Comparison Study of closure models for modeling a flow on curved and flat plates. Film Cooling of Gas Turbine Blade Application.

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Abstract

Accurate prediction of turbine blade heat transfer, so crutial to the efficient design of blade cooling schemes, still remains important work in the turbomachinery area. The main cause for the lack of agreement with experimental data in such predictions is usually cited to be the turbulence modeling. This is due to complex flow phenomena which are encountered in turbine passage and to the interaction of the injection with the aerodynamic curved surface flow around the blades. Stagnation flow heat transfer, heat transfer in the presence of steep pressure gradients both favorable and adverse, free stream turbulence, high Mach number, blowing rate ratio and three-dimensional effects are only some of the items in a long list of phenomena present in these passages.

The experimental flow field and heat transfer measurements are available for the flat plate at many axial locations for fixed inlet Mach number, Reynolds number, inlet turbulence intensity as well as the inlet boundary layer thickness. By far the most popular turbulence models utilized today for flow and heat transfer calculations are the high and low Reynolds number two-equation eddy viscosity models. The k-ε and k-ω are the most utilized models. These models often offer a good balance between complexity and accuracy. The ability to predict transition to turbulence which is often present on turbine blades and the ability to integrate to the walls are other reasons for their widely using.

In this paper, the numerical simulation has been performed using the Fluent code which is an explicit multigrid finite volume solver, with a k-ε and SST (shear stress transport) turbulence models. The SST model encompasses both the k-ω model (Wilcox, 1988) activated in the near-wall region and the standard k-ε model (Jones and Launder, 1973) activated in the outer wake region and in the free shear layers. The single row of jets into cross compressible flow interaction is investigated. The jet-to-cross-stream velocity ratio is 0,6 and the Mach number is 0,8. Components of mean and turbulent velocities and the mean temperature are compared with experimental results at upstream and downstream locations in the x–y plane injection. The velocity is nondimensionalized with the cross-stream velocity, while the temperature is represented by the nondimensional local temperature in film. The turbulent and the thermal fields are discussed and compared with the experimental results. A reasonable agreement with measurements was obtained for the flow field predicted by the SST model at downstream. The turbulent flow field appears to be more difficult to predict just behind the jets and in the region from X=1D to X=6D downstream as shown in figure below.

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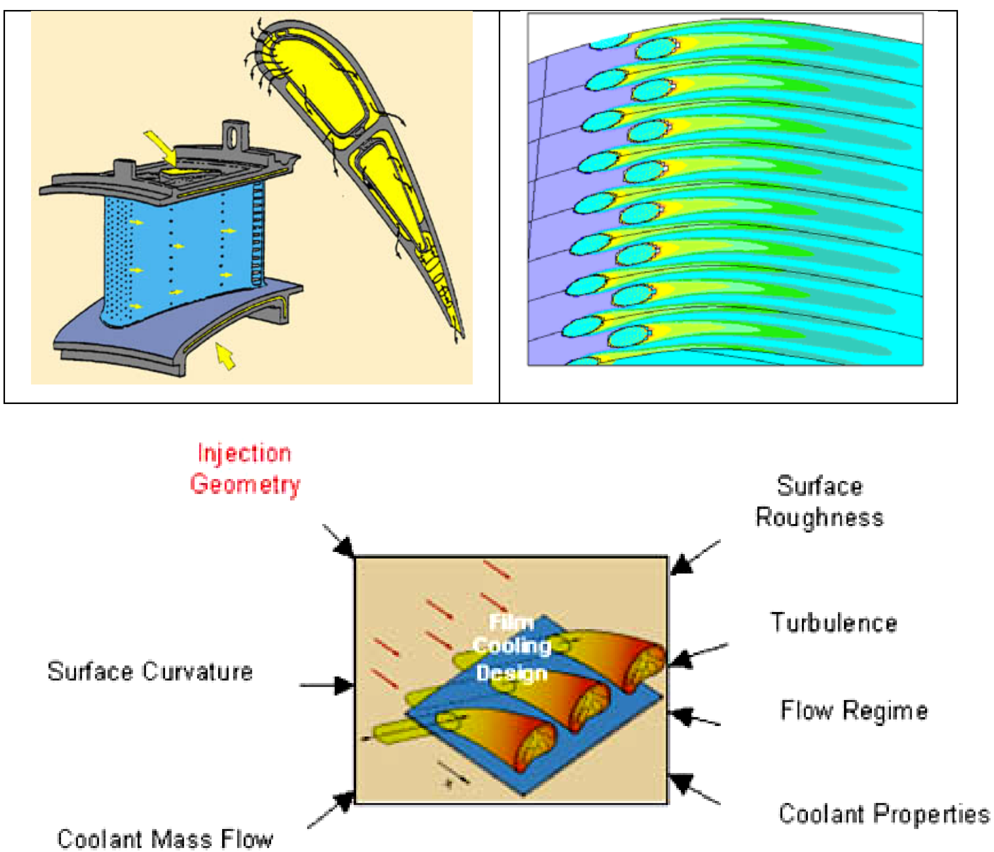

Figure 1:Problem definition and general visualization

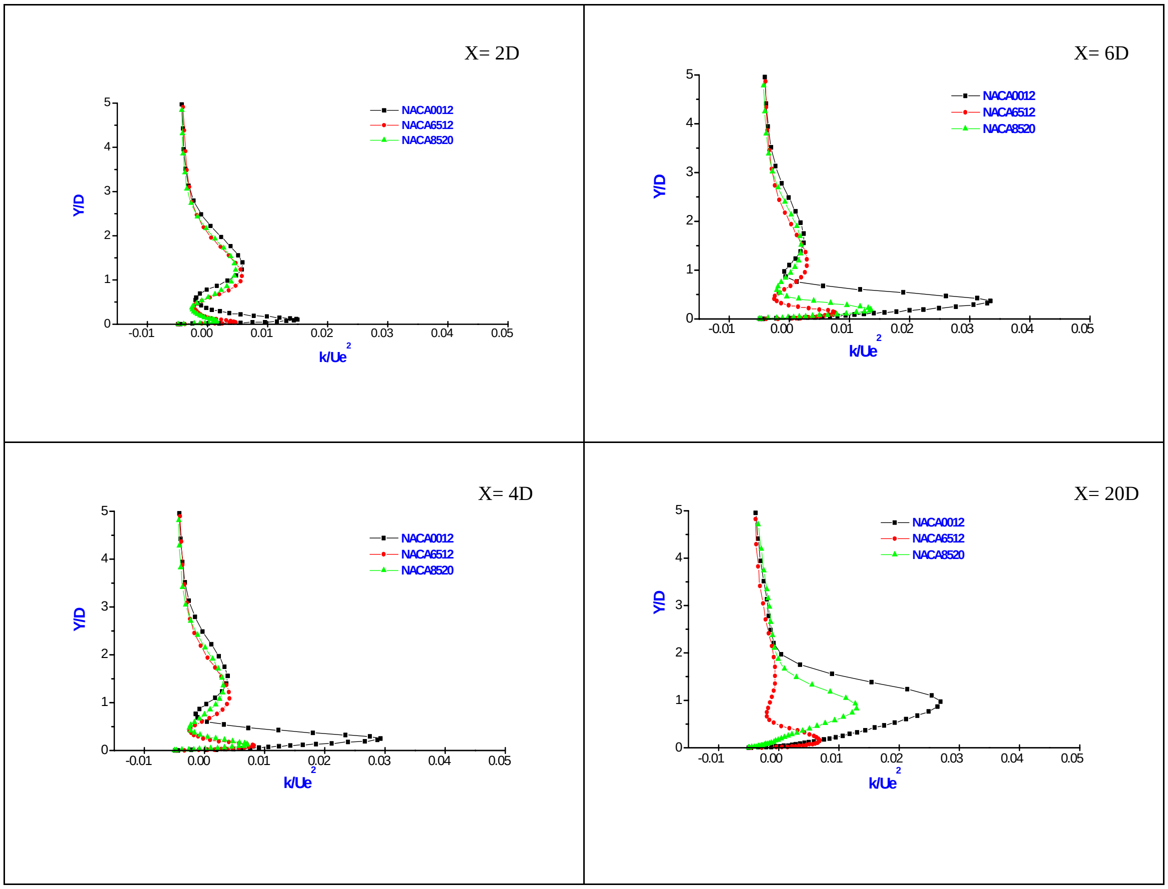

Figure 2: Comparison between predicted kinetic turbulence energy profiles in x – y plane. SST model for NACA0012 ; NACA6512 ; NACA8520