INVESTIGATION OF EROSION BEHAVIOR OF EB-PVD-TBCs AND SACRIFICIAL COATINGS AFTER CMAS INFILTRATION

Lars Steinberg, TU Dresden, Institute of Materials Science, Dresden, Germany
Lars.Steinberg@tu-dresden.de
Ravisankar Naraparaju, German Aerospace Center, Institute of Materials Research, Cologne, Germany
Christoph Mikulla, German Aerospace Center, Institute of Materials Research, Cologne, Germany
Filofteia-Laura Toma, Fraunhofer Institute for Material and Beam Technology, Dresden, Germany
Uwe Schulz, German Aerospace Center, Institute of Materials Research, Cologne, Germany
Christoph Leyens, TU Dresden, Institute of Materials Science, Dresden, Germany

Key Words: Sacrificial coating, EB-PVD, Suspension thermal spraying, Erosion, CMAS

Aero-engines operating in sand laden environments often encounter severe problems with thermal barrier coatings (TBCs) due to erosion damage. Since the turbine entry temperatures are raising, the life-time of TBC coatings as well as its thermal conductivity are additionally influenced by molten sand (calcium-magnesium-alumino-silicate/ CMAS). Few attempts have been made in understanding the combined impact of both erosion and CMAS effects [1,2]. Wellman and Nicholls [1] have found that a fully CMAS infiltrated electron-beam physical vapor deposited (EB-PVD) TBC behaves like a continuum during erosion and slightly improves its erosion behavior under room temperature compared to pure TBC.
Development of CMAS resistant coatings has been a hot topic for the last two decades and one of the proposed method is the application of sacrificial oxide layers such as Al_2O_3, MgO, Sc_2O_3 et al. [3], on top of the TBCs. These sacrificial layers chemically react with the CMAS and modify the melting temperature or the viscosity of CMAS and thus the infiltration of CMAS into the TBC is inhibited.

Since both damage mechanisms (erosion and corrosion) occur parallel and competitively in a turbine, this study focuses on deeper understanding of the erosion behavior of CMAS-infiltrated 7wt.-% yttria stabilized zirconia (7YSZ) TBCs. 400 µm thick 7YSZ coatings with two different microstructures were produced by EB-PVD. Additionally, sacrificial Al_2O_3 coatings were also applied on the top of 7YSZ by means of suspension plasma spraying (SPS) and suspension high velocity oxy-fuel spraying (SHVOF) using water-based suspensions. CMAS infiltration experiments were carried out at 1250 °C using different CMAS compositions and different infiltration times. Erosion tests were realized at room temperature in an in-house erosion test rig and evaluated partly by confocal microscopy. Microstructural examinations as well as crack identification before and after testing were carried out using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX).

Infiltrated TBCs behaved as a continuum material during erosion exposure which lead mainly to surface spallation. Furthermore, the CMAS infiltration in the TBCs and partly the sintering effect at 1250 °C lead to a network of vertical cracks. These vertical cracks are weak areas where severe erosion occurs. The different TBC microstructures, infiltration times and CMAS compositions strongly influence the erosion behavior of the TBC. In case of alumina top coats the microstructure and especially the presence of porosity in the coating has strongly influenced the CMAS infiltration depth, the erosion behavior, and the stability of the entire coating system.

[1] R.G. Wellman, J.R. Nicholls, Erosion, corrosion and erosion–corrosion of EB PVD thermal barrier coatings, Tribology International. 41 (2008) 657–662. doi:10.1016/j.triboint.2007.10.004.
[2] S. Rezanka, D.E. Mack, G. Mauer, D. Sebold, O. Guillon, R. Vaßen, Investigation of the resistance of open-column-structured PS-PVD TBCs to erosive and high-temperature corrosive attack, Surface and Coatings Technology. 324 (2017) 222–235. doi:10.1016/j.surfcoat.2017.05.003.
[3] A.K. Rai, R.S. Bhattacharya, D.E. Wolfe, T.J. Eden, CMAS-Resistant Thermal Barrier Coatings (TBC), International Journal of Applied Ceramic Technology. 7 (2010) 662–674. doi:10.1111/j.1744-7402.2009.02373.x.