Title: Surface Measurements and Predictions of Full-Coverage Film Cooling

Full coverage film cooling is investigated both experimentally and numerically in this study. First, surface measurements of adiabatic film cooling effectiveness and heat transfer augmentation throughout four different arrays are described. Reported next is a comparison between two very common turbulence models (Realizable k-ε and SST k-ω) and their ability to predict the cooling throughout a full coverage array.

The objective of the experiment is the quantification of local heat transfer augmentation and adiabatic film cooling effectiveness for four surfaces cooled by large, both in hole count and in non-dimensional spacing, arrays of film cooling holes. The four staggered arrays are of two different spacings (P/D=X/D=14.5, 19.8) and two different hole inclination angles (α=30°, 45°), all compounded relative to the flow (β=45°) and all cylindrical holes. Arrays of up to 30 rows are tested, to see the superposition effect of the film building, along with shortened arrays in order to study the decay of the film following up to 20 rows of injection.

Tests conditions are low speed, low pressure, room temperature, low turbulence and nominally zero pressure gradient injecting into turbulent boundary layer with a momentum thickness to hole diameter ratio of 0.27. Levels of laterally average effectiveness asymptotically approach values as high as effectiveness=0.5, not yet level even after 20-30 rows due to the large spacings. Levels of heat transfer augmentation asymptotically approach values of h/h₀≈1.35 rather quickly, only after 10 rows, this is due to the boundary layer reaching an equilibrium in which the perturbation from additional film rows has reached a balance with the damping effect resulting from viscosity. The levels of effectiveness far exceeding 0.5 are much higher than expected. The heat transfer augmentation levels off quickly as opposed to the film effectiveness which continues to rise (although asymptotically) at large row numbers. This ensures that an increased row count represents coolant well spent.

The numerical predictions are carried out in order to test the ability of the two most common turbulence models to properly predict full coverage film cooling. The two models chosen, the Realizable k-ε (RKE) and SST k-ω (SSTKW), are both two-equation models coupled with Reynolds' Averaged governing equations which make several gross physical assumptions and have lots of empirical input. Hence, the models are not expected to perform. However, very good average values are seen to be obtained through these simple models. It is seen that if one has the option, using RKE in order to model full coverage film cooling will yield results with 30% less error than selecting SSTKW.

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The public is welcome to attend.