Experimental Analysis of Heat Transfer InGas Turbine Blade

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ABSTRACT

This paper discussed about Heat Transfer rate in gas turbine blade. Theseadvance days we need highly performance machinery. In modern gas turbine when we need high thermal performance then we need to improve high heat transfer rate. Entry pressure and temperature is very high in Gas turbine because of this improve the thermal efficiency and performance of gas engine. Major problem is enhancement of heat in gas turbine blade and this enhancement results in thermal and mechanical stress. This heat increase can be minimize by (i) applying thermal barrier coating on the surface, and (ii) providing coolant to the surface by injecting secondary air. Experiments were performed in blade tip. Film-cooling effectiveness or degree of cooling was assessed in terms of cooling hole geometry, blowing ratio, free stream turbulence, coolant-to-mainstream density ratio, purge flow rate, upstream vortex for blade platform cooling and blowing ratio, and upstream vortex for blade span cooling. The blade tip study was performed in a blow-down flow loop in a transonic flow environment. The degree of cooling was assessed in terms of blowing ratio and tip clearance. Limited heat transfer coefficient measurements were also carried out. Mainstream pressure loss was also measured for blade platform and blade tip film-cooling with the help of pitot-static probes. The pressure sensitive paint and temperature sensitive paint techniques were used for measuring film-cooling effectiveness whereas for heat transfer coefficient measurement, temperature sensitive paint technique was employed.

Keyword:-*Film cooling, Pressure loss, Turbine blade*

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1. INTRODUCTION

Gas turbine working range of 900K to 1500 K. This increase has improved the turbine efficiency, resulting in improved performance and reduced fuel consumption. While some of the increase in temperature has been made possible through the development of new materials, most has occurred because of improvements in cooling technology. The mainstream gas flows over the turbine vanes and blades, the temperature of the gas usually being well above the melting point of the materials from which the airfoils are made.

Due to the pressure difference between the blade pressure and suction side, hot gas leaks through the gap between the blade tip and the shroud. This flow, called leakage flow, creates a thin boundary layer and consequently high heat transfer coefficient on the blade tip. The tip leakage flow is one of the major causes of blade tip failure. To reduce leakage flow and heat transfer on the tip, the modern gas turbines blades possess a recessed cavity on the tip with uniform cavity wall thickness. The cavity wall acts as a labyrinth seal that increases flow resistance and reduces the leakage.

The injected coolant travels through a serpentine passage, absorbs heat from the inner walls as it travels, and finally exits from tiny discrete holes and 2-D slots. The discharged coolant, when adequately supplied, forms a thin layer of relatively cooler air on the surface that keeps the hot mainstream air from coming in direct contact with the airfoil body. Between the vane and the blade row is the rim seal that prevents or limits entry of hot mainstream into the cavity formed between the rotor and stator disks. Any transport of the mainstream gas, through the clearance between the rim seals, will lead to overheating of the disks with a consequent reduction in rotor disk life. As such, cooler air is also injected into the cavities, a part or all of this air is ejected back into the mainstream gas path through the clearance between disk rim seals.

A key objective in turbine design is to accomplish the disk cavity sealing and metal cooling functions using the smallest possible amount of cooling air. This is because the bleed-off of compressor air and its subsequent mixing with the mainstream gas flow exact penalties on turbine performance. Attaining the objective requires sound cooling system design as well as optimization of coolant flow supply based on a comprehensive study of the mainstream and coolant flow parameters that are likely to affect the cooling process.

This work done of film-cooling effectiveness and heat transfer coefficient study on the blade tip. The study of film-cooling effectiveness, heat transfer coefficient, and total pressure loss measurements of a high pressure gas turbine blade tip in transonic flow conditions. The extent of literature available in this area is really vast with majority of the recent work focusing on some form of comparative assessment of two or more hole configurations from among the four mentioned earlier.

The tip surface using an oil dot technique. Investigated heat transfer in a rectangular grooved tip model. They showed that the heat transfer in the upstream end of the cavity was greatly reduced compared to the flat tip, however, at the downstream of the cavity, the heat transfer levels for the grooved tip were higher due to flow reattachment inside the cavity. They also showed that the effect of the shroud velocity on the heat transfer coefficient was very small.

2. LITERATURE REVIEW

Azad et al. [1,2] studied the heat transfer on the first stage blade tip of an aircraft engine turbine (GE-E^3). They presented the effects of tip gap clearance and free-stream turbulence intensity level on the detailed heat transfer coefficient distributions for both plane and squealer tips under engine representative flow conditions.

Azad et al. [3] also studied the effect of squealer geometry arrangement on gas turbine blade tip heat transfer and found that the location of the squealer rim could change the leakage flow and result in different heat loads to the blade tip. They also found that the suction side squealer provided best sealing to leakage flow among all the cases they studied.

Kwak and Han [4, 5] presented heat transfer coefficients on the tip and near tip regions of both plane and squealer tip blades. They showed that the squealer tip could reduce heat transfer coefficients on the tip and near tip regions. Kwak and Han [6] also studied heat transfer and film cooling effectiveness on both plane and squealer tip blades. Their results showed that the film cooling effectiveness on the squealer tip was much higher than that on the plane tip.

Dunn and Haldeman measured time averaged heat flux at a recessed blade tip for a full-scale rotating turbine stage at transonic vane exit conditions. Their results showed that the heat transfer coefficient (Nusselt number) at the mid and rear portion of the cavity floor is on the same order as the blade leading edge value.

Bunker investigated the detailed heat transfer coefficient distribution on the blade tip surface using hue detection based liquid crystal technique. They measured the heat transfer coefficient at three tip gaps and two free-stream turbulence levels with both sharp and rounded edges. Bunker and Bailey studied the effect of squealer cavity depth and oxidation on turbine blade tip heat transfer. They showed that the effect of cavity depth is not uniform over the entire tip cavity surface, but generally, a deeper cavity produced lower heat transfer coefficients. Their results also showed that blade tip heat transfer had low sensitivity to clearance gap magnitude. Rhee studied the local heat/mass transfer on the stationary shroud with blade tip clearances for flat tip geometry. They used the naphthalene sublimation method and concluded that the heat/mass transfer characteristics changed significantly with the gap clearance.

Jin and Goldstein measured local mass transfer on a simulated high pressure turbine blade and near tip surfaces. They showed that the averaged mass transfer rate on the tip surface was much higher than that on the suction and the pressure surface.

Amerialso predicted the effects of tip gap clearance and casing recess on heat transfer and stage efficiency for several squealer blade tip geometries.

Most of the above referenced studies focused on the heat transfer coefficient on the blade tip surface only. The present study applies a hue detection based transient liquid crystals technique to obtain the heat transfer coefficient on the tip surface, shroud, and near tip region of the blade pressure and suction side of the blade with a single or double squealer. This study provides comprehensive information about the heat transfer coefficient on the tip and near the tip regions with the single or double squealer blade tip. The effect of the squealer rim arrangement on the heat transfer coefficient is also presented. The results are compared with the plane tip and the double squealer tip results (Kwak and Han [4,5]).

3. Experimental Procedure

The blow-down facility, shown in could maintain steady flow in the cascade for about 30 seconds. Compressed air stored in tanks entered a high flow pneumatic control valve, which could maintain steady flow by receiving downstream pressure feedback. The control valve could maintain a velocity within (3% of desired value. The cascade consisted of three blades with the center blade acting as the test blade, Fig. 4.2. The adjustment of adjustable sidewalls at the inlet and the exit allowed us to attain the design pressure distribution at the cascade inlet, on the three blades, and at the cascade exit. At the inlet side, the far-side wall (facing the blade suction side) was rotated outwards by few degrees for the mainstream to bleed into a half-passage in order to produce the design flow distribution on the guide and the test blade. Little or no adjustment of the near-side sidewall (facing the blade pressure side) was needed although a small bleed between the leading edge of the guide blade and the end of the sidewall was kept that ensured formation of fresh boundary layer on the guide blade. At the exit, the far-side wall was completely removed to obtain the downstream flow periodicity and the flow level required by the design. The other exit wall more or less followed the trailing edge direction of the guide blade. During the blow-down test, the cascade inlet and exit Mach numbers were 0.29 and 0.75, respectively. Overall pressure ratio (P_t/P) was 1.49 (where P_t is inlet total pressure and P is exit static pressure). Two pitot-tube probes were used-one was stationed 0.5 upstream of the blade leading edge to determine the inlet Mach number and another at 0.5 downstream of the blade trailing edge to determine the exit Mach number. To ensure flow periodicity at the inlet, 19 wall pressure taps (1mm dia., 12.7mm apart) were machined on the top cover of the cascade at a

4. Result and discussion

The film-cooling blade was used for heat transfer coefficient test as well. Near the top of the core body, a recess is made on the inside sidewall where a silicone heater in the shape of the blade tip could sit and heat the tip surface. The heater and its arrangement on the core body is shown in Fig. 4.1. The 0.5mm thick etched foil heater having a watt density of 35W/sq. inch. Covered most of the tip except for the region close to the trailing edge. A copper plate also in the shape of the heater is attached between the heater and the underside of the tip surface for uniform heat distribution

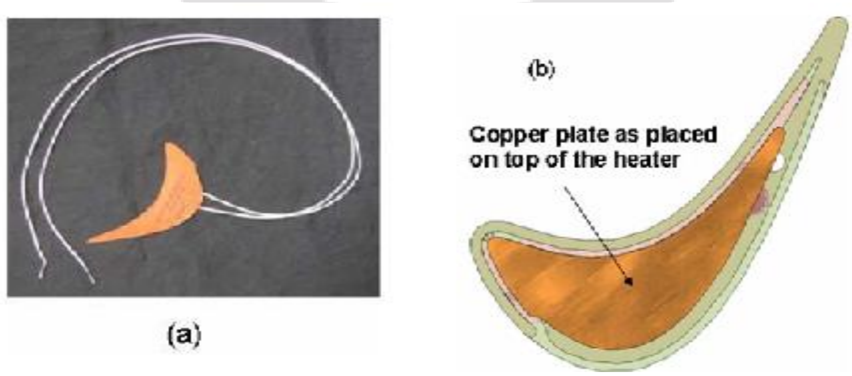

Fig. 4.1 (a) Silicone Heater (b) Copper plate seating on top of the silicone heater

When the tip gap is increased, common sense would suggest that the tip leakage increases thereby producing increased losses. This happens when the tip clearance increases from 1.2mm to 2.2mm but stays more or less the same when it is increased to 3.2mm.

The results of film-cooling effectiveness measurements on the tip surface with coolant delivery from all the cooling holes. Higher the value in the legend, higher is the degree of cooling. Note again that film-cooling study is done for the concept blade tip only.

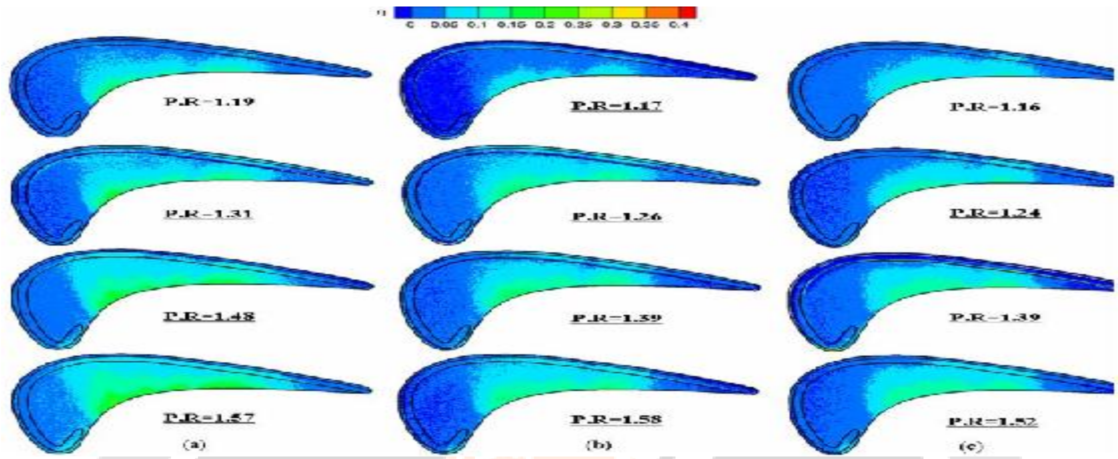

Fig. 4.2 Film-cooling effectiveness on the suction side rail blade tip with only zone I cooling holes open

When coolant is supplied from a common plenum, the coolant exit from the cooling holes is determined by the external mainstream flow around the cooling holes. Thus more coolant exits from tip holes compared to pressure side holes because of higher pressure exerted by the mainstream flow on the latter holes. To eliminate this bias, separate plenums can be constructed for cooling different regions of the blade. For instance, one plenum can supply coolant to leading edge holes, another to pressure side holes, yet another to suction side holes, and so on. In this study, 17 holes on the pressure side and all holes on the leading edge were kept open and rest all holes were sealed off. Thus, in the absence of the other holes, the pressure side holes were fed by a single plenum. This allows us to observe the film-coverage from the pressure side and leading edge holes only. The results are shown in Fig. 4.2. For all the tip clearances, there is an increase in film coverage with pressure ratio. The level of effectiveness is highest at the edge of the pressure side which gradually drops as the coolant is transported down towards the suction side rail. The effect of tip clearance is to decrease the coolant coverage and the level of effectiveness due to increased leakage flow.

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