which is found through the oxidation kinetics presented in Fig. 1. The investigation of Ni-Al coating on DZ125 prepared via pack cementation has been discussed in recent research [23].

Therefore, the aim of this study is to investigate the thermal oxidation behaviour of the diffusion aluminide coating containing silicon on the DZ125 superalloy via the hot-dipping method. In this way, the influence of silicon, which promotes anti-oxidation of the diffusion aluminide coatings on DZ125 superalloys, can be studied.

2. Experimental section

2.1. Hot-dipping aluminium and silicon

The DZ125 superalloy with normal alloy composition (in. wt%) Ni—8.9 Cr—10 Co—7 W—2 Mo—0.5 Ti—4.75 Al—3.8 Ta—1.5 Hf—0.0015 B—0.05 Zr was used as a substrate. The specimens were cut to 14 mm diameter and 3 mm thickness with a wire-cutter. After shot peening using 800 μm emery to remove the oxide scale, these specimens were cleaned in an ultrasonic alcohol bath and then dried. The composition of the plating assistant agent included