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COMPARISON OF OXIDATION RESISTANCE OF YSZ AND YSZ-Al_2O_3 COATINGS ON Ni-BASED SUPERALLOY

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Abstract

Cyclic oxidation of an Y_2O_3-stabilized ZrO_2 (YSZ) coating on Ni-based superalloy was performed in a furnace at 1100 °C for 4 h. After each cycle, the specimen was cooled in the furnace, inspected and its peripheral condition was observed. If there was any crack in coating, the test was stopped to study the coating microstructure. Results showed YSZ-Al_2O_3 composite coating exhibited higher oxidation resistance in comparison with the YSZ coating.
Keywords: Oxidation resistance; YSZ-Al_2O_3 coating; IN-738 superalloy

Introduction

Surface alterations are usually done through corrosion, oxidation or erosion and are cause of reduction of the work piece strength. High temperature coatings are used to prevent surface degradations or as thermal barriers against corrosion and warm atmosphere [1, 2]. The extent of components requiring coatings are widely increasing especially in industrial gas turbines and aero turbines [3].

The earliest ceramic coatings for aerospace applications were frit enamels developed by the National Advisory Committee for Aeronautics (NASA). A coating of calcia-stabilized zirconia on the exhaust nozzle of the X-15 manned rocket plane in 1960s is the first use of thermal barrier coatings (TBCs) in manned flight [4].

Common TBCs, typically comprise a MCrAlY (M: nickel, cobalt or a mixture of them) bond coat and a high temperature resistant YSZ top coat which is applied by thermal spray on superalloys surface [5]. The main disadvantage of TBCs is the formation of thermally grown oxide (TGO) during thermal cycling and high temperature oxidation [6-8].

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The aim of the present research is to compare the oxidation resistance of common YSZ coating and a composite coating comprising of YSZ-Al_2O_3 on the Ni-based superalloy substrate.

Experimental procedure

The substrate was IN-738 Ni-base superalloy. All specimens were in the shape of 25×10 mm disks. Amdry 962 trade mark NiCrAlY micro-powders, Metco 204NS-G trade mark YSZ zirconia powders and Metco 105NS Al_2O_3 powders were prepared and coating was performed using air plasma spray (APS) Metco 3MB process. Before applying coatings, the specimens were shot blasted by 25-50 mesh Al_2O_3 particles under 40-50 psi pressure. The surface oxides were removed using methyl ethyl kethon cleaner, and degreasing was performed under trichloroethylene vapor. After washing specimens were preheated at about 150-200 °C. Argon was the primary and hydrogen was the secondary plasma gas. NiCrAlY coating with a thickness of 150 μm was plasma sprayed on the specimens. Then YSZ and YSZ+Al_2O_3 coatings with a thickness of 350 μm were sprayed separately. To produce YSZ+Al_2O_3 composite, 50 volume percent of each were ball milled with Al_2O_3 cup and Al_2O_3 balls and a rotating speed of 100 rpm for 5 h.

After coating, oxidation test was performed. The specimens were annealed in the furnace at 1100 °C for 4 h and then furnace-cooled. Annealing and cooling was represented one cycle. If at each oxidation cycle cracks were seen on coating, the test was terminated and coating microstructure studied. The aim of this test was to investigate the effects of cyclic oxidation on TGO layer growth on coatings. Optical microscope and scanning electron microscope (SEM) equipped with energy dispersive spectrometer (EDS) were used to study the specimens.

Results and discussion

Macroscopic images of the specimens are depicted in Fig. 1. The coatings have a rough surface and a relatively good cohesion with substrate. The oxidation tests showed the YSZ+Al_2O_3 coating has more resistance to oxidation in comparison with the YSZ coating. The YSZ coating cracked after 192 h (48 cycles) while YSZ+Al_2O_3 coating cracked after 244 h (61 cycles). The macroscopic images of coatings after oxidation tests are depicted in Fig. 2.

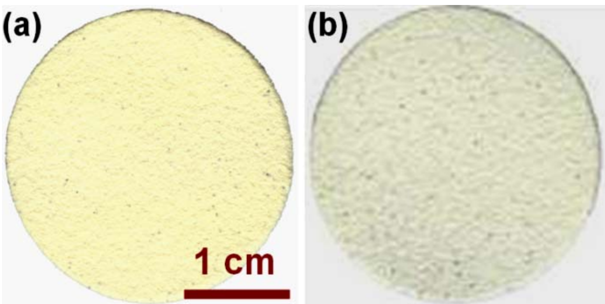

Fig. 1. Macroscopic images of as-sprayed coatings (a) NiCrAlY/YSZ (b) NiCrAlY/YSZ+Al_2O_3.

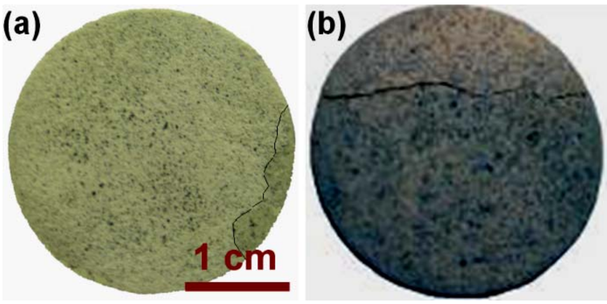

Fig. 2. Macroscopic images of coatings (a) NiCrAlY/YSZ (b) NiCrAlY/YSZ+Al_2O_3; after 48 and 61 cycles, respectively.

The SEM images of TBC layers after oxidation are shown in Fig. 3. Investigation of coatings microstructure shows that they have relatively high amount of porosities and a lamellar structure which states a characteristic of plasma sprayed coatings. During oxidation at 1100 °C, oxygen diffuses from ceramic coating porosities into NiCrAlY bond coat and an oxide TGO layer forms on it. EDS analysis of the mentioned TGO layer showed that it is mainly composed of Al and O (the results have not been presented here for a limited extent of page). Thermodynamic theories state that Al and O strongly react with each other and form Al_2O_3, this is responsible for formation of TGO layer at the interface of intermediate and ceramic layers.

Oxygen has also diffused through interconnected porosities of NiCrAlY bond coat and resulted in formation of oxide layers (dark lines inside the bond coat in Fig.3) which may be defined as internal oxidation of bond coat.

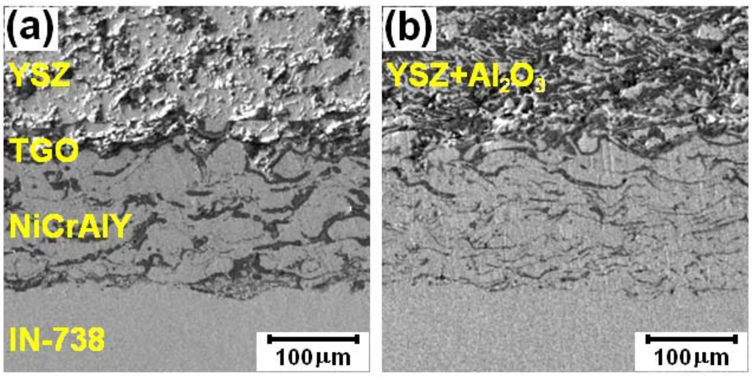

Fig. 3. TBC section microstructure (a) NiCrAlY/YSZ (b) NiCrAlY/YSZ+Al_2O_3; after oxidation.

Generally, the interface of dissimilar layers which significantly differ in mechanical and physical properties is a stress concentration site and crack usually initiates there; thus, TGO layer can be a critical site [9]. The TGO layer thickness drops in YSZ+Al_2O_3 coating in comparison with YSZ coating; indicating that the YSZ+Al_2O_3 coating significantly prevents the oxygen diffusion into NiCrAlY bond coat. More detailed results will be reported in the future research.

Conclusion

From the results of the present paper it can be concluded that the $YSZ+Al_2O_3$ coating in comparison with YSZ coating possesses several advantages which are as follows:

- Less thickness of TGO layer
- Smaller oxidized area of NiCrAlY bond coat
- Higher resistance to oxidation.

References

[1] A.C. Fox, T.W. Clyne, Surf. Coat. Technol. 184 (2004) 311-321.
[2] M. Gell, L. Xie, X. Ma, E.H. Jordan, N.P. Padture, Surf. Coat. Technol. 177-178 (2004) 97-102.
[3] A.N. Khan, J. Lu, H. Liao, Surf. Coat. Technol. 168 (2003) 291-299.
[4] A. Nusair Khan, J. Lu, Surf. Coat. Technol. 166 (2003) 37-43.
[5] X.Q. Cao, R. Vassenb, D. Stoeverb, J. Eur. Ceram. Soc. 24 (2004) 1-10.
[6] M.J. Pomeroy, Mater. Des. 26 (2005) 223-231.
[7] U. Schulz, C. Leyens, K. Fristscher, M. Peters, B.S. Brings, O. Lavigne, J.M. Dorvaux, M. Poulain, R. Mevrel, M. Caliez, Aerosp. Sci. Technol. 7 (2003) 73-80.
[8] N.P. Padture, M. Gell, E.H. Jordan, Mater. Sci. Eng. 296 (2002) 280-284.
[9] K.W. Schlichting, N.P. Padture, E.H. Jordan, M. Gell, Mater. Sci. Eng. A 342 (2003) 120-130.