NASA TECH BRIEF

Lewis Research Center

Turbulent Mixing Film Cooling Correlation

A film cooling effectiveness correlation has been developed to predict the film cooling air flow requirements for gas turbine combustors. Film cooling experiments were conducted in a rectangular sector of a high performance gas turbine combustor where the hot stream turbulence was high. Cooling air was injected through various slot configurations, and film cooling effectiveness was determined by wall temperature measurements on the combustor liner downstream of the slots.

The data from the experiments were compared to several correlations in the literature, and the agreement between the predicted and the experimental values was poor. Some of the literature correlations overestimated the film cooling effectiveness by a factor of five or more.

A turbulent mixing model was developed to account for the high mixing rate which occurs between the cooling film and the hot gas stream in the combustor. The mixing rate in combustors is much higher than that occurring under low turbulence conditions for which correlations have been developed. The resulting equation correlated the data to within ± 20 percent. The new correlation is given by:

$$\eta = \frac{1}{1 + C_m \frac{x}{MS}} \qquad (1)$$

where

$$\eta = \text{film cooling effectiveness} = \frac{T_h - T_w}{T_h - T_c}$$

x = downstream distance from slot exit
S = slot height
M = mass flux ratio of the film to the hot gas (film mass flow rate/slot flow area)/(hot gas flow rate/combustor flow area)
C_m = mixing coefficient
T_h = temperature of the hot gas
T_w = wall temperature
T_c = coolant inlet temperature

The mixing coefficient, C_m, is a measure of the intensity and scale of turbulence and equalled 0.15 for the combustor used. This value was determined by comparing equation (1) with experimental film cooling data, and it was also verified by hot wire measurements within the combustor during cold flow tests.

The correlation also predicted data in the literature taken in low turbulence wind tunnels with typical turbulence levels of approximately one percent; a value of 0.01 for C_m correlated these data.

The new correlation has the following advantages:

1. It can correlate data from widely different flow regimes if the turbulent mixing level can be measured or estimated.
2. The variation of film cooling effectiveness with turbulence level can readily be estimated from the correlation.
3. It is simple to apply, the only input value necessary being: effective slot height, s; mass flux ratio, M; downstream distance, x; and turbulent mixing level, C_m.

Notes:

1. The following documentation is available from:
   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference: NASA TN-D-6360, (N71-29841) Combustor Liner Film Cooling in Presence of High Free-Stream Turbulence

(continued overleaf)

2. Technical questions may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B72-10326

Patent status:

NASA has decided not to apply for a patent.

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