ENVIRONMENTAL BARRIER COATING FRACTURE, FATIGUE AND HIGH-HEAT-FLUX ENVIRONMENT FAILURE MECHANISMS AND STOCHASTIC PROGRESSIVE DAMAGE SIMULATION

Dongming Zhu, NASA Glenn Research Center, USA
Dongming.Zhu@nasa.gov
Noel N. Nemeth, NASA Glenn Research Center, USA
Noel.N.Nemeth@nasa.gov

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Advanced environmental barrier coatings will play an increasingly important role in future gas turbine engines because of their ability to protect emerging light-weight SiC/SiC ceramic matrix composite (CMC) engine components, further raising engine operating temperatures and performance. Because the environmental barrier coating systems are critical to the performance, reliability and durability of these hot-section ceramic engine components, a prime-reliant coating system along with established life design methodology are required for the hot-section ceramic component insertion into engine service.

In this paper, we have first summarized some observations of high temperature, high-heat-flux environmental degradation and failure mechanisms of environmental barrier coating systems in laboratory simulated engine environment tests. In particular, the coating surface cracking morphologies and associated subsequent delamination mechanisms under the engine level high-heat-flux, combustion steam, and mechanical creep and fatigue loading conditions will be discussed. The EBC composition and architecture improvements based on advanced high heat flux environmental testing, and the modeling advances based on the integrated Finite Element Analysis–Micromechanics Analysis Code/Ceramics Analysis and Reliability Evaluation of Structures (FEAMAC/CARES) program will also be highlighted. The stochastic progressive damage simulation successfully predicts mud flat damage pattern in EBCs on coated 3-D specimens, and a 2-D model of through-the-thickness cross-section. A 2-parameter Weibull distribution was assumed in characterizing the coating layer stochastic strength response and the formation of damage was therefore modeled. The damage initiation and coalescence into progressively smaller mudflat crack cells was demonstrated.

A coating life prediction framework may be realized by examining the surface crack initiation and delamination propagation in conjunction with environmental degradation under high-heat-flux and environment load test conditions.