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NUMERICAL INVESTIGATION OF FILM COOLING EFFECTIVENESS USING THE ANTI-VORTEX CONCEPTION

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ABSTRACT

In film cooling flows, especially for high blowing ratios, the two contra rotating vortices are known as main contributor to the dramatic decrease in the film cooling effectiveness. These vortices entrain hot free stream gas and push them toward the blade wall. So, the thermal protection by cold injected air film is rapidly destroyed. One solution to reduce the effect of the contra rotating vortices at high blowing ratios is the use of the anti-vortex concept developed and studied at NASA Glenn Research Center. In the present investigation, a detailed computation of the new anti-vortex concept is realized by the use of a 3D Navier-Stokes code. Several geometrical configurations combined with high blowing ratios and variable density ratios are considered. Numerical results of holes equipped with the anti-vortex concept are compared to a baseline round hole injection and show promising improvement in all thermo-fluid aspects. The turbulence field is resolved by use of the SST turbulence Model. Computational results are presented in details and compared for different blowing ratios.

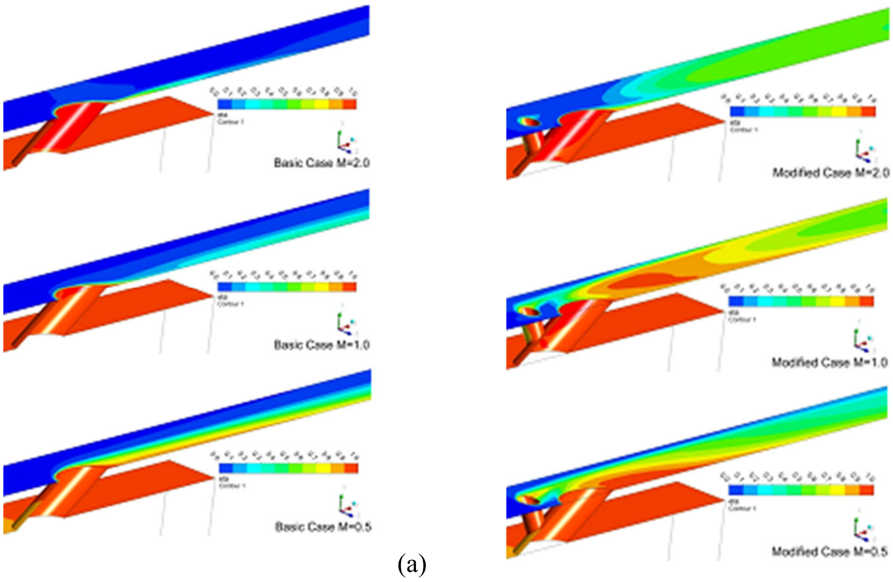
Keywords: film cooling, jet in cross flow, anti-vortex concept.

INTRODUCTION

The film cooling technique is based on injection of the coolant air through simple and complex holes arranged in one or more rows of holes. Different geometries for film cooling are studied using both experimental and numerical approaches. However, when one is testing turbulence models, numerical schemes or new holes geometries, the outcomes are benchmarked against the basic film cooling geometry configuration which consists of a row of round holes in a flat plate. Sinha *et al*. (1991) have provided a well-documented experiment for such case allowing its use as a benchmark test for numerical models. A well observed property of the flow from a round film cooling hole is the counter-rotating vortex pair that is responsible for jet separation from the surface at high blowing ratio. The counter-rotating vortex pair entrains the hot free stream gas from the main flow to the vicinity of the wall. So many research efforts are directed towards finding new geometrical designs that lead to the destruction or reduction of the counter-rotating vortex pair. A good review of such studies is presented by Heidmann, (2008). In the present study we are interested in the anti-vortex film cooling concept.

RESULTS AND CONCLUSIONS

Figure 1(a) shows the effectiveness contours over the wall surface. The low blowing ratio considerably enhances the lateral spreading of the cold jet and leads to the maximum laterally averaged film cooling effectiveness, while high blowing ratio is associated with the jet lift off and a drastic decrease in film cooling effectiveness. When looking to Figure 1(b), with the same parameters but with the additional anti vortex film cooling concept, one can see the great enhancement in the lateral spreading of the cold jet. The surface wall is much more protected and the level of effectiveness is higher. It is also found that this concept is more useful in high blowing ratio than it is for lower one. When looking to Figure 2, the modified cases (MC), the highest values of < η > are provided by M=1.0, which seems to be the optimal case that greatly benefits from the anti-vortex concept.



(a) (b)

Fig. 1 - Contours of wall film-cooling effectiveness distribution for the basic case (BC) and the modified case (MC)

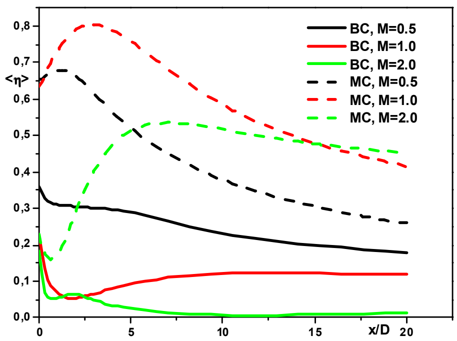


Fig. 2 - Lateral averaged adiabatic film cooling effectiveness for all cases

REFERENCES

[1] Sinha, A.K., Bogard, D.G., and Crawford, M.E., 1991, "Film-Cooling Effectiveness Downstream of a Single Row of Holes with Variable Density Ratio," Journal of Turbomachinery, vol. 113, pp. 442-449.

[2] James D. Heidmann, A Numerical Study of Anti-Vortex Film Cooling Designs at High Blowing Ratio, NASA/TM-2008-215209, GT2008-50845.

[3] Menter, F. R., 1993, Zonal two-equation *k-ω* turbulence model for aerodynamic flows, AIAA Paper.