TEMPERATURE MAPPING ABOVE AND BELOW AIR FILM-COOLED THERMAL BARRIER COATINGS USING PHOSPHOR THERMOMETRY

Jeffrey I. Eldridge, NASA Glenn Research Center, Cleveland, OH, 44135, US
jeffrey.i.eldridge@nasa.gov
Adam C. Wroblewski, NASA Glenn Research Center, Cleveland, OH, 44135, US
Dongming Zhu, NASA Glenn Research Center, Cleveland, OH, 44135, US
Michael D. Cuy, Vantage Partners, LLC, Brook Park, OH, 44135, US
Douglas E. Wolfe, Pennsylvania State University, University Park, PA, 16802, US

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Thermal barrier coatings (TBCs) are typically used in conjunction with air film cooling to maximize overall cooling effectiveness and reliability while minimizing sacrifices in engine performance. The effects of thermal barrier coating (TBC) thermal protection and air film cooling effectiveness have usually been studied separately; however, their contributions to combined cooling effectiveness are interdependent and are not simply additive. The combined cooling effectiveness is always less than the sum of the cooling effectiveness of stand-alone TBC protection and stand-alone air film cooling. These diminishing returns arise because adding the thermally insulating TBC between the cooling air and the surface to be cooled reduces the air film cooling effectiveness and because the air film cooling reduces the heat flux through the TBC and therefore reduces the temperature difference sustained across the TBC thickness. Due to these considerations, combined cooling effectiveness must be measured to achieve an optimum balance between TBC thermal protection and air film cooling. In this investigation, temperature mapping above and below air film-cooled TBCs was performed using luminescence lifetime imaging-based phosphor thermometry. Measurements were performed in the NASA GRC Mach 0.3 burner rig on a TBC-coated plate using a scaled-up cooling hole geometry where both the hot mainstream gas temperature and the blowing ratio were varied. Surface temperature maps were obtained from a Cr-doped $GdAlO_3$ thermographic phosphor deposited on the surface of the electron-beam vapor-deposited yttria-stabilized zirconia (YSZ) TBC. From separate plates, temperature maps from the bottom of the TBC were obtained from a thin Er-doped YSZ layer integrated into the TBC below the overlying undoped YSZ. Procedures for temperature and cooling effectiveness mapping above and below the air film-cooled TBC surface are described. Most importantly, these measurements enable mapping the combined cooling effectiveness below the TBC, which is more important than surface cooling effectiveness when there is a barrier coating between the hot mainstream gas and the surface that needs thermal protection. Advantages of the luminescence lifetime imaging method over infrared thermography, as well as its limitations to steady-state conditions are discussed.