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A COMPARATIVE STUDY OF THE FILM COOLING HOLE CONFIGURATION EFFECTS ON THE LEADING EDGE OF ASYMMETRICAL TURBINE BLADE

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ABSTRACT

The focus of this comparative-numerical study is to investigate the effects of advanced cooling hole geometries on film cooling effectiveness. Computational results are presented for a row of coolant injection holes on each side of asymmetrical turbine blade model near the leading edge (figure 1).

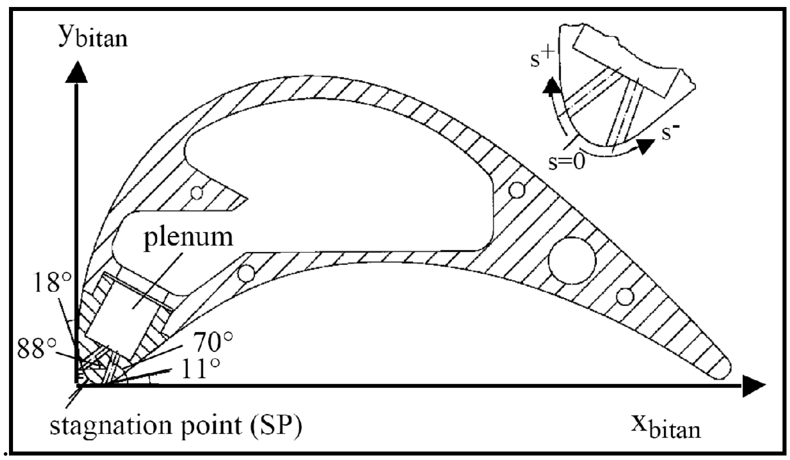

Figure 1. AGTB blade geometry

Figure 2 shows the six film cooling configurations considered in the present study, which will be called: (1) a cylindrical film hole, (2) a shaped film hole, (3) a uniform film slot, (4) a convergent film slot, (5) a crescent film hole, and (6) a trenched film hole. All simulations are conducted for the same density ratio of 1.0 and the same inlet plenum pressure.
A preliminary numerical study [Benabed et al, 2008], concerning cylindrical hole, has already been undertaken for the study of film cooling for the present blade model and compared with the experimental studies of Ardey [1998]. It was found that the comparison of the computational and experimental results was satisfactory on the suction side and on a major part of the pressure side. Once the numerical results for the first cylindrical geometry were validated against the experimental results, it was then used as a benchmark for the other configurations.

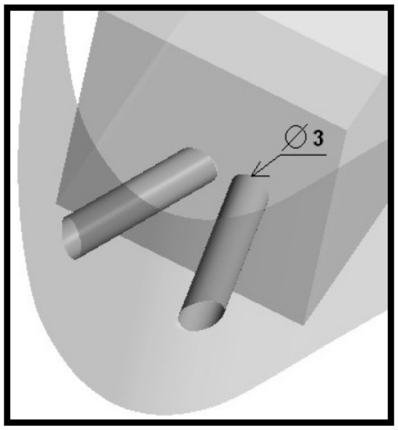

Fig a-cylindrical hole

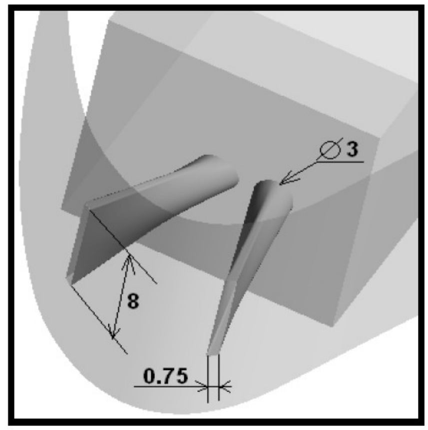

Fig d- convergent slot

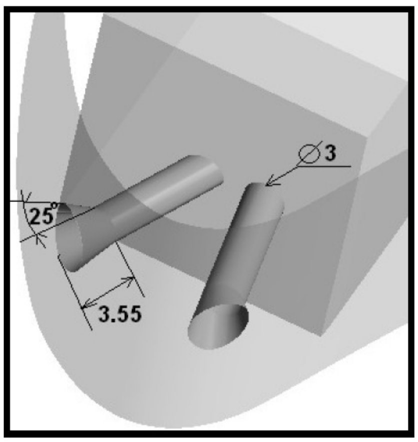

Fig b- shaped hole

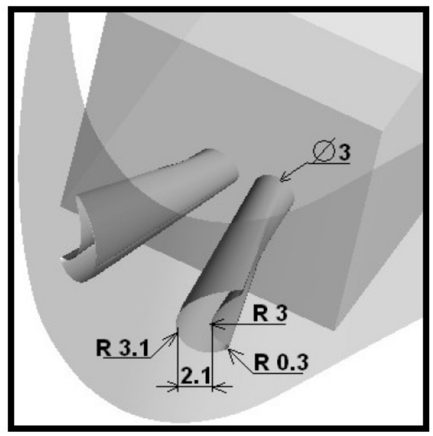

Fig e - crescent hole

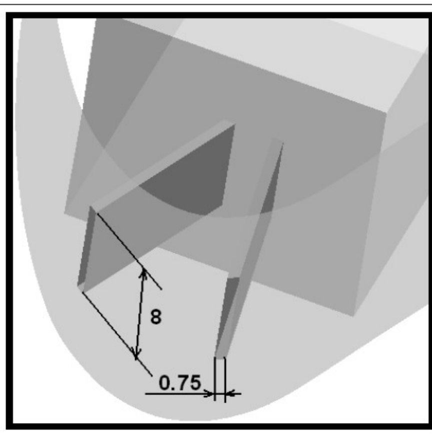

Fig c –uniform slot

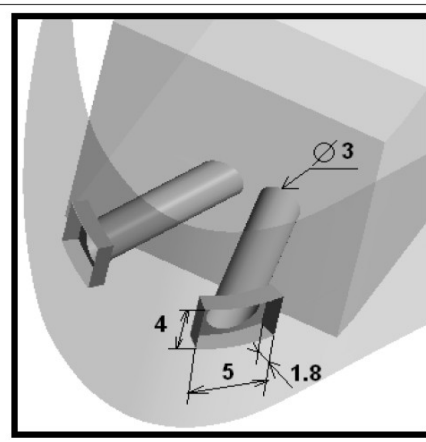

Fig d- trenched hole

Figures 2. Solid model for different film cooling configurations

In general, the numerical results show that holes with surface expansion decelerates the coolant jet and consequently produces lower momentum flux at the jet exit. For the same inlet pressure condition, the coolant jet has fewer tendencies to separate and produces higher adiabatic effectiveness. This phenomenon is more pronounced on suction side (SS) than it is on the pressure side (PS).

The comparison between the various configurations is made amongst other things, in terms of laterally averaged film cooling effectiveness (Figure 3) and film cooling effectiveness isocontours (Figure 4).

In order to compare the global amelioration realized by each of the studied configuration, an enhancement area averaged film cooling effectiveness is defined as follow:

$$\Delta\overline{\overline{\eta_E}} = [(\overline{\overline{\eta}} - \overline{\overline{\eta}}_{\mathbf{baseline}}) / \overline{\overline{\eta}}_{\mathbf{baseline}}]\times 100$$

where $\overline{\overline{\eta}}$ is the area-averaged effectiveness.

Globally and compared to the cylindrical holes, all the five new configurations provide an increase of film effectiveness (Figure 5). When looking at the SS, the maximum enhancement is registered for the convergent slot and the minimum is for the trenchant slot. While at the PS, the maximum is for the crescent slot and the minimum is for the uniform slot. The enhancement realized at PS is less than it is at SS.

Even with the same geometries, the injection holes at SS and PS produce different behavior regarding the film cooling effectiveness. This is due mainly to asymmetrical form of the blade and consequently to the pressure field accompanied each side of the blade. A deeper analysis of the aero thermal field is needed in order to explain the associated phenomenon and propose an optimized film cooling configuration for the present blade model.

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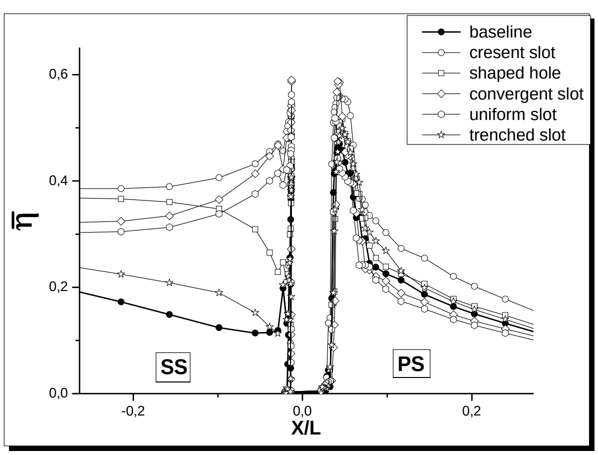
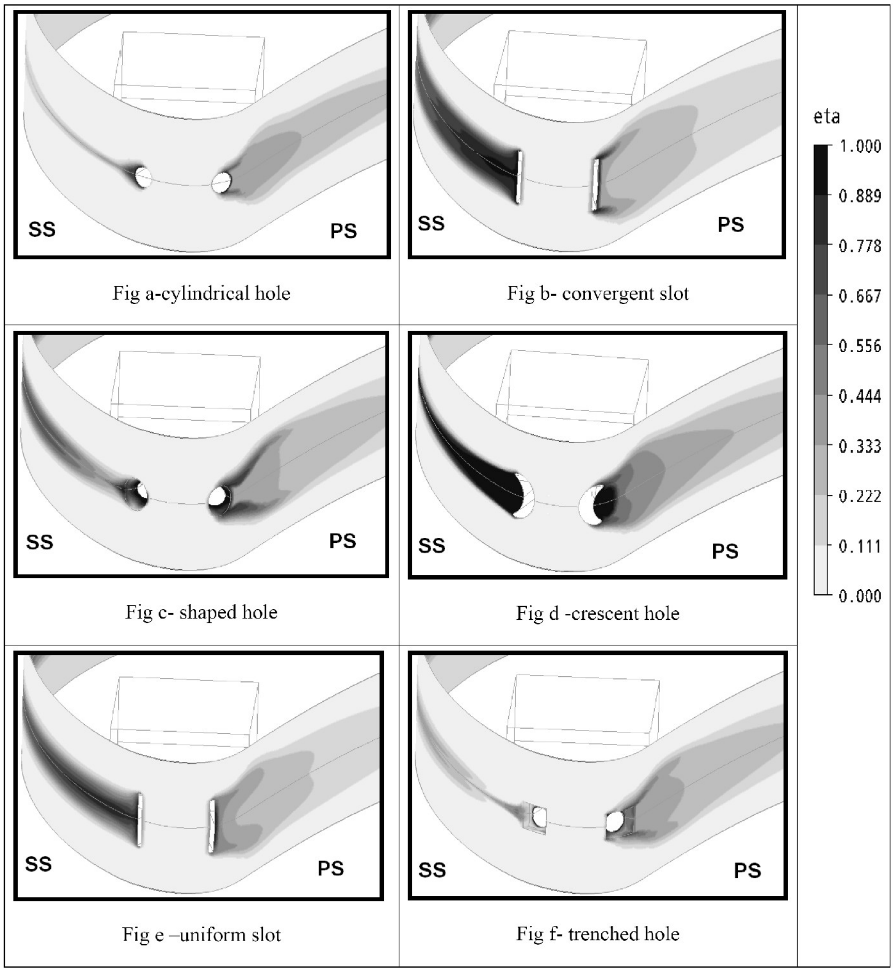


Figure 3. Laterally averaged film cooling effectiveness near the Leading edge



Figures 4. Leading edge Film cooling effectiveness contours (midplane)

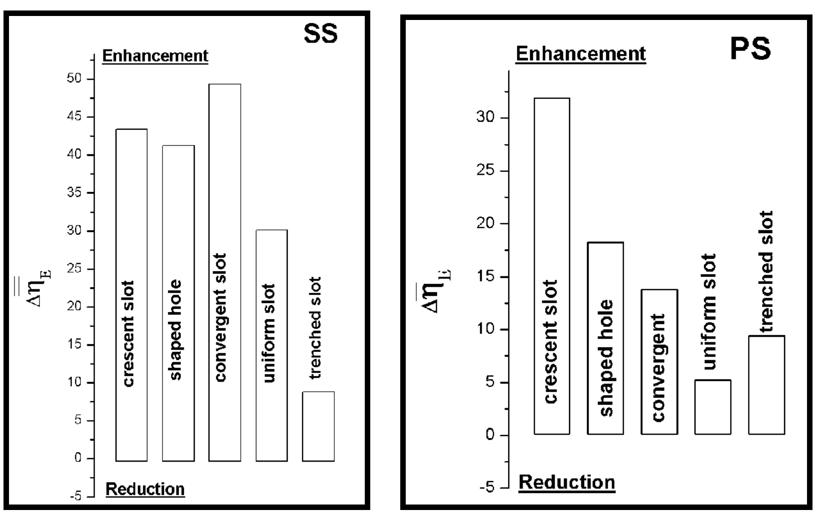


Figure 5. Percent enhancement in area averaged film cooling effectiveness for different hole configuration.