An Inverse BEM/GA Approach to Determining Heat Transfer Coefficient Distributions Within Film Cooling Holes/Slots

Silieti, M., Divo, E., and Kassab, A.J.*

Mechanical, Materials, and Aerospace Engineering

University of Central Florida, Orlando, Florida 32816-2450

Corresponding autor email: kassab@mail.ucf.edu

It is common practice in the gas turbine industry to employ film cooling to protect metal components such as transition sections, endwalls, blades, and vanes, from hot gases by introducing film cooling holes or slots to provide an insulating blanket of cooler air bled from the compressor. The film effectiveness is a common way to report the adiabatic wall temperature which is the driving temperature for convection at the exposed metal surfaces and to simultaneously provide a measure of the efficacy of the film cooling scheme. The film effectiveness can be measured in carefully designed experiments. However, in determining the film coefficient distributions at the exposed surfaces, the thermal conditions within the cooling holes/slots are unknown. As there are no correlations or experimental data available to characterize heat transfer in such cases, and there is a need to determine the film coefficient distributions in film cooling holes/slot.

In this paper, we develop a steady-state inverse boundary element method to evaluate the film coefficient distribution in film cooling holes/slots. Here, Cauchy conditions imposed at the surfaces exposed to the hot gases and to the film cooling supply plenum. The heat flux is imposed at these surfaces, a reference adiabatic wall temperature is defined for the film cooling hole/slot and an initial film coefficient distribution is guessed there. A forward steady-state heat conduction problem is solved using the boundary element method (BEM), and an objective function is defined to measure the difference between the temperatures measured at the exposed surfaces and the temperature predicted by the BEM under current film coefficient estimates at the cooling hole/slot surfaces. A genetic algorithm is the used in an iterative process to alter the film coefficients until the measured surface temperatures are matched. In this study, a conjugate heat transfer solution is obtained using the commercial CFD code FLUENT to provide the boundary conditions used to simulate the measurements in the inverse problem. Results from this study reveal that the film coefficient distribution can be accurately retrieved by the proposed method, providing confidence in applying the approach to experimental data to be soon obtained from a transonic 4 passage linear cascade designed for endwall film-cooling heat studies at the University of Central Florida.

* corresponding authors