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FAILURE ANALYSIS OF ENVIRONMENTAL BARRIER COATINGS UNDER ADVERSE OPERATIONAL ENVIRONMENT: MULTI-PHYSICS MODELING

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ABSTRACT

Under high-temperature adverse environments, the premature failure of environmental barrier coatings (EBCs) is a preliminary phenomenon that can significantly affect their applications in both aircraft engines and land-based gas turbines. The delamination failure of EBCs typically occur at topcoat/TGO or TGO/bondcoat interface due to thermal mismatch and water vapour corrosion, resulting in crack nucleation, propagation and final coating spallation. This presentation reports on a study of the degradation of bi-layer YbDS/Si EBCs using multi-physics modelling as methodologies via the COMSOL package. The model was subjected to periodic boundary conditions on the lateral boundaries to represent an infinitely long system and thermal cycles ranging from 110°C to 1316°C were implemented into the EBC model to simulate the system's in-service operation. The high-temperature creep models of the silica TGO, Si bond coat and SiC substrate are included for the built-up undulated coating geometry. Based on the stress evolution and distribution in the EBC system during thermal cycles due to the combined effect of thermal mismatch, TGO growth and transformation of YbDS to YbMS, the vertical and delamination cracks at the YbDS-YbMS topcoat and TGO were initiated, respectively. The phase-field damage and virtual-crack methodologies were then implemented to investigate the vertical crack propagation in the YbDS topcoat and silica TGO under thermal cycles. The accumulated stress at the crack tip were also evaluated. The delamination crack along the TGO/bond coat interface was simulated, considering the cristobalite TGO a displaced α-β phase transformation between 220ºC and 270ºC with an associated large volume shrinkage on cooling during thermal cycling. The effect of TGO growth rates on delamination crack propagation was examined. The crack propagation path via COMSOL multi-physics modelling is compared to those observed in the SEM image available.

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Keywords: environmental barrier coatings, phase-field damage, crack propagation, rare-earth silicates.