FAILURE BEHAVIOR OF MODERN DOUBLE-LAYER THERMAL BARRIER COATINGS SUBJECTED TO COMPRESSION TESTS

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Demands for reduced emissions and higher efficiency of stationary gas turbines and jet engines lead to the necessity for increased operating temperatures. Therefore, thermal barrier coating (TBC) systems deposited to high-temperature impinged parts, e.g. turbine blades and vanes, as well as combustor liners, containing an yttria-stabilized zirconia (YSZ) top layer are well established. Currently, surface temperatures of YSZ coated turbine parts are limited to approximately 1250 °C in long-term operation, due to the rapid degradation of YSZ caused by sintering and phase instability. Double-layer TBC based on gadolinium zirconate (GZO) applied on top of a 7 to 8 wt. % YSZ layer seem to be proper candidates for advanced coating architectures to withstand temperatures up to 1550 °C. The present work investigates the failure behavior and fracture process of double-layer thermal barrier coatings under uniaxial compressive loading conditions. Coating systems of type GZO and YSZ with low and high GZO porosity (LP, HP) were fabricated, to examine the influence of microstructure and spray process parameter on failure behavior and compressive strain energy. A conventional YSZ-HP single-layer coating serves as a reference. All systems were deposited via atmospheric plasma spraying (APS) on cylindrical rods made from CoNiCrAlY (LCO-22) coated, nickel-based, single crystal superalloy (PWA 1483). The total thickness of ceramic layers was about 600 µm. Effects of thermal ageing were taken into account by isothermal pre-oxidation at 1050 °C and dwell-times of 100, 500 and 1.500 hours and compared to cyclic annealed TBC systems (50 to 1050 °C, up to 500 cycles). Failure and cracking processes during compression tests were monitored by an acoustic emission (AE) system and piezo-electric, wideband sensors. Furthermore, a stereo camera system provides information about three-dimensional displacements and TBC surface strain. In as-sprayed condition, the stored volume related strain energy to failure of double-layer coatings is comparable to the referenced single-layer system. AE analysis indicates coating failure at earlier stages after thermal ageing. Consequently, pre-oxidation leads to reduced strain energies with increasing dwell-time in all investigated coating systems. Based on digital image correlations (DIC), the failure behavior of as-sprayed GZO/YSZ coatings has been identified to be similar to the YSZ single-layer system. A different behavior was observed for pre-oxidized coatings, where cracking and spallation of GZO occurs predominantly.

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