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Improvement of Gas Turbine Performance Based on Rib Augmented Cooling Systems : A Review

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ABSTRACT

The technology of cooling gas turbine components via internal convective flows of single-phase gases has developed over the years from simple smooth cooling passages to very complex geometries involving many differing surfaces, architectures, and fluid-surface interactions. The fundamental aim of this technology area is to obtain the highest overall cooling effectiveness with the lowest possible penalty on the thermodynamic cycle performance. A number of traditional rib cooling concepts are used in various combinations to adequately cool the turbine blades; these techniques are identified and describe in this paper.

Keywords: Rib Cooling, Hydraulic Diameter, Heat transfer, Friction Factor.

I. INTRODUCTION

Rib turbulators are the most frequently used method to enhance the heat transfer in the internal serpentine cooling passages. The rib turbulence promoters are typically cast on two opposite walls of the cooling passage. Heat that conducts from the pressure and suction surfaces through the blade walls is transferred to the coolant passing internally through the blade. The heat transfer performance of the ribbed channel depends on the channel aspect ratio, the rib configurations, and the Reynolds number of the coolant flow. Many fundamental studies have been conducted to understand the coolant flow through a stationary ribbed channel. The studies show as the coolant passes over a rib oriented 90° to the mainstream flow, the flow near the channel wall separates. Reattachment follows the separation and the boundary layer reattaches to the channel wall; this thinner, reattached boundary layer results in increased heat transfer coefficients in the ribbed channel. This rib induced secondary flow. If the rib turbulators are skewed to the mainstream flow direction, counter-rotating vortices are created. Channel with angled ribs, two counter rotating vortices are formed in the cross-section of the cooling passage. However, if V-shaped rib turbulators are used, four vortices are generated. The additional set of counter-rotating vortices associated with the V-shaped ribs results in more heat transfer enhancement in a channel with V-shaped ribs than angled ribs. The ribs also create turbulent mixing in the areas of flow separation. With this additional mixing, the heat is more effectively dissipated from the wall, and thus additional heat transfer enhancement. Because only the flow near the wall of the cooling channel is disturbed by the ribs, the pressure drop penalty by ribs affordable.

II. RIB SHAPE USED

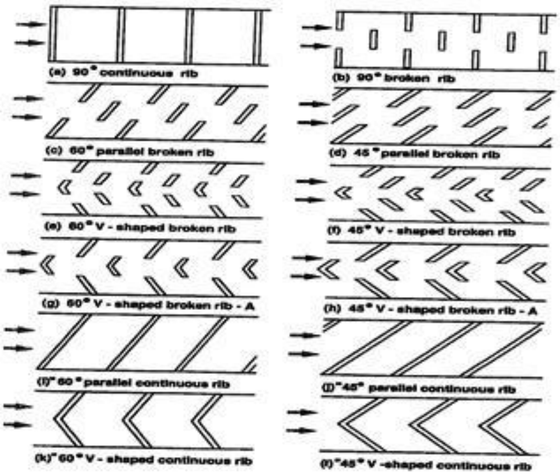

Figure 1. Various Rib Arrangement

Turbulent heat transfer and friction with in line rib turbulators

III. EFFECT OF RIB ORIENTATION

A. Rib angle orientation

The effect of rib angle orientation on the local heat transfer distribution and pressure drop in a square channel with two opposite in line ribbed walls investigated by J C Han for Reynolds no. from 15000 to 90000. The square channel composed of ten isolated copper sections has a length to hydraulic diameter ratio of 20; the rib height to hydraulic diameter ratio is 0.0625; the rib pitch to height ratio equals to 10. Nine rib configuration studied; 90 deg rib,60 to 45 deg parallel ribs,60 to 45 crossed ribs,60 and 45 deg V shape ribs;60 to 45 Λ shape ribs. The result show that the 60 deg (or 45 deg) V shape rib perform better than 60 deg (or 45 deg) parallel rib and, subsequently, better than the 60 deg (or 45 deg) crossed ribs and the 90 deg ribs. The V shape rib produces the highest heat transfer augmentation; while the Λ shaped rib generate the greatest pressure drop. The crossed rib has a lowest heat transfer enhancement and the smallest pressure drop penalty[1].

B. Low Aspect Ratio

Cooling channels, roughened with repeated ribs, are commonly employed as a means of cooling turbine blade. The increased level of mixing induced by these ribs enhances the convective heat transfer in the blade cooling cavities. Many investigations have focused on the heat transfer coefficient on the surfaces between these ribs and only the few studied report the heat transfer coefficient on the rib surfaces themselves. The heat transfer coefficient on the surfaces of round-corner, low-aspect-ratio (ARrib=0.667) ribs. Twelve rib geometries, compromising 3 rib height-to-channel hydraulic diameters (blockage ratio) of 0.133, 0.167 and 0.25 as well as three rib spacing's (pitch to height ratios) of 5,8.5,10 were investigated for two distinct thermal boundary condition of heated and unheated channel walls. Rib have highest blockage ratio shows high heat transfer rate[2,4].

C. Discrete rib turbulators

Experiments study the turbulent heat transfer and friction for fully developed flow of air in square channel with discrete rib turbulators. The discrete ribs are staggered on two opposite walls of the channel in alternate rows 2 and 3 ribs. nine ribs configuration are examined; transverse ribs with an angle of attack (α) of 90 deg, discrete ribs with α= 90 deg, parallel arrays of discrete ribs with α= 45 deg and -45 deg on alternate rows, and parallel and crossed array of discrete ribs with α= 60, 45 and 30 deg. the rib height to hydraulic diameter ratio and the rib pitch to height ratio are 0.0625 and 10, respectively. The Reynolds ranges from 10000 to 80000. Result shows that the average Stanton no in the 90 degree discrete rib case is about 10 to 15 % higher than that in the 90 deg transverse rib case. Turning the discrete ribs on the opposite walls 60, 45 or 30 degree in the same direction with respect to the mean flow increases the average Stanton no 10 to 20 % over that in the 90 deg discrete rib case. parallel oblique discrete ribs with α = 60,45 and 30 deg have comparable performances and have higher overall heat transfer per unit pumping power than 90 deg discrete ribs. Crossed oblique discrete ribs perform poorly compared with 90 deg discrete ribs and are not recommended[3].

D. Angle of attack

An investigation of rib-roughened surface was undertaken to determine the effects of rib shape, angle of attack and pitch to height ratio friction factor and heat transfer results. Parallel plate geometry was used. Based on law of wall similarity and the application of the heat-momentum analogy developed by Dipprey and Sabersky, a general correlation of friction factor and heat transfer was developed to account for rib shape, spacing and angle of attack. Ribs at a 45^0 angle of attack were found to have superior heat transfer performance at a given friction power when compare to ribs at a 90^0 angle of attack or when compared sand-grain roughness.

The effect of the broken rib orientation on the local heat transfer distributions and pressure drop in a square channel with two opposite in-line ribbed walls is investigated for Reynolds nos. from 15000 to 90000. The rib height-to-hydraulic diameter ratio is 0.0625 and the rib pitch-to-height ratio equals to 10. The results show that the 60 deg parallel broken rib or 60 deg v-shaped rib provides a higher heat transfer augmentation than the 45 deg parallel broken rib or 45 deg v-shaped broken rib and subsequently, higher than the 90 deg broken rib. The parallel ‘broken rib’ or v-shaped ‘broken rib’ has 2.5-4 times heat transfer augmentation compared with the previous parallel ‘continuous rib’ or v-shaped ‘continuous rib’ with 2-3 times heat transfer augmentation for the same amount of 7-8 times pressure drop penalty[6,7].

IV. CONCLUSION

As cooling of turbine, increase efficiency of gas turbine. Number of cooling method available for gas turbine. Rib cooling mostly used in middle portion of gas turbine. Result shows that 45º and 60º degree V shape rib give high heat transfer rate. For parallel oblique discrete ribs with α = 60,45 and 30 deg have comparable performances and have higher overall heat transfer per unit pumping power than 90 deg discrete ribs. . Ribs at a 45^0 angle of attack were found to have superior heat transfer performance at a given friction power when compare to ribs at a 90^0 angle of attack.

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