NUMERICAL INVESTIGATION OF HEAT TRANSFER ON FILM-COOLED TURBINE BLADES

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Film cooled turbine blade flow and heat transfer computation is still a challenging problem in spite of the enormous progress achieved in the last decade[1]. At the meantime, there is a common trend to consider, whenever it is possible, the complete geometry of injection[2].

The objective of this paper is the assessment of a method devoted to 3D Navier-Stokes computation of film cooled turbine blades. The approach is similar to that used by Fougères and Heider[3].

The method is based on the CANARI-COMET solver developped at ONERA[4] which uses a node centered finite volume multi-domain technique. Time integration is performed through a four step Runge-Kutta scheme and space integration through a centered second order scheme with second and fourth order artificial dissipation. An implicit residual smoothing phase is applied in order to improve time step and robustness. The algebraic Michel (M) model[5] and the one-transport-equation Spalart-Allmaras (SA) model[6] are available for turbulence closure.

Taking advantage of the multi-domain approach of the code, the main flow domain is discretized on a fine HOH mesh and the injection holes on overlapping cylindrical O meshes.

Several test cases have been investigated. The operating conditions are presented in Table 1. Computations have been conducted with constant wall temperature and plane profile at the injections entrance.

The first case is a linear HP nozzle guide vane with two double-rows of injections (Fig. 1) tested in the CT-2 facility at the von Karman Institute. The configuration periodicity is used in order to minimize the span of the blade to be calculated. The flow field near injection is displayed in Fig. 2. The computed isentropic Mach number with both turbulence models shows good agreement with experiment except downstream the shock on the suction side (Fig. 3). The span averaged wall heat fluxes show the same behavior of the two turbulence models on the pressure side(Fig. 4), while on the suction side, the two models behave quite differently (Fig. 5). The Michel model dissipates more the jets at the injection area whereas the Spalart-Allmaras model provides more dissipation further downstream (Fig. 6).

The second test case is a linear HP nozzle guide vane with 13 rows of injections with different pitches (Fig. 7) also tested in the same facility at the VKI. Assumption of periodicity is made in order to minimize the span of the blade to be calculated with a total of twenty eight injection holes. Calculated isentropic Mach number shows good agreement with experimental data (Fig. 9). Span averaged wall heat fluxes show over-predicted effects of film cooling for both models (Fig. 8 and 10).

Computations of film cooled turbine blades have been achieved with two different turbulence models. The results show that these simulations display the main features of film cooling flows. In the final paper, a third test case and more analysis of the film cooling phenomena will be presented.

	CASE 1	CASE 2
$P_\infty(bar)$	3.218	1.84
P_s (bar)	1.5025	0.943
T_{Wall} (K)	296.6	298.25
T_∞ (K)	423.7	420.9
$T_{coolant}$ (K)	330.	260 to 273

Tab. 1 – *Test Operating Conditions*

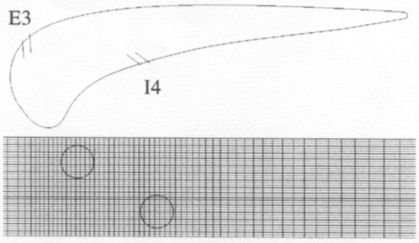

FIG. 1 – *Geometry and mesh in the injection zones*

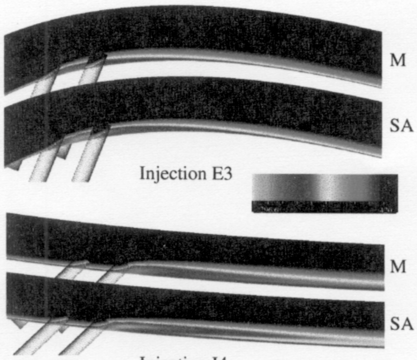

FIG. 2 – *Total temperature in the injection zones*

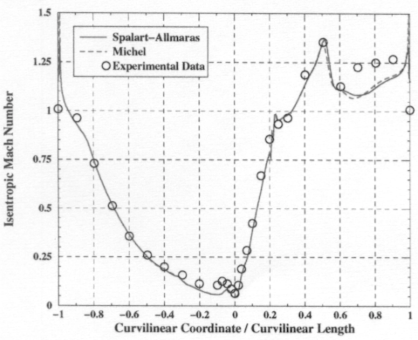

FIG. 3 – *Isentropic Mach number*

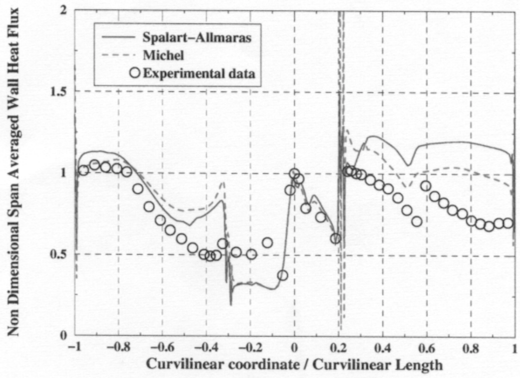

FIG. 4 – *Wall heat flux*

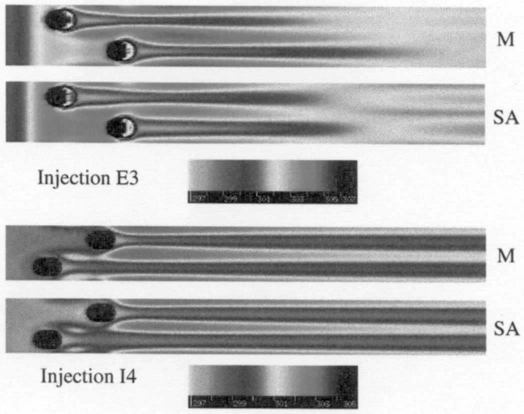

FIG. 5 – *Static temperature near the wall in the injection zones*

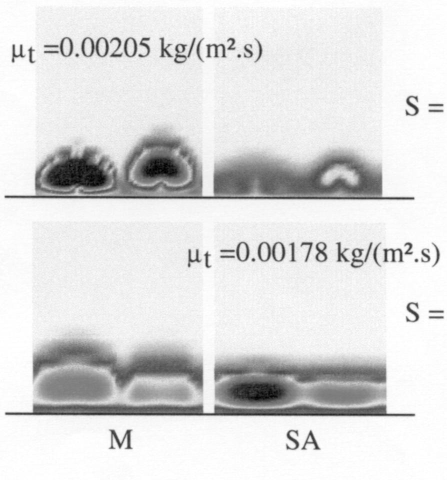

FIG. 6 – *Turbulent viscosity downstream injection E3*

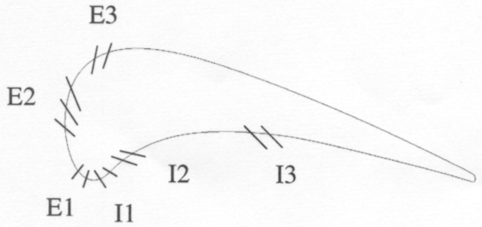

FIG. 7 – *Geometry*

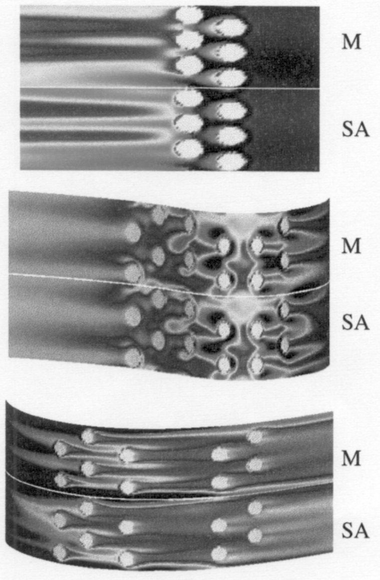

FIG. 8 – *Static temperature near wall : I3; I2,I1 and E1; E2 and E3*

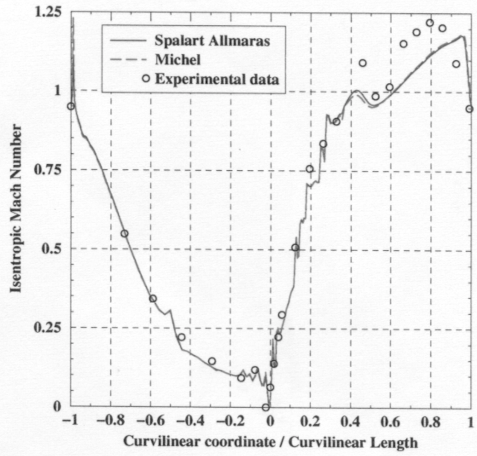

FIG. 9 – *Isentropic Mach number*

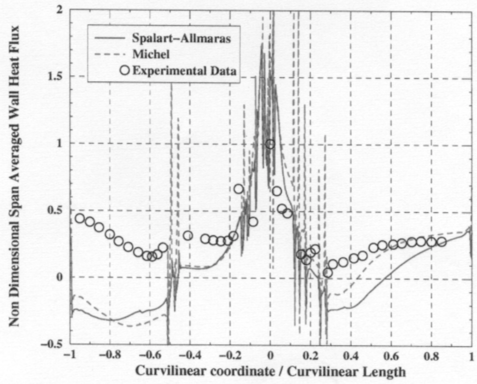

FIG. 10 – *Wall heat flux*

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