TRANSONIC INJECTION IN INTERACTION WITH TRANSVERSE COMPRESSIBLE FLOW

R. DIZENE[1], J.M. CHARBONNIER[2], E. DORIGNAC[3] and R. LEBLANC[3]

Aerodynamic Study Laboratory of CEAT
43, route de l'Aérodrome
86036 Poitiers cedex France

A large program devoted to the blade cooling modelization was undertaken at CEAT (Centre d'Etudes Aérodynamiques et Thermiques) a few years ago in collaboration with SNECMA (Société Nationale d'Etudes et de Construction de Moteurs d'Avions). For the turbo-machinery applications, experimental configuration of turbulent boundary layer with heat transfer was studied for compressible and incompressible flows. The research presented here is a part of that study and the present paper reports on the experimental results of an investigations which was concerned with a normal transonic jet interacting a transverse flow and film cooling utilising injection of air through inclined circular holes into an air mainstream. In many applications the cooling layer does not emerge onto the surface from a tangential slot but comes from a slot normal or inclined to what is otherwise a flush surface. In this case the free-stream will interact with the coolant flow as shown in Figure below in accordance to ANDREOPOULOS [1].

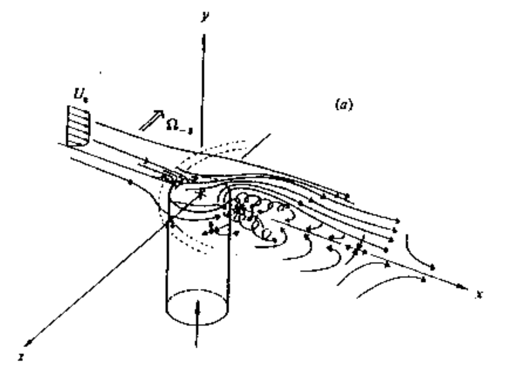

Figure: The slot flow field with low blowing rate ratio injection.

THE EXPERIMENTAL APPARATUS

An experimental investigation of the interaction of jets with a transverse flow has been performed in a transonic wind tunnel. A complete description of the first experimental apparatus has been presented by CHARBONNIER [2] in subsonic study and followed by a transonic study in a similar configuration and presented by DIZENE [3]. The experiments have been performed in small transonic wind tunnel. The tunnel was a structure of 250 mm long with 65x85 mm square cross

---

[1] Department of Mechanical Engineering, USTHB BP.32 El Alia ;
16111 Bab Ezzouar ALGIERS ALGERIA.

[2] CNES – Toulouse France.

[3] Thermal Study Laboratory, LET / ENSMA BP.109 Chasseneuil du Poitou
86960 Futuroscope cedex France.

section. The cross flow travels horizontally, while the jet is injected vertically upward. The injection of the secondary air is through a 5 mm-ID and is introduced at angles of 90 deg to the mainstream flow direction. The nominal Mach number is 0,8 and the Reynolds number based on the orifice diameter is $0{,}7.10^5$.

The second test apparatus has been presented detailed in [4]. The experimental investigation was performed in the small transonic wind tunnel, with structure of 600 mm long and 40x80 mm square cross section. The injection of the secondary air is through a 5 mm-ID and is introduced at angles of 45 deg to the mainstream flow direction. The nominal Mach number is 0,8 and the Reynolds number based on the orifice diameter is $0{,}7.10^5$. The air heated at 333°K is injected at various blowing rates in the main stream (U_e = 240 m/s) at the ambient temperature and pressure, by a row of five 45 deg holes.

Flow-visualisation studies, laser anemometer, Pitot probe and thermocouple sense has been used to acquire detailed measurements in the flow and in the wake interaction: mean velocities and their fluctuations. The temperature on the flat plate was deduced from the measurements of an infra – red camera. In the investigation, which is concerned with a single perpendicular jet, the flow field is visualised by the Schlieren technique with continuous and spark light sources, even though an oil-powder mixture is used in both configurations to observe the wall streamlines. In addition to this, we will consider the analysis of the measurements and visualisations temperature and heat fluxes obtained with using a scanning camera. Results are reported for three blowing-rate parameters (ratio of mass flux of injected air to mass flux of free stream): 0,24; 0,37 and 0,5 for 45 deg injection. The analysis of temperature and heat fluxes visualisations for the interaction description is discussed and compared with incompressible case.

RESULTS

In spite of the small dimensions of wind tunnels, reliable characteristics of a two transonic transverse flow were obtained and discussed below.

Jet/Cross flow structures in single normal hole:
General description of the flows interaction for the single perpendicular jet was acquired by stereoscopic and surface flow pattern visualisations. Several features are immediately apparent:

- The jet penetration and the vertical spreading increase as the blowing rate increases.
- Intrusions of free stream fluid occur along and around jet boundaries.
- The comparison with detailed incompressible results for the same blowing rate and Reynolds number show similar behaviour in the penetration and the wall pressure distribution.
- Larger total pressure losses are obtained for compressible case than the incompressible one.

Jets/Cross flow structures in a row of holes:
General description of the flow interaction for the jet raw configuration is based on a closer examination of surface temperature and heat transfer distribution. For the highest blowing rate tested (R=0,5), the jet patterns on the surface are well separated. The effect of injection rate values is investigated for blowing rates ratios of 0,24 and 0,37 in addition to the value of 0,5 for a Mach number 0,72 cross -flow. In fact, examination of these cases of lower blowing rates ratios suggests that the jets start to coalesce increasing the surface of the wall protected by the film. Such cases are very significant in appearance in comparison to the higher value of blowing rate ratio.

REFERENCES

1. Adreopoulos, J. & Rodi, W. 1984. Experimental investigation of jets in a crossflow. *J. Fluid Mechanics.* Vol. 138: 93-127.
2. Charbonnier, J.M. 1992. Etude expérimentale et numérique d'une interaction d'un jet droit avec un écoulement transversal subsonique. *Thésis. In CEAT*, University of Poitiers.
3. Dizene, R. 1993. Etude expérimentale d'interaction de jets avec un écoulement transversal compressible. Première partie: jet unique perpendiculaire. *Thésis. In CEAT,* University of Poitiers.
4. Dizene, R. 1993. Etude expérimentale d'interaction de jets avec un écoulement transversal compressible. Deuxième partie:Rangée de jets obliques. *Thésis. In CEAT*, University of Poitiers.