Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/02/jls.htm
2015 Vol. 5 (S2), pp. 1202-1208/ Bakhtiyarikhoei and Motallebi
Review Article

COMPARISON AND OPTIMIZATION OF DIFFERENT METHODS TO COOLING IN GAS TURBINES AND EFFICIENCY INCREASE

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ABSTRACT
Advanced gas turbines cycles for increased inlet temperature of turbine, cooling blades advanced technologies benefit. Accuracy modeling and optimization of cycles to the model depends on blades cooling. In this paper, various models of cooling are offered with different ways to calculate required air to cooling, pressure inertia drop and pressure classes' ratio. Then, the examination of cooling methods and their impact on turbine efficiency and advantages and superiority giving each other than.

Keywords: *Gas Turbine Blade, Blade Cooling, Efficiency Increase*

INTRODUCTION
In this paper, the examination of variety methods and models to cooling gas turbine blade is discussed. The main objective of this article is evaluation and optimization of two different models for gas turbines.

MATERIALS AND METHODS
Different Methods of Cooling
Continued Optimization Models and New Straticulate Model
To increase potential and efficiency at the same time should be increased inlet gas turbine temperature. But, because of temperature restrictions is cooled hot turbine sections.
The air-cooled turbines, injected gas into main flow and mixing will be leading to stagnation temperature and pressure stationary drop. Since those cooling flows, often taken from different parts of compressor, is affected on compressor work and combustor flow. Over the past 50 years, numerous articles have been published in connection with the blades cooling. Initial models for blades cooling have been developed by (Rohsenow, 1955), (Hawthorne, 1955) and (Ainley, 1957).
In the past 20 years until now, many models are provided by (El-Masri, 1986-1988), (Consonni, 1990), (Young and Wilcock, 2002), and (Torbidoni and Horlock, 2002).
A partial gas model to combined five gas (nitrogen, oxygen, argon, water and carbon dioxide) based on temperature, is used and presence of products incomplete combustion have been approved by defining a combustion efficiency.
The objective of this article is evaluation and optimization of two different models for gas turbine. The first model, an optimized contiguous model is based on (Bolland and Stadaas, 1995) work and second model is a new model based on (Jordal, 2001) and (El-Masri, 1988) models.
Cooling (Tape) Film
Most of gas turbines are used for cooling from cooling film (tape) (Letebver, 1983), (Leger, 2002), (McGurik, 1995), (Maja, 2008). In this way, 40% of compressors air is used in the cooling process (Maja, 2008). The combustion of an outer shell and an inner cylinder is made. In combustion, the air path after pass of combustion diffusion is divided to two parts (Figure 1).
The Part of inlet air enters into cylinder through Soiler (air-condition) and helps to form a flame and another portion of the air entering to foreign channels that the same are cooling channels, by holes is embedded in the wall of combustor chamber, enters into combustion and in addition to cooling of combustor chamber, is caused completing of combustion after initial combustor chamber and also help to cooling of hot gases due to fuel combustion and air in dilution region (Maja, 2008), (El-Masri, 1988).

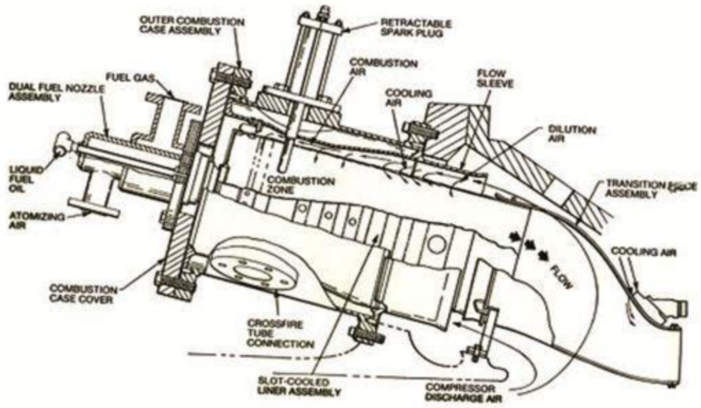

Figure 1: Combustion Chamber

Regarding to thermal tolerance of turbine blades, especially in first row, cool of hot gases has a great importance in dilution area, because otherwise, as time passed the hot gas will cause damage and deformation turbine blades. Therefore, the design of the combustion chamber, should properly estimate be taken the heat transfer and produce process to can be design a suitable method for cooling and increase turbine efficiency. Much work has been done in this connection. Shinjo and colleagues, using LES method have examined the effect of flame behavior on turbines gas combustion (Shinjo, 2007), (Sunden, 2006). Another group, the design importance of air holes used to liner of combustion chamber have examined by CFD simulation (Letebver, 1983), (McGurik, 1995).

Walls with Several Holes

One of the most effective cooling methods, using multiple holes way on the cylinder wall that its picture you can see in Figure 2.

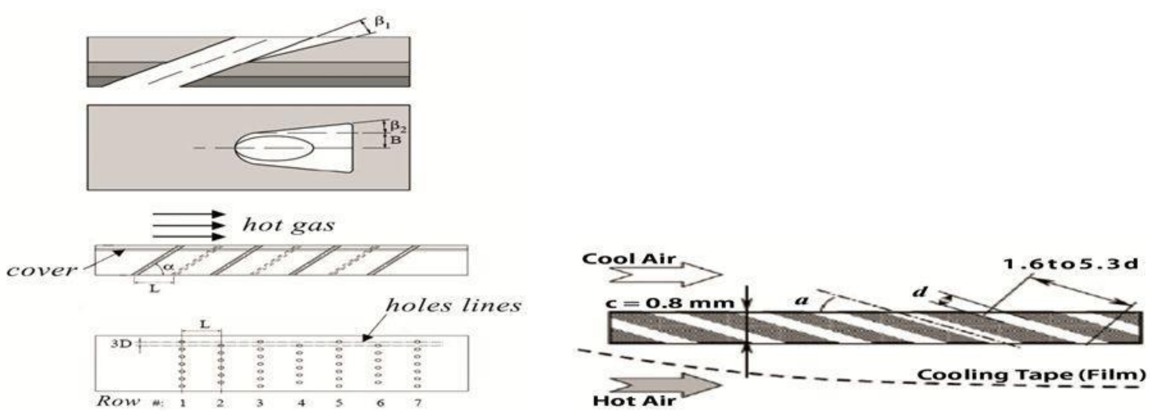

Figure 2: Several holes on the cylinder wall

In this way, the arrangement of the holes, holes diameter and cutting holes angle has a special significance that leads to correct direct to cooling air. To direct to cooling air, not only can be increases the cooling effects but can be used cool-air to increase combustion and output pressure of combustor chamber. Dieter Boone and Norbert Moritz, in his researches are examined this issue by considering two structures.

Boundary Layer Excitement

Cooling of turbine blades is a basic and necessary operation for safe and efficient exploitation of gas turbine which causes turbine blades work at temperature and finally allowed to rise their life. In relation to stimulate application of boundary layer to help various obstacles, very little research has been done for cooling turbine blade. One of the ways of stimulate boundary layer is placing obstacles with different dimensions and shapes within a distinct space of page. Therefore, by placing a square block and a triangular block with variable dimensions and distances within a boundary turbulent layer have been studied effect of four factors such as vortex, inertia, return area and jet to increase or reduce rate of heat transfer in turbine blades.

(Bard and colleagues) rectangular bulge placed on a surface and with help speedometer of hot wire, have measured intensity of turbulence changes in boundary layer and beyond. A similar experiment by placing rectangular section on a flat plate into a boundary tranquil layer and measurements of correlation between turbulent of boundary layer, length of transition region to turbulence and section dimensions carried out by Durst and Becker.

The measurements shown that even if boundary layer has a nature of layer, placing a barrier with rectangular section can also confuse the layer, under quiet layer of y + <~ 30 create turbulence to significantly intensity.

Worner and colleagues, a semi-circular block and also a rectangular section with different dimensions ratios placed on a flat surface and stability of boundary quiet layer examined as a result of existence of vortices due to wake of object behind (Sohankar and colleagues), creating instability and heterogeneous pressure distribution around a cylindrical section inspected at different Reynolds.

The basis of boundary layer excitement is use of different fluid phenomena, such as inertia, vortex, separation of boundary layer, creating a fluid jet into boundary layer.

Using this phenomenon, the flow pattern inside boundary layer is confused and thickness of boundary layer is changed. A great way to make this effect, putting external barriers within boundary layer and or be creating variety bumps and dimples on surface of screen.

Shape Injection Holes Effect on Layer Cooling

In this way, the coolness fluid that through cracks or holes to be injected into mainstream, the blade surface has been cover and it protect from direct contact with hot gases. So far, many experimental and numerical studies are done on injection holes in cooling phenomenon of layer. Goldstein and his colleagues (1974) were among the first people begun to examine shape of holes to increase cooling efficiency. They took advantage of holes in direction along row of holes, 10º were drawn, and concluded that holes deformation causes would be better cooling parameters. They stated that reason of this phenomenon, is weak due to fluid jet of cooling and reducing its momentum and thus less permission of injection current into mainstream.

Sen *et al.,* (1996) and also Schmidt *et al.,* (1996) experimented the holes that 15ºdrawn in front and concluded that for holes of drawn in front, better results is obtained than cylindrical holes.

Yu *et al.,* (2002) concluded that combination of holes stretched in horizontal and forward direction, causes a significant increase in characteristics of cooling layer compared with cylindrical holes.

Kim and Kim (2002), the impact of five different holes is experimentally examined the including a cylindrical hole, two holes with pull 10º, in the row of holes as well as in the flow on surface (teardrop shape) with 30 degree angled injection, blowing different ratio on efficiency of cooling and temperature distribution on surface of a cylindrical model. The results showed that cooling efficiency of blowing ratio, under increased and cooling features in cylindrical slim holes is better than cylindrical conventional holes and teardrop-shape.

TabriziAlavi *et al.,* (2008) considered to examine numerical of four variety holes on a flat-screen which consisted of a cylindrical hole and a hole drawn in the front 15º and a flattened cylindrical hole and a hole in the front 15º drawn and in end is broaden, concluded that efficiency of cooling in flattened holes is more than any other shape and also holes that are broad as well as in the front drawn up have better characteristics of cooling than other holes.

Efficiency of Medium Cooling

The cooling layer efficiency has a direct connection with momentum rate of key and injection currents that these characteristics can be changed with alteration blowing ratio of currents, holes shape and injection angle and seemed to be optimal. Average efficiency of layer cooling on front surface of cylinder and percent of increase compared to use injection conventional cylinder tube, in order to compare performance of different holes are provided in the below table. Regards to this table, use of D hole by increase about 30%, compared to normal mode has maximum cooling efficiency and optimal.

Table 1: Average efficiency of cooling on surface of cylinder and percentage increase compared to (A)

	Cooling efficiency of layer	Relative increase (%)
A	0.263	0
B	0.299	12.2
C	0.335	21.6
D	0.372	29.3
E	0.337	22

Cooling layer performance can be improved significantly by shape control of injection holes. For a blowing unit ratio and a fixed position of injection, use of pipes were opened in y direction (Figures E and C) or in Z direction (Figure B and D), the current momentum of injection reduced and will cause less influence of this current to air main flow. This leads to more complete coverage and a better distribution of cool air on a hot surface of blade and efficiency increase of layer cooling will result than holes of cylindrical common (A shape). Figure D, especially with about 30% increase in cooling efficiency than the A shape, has maximum coverage of blade surface with cool air and higher efficiency of cooling between five types of studied hole.

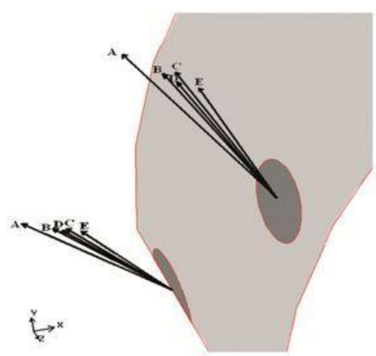

Figure 3: Layer cooling- injection holes

The Effect of the Injection Groove Angle

One of common methods for protection turbine blades of hot gases, using approaches of layer cooling through continuous groove that in this study to examine it. Jackson and Eckert (1951), experimental addressed to study of effects of multiple structures of track and hole on phenomenon of layer cooling in edge of turbine blades by using make-visible methods of fluid. Their own visual observations, they concluded that a continuous groove is a structure that is created most effective layer for cooling of blade surface.

Rahni and Mahjoub (2003), examined the numerical study of layer cooling of groove and detached holes at 30º, 60º, 90º injection angles and blowing ratio of 0.5, 1 and 1.5 on a flat page. Their results indicate that in layer cooling through groove, the best cooling efficiency is at 30 degree angle and 5.1 blowing ratio. Also, with check two mentioned methods of layer cooling, they concluded that performance of groove cooling is much longer and with greater efficiency than cooling to detached holes.

Mehlman (1990), parametric study carried out on angle effect of injection groove on cooling efficient of $\eta = \frac{Tm - Taw}{Tm - Tc}$ adiabatic layer to main accelerated and non-accelerated currents. In (η) define, T_{aw} is adiabatic wall temperature, T is temperature of fluid and c and m indexes indicate main correct and cooling flow of injected, respectively. He found out that in study and compare to 0, 5, 8.5, 11.5 and 15 degrees angles of injection groove, optimal injection angle is 5.8 degrees that it has maximum efficiency. Also, performed numerical results with the software FLUENT to compare with the experimental results, suitability compatibility is showed in

$M=\frac{(\rho U)c}{(\rho U)m}$ less blowing ratio.

In above equation, fluid density and U velocity is describing cooling and main current to c and m indices. Diller (2002) was first that carried out the efficiency experiment of the bottom wall to flow injection through slot on the edge of turbine blade to M = 0.75 blowing ratio and concluded from their experiments, the gradient of occurred yield in the blade, causes cooling matter injection of pressure part to the suction part.

Han and Ou (1992), investigated effect of turbulence intensity and blowing ratio on efficiency of film cooling through two rows of discontinuous slots with 15 and 45 degree angles on a semi-cylindrical edge. The results is indicative that 0.8 optimal blowing ratio in different turbulences intensity to compared with 0.4 and 1.2 blowing ratio. Whitelaw (1967), were studied importance of groove edge thickness and angle of injection on cooling efficiency. Check the 30, 60 and 90 degrees injection angles showed that injection angle increases causes pressure loss and also decreases cooling efficiency is reduced to increasing the thickness of the slot edge. Talita, in their research, is addressed to numerical analysis of effect of cooling gases except air, such as nitrogen, hydrogen, helium, through a continuous groove on a cylindrical model on supersonic air flow.

Comparison of different modes showed that injecting gas with lower molecular weight and greater thermal capacity has maximum cooling efficiency, which in this study was obtained hydrogen gas. Leger and Sunden (2003), have given to check film cooling numerical studies of gas turbine combustor, using turbulence models and comparing carried out about to obtained results of already done LDV experiments in this direction. They were examined experiments for 15, 30, 40, 60 and 90 degrees groove angles and range of 2 to 9 of blowing ratios. These results express that downstream backflow of slot for injection grooves angles is greater than 40 degree and for angles less than 30 degree disappear the backflow and good agreement be obtained with experiments.

CONCLUSION

Continuous Model Optimized and New Straticulate Model

By fixing the number of classes, pressure ratio alterations increases difference between calculated and actual data of gas turbine performance but with number change of classes to pressure ratio are reduced differences. The continuous model despite of little need to suitable data has a good accuracy, but inside of turbine and particularly cognitive classes does not provide. While the laminate model indicates a more realistic modeling of the turbine, it requires considerable number of suitable data that reduction of data is reduced its accuracy.

Change ability of laminates number in the straticulate mode, its operation does better in variety pressures ratio. First row cooling because considerably temperature losses has a great importance. For this reason as highest cooling technology is applied in this area.

Cooling Film (Tape)

Despite various cooling methods, the best approach is use cooling tape by multiple pitting on cylinder's combustion chamber. The tape to increase heat exchange and creation a tape of cool air, prevent thermal stresses on cylinder and in addition to participate in combustion, resulting in does better combustion in cylinder. This method is the cheapest, most efficient and easiest way to increase the cooling effect in combustion chamber. This had observed that with method, wall temperature of cylinder can be reducing of 640 Kelvin degree to 440. In addition to make angle of the cooling air, lead to fuel and air swirl, better mix of fuel and air in cylinder and result in does better combustion.

Boundary Layer Excitement

To choose the best obstacle with the greatest stimulatory effect to increase heat transfer coefficient can be used optimized methods such as genetic algorithms. Generally, regards to length of blade and the

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stimulation region of every obstacle, barriers can be placed at specific intervals of each other to cooling process in length of turbine blade can be best done.

Shape Effect of Injection Holes on Cooling Layer

According to average cooling efficiency chart for each type of injection holes are plotted in Figure 4, the effect of film cooling in close holes has a maximum value to distance from inertia point and because mixing of injection and main processes is declined.

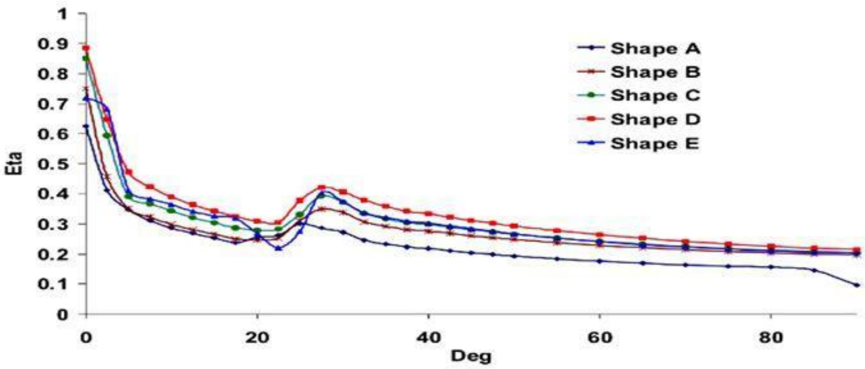

Figure 4: Average cooling efficiency

Average Cooling Efficiency

In this paper, is discussed to two-dimensional analysis of film cooling, through a row of continuous groove at 0, 10, 20, 30, 40 and 50 degrees six angles, and in blowing ratios on the cylindrical model from edge of gas turbine blade. The results show that the most optimal case, is obtained $\theta = 40$ degree injection groove angle. Since the most efficient of layer cooling, (η) gives the result. Also, numerical results of pressure distribution compare with experimental data to low blowing ratio have a better compatibility.

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