A Numerical Study of Hypersonic Turbulent Film Cooling

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Following on from a previous laminar study, the effectiveness of film cooling in hypersonic turbulent flow ($M_\infty = 8.2$) has been investigated. Coolant inlet geometry, coolant flow turbulence level and coolant injection angle have been studied in order to check their effects on heat transfer rate prediction. Dilatation-dissipation corrections of the $k-\omega$ turbulence model have been tested and found to be very important in predicting the heat transfer rate for complex flow under high Mach number. Coolant injection rate and slot height were checked against the experimental results and similarly successful levels of agreement to the laminar study were achieved.

Nomenclature

\begin{itemize}
  \item $\dot{q}$ \quad heat transfer rate
  \item $\dot{w}$ \quad injection rate
  \item $c$ \quad speed of sound
  \item $k$ \quad turbulent kinetic energy
  \item $p$ \quad pressure
  \item $Pr$ \quad Prandtl number
  \item $s$ \quad slot height
  \item $L$ \quad length of the flat plate downstream of the slot
  \item $M$ \quad Mach number
  \item $T$ \quad temperature
  \item TFC \quad turbulent film cooling
  \item $U$ \quad velocity
  \item $y^+$ \quad dimensionless wall distance
  \item $\alpha$ \quad injection angle
  \item $\beta$ \quad coefficient of the $k-\omega$ turbulence model
  \item $\zeta, \Lambda$ \quad coefficients of dilatation-dissipation corrections
  \item $\mu$ \quad laminar molecular viscosity
  \item $\mu_t$ \quad turbulent eddy viscosity
  \item $\eta$ \quad film cooling effectiveness
  \item $\rho$ \quad density
  \item $\omega$ \quad specific turbulent dissipation rate
\end{itemize}

Subscripts

\begin{itemize}
  \item $c$ \quad coolant flow
  \item $p$ \quad plenum
  \item $t$ \quad turbulent
  \item $\infty$ \quad primary freestream flow
\end{itemize}

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