Hole Configuration Cooling Techniques for Gas Turbines Blades

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Abstract-
This paper is focused on internal cooling of blades and vanes on gas turbine. In this paper a hole configuration technique is used to predict the metal temperature of a gas turbine vane. This study is performed the solution of external and internal flow of high temperature and gases effect on blades of turbine. At first one of the commonly used cooling hole geometry is investigated; cylindrical holes and then two other configuration are simulated. Gas turbine are extensively used for aircraft propulsions, land based power generation, and industrial application. Thermal efficiency and power output of gas turbine increase with increasing turbine rotor inlet temperature. Therefore, along with high temperature material development, a sophisticated cooling scheme must be developed for continuous safe operation of gas turbine with high performance. Gas turbine blades are cooled internally and externally.

Keywords:
Gas turbine; Hole configuration; Cooling film

1.INTRODUCTION

Increasing the life of gas turbine blades can be achieved by cooling the blade effectively. Typically, this cooling process involves film cooling of blade surface. The present research about film cooling is focused on the improvement of film cooling effectiveness and the reduction of the coolant simultaneously. Film cooling holes with a diffuser-shaped expansion at the exit portion of the hole are believed to improve the film cooling performance on a gas turbine blade [1-5].

A turbine is a rotating device that uses the action of a fluid to produce work. In gas turbine, a pressurized, high temperature gas is the driving force. One way to increase power and efficiency of gas turbines is by increasing turbine operating temperatures. The motivation behind this is that higher temperature gases yield higher energy potential. However, the components along the hot gas path experience high thermal loading, which can cause distress. The HPT (High Pressure Turbine) first stage blade is one component that is extremely vulnerable to the hot gas. The turbine blades are exposed to a continuous flow of gas that may enter the turbine at a temperature between 850 0C to 1700 0C.This temperature is far beyond the melting point of current materials technology. The turbine blades are required to perform and survive long operating periods at temperatures above their melting point, In internal cooling, relatively cold air is bypassed from the compressor and passed through the hollow passages inside the turbine blade. In external cooling, the bypassed air is exited out through small holes at discrete locations of the turbine blade. [6][7]

Improving the performance of gas turbines can be achieved by increasing the turbine inlet temperature. This subject requires highly effective cooling techniques to maintain the temperature of the components in contact with the hot gases at acceptable levels. Film-cooling has been widely used to protect gas turbine blades from hot gases by injecting compressor blades air through discrete holes in the blades Surface. [8][9][10].

2.DESIGN OF BLADES

Gas turbine blades usually have a gap between the blade tip and the stationary casing or the shroud surface known as tip gap. This clearance gap is necessary to allow for the blade's rotation and for its mechanical and thermal growth. Due to the pressure difference between the pressure side and the suction side of the blade, hot gas leaks through this gap from the pressure side to the suction side. This is known as tip leakage flow. [11].A perfect blade tip will not allow any leakage flow, generate no secondary flows to neither reduce stage efficiency nor create losses for downstream airfoil stages and will not require any cooling thereby presenting no thermodynamic losses from the use of compressed air.

Therefore, the two main objectives of blade design engineers are

(1) To reduce the leakage flow either by reducing the tip gap or by implementing a more effective tip leakage sealing mechanism and
(2) To cool the blade tips with the least possible usage of cooling fluid. However, all the blade tips used in today's engine do allow some leakage flow and generate secondary flows.

The three major types of blade tips that are being used today:

(1) Plane tip,
(2) Recessed tip with peripheral squealer sealing rims,
(3) Attached tip shrouds used with plane or flared blade

2.1 Plane tip blade:

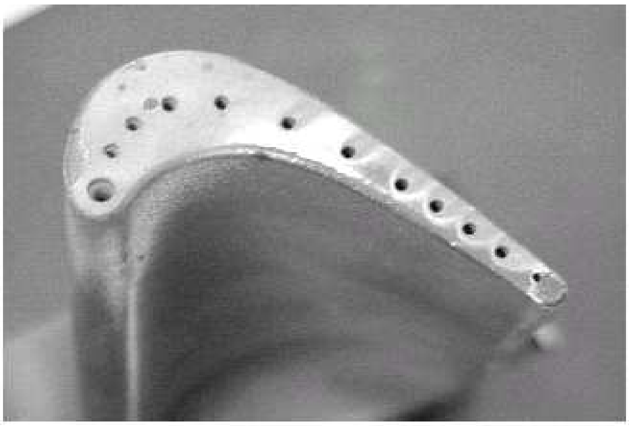
A very few engines now-a-days use plane blade tip. Figure 2.1 shows a plane tip. Since, any physical leakage resistance sealing mechanisms are absent in this type of blade tip, it provides the lowest aerodynamic efficiency due to relatively high leakages. Plane blade tips may also be more susceptible to damage if and when they do rub against the shroud. But it is easy to design this type of blade tip, as there are no extended surfaces to be cooled like in recessed tip with squealer sealing rims. Film cooling holes on the top can be seen in the figure. The location of the film cooling holes is the direct consequences of the internal cooling passages within the blade. These holes are called purge holes. The functions of the dirt purge holes include the following:

(1) Purge holes allow centrifugal forces to expel any dirt ingested by the compressor into the turbine rather than clogging the smaller diameter film cooling holes prevent loss by oxidation and erosion. The rim acts as an extended fin that sometimes requires many pressure side film cooling holes, to adequately cool the rim. Manufacturing process, and (3) the extra coolant helps in reducing thermal load at the tip. [12]

(2) Purge holes provide a way to support the ceramic core during the lost-wax investment casting of the blades.

Fig. 2.1**.** Plane tip blade

2.2 Recessed tip blade:



Recessed tip with a perimeter seal strip is the most common design in practice today within. HPT (High Pressure Turbine) blades. Figure 2.2 shows an example of a squealer tip blade. The squealer rim is a natural radial extension of the aerodynamic surface of the airfoil.The function of the squealer rim is to act as a simple two-tooth labyrinth seal. Tip leakage gas is first forced to contract between the pressure side rim and the shroud, then expand into the cavity, and then contract again to pass the suction side rim restriction before expanding into the main flow. A recessed tip with peripheral rim allows a smaller tip clearance, but reduces the risk of blade damage, if the tip rubs against the shroud. This type of blade tip running with a very tight clearance can be a very effective seal. However, the design of recessed tip blade is more complex than the plane tip because of the cooling of the rim to

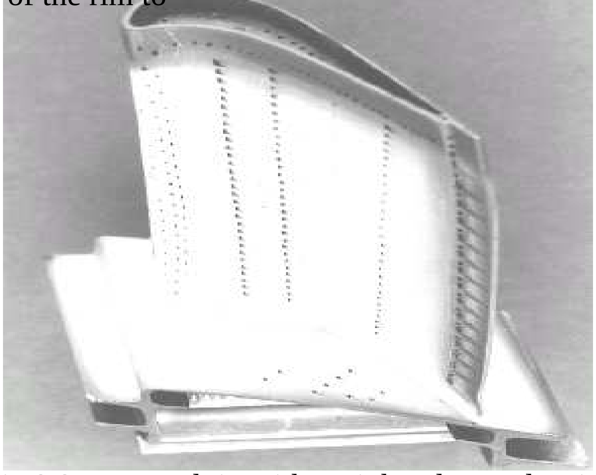


Fig.2.2.Recessed tip with peripheral squealer rim

2.3 Blades with attached tip shrouds;

Blades with attached tip shrouds are mostly used in LPT (Low Pressure Turbine) blades. Figure 2.3 shows an example of such blades. The tip shroud is in essence an inner shroud that moves with the blade tip. There is a stationary shroud casing outside of this tip shroud. Of all the current blade tip design in use today, the tip shroud has the lowest aerodynamic loss when properly installed. But designers have to pay great attention to stress because this blade tip is heavier than plane or recessed tip with squealer rim blade tip due to added mass. This also requires a much more complex cooling system, not only because of the geometry, but also to maintain material temperatures for acceptable stresses. [13]

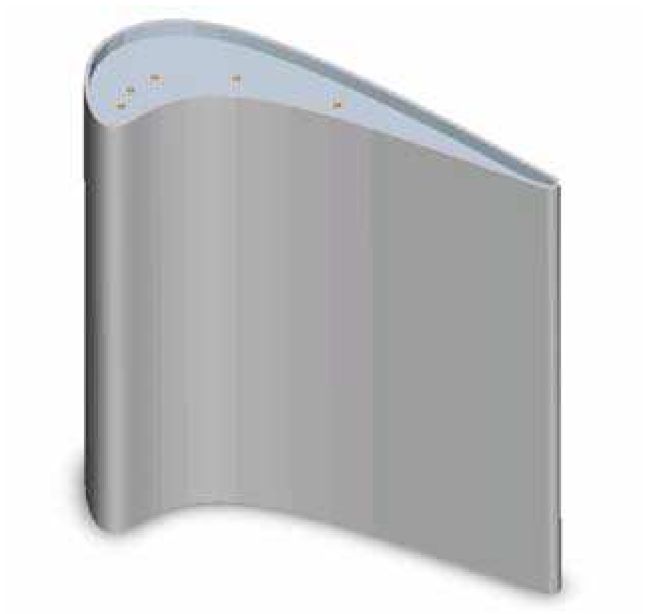
Figure 2.3: Blades with attached tip shrouds.

3. FORMATION OF HOLE IN DIFFERENT SECTION ON BLADE

3.1 Tip injection hole

Pressure data on the shroud and heat transfer data on the blade tip for both plane tip and recessed tip with peripheral squealer rim blade for blowing ratios M=0, 1.0, 2.0 and 3.0 will be given. The gap between the tips of the squealer rim to the shroud is maintained at 1 %.

(a) Plane tip



(b) Recessed tip

Fig.3.1.Plane and recessed tip blade with tip coolant injection holes

3.2 Pressure Side Hole Injection

Pressure data on the shroud and heat transfer data on plane tip and recessed tip for coolant injection from the pressure side holes are presented. Experiments were run for blowing ratios of M=0, 1.0, 2.0 and 3.0. Figure 3.2, shows the plane and recessed tip blade used for this study.

(a) Plane tip

(b) Recessed tip

Figure 3.2: Plane and recessed tip blade with pressure side coolant injection holes

3.3 Tip and Pressure Side Injection

Results for combination cooling or when coolant is injected from both tip and pressure side holes will be presented. Figure 3.3 shows the plane and recessed tip blade used for the experiment. [14]

(a) Plane tip

(b)Recessed tip

Figure 3.3: Plane and recessed tip blade with tip and pressure side coolant injection holes.

4. DIFFERENT TYPES OF HOLE SHAPE

The 3-in-1 hole had a 15° lateral expansion both at the inlet and outlet of the hole while the fanned hole had an expansion only at the outlet of the hole. The inlet expansion of film cooling hole was believed to significantly increase the discharge coefficients of film cooling holes. The ratio of the width to diameter of the inlet and the outlet of 3-in-1 hole was 1.5. The measurements were carried out downstream of the holes from x/d=3 to x/d=50, where x was stream wise coordinate originating from the centre of film cooling hole and d the diameter of film cooling hole.[15]

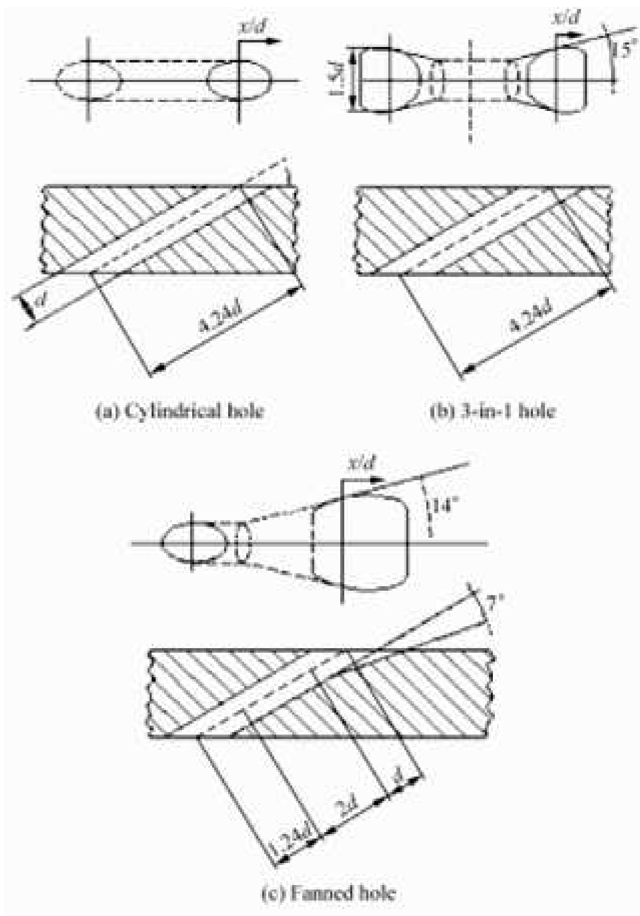


Fig.4.1. Geometrics of three film cooling holes.

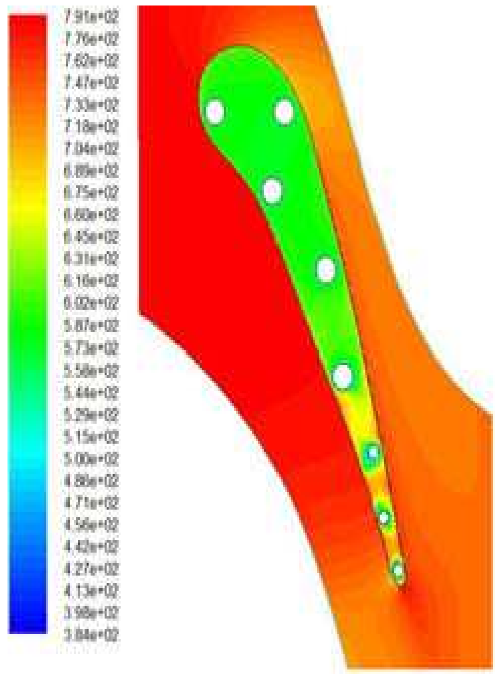
5. TEMPERATURE DISTRIBUTION IN HOLE CONFIGURATION

In this section the result of other configurations and arrangements of cooling holes are indicated. Because of comparison the result, Figure 5.1 shown the temperature profiles for the case1 and 2 and the magnitude of average temperature on the vane surfaces are listed in Table 1.

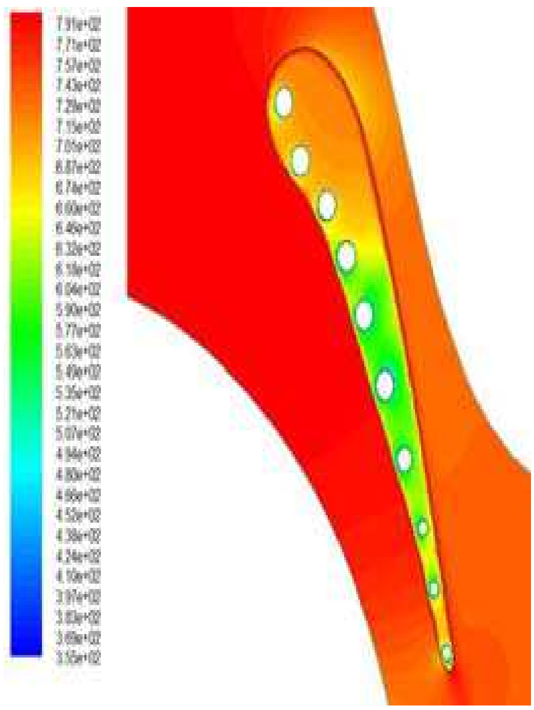
TABLE I
AVERAGE TEMPERATURE ON THE VANE SURFACE

Case	1	2
Average Static Temperature (K)	658	664

Fig. 5.1 exposes the temperature profiles of case 1, 2. It is clear that in the case 1 streaming of blade temperature is very steady. Perhaps it be seems that in another case this state had been happened. But by respect to the average temperature such as other parameter for comparison is considered (Table 1) . By this reason case 1 is selected such as best arrangement and configuration between the hole shapes. It means that with this hole shapes the vane resistance can be improved in relation to thermal collapse and satisfied the blade cooling goal. [17]



a- case 1



b- Case 2

Fig. 5.1 Contours of Static Temperature

CONCLUSION

The present study was done to highlight the relative new tools in gas turbine heat transfer design, wherein the individual heat transfer problems (external/internal convection, conduction in the metal) are coupled in a single simulation. The benefits of the conjugate approach are inherently better accuracy and reduced turn-around time as compared to the common practice of decoupled simulations. The vane was cooled by air flowing Radials through ten smooth-walled channels .More studies are needed for the blade shaped coolant passages with high performance tabulators and with or without film cooling holes under realistic coolant flow, thermal, rotating conditions.

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