

Sulfidation behavior of a non harmful water based Al and Al-Si slurry coating on CM247 superalloy



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Introduction

The overall objective of the PARTICOAT project is to develop a novel, non-conventional and cost efficient multipurpose high temperature coating system with the potential to serve as thermal barrier produced in one manufacturing step. Aluminium does not form meta-stable oxides in a particle size window of 2 to 20 μm , but hollow spheres consisting of $\alpha\text{-Al}_2\text{O}_3$. These observations led to the idea of depositing such Al particles on an alloy substrate using a non harmful water based slurry and convert them into a coating by heat treatment. The result is a coating structure consisting of a ceramic quasi-foam top coat comprising spherical hollow alumina particles and an Al rich intermetallic diffusion layer below, which has the potential to serve as a bond coat and to form a protective alumina scale. The presented case is oriented to evaluate the oxidation and sulfidation resistance of a nickel base superalloy coated by Al or Al-Si particles containing slurries.

Experimental procedure

Spherical Al particles and Al-Si alloy particles were deposited by air brush on CM 247 alloy and heat treated in air at 1000°C during 2 hours. These coatings were exposed to air and to synthetic air + 1.5 % SO_2 at 1000°C. Oxide formation and the microstructure of the coating were studied using thermo gravimetric analysis, X-ray diffraction, light microscopy, scanning electron microscopy (SEM) combined with energy dispersive X-ray spectroscopy and electron probe micro analysis (EPMA). A statistical evaluation of the corrosion data was performed to determine the cumulative distribution of corrosion depth and the remaining un-damaged coating. The cumulative distribution was obtained by determining the number of spots with values above a given corrosion depth.

Results

The weight gain evolution is shown in fig. 1. The highest weight gains are observed for the exposure in SO_2 containing atmosphere. The Al slurry based coating showed slightly lower weight gains than the Al-Si slurry based on data after 1000 hours of exposure in both atmospheres.

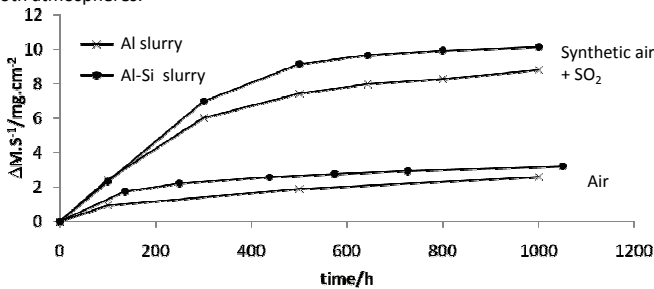


Fig. 1: Mass gain evolution of the coated alloys at 1000 C in air and synthetic air + 1.5% SO_2

The cross-section of Al-Si slurry coated CM 247 after 500 hours of exposure in air at 1000°C (fig.2) shows that Si is mainly localized in the diffusion layer close to the top coat interface.

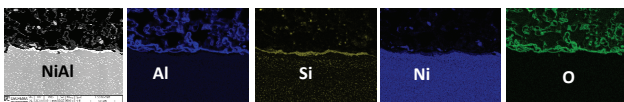


Fig. 2: SEM cross-section Al-Si slurry coated CM247 after 500h exposure at 1000 C in air

The SEM cross-section of the Al slurry coated CM 247 after 500 hours in SO_2 containing atmosphere (fig. 3b) reveals a typical type I hot corrosion attack related to sulfidation/oxidation in the diffusion layer (indicated by arrow). The element mapping for the sulfidizing atmosphere (fig. 3c) reveals accelerated oxide formation and sulfur presence.

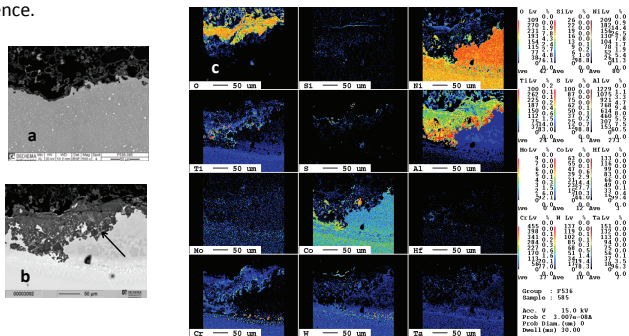


Fig 3: SEM cross-section of Al slurry coated CM 247 exposed at 1000 C in air (a) and SO_2 containing atmosphere (b) and EPMA mapping of the later (c).

The coating damage diagram, which represents the relative diffusion layer which has been affected by sulfidation, is shown in fig. 4. After 500 hours of exposure under SO_2 containing atmosphere the damaged coating diffusion zone is slightly higher (around 25%) for the Al than for the Al-Si slurry coating. After 1000 hours of exposure these values increased for both coatings (ranging around 45%), but interestingly the damage values are inverted, the Al-Si slurry based coating being more prone to attack. A similar inversion has also been observed in the initial stages of weight gain evolution (see fig. 1).

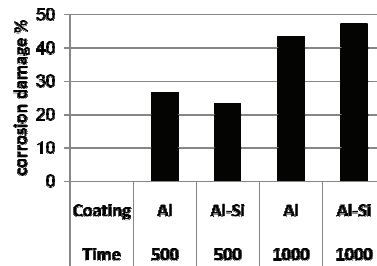


Fig. 4: Quantification of the damaged diffusion layer after image analysis of SEM cross-sections of CM 247 slurry coated samples exposed at 1000 C in SO_2 containing synthetic air.

The corrosion depth is higher after 500 hours for the Al slurry coated sample as for the Al-Si coated one (fig. 5); however, the damage seems to be more homogeneous for the Al slurry coated sample. This information confirms the beneficial effect of a silicon rich diffusion layer at least during the first 500 hours of exposure. After 1000 hours of exposure, the corrosion depth increases for both coatings, showing higher depths for the case of the Al-Si slurry coating, which demonstrates a time limitation for the improvement by silicon in the modified aluminide coating. In other words, silicon in the diffusion layer has been beneficial until its entire transformation into corrosion product.

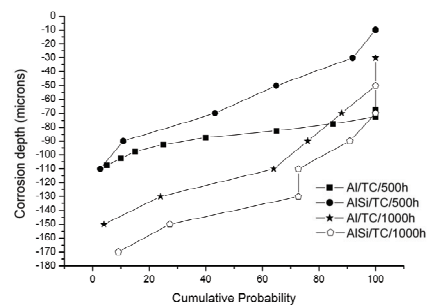


Fig. 5: Cumulative probability graphs of CM 247 slurry coated samples exposed at 1000 C in SO_2 containing synthetic air.

Summary and perspective

When exposed to sulfidizing/oxidizing atmosphere, the quantification of the damaged coating shows that Si modified coatings behave better than the simple aluminide slurry coatings as long as the silicon is maintained in the coating (the first 500 hours). Exposure of the coatings has demonstrated the possibility of forming an oxidation and sulfidation resistant thermal barrier coating system produced in air in a single step by the slurry route which offers unique advantages that can be very favourable especially as a repairing technique.

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