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Oxide coatings in aero-turbine engines

Final Report

Submitted to:
Office of Naval Research

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February 28, 2008

Executive Summary

Oxide coatings used for various components in the hot section of aero-turbine engines experience temperature gradients at various stages during their flight cycle. One gradient exists during steady-state, due to the combination of the combustion environment next to the free surface and internal cooling of the underlying superalloy substrate. Other gradients develop during cooling of the surface when engine power is reduced. It is argued that deep delaminations, when observed within the oxide layer, can only be explained by the presence of a significant stress gradient in the coating, governed by these thermal circumstances. Two extreme cool-down scenarios are addressed. In one, the surface is cooled suddenly to a lower temperature, followed by slow uniform cooling. In the other, the entire system reduces its temperature uniformly before the temperature gradient in the TBC is eliminated. Criteria for guarding against delaminations within the oxide layer and along the interface with the substrate are provided and the outcome visualized in the form of delamination maps. A comparison with engine experience has provided a preliminary assessment of the relevant thermal scenarios.

Sub-surface delaminations have also been investigated under conditions of high thermal flux. A crack disrupts the heat flow thereby inducing crack tip stress intensities that can become critical. A complete parametric dependence of the energy release rate, G, and mode mix is presented in terms of the ratio of the crack length to its depth below the surface. Proximity to the surface elevates the local temperature, which in turn, significantly increases the crack driving force. A detailed assessment reveals that the energy release rates induced are capable of extending sub-surface delaminations, but only when the modulus has been elevated by either CMAS penetration or sintering. Otherwise, G remains well below the toughness.