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Review of Cooling Effect on Gas Turbine Blade

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Abstract: *To Performance of a gas turbine is mainly depends on various parameters. There are ambient temperature, compressor pressure ratio, turbine inlet temperature. The most important parameter to increasing the life of the Aircraft turbine blade is the cooling effect of the blade. Film cooling is one of the cooling techniques to cool the hot section components of a gas turbine engine in Aircraft. Which is operate according to the Brayton cycle. It is operating at very high temperature .which has to be fall in the region of Aircraft turbine blade material are melting point at high temperature. In this paper the cooling effect of provision of pins of two different diameters and heights over the Aircraft turbine blade tip at the corners. The inlet temperature of the turbine Blade and previous research are said that the temperature above 1123K, require cooling of the blade.*

INTRODUCTION TO GAS TURBINE BLADE

Modern gas turbines operate at very high temperatures for increasing the efficiency and performance of the turbines. But these high temperatures may exceed the material melting temperature of the turbine blades. They are used different types of material which are nickel, titanium, aluminium etc. These materials are varying temperature in gas turbine engine blades. To increasing the life time of material in the gas turbine blade. Hence the cooling of the turbine blade tip must be given a special attention for safe and efficient working of the turbines. There are several methods to cooling the turbine blades. In this paper to used in film cooling effect on gas turbine blades. Ron S. Bunker [1] experimentally investigated the effect of providing pin arrays to the internal tip cap of turbine blades. Also this method resulted in negligible pressure drop as compared to that of a smooth surface of the turbine internal tip. Gongnan Xie and Bengt Sunden [2] simulated the same geometry as given by Bunker.

Literature Survey on Gas Turbine Blades

In yet another analysis Gongnan Xie [3] carried out numerical simulations for six different arrangements of the guide rib/vanes in a two pass serpentine passage. Another option of tip cooling was proposed by Gongnan Xie and Bengt Sunden [4] which stated the use of pin fins for the cooling of tip of the turbine blades. V.Veeraragavan [5] had mainly done the research on the aircraft turbine blades; his main focus was on 10 C4/ 60 C50turbine blades models. By JE Chin Han and Srinath Ekkad[6], Film cooling is the introduction of a secondary fluid at one or more discrete locations along a surface exposed to a high temperature environment to protect that surface not only in the immediate region of injection but also in the downstream region.

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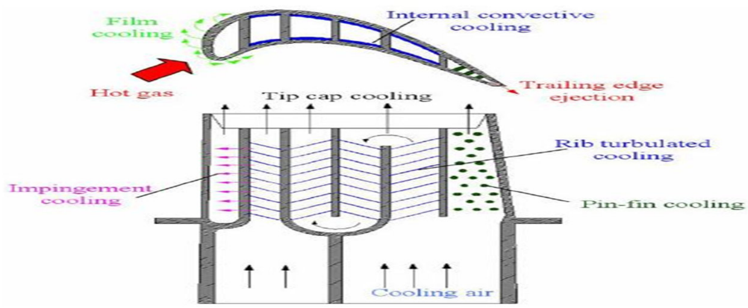

Figure 1:Typical cooling techniques of turbine blade

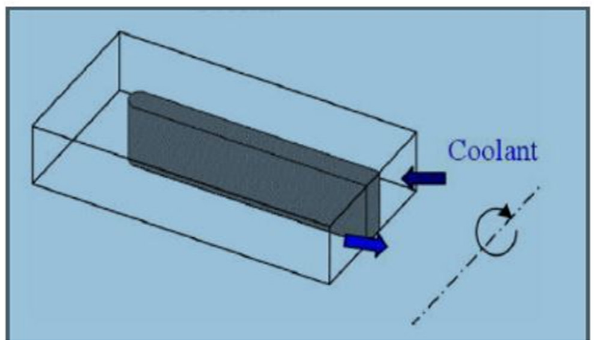

Figure 2: Two pass serpentine passages inside a turbine blade [2]

Geometry of Physical Model

The physical model considered for this study is as shown in the Fig 1. It consists of a two pass rectangular channel with inlet and outlet sections having a cross sectional area of 7.99 x 14.03 sq.cm. The hydraulic diameter from the geometry is calculated as 8.2 cm. A gap of 8.89 cm is assumed from the tip surface to the turn surface i.e. between the divider and the tip wall. The thickness of the internal separation tip is 1.5cm. The height of the two pass channel is 15.96 cm. Rest of the features of the geometry are similar to those of Bunker [1] for a smooth tip two pass channel. But the geometry varies at the tip surface when the case of pins is considered

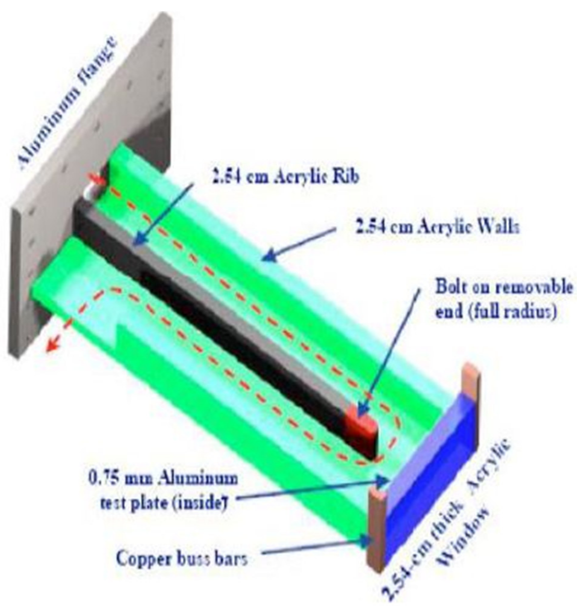

Figure 3: Experimental model [1]

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Governing Equations

The governing equations for the flow are as expressed below Continuity equation [2]

$$\frac{D\rho}{Dt} + \rho \nabla . V = 0$$

Momentum Equation

X-momentum

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x$$

Y-momentum

$$\rho \frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho f_y$$

Z-momentum

$$\rho \frac{Dw}{Dt} = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + \rho f_z$$

Energy Equation for fluid [2]

$$\frac{\partial u_i T}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\left(\frac{\mu}{\Pr} + \frac{\mu_t}{\Pr}\right)\frac{\partial T}{\partial x_i}\right)$$

Cooled Gas Turbine

Turbine produced power to drive engine compressor due to expansion of gas stream apart from the excess work developed at the shaft of the turbine. A general model that represents the gas turbine with turbine blade cooling has been developed. The model is intended for use in cycle analysis applications. Aerodynamic losses and hence the inefficiency of gas turbine is taken care by considering polytropic efficiency of turbine.

$$\frac{T_i}{T_e} = \left(\frac{p_i}{p_e}\right)^{\frac{\eta_{pt} \cdot (\gamma_t - 1)}{\gamma_t}}$$

Pressure ratio, the temperature and other variables for each stream are calculated for a given polytropic efficiency. Wt is the work developed by turbine, and ηm is the mechanical efficiency which is used to account for the losses due to windage, bearing friction, and seal drag and is defined as,

ηm=

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Work Ratio: Work ratio is also very important parameter for the selection of a gas turbine cycle. The work ratio is given by the following equation:

WR = Wnet Wt

Specific Fuel Consumption**:** Specific fuel consumption is defined as the fuel consumed by the combustor per unit net work of the cycle; if the mass of fuel consumed is given in kg/s and the net work developed is in kW then the specific fuel consumption will be calculated in kg/kWhr.
SFC = 3600 × mf Wnet (kg/kWhr)
Net Power: Net power available is calculated by the following equation.
Net Power = ma × wnet × ηgen

Boundary Conditions

SI.NO	Part	Boundary Type
1	Main stream inlet and coolant inlet	Velocity inlet
2	Main stream outlet	Pressure outlet
3	Coolant outlet	interior
4	wall	wall
5	Solid surface	wall
6	fluid	fluid

Table 1: Boundary Conditions

The type of boundary conditions applied in all the computational models are shown in the Table 1. The boundary condition values are used same as experimental test values. Film temperature and velocity contours for all the models are numerically simulated by varying the blowing ratios. By using this surface film temperature values obtained from CFD, cooling effectiveness is calculated for all the models

Table 2: Experimental test condition

Blowing ratio	Coolant velocity in m/sec	Mainstream velocity in m/sec	Coolant temp in °K	Mainstream temp in °K
1.50	21.50	300	243	21
1.75	25.62	300	243	21
2.0	30.40	300	243	21
2.50	34.75	300	243	21

Results and Discussion

The above boundary condition, velocity and temperature distribution at various angle (30,45)degree by using below fig surface flim temperature values are obtained from software and cooling effect is calculated for all the models. From the figures highest cooling effectiveness is observed from 45degree. Because of the blade model less resistance from the main stream flow with the increasing in blowing ratio the cooling effectiveness will increased.

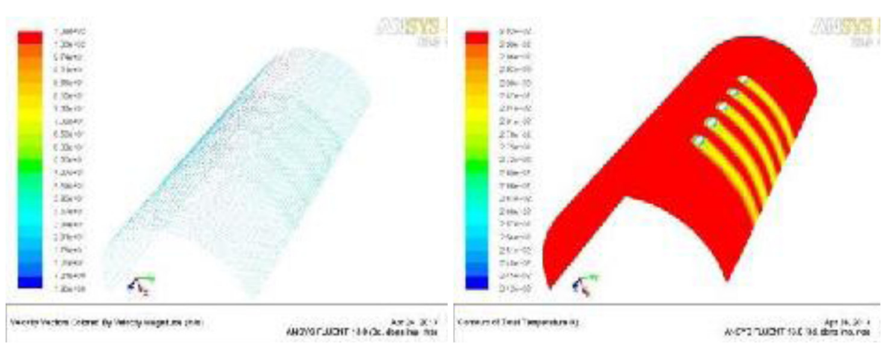

Figure 4: velocity and Temperature contours for 30deg. Cooling hole model at B.R = 1.50

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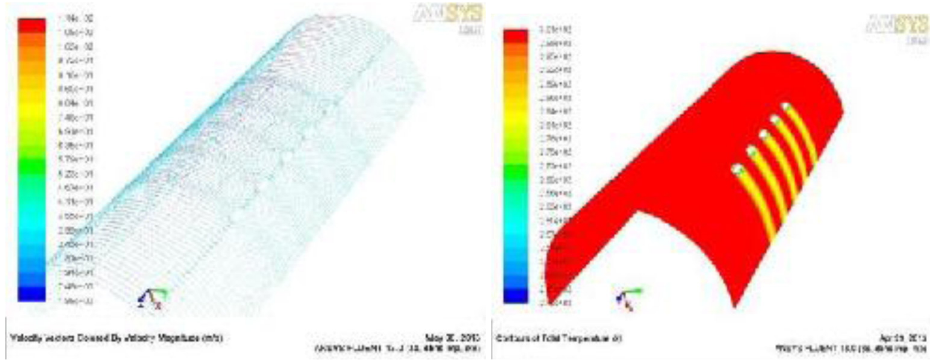

Figure 5: velocity and Temperature contours for 45deg. Cooling hole models at B.R= 1.75

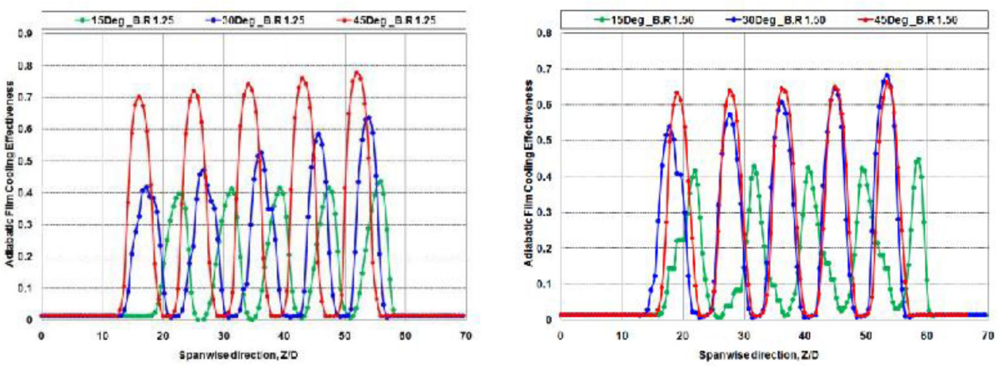

Figure 4: Numerically evaluated (CFD) adiabatic film cooling effectiveness in the spanwise direction at the downstream of holes for the 30 and 45 deg. models at B.R =1.50 and B.R1.75

Conclusion

From the Analysis of the cooling effectiveness increase with the increasing hole orientation angle and it is observed higher value for the 45 degree. Because the blowing ratio for 30 degree is 1.50 but 45 degree of the blowing ratio is 1.75. So the variation of the hole orientation in increasing the cooling effectiveness. From our analysis cooling effectiveness is increased 14% from 30 degree to 40 degree hole orientation.

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