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A REVIEW ON HOW TO INCREASE TURBINE BLADE COOLING EFFICIENCY

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Abstract : One of the most significant systems which play a crucial role in power plant for power production is the Turbine. Turbine blade was revolve with the help of high temperature’s steam. The temperature of hot steam was far above the permissible temperature of blade materials. Advanced cooling technologies must be applied to cool the blades, so they can withstand the extreme conditions. Film cooling is mostly used in high temperature and high pressure blades as good cooling effect. In this study, the film cooling cogency in different regions of gas turbine blades was investigated with diversified film hole / slot shapes and mainstream flow situation. The study consisted of four parts: 1) effect of upstream wake on blade surface cooling, 2) effect of upstream vortex on platform purge flow cooling, 3) influence of hole shape and angle on leading edge film cooling and 4) slot film cooling on trailing edge. Pressure sensitive paint (PSP) technique was used to get the conduction-free film cooling effectiveness distribution.

***IndexTerms* - Gas Turbine,,Convection cooling, Impingement cooling, Film cooling, Hole Configuration.**

I. INTRODUCTION

Gas turbines are widely used in power generation equipment and also used in industrial applications. Thermal efficiency and power output of gas turbine increase by increasing turbine rotor speed and it should be increased by steam inlet temperatures. The working temperatures of steam are higher then permissible temperatures of metal material. So cooling technologies must be used to the turbine blade, so they can working on such high temperature of steam conditions. Han et al. [1] shows various cooling techniques that are generally used in various combinations to increase the lifetime of the turbine blades. Various cooling technology like, Impingement cooling, rib tabulated cooling, and pin-fin cooling. These are typically method used to remove heat from the inner walls of the blades. Among of all method, film cooling has been widely accepted as an active cooling method.

In order to overcome the hazard from the severe environment and prevent failure of turbine components, film cooling has been widely accepted as an active cooling method. In a film-cooled component process, relatively cooler air is provided by discrete holes to provide a protective film between the hot main gas and the turbine component to maintain the surface at a lower temperature thereby protecting the surface turbine component. However, excessive use of coolant reduces the gain in the upper inlet temperature because the compressed air consumption and mixing between the hot main stream and the coolant reduces the thermal efficiency of the entire system. Thus, much research has been conducted to understand the physical phenomena related to the film cooling process and to find better configurations that can provide more protection with less coolant.

LITERATURE REVIEW

Among the vast literatures related to the film cooling, majority of the recent work focuses on comparative assessment of two or more film cooling hole configurations. Of the variety of film cooling hole designs, four types of hole geometries are generally considered: cylindrical holes, laterally diffused holes (fan-shaped), forward-scattered holes (peeled off) and Diffused holes laterally and forward (casual fan shape) holes. Figure 1 shows the four types of hole geometries with the cross-sectional view intersecting along the midline of the hole. As a function of the angle (β) of the center line of the projected hole on the surface with respect to the main direction, a cooling hole of the film can be identified as being an axial hole (if $\beta = 0$ °) or a hole at compound angle (if $\beta > 0$ °). Figure 1 also shows conceptually the distribution of film cooling efficiency associated with different hole patterns. In general, the compound angle hole gives better efficiency because the coolant is deflected by the main stream and covers a larger area. The shaped holes work better than the cylindrical holes because the rupture zone of the expanded holes reduces the amount of movement of the jet and decreases its uplift. Cooling the film on a flat plate is often chosen as a basic study. Goldstein et al. showed the advantages of film cooling with shaped holes. They compared the cooling efficiency of the film for straight round holes and axial shaped holes with 10 ° lateral diffusion. The axes of the two hole geometries were inclined at 35 ° to the test surface. They reported a significant increase in the cooling efficiency of the film immediately downstream of the shaped holes as well as an increased displacement of the side coolant. They attributed this effect primarily to the reduction in the average coolant velocity at the exit of the hole, which allowed the jet to stay closer to the surface. Thole et al. did an experiment on flow field measurements using LDV at the output of three different hole geometries.

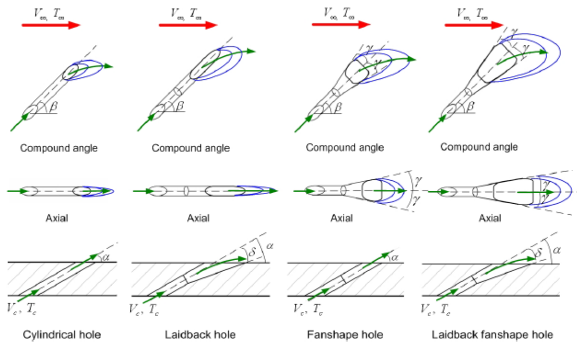

Fig.1 **Film cooling hole configurations**

The geometries of holes consist of a round hole, a type of hole varied, for example with a lateral expansion at the exit, and a hole with an enlarged outlet forwards and laterally. All holes were inclined at 30 ° from the surface. After experimenting, they discovered that the two holes had less mixing between the injection fluid and the main fluid and a greater spread of the coolant with respect to a round hole. It has also been found that the laterally-formed hole has a comparatively lower film efficiency than the laterally-expanded hole due to the greater diffusion of the coolant and subsequent mixing of the main stream. Gritsch et al. studied the same configurations and orientations of cooling holes with a density ratio of 1.85. Film cooling efficiency limited to x / D = 10 to focus in the near field of the cooling hole. For the cylindrical hole, the two expanded holes showed a considerable improvement in thermal protection of the surface downstream of the exit point, mostly at high lifting speeds. In the same vein, Yu et al. experiment on filtering and heat transfer distributions on a flat plate with the help of straight circular hole, a 10° forward scattering hole, and another hole type with an additional 10 ° diffusion .

In each case, the axis of the hole was oriented 30° relative to the mainstream direction. The last mentioned hole provided the highest film cooling performance as well as overall heat transfer reduction.

All previous studies were performed on a flat plate with axially oriented holes. Schmidt et al. examined the cooling performance of the 60 ° composite hole film on a flat surface, with or without a forward expanded profile outlet, and compared it with the cylindrical holes aligned with the main body. The round and shaped outlet holes with a composite angle had significantly higher efficiency with higher moment flow rates. Composite angle holes with enlarged outlets had a much larger lateral distribution of coolant near the hole for all pulse flow ratios. Dittmar et al. in a slight deviation, the measurements made in a model of the suction side of a real turbine guide vane in a wind tunnel. Four different configurations of cooling holes were chosen: a double row of cylindrical holes, a double row of discrete slots, a row of straight fan-shaped holes and a row of composite holes in the corners, for the efficiency of the film Adiabatic cooling study and heat transfer coefficient. The two holes formed exhibited expansion only in the lateral direction. The injection angle in the direction of flow was 45 ° for all cases, with an additional lateral angle of 35 ° with respect to the main direction for the holes in the form of compound. According to his study, the fan-shaped holes provide good efficiency values for moderate and high blowing rates as opposed to cylindrical holes that undergo jet separation. In another study on pressure side and suction side models in a wind tunnel, Chen et al. Axial and composite holes with forward dispersion were studied. The composite angle in his study was 45 °. On the concave surface, there was an improvement in average efficiency laterally due to the addition of a composite angle to a high swelling rate of 2. On the convex surface, a significant improvement in efficiency is observed at high and low blowing speeds

The study of the shape of the holes in the linear cascades is less frequent than that of the flat plate and the profiles of the model. Teng and Han studied a row of film holes near the hole in the suction side. The geometries of the holes considered in his study were the same as those with an angle of inclination slightly greater than 45o. They indicated that the average effectiveness of the arrays of the holes formed could be approximately double that of the cylindrical holes. In addition, the holes of the fans worked better than the holes of the casual fans. More recently, Mhetras et al. observed the excellent refrigerant coverage provided by the composite-shaped orifices near the region of the pressure-side tip.

His study showed that shaped holes in the pressure side of the blade could be used to cool the cut-out area of the floor of the tip cavity.

The effect of a rotating and unstable wake on the cooling efficiency of the film and the temperature profiles of the cooling jet on the suction side of a turbine blade was studied by Teng et al. In a waterfall at low speed. A spoke wheel mechanism was used to generate the furrows upstream. They found that this unstable wake reduces efficiency. It was found that the local heat transfer immediately downstream of the orifices increased up to 60% due to the film injection.

Ou et al. studied Unstable wake conditions simulated using the same mechanism as in a cascade of linear turbine blades with film cooling. They tested cases of not waking up and aroused Strouhal numbers of 0.1 and 0.3. Air and CO2 were used to study the effect of the density ratio. It was found that the increase in the wake step frequency increases the local Nusselt numbers for all blow ratios, but this effect is reduced at higher blow ratios. It was concluded that additional increases in Nusselt number due to wake instability, blowing speed and density ratio were only secondary to the dramatic increases in Nusselt numbers due solely to the injection of film into the shell without movie. They concluded that the heat transfer coefficients increased and that the cooling efficiency values of the film decreased with the increase in unstable wake strength. In addition, Mehendale et al. In the same test facility and under the same experimental conditions, it was found that the increase in the number of strobes for awakening resulted in a decrease in the effectiveness of the film on most of the surface of the blade for injections. With relation of density and for all the proportions of blowing. Du et al. He performed a similar experiment with the addition of refrigerant ejection from the trailing edge of the wake bars. The addition of wake coolant had a relatively small effect on the heat transfer coefficient of the downstream blade, but it reduced the effectiveness of the front edge film below the wake box without refrigerant ejection. Detailed measurements of heat transfer in a dawn of cooled and undamped cooled transonic film and CNV awakenings were performed by Rigby et al. It was found that the cooling behavior of the film on the suction surface had changed considerably when the simulated instantaneous effects of NGV were introduced.

Heidmann et al. studied the effect of the wake step on the cooling performance of the shower head film in an annular cascade with a row of cylindrical rods rotating upwards. A high number of Strouhal in the previous day reduced the efficiency, but also directed the refrigerant towards the pressure side, which resulted in a slightly higher pressure side cooling.
Most of the experimental studies on film cooling focused only on the median region, not taking into account the effect of the wall. Using pressure sensitive paint (PSP) techniques, Mhetras et al. and Narzary and. Alabama. We were able to obtain a detailed distribution of the cooling efficiency of the film on a completely cooled knife surface. Both tests were performed in the same cascade. The flow conditions, the location of the film cooling holes and the internal refrigerant supply cavities were similar for both studies. The two test blades had three rows of cylindrical holes in the shower head at an angle of 30 ° radially in the frontal region. However, the configurations of the holes in the surfaces of the blades were different. These were cylindrical, angular holes composed of Mhetras et al. studying, while the occasional holes in the composite angle fan in Narzary et. Alabama. study. During the film cooling test, the holes on the pressure side and on the suction side were open, as were the holes in the shower. They showed that the suction side refrigerant was discharged substantially in the middle range range due to final leak vortices and final wall vortices. It was shown that the highest efficiency was obtained with M = 0.9 for the cylindrical holes, while the profiled holes did not have the optimal blowing rate from M = 0.3 to M = 1.2. The efficiency continues to increase with increasing blow in the blow speed range studied for the holes formed. A comparison of the two-hole cooling orifice designs shows that the suction side is more efficient with shaped holes. The pressure side efficiency was comparable for two-hole configurations. The upstream wake effect was also simulated by the fixed rods placed periodically upstream of the blade. Depending on the position of the activation bars, the cooling efficiency of the film has degraded to different degrees. In another article by Mhetras and Han, they investigated the effect of the cooling build-up of the film upwards in the downward cooling of the film using the superposition method. Depending on the position of the activation bars, the cooling efficiency of the film has degraded to different degrees. In another article by Mhetras and Han, they investigated the effect of the cooling build-up of the film upwards in the downward cooling of the film using the superposition method. Four rows and two rows of composite angle cylindrical holes were arranged on the pressure surface and the suction surface, respectively. The results showed that the cooling efficiency of the suction film was much greater than the pressure side, although the pressure side had more cooling holes in the film. The superposition of the cooling holes of the individual film showed good agreement with the experimental data.

Figure 3 shows the variation of the spatially averaged heat transfer coefficient with the increase in the momentum flux ratio (I). The ratio of the heat transfer coefficient increases with the increase of I for the round hole (CA = 0) and the round hole (CA = 60). The ratio of heat transfer coefficient is very high for the front expansion hole. This may be due to the increased lateral mixing of the jets with the main stream. However, the ratio decreases with increasing dilation hole in large I. The ratio values for the round hole, CA = 60, increase continuously with increasing I.

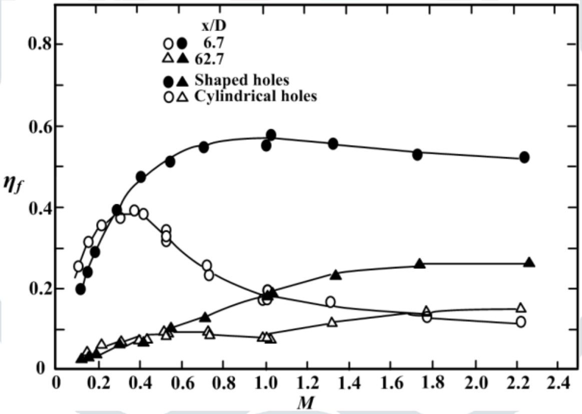

Fig.2 Comparing diffuser hole performance with cylindrical hole

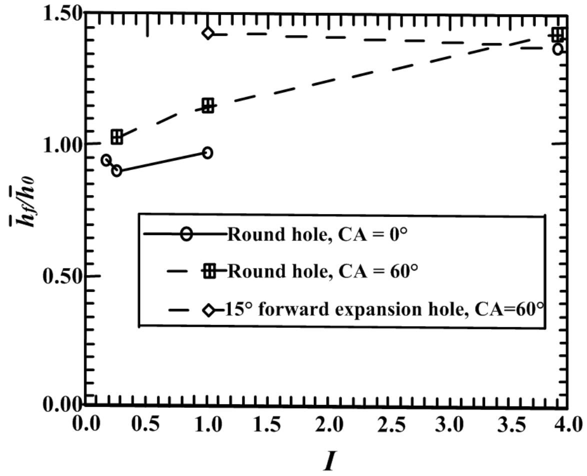

Fig.3 heat transfer coefficient ratios

Figure 4 compared the efficiency of the spatially averaged film for the three geometries in the moment flow relation (I). The results are presented in two hole / hole ratios of 3.0 to 6.0. Again, it is obvious that the geometry of the hole does not produce a significant effect in a low moment flow relation (or blow speed). But with the composite angle hole injection (CA = 60 °), the efficiency of the film improves significantly with higher pulse ratios. With extended forward outlets and CA = 60 °, the efficiency of the film is further improved with higher I values. The effect is reduced for the higher P / D ratio of 6.0. The values of general efficiency are also lower for each case with a higher P / D ratio.

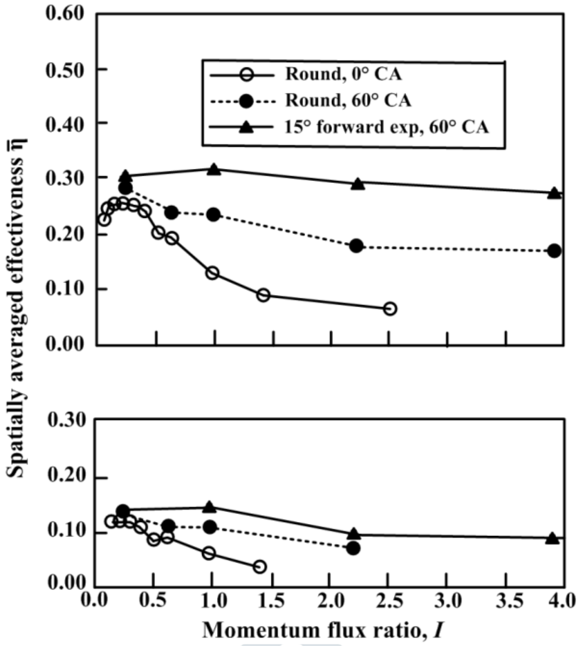

Fig.4 film cooling effectiveness for configurations

EFFECT OF COOLANT DENSITY:

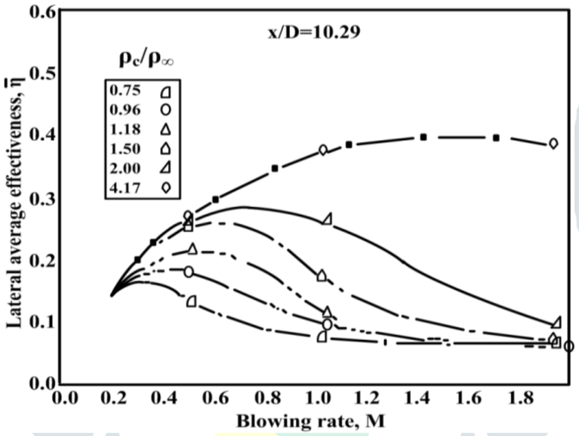

Fig.5 Effect of blowing ratio on laterally averaged film effectiveness for different coolant density ratios

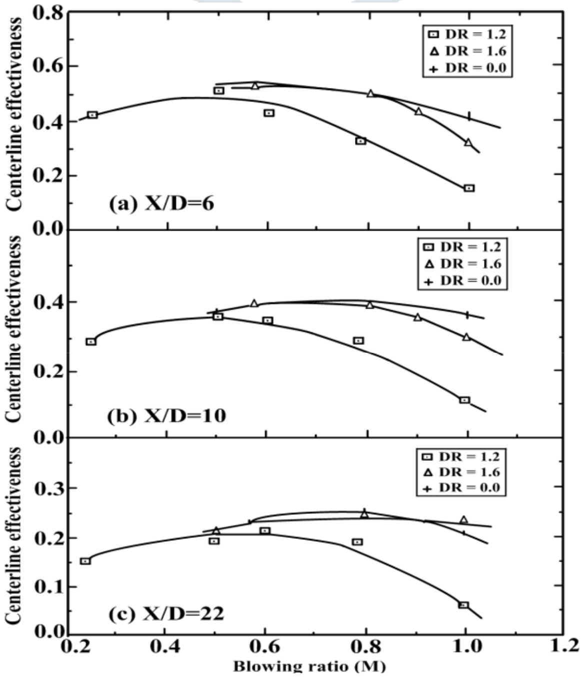

Fig.6 Effect of blowing ratio and density ratio on film effectiveness

(a) $X/D = 6$ (b) $X/D = 10$ (c) $X/D = 22$

SUMMARY:

Film cooling method is widely used in modern high pressure and high pressure blades as an active cooling system. In this study, the cooling efficiency of the film was investigated on various regions of gas turbine blades with various hole / film slot shapes and customary flow conditions. The study consisted of four parts: 1) effect of the wake upstream in the cooling of the film on the surface of the blade, 2) effect of the vortex upstream in the cooling of the purge flow of the platform, 3) influence of the shape and angle of the hole in the cooling of the film of the leading edge and 4) the cooling of the film cut in the trailing edge. The technique of pressure sensitive paint (PSP) was used to obtain the distribution of the cooling efficiency of the film without conduction.

CONCLUSIONS

The efficiency of the film on the slots, the lands and the flanks increases with the increase of the blowing rates. However, the increment is mild from M = 0.5 to M = 1.5.

The thinner lip offers greater efficiency due to small wakes. The effect of lip thickness is most evident in the downstream region of the bottom of the slit where x / s> 4. In this region, vortex excretion enhances the interaction (mixing) between the main fluid and the cooling fluid. The advantage of the thinner lip has also featured on the flanks and lands with increased overall efficiency.

The interaction between the main fluid and the coolant increases with the thinner limit. More coolant is dispersed from the slots to the land. As a result, the thinner thickness of the boundary layer reduces the efficiency on the slots but increases the efficiency on the grounds.

As the height of the side wall decreases in the direction of the current, the lateral expansion of the coolant increases. As a result, efficiency increases on land in the direction of the current.

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