A detailed analysis of film cooling physics: Part IV—compound-angle injection with shaped holes

The flow physics of film cooling with compound-angle shaped holes is documented for realistic gas turbine parameters. For the first time in the open literature, the combined effects of compound-angle injection and hole shaping are isolated and the dominant mechanisms are examined. Results provide valuable insight into the flowfield of this class of film-cooling jets. Computational and experimental results are presented for a row of holes injected at 35 deg on a flat plate with three distinct geometric configurations: (1) streamwise injected cylindrical holes (reference case); (2) 15 deg forward-diffused holes injected at a 60 deg compound angle; and (3) 12 deg laterally diffused holes injected a 45 deg compound angle. Detailed field and surface data, including adiabatic effectiveness ($\eta$) and heat transfer coefficient ($h$), of the two compound-angle shaped holes are provided and compared to: (i) the references streamwise cylindrical case; (ii) results from Part II detailing the compound-angle flowfield for cylindrical holes; (iii) results of Part III detailing the streamwise injected shaped-hole flowfield; and (iv) experimental data. The 60 deg compound-angle forward-diffused holes provided excellent lateral coolant distribution, but suffered from crossflow ingestion at the film-hole exit plane. The 45 deg compound-angle lateral-diffused hole and had much steeper lateral effectiveness variations. A previously documented and validated computational methodology was utilized. Computations were performed using a multiblock, unstructured-adaptive grid, fully implicit pressure-correction Navier–Stokes code with multigrid and underrelaxation type convergence accelerators. All simulations had fixed length-to-diameter ratio of 4.0, pitch-to-diameter ratio of 3.0, nominal density ratio of 1.55 and film-hole Reynolds number of 17,350, which allowed isolation of the combined effects of compound-angle injection and hole shaping for nominal blowing ratios of 1.25 and 1.88. The results demonstrate the ability of the prescribed computational methodology to predict accurately the complex flowfield associated with compound-angle shaped-hole film-cooling jets. [S0889-504X(00)01501-4]


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