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Procedia Materials Science 12 (2016) 83 – 88

Procedia Materials Science

www.elsevier.com/locate/procedia

6th New Methods of Damage and Failure Analysis of Structural Parts [MDFA]

Delamination property of modeled air plasma sprayed-thermal barrier coatings under shear loading: effect of difference in chemical composition of bond coat

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Abstract

In order to understand the effect of the difference in chemical composition and microstructure of bond coat (BC) layer on delamination properties, pushout tests were performed on modeled air plasma-sprayed thermal barrier coatings (APS-TBCs). Nickel-platinum-aluminides (Ni-Pt-Al), hafnium modified nickel-platinum-aluminides (Ni-Pt-Al-Hf) and NiCoCrAlY alloys were used as BC alloy. Hafnium and aluminum oxide were formed in needle like shape when the Ni-Pt-Al-Hf alloy was used. Vickers hardness of BC alloy decreased up to 50 hours heat exposure and then increased with increasing heat exposure time. Interfacial delamination toughness increased and then decreased with the increase in heat exposure time.

Selection and peer-review under responsibility of the VŠB - Technical University of Ostrava,Faculty of Metallurgy and Materials Engineering

Keywords: modeled APS-TBCs, Vickers hardness, pushout test, interfacial delamination toughness;

1. Introduction

Thermal barrier coatings (TBCs) have been widely used to increase the operating temperature of hot section components in gas turbines blade and vanes. APS-TBCs usually composed of an outer oxide ceramic thermal barrier coating (TBC) layer and an inner intermetallic bond coat (BC) layer to protect the substrate from high temperature and oxidation. During the service in TBCs, oxygen and aluminum diffuses from atmosphere and BC layer,

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Selection and peer-review under responsibility of the VŠB - Technical University of Ostrava,Faculty of Metallurgy and Materials Engineering
doi:10.1016/j.mspro.2016.03.015

respectively and formation and growth of the thermally grown oxide (TGO) layer occurs at TBC/BC interface. The main composition of TGO is α-Al_2O_3. In service, the TBC and TGO layers are under nominal biaxial compression condition because of the thermal expansion mismatch among the layers. This compression condition damages TBCs and finally TBC layer spall off from the blades. As reported by Evans et al. (2001) the crack initiates under mode I loading condition (perpendicular to the interface) and then the delamination of TBC layer occurs mainly by mode II loading (parallel to the interface). Thus, evaluating the durability of TBC system under mode II loading is important.

Recently, many types of BC layer are applied to the TBCs by Gell et al. (1999) to improve the delamination life of the coatings. However, the evaluation of interfacial delamination toughness on TBCs has not been still performed enough. In this study, the effect of the difference in chemical composition and microstructure of bond coat on modeled APS-TBCs in interfacial delamination toughness was evaluated.

2. Experimental Procedure

Nickel-platinum-aluminides (Ni-Pt-Al), hafnium modified nickel-platinum-aluminides (Ni-Pt-Al-Hf) and NiCoCrAlY alloy were selected as BC alloy. Chemical compositions of BC alloys were Ni-43Al-9Pt, Ni-42Al-9Pt-0.3Hf and Ni-25Al-19Co-16Cr-0.4Y (mol%). Ni-Pt-Al and Ni-Pt-Al-Hf alloys were processed by argon arc melting and NiCoCrAlY alloy was produced by high velocity oxygen fuel (HVOF) process. The BC alloys were then cut to the plate with the size of 30 x 20 x 4 mm and heat treated in a vacuum at 1413 K for 1 hour. After the treatment, modelled TBCs have been formed by APS process. TBC layer of an 8 mass% Y_2O_3 partially stabilized ZrO_2 was coated on the BC alloy in 250 μm thick at the both side of the area having 30 x 20 mm. The TBCs were heat exposed in an air at 1323 K from 10 to 200 hours. Changes in microstructure during heat exposure were characterized on the polished transverse section of the TBCs by SEM. Vickers hardness of BC layer in as-sprayed and heat exposed TBCs was measured. The load was applied up to 0.49 N for 5 s and then unloaded. To evaluate the delamination toughness of the TBCs under shear loading condition, pushout tests which were reported by Kim et al. (2007), Tanaka et al. (2008) and Hasegawa et al. (2009) were performed. The surfaces of the pushout test specimens were polished up to 0.5 μm diamond paste finish. Fig. 1 shows the schematic configuration of the test method. The size of the specimen was 4 mm in height, c, 5 mm in width, w, and 4 mm in thickness, b. WC blocks were used for the specimen support. Only the TBC layers of the specimen came to the specimen support. The pushout tests were performed in an air at room temperature using screw-driven test machine with the constant cross head speed of 0.1 mm/min. After pushout test, fracture surfaces were observed from the side of the specimen using OM and SEM.

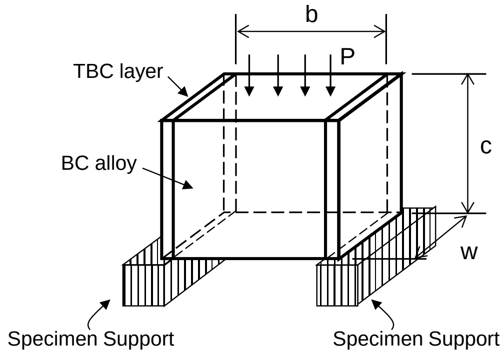

Fig.1: Schematic configuration of pushout test (P: applied load).

3. Results and Discussion

3.1 Microstructural change

Fig. 2 shows a typical polished transverse section of the modeled APS-TBCs under as-sprayed state. TBC layers and BC alloys are clearly seen. Pores and inter-splat boundaries are observed in the TBC layer as black spots and