THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
345 E. 47 St., New York, N.Y. 10017

92-GT-76

Hot Streaks and Phantom Cooling in a Turbine Rotor Passage Part 2—Combined Effects and Analytical Modelling

RICHARD J. RDBACK and ROBERT P. DRING

United Technologies Research Center
East Hartford, CT 06108

ABSTRACT

This paper presents experimental documentation and analytical correlations demonstrating the effects of hot streak accumulation and phantom cooling on turbine rotor airfoil surface temperature. In particular, results are shown which quantify the impact of (1) a non-uniform temperature profile at the entrance of a turbine due to combustor-generated hot and cold streaks, and (2) cooling air discharged from the trailing edge of the upstream stator.

In Part 1 of this paper, experimental results are shown for a range of controlling variables to identify where streak accumulation and phantom cooling were most likely to be strongest. These variables include streak-to-free stream density ratio, streak injection location and coolant-to-free stream density and velocity ratios.

In Part 2 of this paper, experimental results are shown for the combined effects of hot streak and stator coolant on the adiabatic recovery temperature on the rotor. An analytical model is also developed to correlate the experimental results documented in Parts 1 and 2 of the paper.

NOMENCLATURE

Symbols

AR	Aspect ratio
Bx	Airfoil axial chord
C	Absolute flow speed
Cx/U	Flow coefficient
P	Pressure
Q	Dynamic pressure
S*	Scaled airfoil surface distance
U	Wheel speed at midspan
V	Fluid velocity
α	Absolute flow angle (from tangential)
β	Relative flow angle (from tangential)
ϕ	Flow coefficient, Cx/U
ρ	Density

Subscripts

C or c	Coolant, cold
F or f	Freestream
J or j	Jet
rel	Relative frame of reference
tot or t	Total
x	Axial distance

INTRODUCTION

An efficient turbine airfoil cooling scheme necessitates a delicate balance of aerodynamics and thermodynamics. External aerodynamics dictates the character of the inviscid velocity distribution on the airfoil surface. The surface boundary layer governs the heat load that the airfoil cooling scheme must absorb. The heat load is also influenced by at least two additional factors: (1) a non-uniform temperature profile at the entrance of a turbine due to combustor-generated hot and cold streaks, and (2) cooling air discharged from the trailing edge of an upstream airfoil.

Hot and cold streaks are rectified as they pass through the rotor of a turbine and accumulate at various locations on the rotor airfoil and endwall surfaces. As a result, airfoils rarely burnout "on average" but burn out locally. Therefore, the designer's goal is to devise an airfoil cooling scheme which produces not only the desired average temperature but also an acceptably uniform temperature: i.e. controlling the temperature gradient.

Since the adiabatic recovery temperature of the flow is the driving potential for the heat load, it would be of value to the

Presented at the International Gas Turbine and Aeroengine Congress and Exposition
Cologne, Germany June 1-4, 1992
This paper has been accepted for publication in the Transactions of the ASME
Discussion of it will be accepted at ASME Headquarters until September 30, 1992

designer to be able to predict the impact of the migration and accumulation of hot and cold streaks and coolant flow from an upstream row on the adiabatic temperature recovery. In Part I of this paper, (Roback and Dring, 1992), experimental results were documented for a variety of controlling parameters to identify where the separate effects of streak accumulation and coolant flow were strongest. In Part 2 of this paper, experimental results are presented for the combined effects of hot streak and stator coolant on the simulated adiabatic recovery temperature on the rotor.

The experimental data which are presented in this paper provide considerable insight into the various mechanisms that drive the accumulation process. These data are of value in the form presented for the assessment of viscous and inviscid computational simulations of the flow. However, to be of direct value to the turbine design community, they must be generalized into some analytical framework that can be used to estimate the impact of these mechanisms on the heat load of specific turbine rotor airfoils. A simple physical argument was developed into a correlating parameter which gives good correlation for both the hot and cold streak accumulation as well as for the accumulation of stator coolant.

DESCRIPTION OF THE EXPERIMENT

The facility, equipment and the trace gas technique that was used in the experimental portion of this study were described in detail in Part I of this paper and will not be repeated here.

TEST CONDITIONS

A series of tests were conducted to determine the combined effects as a hot streak passing through the rotor while coolant was being injected from the trailing edge of the upstream stator. The question to be answered was whether the various accumulation effects observed independently for the hot streak and stator coolant in Part 1 of this paper were additive. For these tests, a coolant-to-free stream density ratio of 1.5 and a coolant-to free stream velocity ratio of 0.57 were chosen. These ratios result in an average trace gas concentration entering the rotor which is about the same as that of the hot streak. If there had been a large difference between the two, the larger one would have dominated the experiment and obscured the effects of the smaller one.

EXPERIMENTAL RESULTS

Data Presentation Format

The trace gas distributions measured on the airfoil are presented as contour maps of equal concentration. However, the shape of the rotor airfoil surface, unwrapped and flattened on a plane, is complex. To alleviate the complexities involved with generating contours in this form, a special coordinate system was developed to project the complex airfoil surface shape onto rectangles with the same span/arc-length ratio. This coordinate system uniquely identifies a position, S*, on the rotor airfoil surface (1) radially in terms of percent span, and (2) chordwise in terms of percent distance along the respective (pressure or suction) surface. It was decided to non-dimensionalize all lengths by the span, thus not only making grid increments equal for both the pressure and suction portions of the horizontal and vertical scales but also making the horizontal scale equal to the vertical scale. The rationale for this data presentation format is discussed more completely in Part I of this paper.

Combined Fullspan Measurements

Four experiments where the hot streak was introduced at 25%, 50%, and 75% span at mid pitch and at 50% span at the "on stator" location were repeated with coolant flow discharging from the trailing edge of the first stator. Care was taken to achieve essentially the same flow conditions as were used in the separate hot streak and stator coolant tests. The results for these combined tests are shown in the bottom panel of Figs. 1 through 4. The results of each separate hot streak test are repeated in the top panel of the figures while the results of the separate coolant test are repeated in the center panel of each figure.

For ease of interpretation and because the data for the separate tests were normalized by two different reference concentrations, the combined data were presented in terms of measured surface concentration, ppm above ambient (as opposed to normalized concentration). In this way the separate results could be compared with the combined result by simply adding them. For all four cases it can be seen that both qualitatively and quantitatively, the combined result was very closely approximated by the sum of the two separate results.

To further demonstrate this additivity of results, a comparison was developed in Fig. 5 for the cases with the streak located at 25%, 50%, and 75% span and at mid pitch. The distributions in the left hand column are the measured combined results. Those in the right hand column were determined by adding the separate measurements for the streaks and the stator coolant. Clearly there is a strong correspondence between the measured results with the combined flows and those obtained by adding the results of the two flows operating separately.

An important conclusion can be drawn by comparing the results shown in the upper and center panels of Figs. 1 through 4. Coolant flow from the stator trailing edge will not neutralize hot streak accumulation on the rotor surfaces. Coolant flow under typical turbine operating conditions will not reach the pressure surface where hot streak accumulation is strongest. Under the same conditions, hot streaks will not reach the suction surface where coolant accumulation is strongest. In addition, the combined results indicate that when there is both a hot streak and stator coolant, the difference between the adiabatic recovery temperatures on the suction and pressure surfaces will be the sum of those that occur when the two flows are operating separately.

This additivity effect for combined flows is also observed on the rotor hub endwall shown in Fig. 6. The measured results obtained on the endwall for the combined streak/coolant condition are compared with the added results for separate streak and coolant flows. As shown, the added result at the right side of the figure very closely approximates the result of the combined experiment shown to the left.

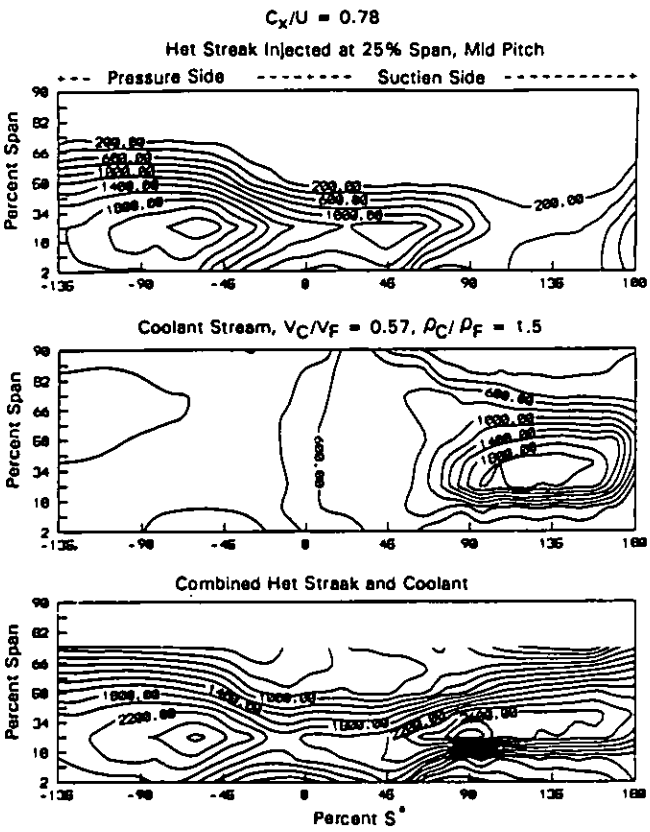

Figure 1. Full Span Trace Gas Concentration for Hot Streak Injected at 25% Span and Mid Pitch.

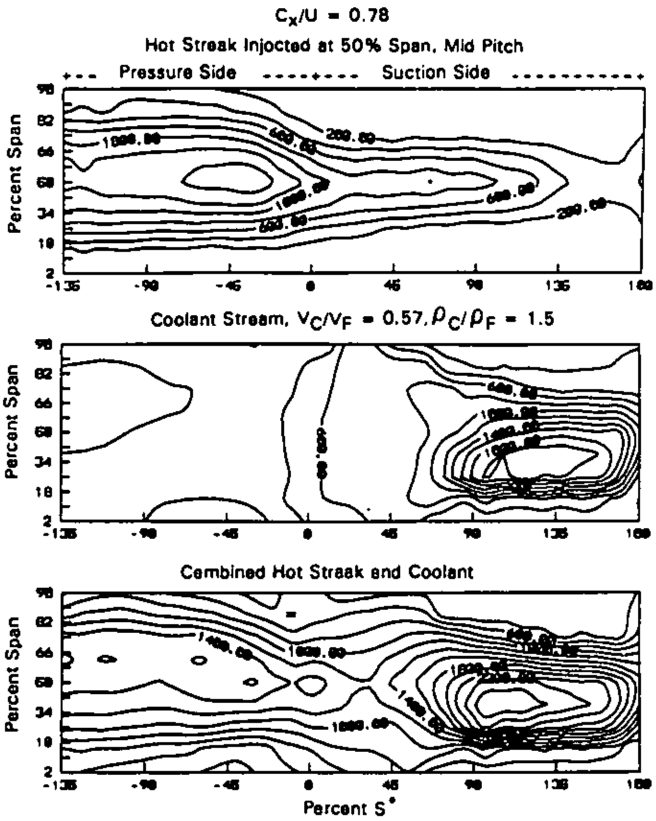

Figure 2. Full Span Trace Gas Concentration for Hot Streak Injected at 50% Span and Mid Pitch.

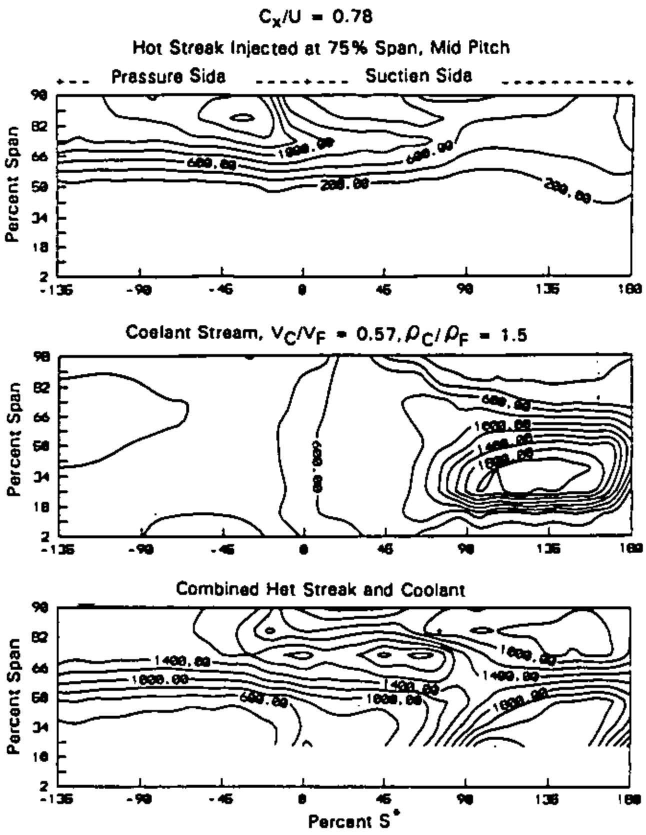

Figure 3. Full Span Trace Gas Concentration for Hot Streak Injected at 75% Span and Mid Pitch.

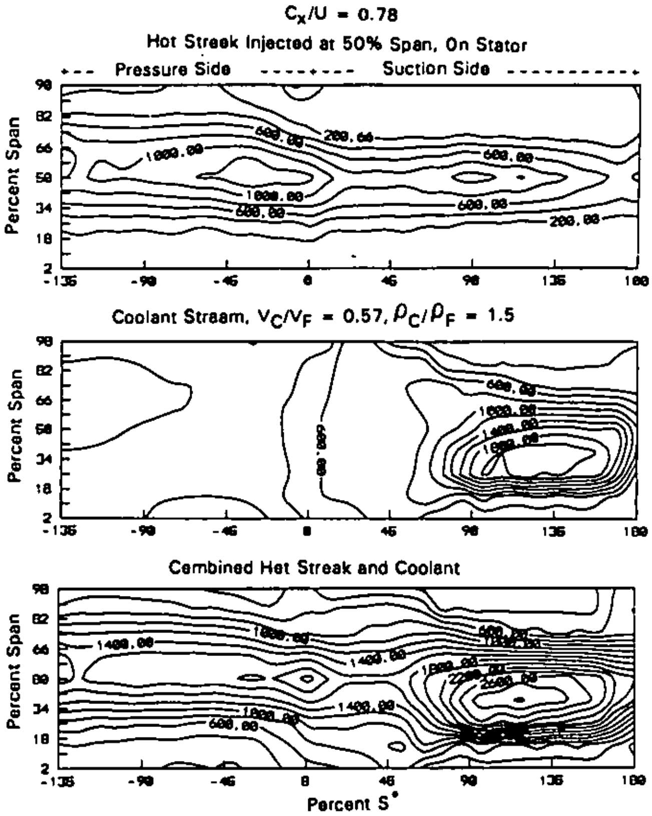

Figure 4. Full Span Trace Gas Concentration for Hot Streak Injected at 50% Span and On Stator.

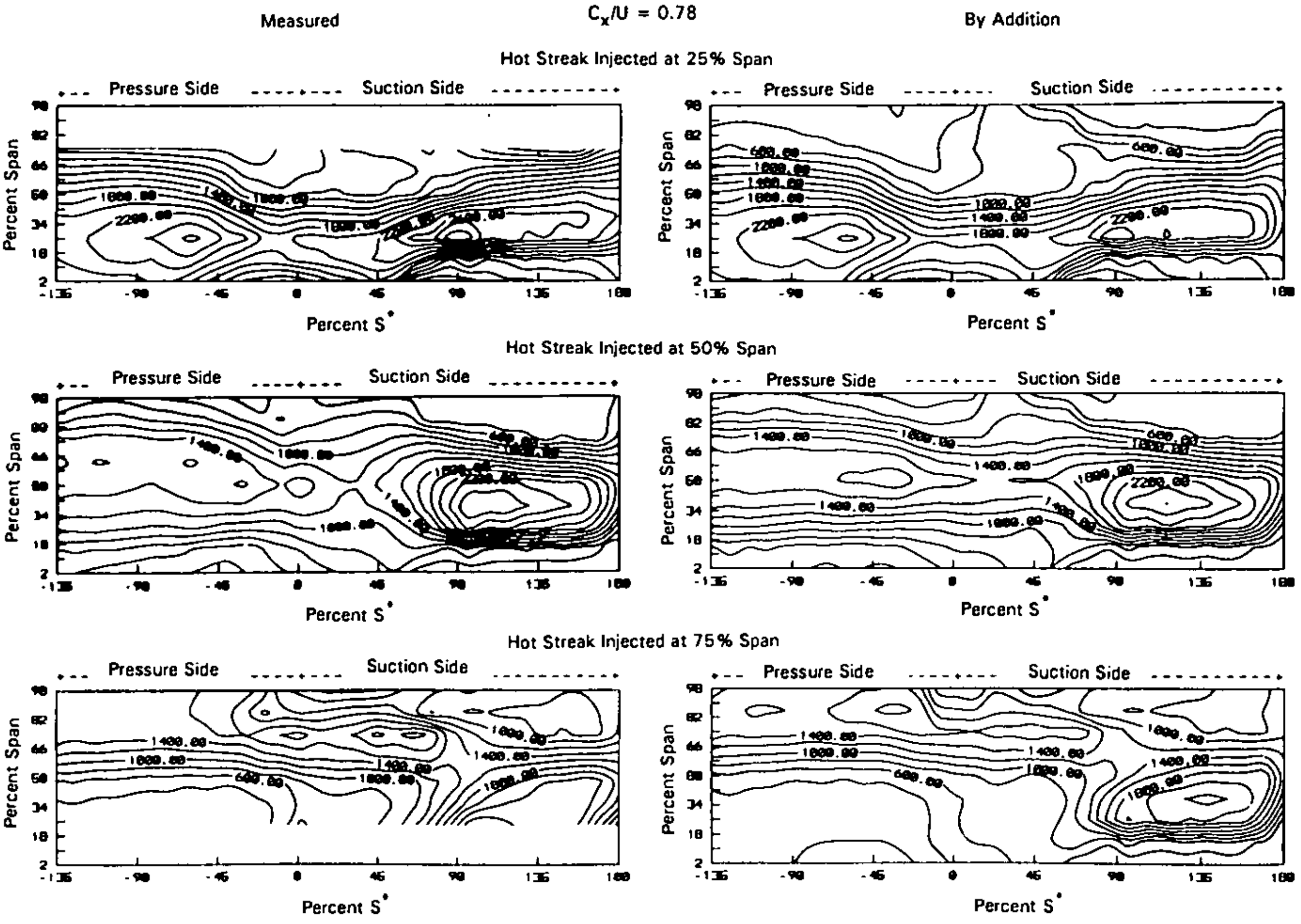

Figure 5. Additive Effect of Hot Streak and Stator Coolant.

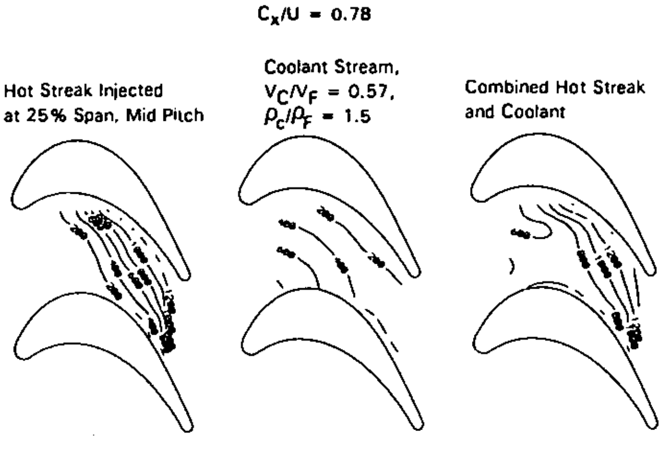

Figure 6. Hub Endwall Trace Gas Concentration Profile, Combined Hot Streak/Stator Coolant.

ANALYTICAL MODELING

The streak and stator coolant accumulation data that have been presented and discussed in both parts of this paper have provided considerable insight into the various mechanisms that drive the accumulation process. These data are of value in the form presented for the assessment of viscous and inviscid computational simulations of the flow. However, to be of direct value to the turbine design community, they must be generalized into some analytical framework that can be used to estimate the impact of these mechanisms on the heat load of specific turbine rotor airfoils. Such an analytical model is presented in the following paragraphs. As will be seen, a simple physical argument leads to a parameter which gives a surprisingly good correlation for both hot and cold streak accumulation as well as for the accumulation of stator coolant.

The nature of the flow incident on the rotor was modeled by assuming that it is composed of two streams of fluid with different properties: a "jet" of hot or cold fluid and the free stream fluid around it. The jet can correspond to either a hot or cold streak, or to stator coolant. It was assumed that in the axial gap between the stator and the rotor, both the jet and the free stream fluid were at the same static pressure and that they had the same flow direction in the absolute frame of reference (Munk and Prim, 1947).

Since the cause of most secondary flows is a gradient in total pressure, the difference between the jet and the free stream

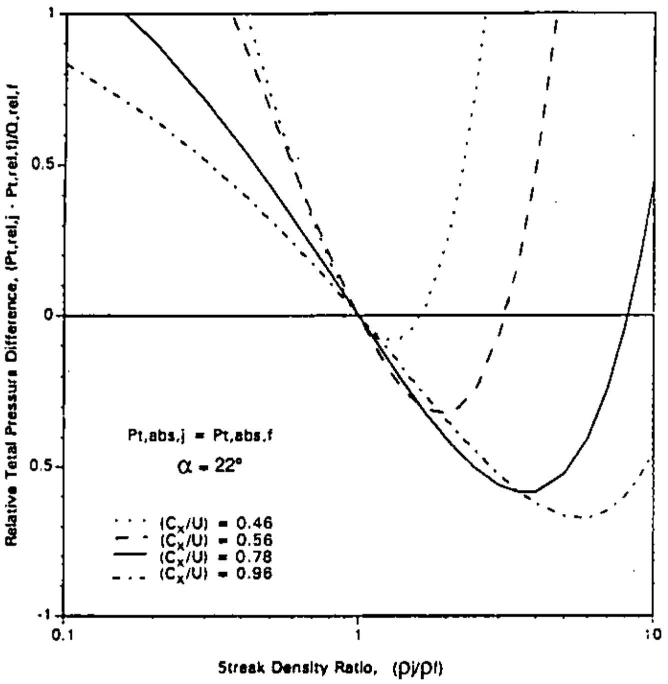

Figure 7. Jet-to-Free Stream Relative Total Pressure Difference, Effect of Streak Density Ratio.

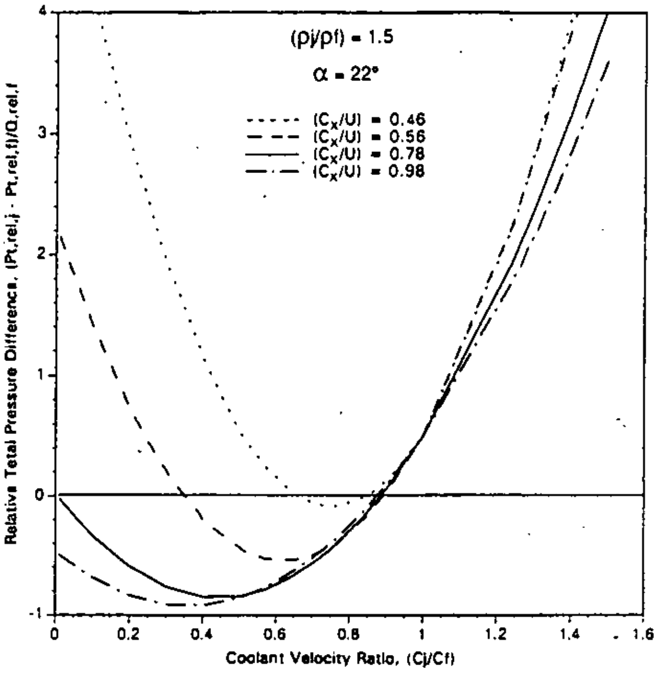

Figure 8. Jet-to Free Stream Relative Total Pressure Difference, Effect of Coolant Velocity Ratio.

relative total pressures might be indicative of the strength of the flow that produces jet accumulation. Therefore, the following expression was derived for the difference between the relative total pressures of the jet and the free stream, normalized by the relative dynamic pressure of the free stream.

$$\left(\frac{Pt,rel,j\ -\ Pt,rel,f}{Q,rel,f}\right) = \left(\frac{\rho_j}{\rho_f}\right)\left(\frac{1-2\Phi_f \mathrm{Cot}\alpha\left(\frac{C_j}{C_f}\right)+\Phi_f^2\left(1+\mathrm{Cot}^2\alpha\right)\left(\frac{C_j^2}{C_f^2}\right)}{1\ -\ 2\Phi_f \mathrm{Cot}\alpha\ +\ \Phi_f^2(1+\mathrm{Cot}^2\alpha)}\right) - 1$$

Since radial variations were not accounted for in the analysis, correlations with measurements were limited to the data taken at midspan.

This expression was applied to both hot and cold streak accumulation and to the accumulation of stator coolant on the rotor airfoil at midspan. For the case of hot and cold streaks it was assumed that the absolute total pressure of the streak was equal to that of the free stream. This assumption is reasonable because the source of the hot or cold streaks is the combustor where the Mach number is typically very low. Under this assumption, Equation (1) was used to calculate the difference between the streak and free stream relative total pressures as a function of jet-to-free stream density ratio and flow coefficient. For the calculations, a stator exit flow angle, α = 22° (from tangential) was used which is the design angle for the turbine model used in the experiments. The results of the relative total pressure difference calculations for streaks is shown in Fig. 7. A wide range of density ratios (0.1 to 10.) was used to generate the results shown in Fig. 7. However, values of density ratio used in the experiments ranged from only 0.5 to 1.5 which is felt to be typical of the density ratio range one might expect from combustor-generated hot streaks and from combustor dilution jets in a gas turbine.

Relative total pressure differences were also calculated for the stator coolant case. Results of these calculations are shown in Fig. 8 for the same four values of flow coefficient and a range of coolant-to-free stream velocity ratios. For these calculations, the jet-to-free stream density ratio was assumed to be 1.5. This value was used in the experiments; however, it is somewhat low compared to typical design values of 1.7 to 2.0. The jet-to-free stream velocity ratios used in most of the experiments were 0.57, 0.91, and 1.25. Typical design values are in the range from 0.4 to 0.7. The highest value in the experiment was chosen to get sufficient range to clearly define the trends in the measured results.

Before discussing several general observations which can be made from the results shown in Figs. 7 and 8, it should be noted that a positive jet–to free stream relative total pressure difference will tend to cause the jet to accumulate on the rotor pressure surface while a negative difference will tend to cause it to accumulate on the suction surface.

The first observation that can be made from the results shown in Figs. 7 and 8 is there is no limit to accumulation on the pressure surface but accumulation is limited on the suction surface. For very large values of flow coefficient, the minimum pressure difference approaches a value of −1. Thus, while there is no limit to the intensity with which a jet can impinge on the pressure surface, there is a limit to the intensity with which it can impinge on the suction surface.

A second observation from Fig. 7 is that for a given flow coefficient, hot streaks (density ratio < 1.0) will accumulate on the pressure surface. Cold streaks with density ratios not too far above 1. will accumulate on the suction surface. These trends were observed experimentally in Part 1 of this paper.

The results shown in Fig. 8 are consistent with the stator coolant results obtained experimentally as shown in Part 1 of this paper. At a velocity ratio of 0.57, the relative total pressure difference is negative and accumulation occurs on the suction surface. At the velocity ratio of 0.91, the relative total pressure difference is close to zero and accumulation should be weak on both the suction and pressure surfaces. For the highest velocity ratio considered in the experiment (1.25), strong accumulation occurs on the pressure surface and the relative total pressure difference is large.

The consistency between the experimental results and the analytical model suggested that a correlation of accumulation with relative total pressure difference may be possible. The experimental results were compared to the analytical model by plotting the normalized midspan surface-averaged trace gas concentration against the dimensionless relative total pressure difference. These comparisons include data taken: (1) at axial gaps of 15% and 30% Bx, (2) for three streak-to-free stream density ratios (0.5, 1.0 and 1.5), (3) for both of the jet-to-free stream density ratios used in the stator coolant tests (1.1 and 1.5) and (4) for several rotor incidences. In each case a least-squares fit was included with the data.

The results for hot and cold streaks are shown in Figs. 9 and 10 for the pressure and suction surfaces. The results for the stator coolant tests are shown in Figs. 11 and 12. The hot and cold streak data had been normalized with the maximum concentration measured on the rake mounted on the rotor hub at the airfoil leading edge plane. The stator coolant data had been normalized with the span-average of the rotor leading edge rake measurements.

The pressure surface data for the hot and cold streaks (Fig. 9) showed a very strong correlation with the results of Eq. 1, while the suction surface data (Fig. 10) showed little or no correlation and greater scatter. The relative degree of correlation is consistent with the relative strengths of the pressure and suction surface accumulation processes. Part of the variation in the suction surface data was probably due to the strong secondary flows on this relatively low aspect ratio airfoil (AR ≈ 0.95). With a higher aspect ratio there might be less variation and stronger accumulation. However, it is unlikely that a higher rotor aspect ratio would change the weak dependence of the accumulation on the jet-to-free stream relative total pressure difference.

A neutral condition exists when the difference between the streak and free stream relative total pressures is equal to zero. Therefore, no accumulation should occur and the surface average should be unity. However, as shown in Figs. 9 and 10, the correlated surface averages on both surfaces are 0.73. Molecular and turbulent mixing bring low concentration flow into the midspan region while radial transport is moving higher concentration material out. The net result is concentrations less than one.

Results similar to those which were obtained for streaks were obtained for the stator coolant data. The pressure surface data

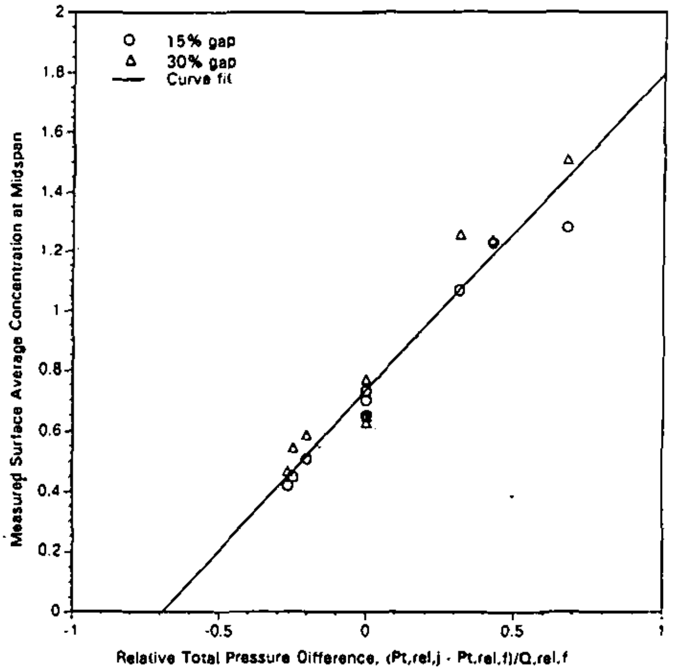

Figure 9. Correlation for Hot and Cold Streaks on the Rotor Pressure Surface.

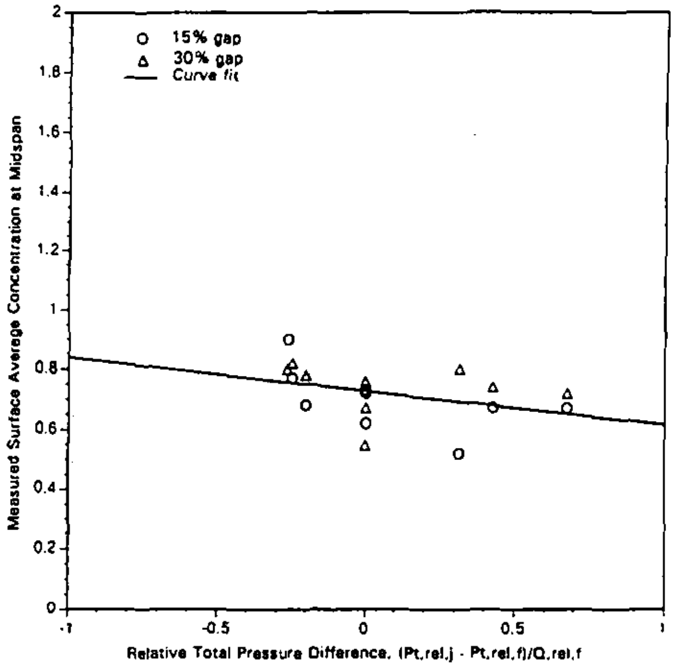

Figure 10. Correlation for Hot and Cold Streaks on the Rotor Suction Surface.

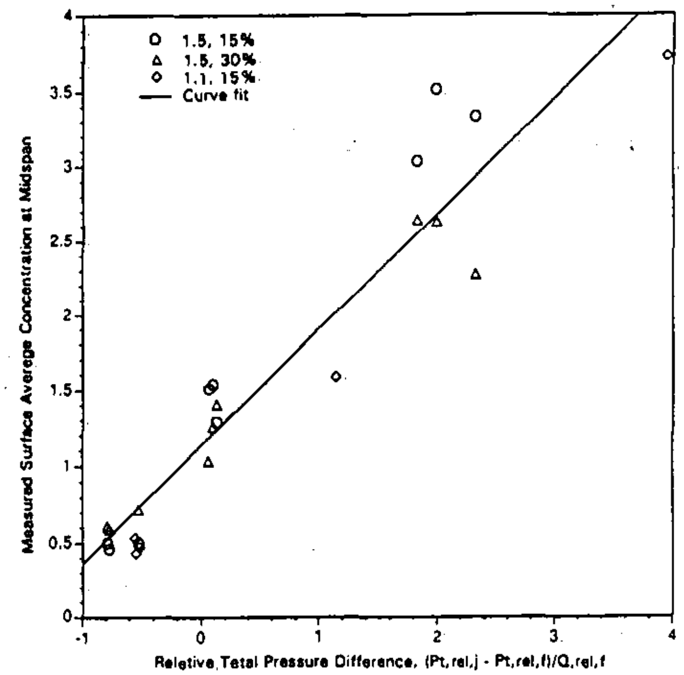

Figure 11. Correlation for Stator Coolant on the Rotor Pressure Surface.

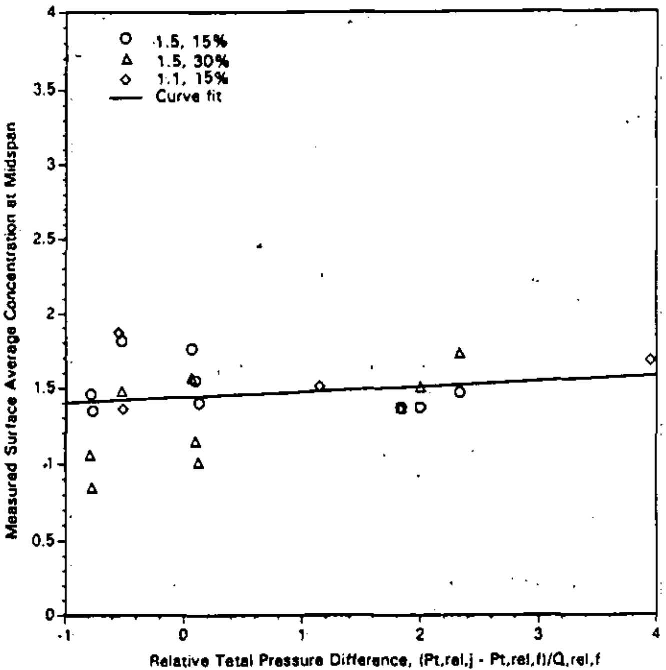

Figure 12. Correlation for Stator Coolant on the Rotor Suction Surface.

(Fig. 11) showed a very strong correlation, while the suction surface data (Fig. 12) showed little or no correlation. When the difference between the jet and free stream relative total pressures is zero, the correlation gives a surface average on the pressure surface of 1.15 and a value of 1.45 on the suction surface. The high value on the suction surface is probably due to the hub and tip secondary flows which tend to constrict the coolant flow to the midspan region.

Gas Turbine Applications

The analytical model can be applied to determine the effect of hot and cold streaks on the average heat load on gas turbine airfoils. For example, assume that the average exit temperature of a typical gas turbine combustor is 3000 F. If a defective fuel nozzle caused a stoichiometric streak at 4100 F, then its jet-to-free stream density ratio would be 0.76. If there was also a 1100 F dilution jet in the combustor which was not mixing out, it would have a jet-to-free stream density ratio of density ratio of 2.2. Also assume that these jets were at midspan, the turbine flow coefficient was 0.78, and the stator exit flow angle was 22°; i.e., the value for the turbine model used in the experimental program.

From Fig. 7, the jet-to-free stream relative total pressure differences for the hot and cold jets would be 0.17 and -0.45. The pressure surface correlation in Fig. 9 indicates that these correspond to surface average ratios of 0.91 and 0.25. The correlation also indicates that when the jet and free stream relative total pressures are equal, the surface average ratio for the jet is 0.73. A measure of accumulation or temperature rise is the ratio of the surface average of the hot or cold jet to the surface average for a neutral jet; i.e., a streak density ratio of one. Therefore, the hot streak ratio is (0.91/0.73) or 1.25 and the cold streak ratio is (0.25/0.73) or 0.34. Thus, for every degree that the hot streak increases the average rotor inlet relative total temperature, it will increase the pressure surface average gas temperature by 1.25 F. Similarly, for every degree that the cold streak reduces the rotor inlet relative total temperature, it will reduce the pressure surface average gas temperature by 0.34 F.

If the hot streak made up 10% of the mass flow, it would represent an increase in the absolute total temperature above the 3000 F average of (4100-3000)x0.10, or 110 F. Similarly, if the cold streak made up 5.8% of the mass flow, it would represent a decrease in the absolute total temperature of (3000-1100)x0.058, or 110 F below the average. At these mass flows the streaks offset each other for an average inlet temperature of 3000 F.

Assume that the relative total temperature would be affected by the streaks in the same way as they affected the absolute total temperature. Using the results of the correlation above, the + 110 F contribution to the total temperature due to the hot streak will increase the average rotor pressure surface gas temperature by (110x1.25) or 138 F. Similarly, the cold streak will decrease the average rotor pressure surface gas temperature by 37 F. The hot and cold streaks together will cause an increase of (138 - 37) or 101 F above the average pressure surface temperature that would have occurred with a uniform inlet temperature (no streaks).

The model can be used in a similar way to determine the impact of stator coolant on the average rotor surface temperature. Assume for example, that a stator had trailing edge discharge cooling air with a density 1.5 times that of the hot free stream fluid, and that the velocity of the coolant was half that of the free stream. Also, as above, assume that the turbine flow coefficient was 0.78, and that the stator exit flow angle was 22°. From Fig. 8, the jet-to-free stream relative total pressure difference for the stator coolant jet would be -0.84. Using this value in the pressure surface correlation shown in Fig. 11 gives a surface average ratio of 0.50. When the difference between the jet and free stream relative total pressures is zero, the correlation gives a surface average ratio of 1.15. Thus, for every degree that the stator trailing edge coolant reduces the average rotor inlet relative total temperature, it will reduce the pressure surface gas temperature by 0.50/1.15 or 0.43 degrees.

For the heat load calculation, also assume that (1) the gas path flow entering the turbine was 80% of the gas generator flow and that its temperature was 3200 F, (2) 10% of the gas generator flow was used for first stator cooling with 2% being discharged from the stator trailing edge, and (3) the cooling air entered the stator at 1100 F. These assumptions lead to an average stator exit gas temperature of 2967 F, which corresponds to a dilution of 233 F with 47 F due to the stator trailing edge coolant. These dilutions in absolute total temperature correspond roughly to the dilution in relative total temperature. While the average dilution due to the stator trailing edge cooling is 47 F, this dilution will reduce the pressure surface gas temperature by only (0.43 x 47), or 20 F. Thus, the average pressure surface gas temperature would be 27 F higher than would be expected in the absence of accumulation. The remaining 8% of stator cooling air would cause this difference to be larger. If all 10% of the stator cooling air had been discharged from the stator trailing edge, the average pressure surface gas temperature would have been 135 F higher than would be expected in the absence of accumulation.

From the suction surface correlations presented in Figs. 10 and 12 it can be seen that the suction surface average ratios are not very sensitive to the relative total pressure differences. Therefore, for both the hot and cold streak and the stator coolant examples cited above, the impact on the average suction surface temperature would be small.

Liquid Rocket Turbopump-Drive Turbine Applications

The large density differences in the gases flowing through the drive turbine in a liquid rocket turbopump can cause significant hot and cold streak accumulation and heat loading on the turbine rotor surfaces. The impact of this accumulation on rotor heat transfer can also be estimated by applying the correlations. Assume that the turbopump is driven by the high pressure combustion products of liquid hydrogen/liquid oxygen with the following mixture of flows entering the turbine: (1) 3% makes up a hot streak of stoichiometric combustion products (water) at ≈6000 R; (2) 7.2% of the flow is a cold streak (hydrogen) at the hydrogen inlet temperature of ≈ 200 R and (3) the remainder of the flow is a hydrogen-rich mixture (molecular weight = 4.2) at an average temperature of 1900 R. Also, the turbine flow coefficient is assumed to be 0.61 and the stator exit flow angle is 22°.

For the conditions described above, the hot and cold streak density ratios are 1.36 and 4.52 respectively. From Fig. 7, the relative total pressure differences corresponding to these density ratios are -0.22 for the hot streak and 0.19 for the cold streak. Note that because of the large differences in molecular weights of the working gases between the gas turbine and rocket turbopump applications, the relative pressure differences for the two applications are very different and are in fact of different signs.

Applying the pressure surface streak correlation (Fig 9), the hot streak would cause a 278 R increase in the average gas temperature on the pressure surface and the cold streak would cause a 524 R decrease. The net decrease in pressure surface average gas temperature below the 1900 R average gas temperature would be 246 R. This significant decrease in temperature was produced by hot and cold fluid making up only 10.2% of the total fluid entering the turbine.

All of the applications cited here were based on the correlations in Figs. 9 through 12 which give average surface results. However, airfoil seldom burn out on an average basis; they burn out locally. Thus, while these correlations provide a quantitative guide for average accumulation, they do not take into account the extreme variations of the local accumulation. For this effect, one must turn to the in-depth fullspan data presented Part I of this paper.

CONCLUSIONS

The results presented in this paper have provided insight as to the combined effects of hot streak and stator coolant accumulation on the simulated recovery temperature on the rotor. The main conclusion that can be derived from the discussion of results is that the hot streak and stator coolant do not interact significantly but behave as the sum of the two flows operating separately. The analytical study described in this paper demonstrated that the difference between the relative total pressures of the hot or cold streams and the surrounding free stream is a good correlative parameter for both the hot and cold streak accumulation as well as stator coolant accumulation. Other conclusions which can be drawn include:

1. Coolant flow accumulated on the rotor suction surface where hot streak accumulation was weakest. Under typical turbine operating conditions, coolant flow and hot streak flow accumulated at different places on the airfoil and hence, they can not be used to off-set each other.

2. The analytical model of the accumulation process showed that there is no limit to the relative total pressure difference (of a jet and a free stream) on the pressure surface accumulation, but there is a limit on the suction surface.

3. The analytical model gave a strong correlation for the pressure surface accumulation.

4. The correlation for suction surface accumulation was much weaker as one might expect from the lower limit of the relative total pressure difference.

5. The analytical model was applied to estimate the average heat loading on a turbine rotor surface. For a gas turbine example, hot and cold streak accumulation and stator coolant accumulation could account for the rotor pressure surface being as much as 100 F hotter than one would have expected with a uniform inlet temperature. For a rocket turbopump application, hot and cold streak accumulation caused a net reduction in the average rotor pressure surface temperature of 240 F.

ACKNOWLEDGEMENTS

The authors owe a debt of gratitude to a number of our colleagues for their helpful and patient support in carrying out the work reported here. We are indebted to Mike Quinn for his skill in running the LSRR and acquiring the data; to Bill Tierney for the speed with which he often had to breathe life back into our data system; to Jerry Jaminet for his patience while making many modifications to the data system software; and to Sue Orr for her untiring effort in producing the graphics utilized throughout this paper.

The majority of the results which are reported here were obtained in an experimental program carried out with Air Force funding (Contract No. F33615-88-C-2829) under the direction of Mr. Michael J. Kinsella, Wright Laboratory (WL/POTC). The results which show the effect of axial gap and the traverse results obtained aft of the rotor were obtained in an experimental program funded by NASA Marshall Space Flight Center, (Contract No. NAS8-36801) under the direction of Ms. Lisa W. Griffin.

REFERENCES

Munk, M., and Prim, R. C., 1947, "On the Multiplicity of Steady Gas Flows Having the Same Streamline Pattern," Proceedings of the National Academy of Sciences, U. S., Vol. 33.

Roback, R., and Dring, R. P., 1992, "Turbine Heat Transfer Research – Hot Streaks and Phantom Cooling, Part I – Separate Effects." To be presented at the ASME International Gas Turbine Institute Conference, Cologne, Germany.