A MECHANISM-BASED APPROACH FOR ASSESSING THE STRUCTURAL INTEGRITY OF PLASMA-SPRAYED MULTILAYER THERMAL BARRIER COATINGS

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Since the lifetime of gas turbine components exposed to high temperatures is strongly influenced by the reliability of the protective coatings, assessing the structural integrity of the entire material compound at any time during an envisaged operation becomes an important aspect in life prediction. The majority of lifetime models associates the failure of thermal barrier coatings (TBCs) to an oxidation of the bond coat (BC). A thickening of the thermally grown oxide leads to a conversion of stresses at the undulated top coat / bond coat interface, supporting the propagation of existing micro cracks and resulting in a black failure. However, at high temperatures and large thermal gradients damage transition phenomena shifting the failure site into the top coat layer leading to a white failure appearance. A very similar behavior has been observed for multilayer TBCs of type gadolinium zirconate (GZO) and yttria-stabilized zirconia (YSZ) under isothermal conditions. Thus, an exclusively oxide-based formulation is not sufficient to describe the damage transition. Therefore, this paper outlines a mechanism-based approach for assessing the structural integrity, considering all relevant thermally activated processes as well as the evolution of the top coat microstructures. Oxidation of BC, creep of compound materials and sintering of plasma-sprayed ceramics are modeled in terms of temperature and exposure time. Finite element analysis (FEA) of GZO-YSZ pairings with different microstructures reveal a strong influence of the initial porosities on the sintering behavior and thus on the resulting mechanical stresses and potential crack driving forces at the bi-material interfaces. Even more, the developed approach in combination with the FEA provides an explanation for the previously misunderstood failure shifting mechanism depending on the thermal stress history. As part of a material and component design process, it allows to derive recommendations for multilayer TBCs in terms of microstructural features and coating architecture for example in a way that they can be expected to have a long service life.