INVESTIGATION ON HEAT TRANSFER CHARACTERISTICS AND CORRELATIONS OF JET IMPINGEMENT COOLING OF GAS TURBINE

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Abstract:

This paper represents and describes the experimental results for heat transfer characteristics and optimization strategies for the blade design through the obtained heat transfer correlations carried out at Mechanical Systems and Control Lab., Jadavpur University, Kolkata, India.

Impingement heat transfer is considered as a promising heat transfer enhancement technique. In particular, in gas turbine cooling, jet impingement heat transfer is suitable for the leading edge of a rotor airfoil, where the thermal load is highest and a thicker cross-section enables accommodation of a coolant plenum and impingement holes. This technique is also employed in turbine guide vanes (stators).

The choices of heat transfer enhancement techniques and usages are core concerns for modern gas turbine designers. Many researchers have contributed their efforts towards better understanding of Impingement cooling. Studies on impingement heat transfer enhancement technique focused on single jet impingement (round jet or slot jet) and then expanded to impingement jet arrays.

The open literature showed that the influence of the impingement plate, the plate through which the cooling air passes, on the heat transfer at the target surface is not well understood. There is great lacking of the impingement plate thermal boundary conditions data in the literature. The temperature of this plate must be different from both the cooling gas temperature and the target plate temperature and is significantly affected by lateral conduction at impingement insert attachment points. This work is a new experimental attempt to report data on the effect of the impingement plate temperature on the target surface for an array of impinging jets.

Today's higher engine compression ratios (approaching 30:1) can increase turbine entry temperature (TET) and improve thermal efficiency, greatly reducing fuel consumption. Higher TETs required for increased performance will cause higher

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thermal fatigue and higher stress problems for the designer. With hot section design life equipments now 50% of the airframe life, users are demanding reliable, long-life performance. A reduction of blade metal temperature of 40^0C can improve blade life 10 fold [1]. There are comprehensive surveys of turbine cooling [2] and [3] and more specifically that of impingement cooling by Gauutner et al. [4], Downs and James [5], Yeh and Stepka [6] and Jambunathan et al. [7].

An experimental investigation on heat transfer characteristics of arrays of impinging jets in the midchord region of a turbine blade was carried out. There is usually a region of high temperature at the passage midspan. The turbine designer often uses an array of jets impinging on the inner blade surface to reduce the effect on metal temperature of this temperature spike.

The heat transfer capability of radial expanding flow is believed to be higher than the axial flow as the expanding flow actually impinges directly on the combustor wall surface, which generally results in a higher heat transfer rate. However, due to the fact that the expanding flow impingement only occurs at a small region at the upstream of the combustor, therefore the effect on an overall heat transfer is limited. Some of the important factors such as Reynolds number, crossflow ratio, jet to impingement target spacing, jet to jet spacing and hole patterns were taken into consideration in this study.

The conclusions from the present data are that, for a given air flow rate, of the configurations tested, a staggered configuration with a z/d = 2 provides not only the most uniform local heat transfer through the array, but a higher average Nu. The pressure drop through the z/d = 2 array is also less than for the z/d = 1 array. Near the array exit, the Reynolds number dependence departs from the exponent of 0.5. Correlations are presented for stagnation point heat transfer for inline and staggered arrays with z/d = 1 or 2 which are valid when little or no crossflow is present.

References:

[1] Cowie, W. D., “Engine Life Development Programs, ENSIP Damage Tolerant Designs,” *United States Air Force Aeronautical Systems Division,* University of Tennesse Space Institute Short Course, April 23-27, 1990.

[2] Metzger, D. E., “Cooling Techniques For Gas Turbine Airfoils – A Survey,” *AGARD Conference on Heat Transfer and Cooling in Gas Turbines,* CP390 Paper No. 1, 1985.

[3] Holland, M. J., and Thake, T. F., "Rotor Blade Cooling in High Pressure Turbines," *AIAA Journal of Aircraft*, Vol. 17, No. 6, pp. 412-418, 1980.

[4] Gauntner, J. W., Gladden, H. L., Gauntner, D. J. and Yeh, F. C., "Crossflow Effects on Impingement Cooling of a Turbine Vane," *NASA TM X-3029*, 1974.

[5] Downs, S. J., and James, E. H., "Jet Impingement Heat Transfer – A Literature Survey," *National Heat Transfer Conference*, ASME Paper No. 87- HT-35, 1987.

[6] Yeh, F. C., and Stepka, F. S., "Review and Status of Heat Transfer Technology for Internal Passages of Air-Cooled Turbine Blades," *NASA TP- 2232*, 1984.

[7] Jambunathan, K., Lai, E., Moss, M. A., and Button, B. L., "A Review of Heat Transfer Data for Single Circular Jet Impingement," *int. J. Heat and Fluid Flow*, Vol. 13, No. 2, pp. 106-115, 1992.