EXPERIMENTAL INVESTIGATION OF FILM COOLING FLOW INDUCED BY SHAPED HOLES ON TURBINE BLADE

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The present study is the second part of a collaborative work with SNECMA. The purpose is to investigate a new shaped hole film cooling in a numerical and experimental way. The first numerical part (not presented in this paper) is a calculation of film cooling phenomena around cylindrical and shaped holes on a flat wall .

The second part is the subject of the paper. It is an experimental investigation of the film cooling induced by shaped holes on a large scale turbine blade (1.4 m chord).

A large scale turbine inlet guide vane cascade is used. The test section is 0.80 m large and 1.80 m high, limited by the first and the third blades, figure 1. At their leading edges, a leakage flow is used to simulate the stagnation region. At their trailing edges, two straight flaps are used to obtain equivalent cascade conditions. The central blade is the test airfoil. A 50° inclined row of nine shaped holes (diameter D=12mm) is placed at the point A on its suction side. The wind tunnel, the experimental apparatus and the way of settling the wind tunnel flow are fully described in [1].

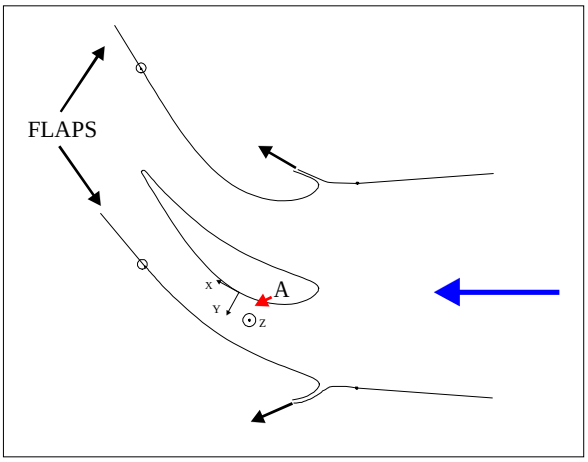

figure 1 : Test section (not to scale).

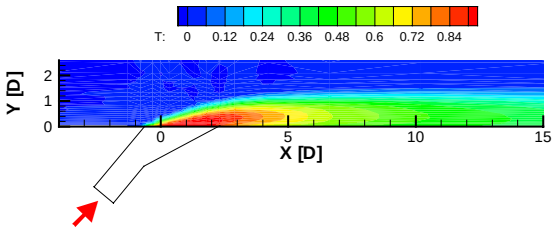

figure 2 : Mean temperature field (median jet plan) $T = (T_{mes} - T_{\infty}) / (T_{jet} - T_{\infty})$

The large dimensions of the blade allow to do detailed measurements near the wall in the jet and in the orifice. The jet flow is heated at 55°C above the ambient temperature in the main wind tunnel flow. Velocity and temperature field measurements have been done.

Cold wire thermometry for mean and fluctuating temperature measurements, pressure probe for stagnation pressure measurement and PIV for mean and fluctuating velocity measurements are used. Comparisons with the results obtained by C. Béral. [1] (same experimental apparatus and test conditions for a 50° inclined row of cylindrical holes) are made.

Considering the designer point of view, the cooling effectiveness over mass flow ratio (used for the cooling) must be increased. From the temperature plots, it can be seen that shaped hole film cooling has a better effectiveness than the cylindrical one. The figure 2 shows the thermal effect of the shaped hole jet far downstream (over 15 diameters) in the median jet plan.

This increase of cooling effectiveness by using shaped holes is due to the decrease of the orifice outlet velocity (for the same cooling mass flow). But the structure of the jet induced by shaped hole is also quite different from that of a classical jet (cylindrical hole). Some new structures (anti-kidney vortices) appear [2]. These differences can also explain the higher performance of shaping holes.

The presence of anti-kidney vortices is brought into light from the results of PIV measurements. The development of the vorticity in the streamwise direction of the jet is analysed. The vorticity plot in figure 3 and figure 4 (averaged velocity field) reveals the presence of these structures in the upper zone of the jet. The "classical" kidney vortices are present close to the wall. They have the same vorticity sign as the kidney vortices and are located in the same upper zone. It seems that the alternation of the vorticity sign of this pair of structures is due to the warping of the jet frontal interface [3]. They may be the two parts of a vortex tube initially located within the jet leading edge known as the bound vortex described by J. Andreopoulos [4].

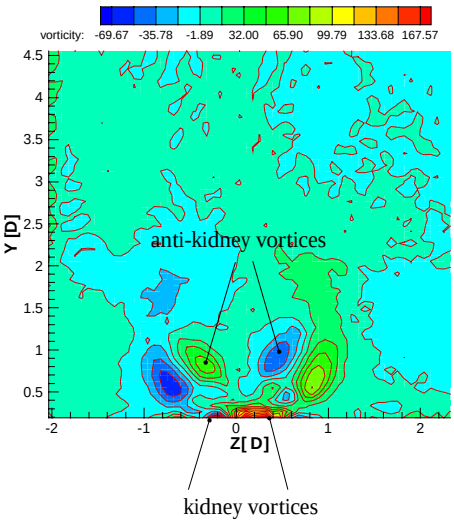

figure 3 : mean vorticity field - X=0D.

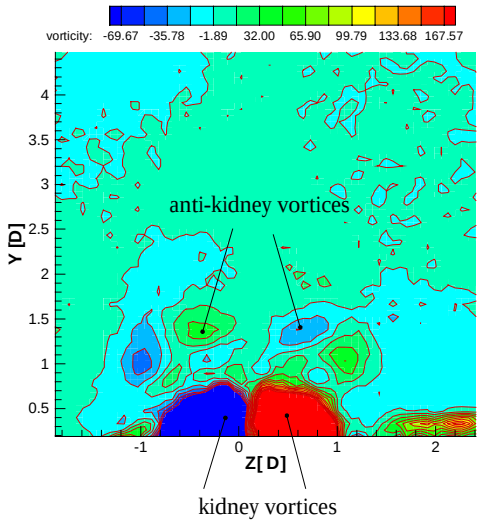

figure 4 : mean vorticity field - X=1.5D.

CONCLUSION

We know the better effectiveness of the shaped hole film cooling. It is mainly due to the reduction of the coolant velocity. The vortex motions, specially the induction of anti-kidney pair which could be related to this better effectiveness, are presented in this study.

PIV for mean and fluctuating velocity measurements were made to investigate the vortex motion around the shaped hole. Cold wire thermometry for mean and fluctuating temperature measurements allows to show the effects of shaping on the film cooling effectiveness.

REFERENCES

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