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Pulsed electron beam treatment of MCrAlY bondcoats for EB PVD TBC systems part 2 of 2: Cyclic oxidation of the coatings

R.G. Wellman [a,*], A. Scrivani [b], G. Rizzi [b], A. Weisenburger [c], F.H. Tenailleau [a], J.R. Nicholls [a]

[a] *Cranfield University, College Rd Cranfield, MK43 OAL, UK*
[b] *Turbocoating, Italy*
[c] *Forschungszentrum Karlsruhe GmbH, IHM, O.O. Box 3640, 76021 Karlsruhe, Germany*

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Abstract

This paper discusses the effect of pulsed electron beam (PEB) treatment of thermal sprayed MCrAlY bondcoats on the cyclic life of thermal barrier coatings (TBCs). Standard MCrAlY bondcoats were produced via HVOF, VPS and LPPS thermal spray methods. Some of the HVOF and VPS coatings were then given a PEB treatment before all the samples were coated with an EB PVD 7-8 wt.% yttria partially stabilized zirconia topcoat. The samples were all tested under cyclic oxidation conditions at 1150 °C with 1 h at temperature and 15 min cooling, samples were removed after 20% coating spallation and prepared for cross sectional analyses.

Cyclic testing revealed that although the PEB treatment had no measurable effect on the VPS sprayed samples, the HVOF coatings showed a significant increase in the cyclic life after the PEB treatment. The effect of the PEB treatment on the various samples is discussed as well as its effect on TGO growth morphology. PEB treatment of the HVOF bondcoat was found to reduce the rate of alumina growth and to suppress the formation of oxide pegs resulting in a smoother bondcoat interface.

Keywords: Oxidation; Pulsed electron beam (PEB); TBC

1. Introduction

Thermal barrier coatings in various forms have been in commercial use for a number of decades [1,2] with oxidation recognized as the primary cause of failure [3–5] and erosion as a secondary cause of failure [6,7]. A significant amount of research has been conducted over the years on the oxidation behavior of TBCs often focusing on the growth and morphology of the thermally grown oxide (TGO) [8]. Ideally the aim is to obtain a continuous alpha alumina oxide that is slow growing and to minimize the rate of internal oxidation of the bond coat.

The aim of the project was to determine the effect of pulsed electron beam (PEB) re-melting treatment on the cyclic oxidation life of EB PVD TBCs with MCrAlY bondcoats. This paper is part two of two papers where paper one [9] discusses the production of the coatings and the PEB treatment in greater detail. Various TBCs have been used in gas turbine engines for a number of decades, however, oxidation of the bondcoat is the primary cause of failure of TBCs, with erosion often reported as the secondary cause of failure. The thermally grown oxide (TGO), ideally a continuous alpha alumina scale, grows throughout the life of the TBC. This growth introduces stresses into the TBC system which eventually results in spallation of the TBC.

2. Sample production

The samples were produced by a consortium. The MCrAlY bond coats, the composition of which is given in Table 1, were

Table 1
Nominal chemical composition of the CoNiCrAlY powders used for all deposition tests

	Cr	Ni	Al	Y	Co
Wt.%	21.0	32.0	8.0	0.5	Bal.

* Corresponding author. Bldg 57, Cranfield University, MK43OAL, Bedfordshire, UK. Tel.: +44 1234 750111x3524; fax: +44 1234 752473.
E-mail address: R.Wellman@Cranfield.ac.uk (R.G. Wellman).

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Table 2
Results of the testing in cycles to failure at 1150 °C

	Test 1	Test 2	Test 3
HVOF	471	215	545
HVOF PEB	921	778	–
VPS	323	98	170
VPS PEB	261	98	213
LPPS	110	102	196
PtAl	210	313	148

sprayed by Turbocoating and the PEB treatment was done by Forschungszentrum Karlsruhe. Finally an 8 wt.% yttria stabilized zirconia top coat was applied by EB PVD at Cranfield University, who also produced the PtAl diffusion bond coat.

Inconel 738, a nickel based superalloy often used for the production of gas turbine blades and vanes, was used as the substrate for the samples with the sprayed bond coats, which were 3 cm squares 5 mm thick. Before the deposition of the MCrAlY bond coat, the substrates were grit blasted using corundum with a grain size of 60–80 mesh, in order to remove surface oxides and grease and to obtain a suitable roughness for coating adhesion.

CoNiCrAlY commercial powder was used, with a nominal chemical composition equivalent to the powder known as AMDRY 995, again widely used for coating gas turbine components. The grain size distribution of the powder was different according to the process used for the deposition. Coating thickness varied in the range 100–150 µm. After coating, the samples were heat treated in a vacuum at 1100 °C for 2 h to obtain metallurgical bonding between the base material and the coating. Three different processes were used for depositing the sprayed bond coats, Vacuum Plasma Spray (VPS), Low Pressure Plasma Spray (LPPS) and High Velocity Oxygen Fuel (HVOF). After diffusion heat treatment some of the samples were given a pulsed electron beam (PEB) treatment to re-melt the top layer of the bond coat this is discussed in more detail in part 1 [9].

The PtAl bond coats were produced at Cranfield University by sputter coating a 7 µm Pt layer onto 20 mm diameter 5 mm thick CMSX-4 buttons. The Pt was then diffused into the substrate in a vacuum for 2 h at1140 °C. After diffusion heat treatment, samples were aluminized in a CVD rig at Cranfield using an in pack high activity method for 25 min. The samples were then given a recovery heat treatment of 2 h at 1120 °C followed by 24 h at 843=BOC in a vacuum, before being prepared for deposition of the ceramic top coat.

All of the samples were given a very light grit blast before the 8 wt.% yttria stabilized zirconia top coat was applied to the finished bond coats in the EB PVD evaporator at Cranfield University. The thickness of the ceramic top coat applied to all the samples was 150–175 µm.

3. Cyclic testing

The samples were tested in one of the Cranfield cyclic oxidation test rigs at 1150 °C for 1 h 12 min cycles (1 h at temperature) with 15 min forced air cooling. The samples were all cycled continuously and examined on a regular basis throughout the day during the cooling cycle. When the samples were close to failure, they were examined more frequently. The samples were considered to have failed after 20% of the coating had spalled from the surface. After the 20% failure criterion was reached and the samples were removed from the furnace it was found that they were prone to desk top failure. A number of samples suffered from desk top failure within a few minutes of removal from the test rig resulting in significant loss of the ceramic topcoat.

4. Results and discussion

The results of testing conducted to date are given in Table 2. As can be seen from the table, the PEB treatment has no significant effect on the VPS bond coats however, initial results indicate a significant improvement in the life of the HVOF

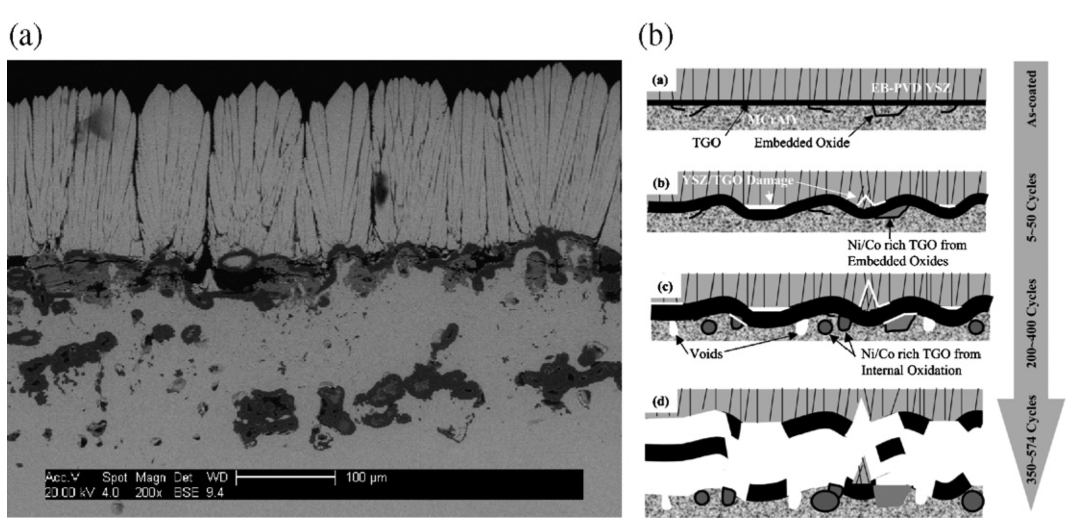

Fig. 1. (a) Micrographs of the as sprayed HVOF bond coat system after cyclic oxidation testing at 1150 °C (b) Schematic illustrating the evolution of damage during cyclic testing [8].