

214

GAS-SIDE HEAT TRANSFER WITH ROTATION

Robert P. Dring
United Technologies Research Center

The primary basis for heat transfer analysis of turbine blades is experimental data obtained in linear cascades. These data have been very valuable in identifying the major heat transfer and fluid flow features of a turbine airfoil. The question of major interest is how well all of these data translate to the rotating turbine blade. It is known from the work of Lokay and Trushin (ref. 1) that average heat transfer coefficients on the rotor may be as much as 40 percent above the values measured on the same blades non-rotating. Recent work by Dunn and Holt (ref. 2) supports the Russian conclusion. What is lacking is a set of data from a rotating system which is of sufficient detail as to make careful local comparisons between static cascade and rotor blade heat transfer. In addition, data is needed in a rotating system in which there is sufficient documentation of the flow field to support the computer analyses being developed today. A second major question is the influence, if any, of the first stator row on the heat transfer of the second stator row after the flow has passed through the rotor.

The first objective of the present program, is to obtain a detailed set of heat transfer coefficients along the midspan of a blade in a rotating turbine. The turbine stage to be examined is that of Dring et al. (ref. 3), as shown in figure 1. Aerodynamic testing of this stage has already been conducted to document, among other things, the impact of rotor-stator interaction on the airfoil unsteady pressure distributions. The time averaged and unsteady pressure envelopes are shown in figure 2. The rotor heat transfer data are to be such that they can be compared directly with data taken in the static cascade experiment of Graziani et al. (ref. 4), as illustrated in figure 3. The data are also to be compared to some standard analysis of blade boundary layer heat transfer which is in use today. In addition to providing this all-important comparison between rotating and stationary data, this experiment should provide important insight to the more elaborate full three-dimensional programs being proposed for future research. A second program objective is to obtain a detailed set of heat transfer coefficients along the midspan of a stator vane located in the wake of a full upstream turbine stage. Particular focus here is on the relative circumferential location of the first and second stators. The final program objective is to improve the analytical capability to predict the experimental data.

The program is divided into two phases. The first phase is designed to provide a high density of high accuracy heat flux measurements on both the pressure and suction surfaces of a rotating turbine blade, figure 1. The program will include two rotor-stator spacings to assess the influence of rotor-stator interaction as in the experiment of Dring et al. (ref. 3). It will also include both positive and negative incidence as well as the design incidence. Finally, the first phase program will include comparison of the data with static cascade data, figure 3, and with a common boundary layer heat transfer analysis. The second phase will be designed to provide

a high density of high accuracy heat flux measurements on both the pressure and suction surfaces of a second stator row turbine vane. The program will be run at one of the rotor-stator spacings used in the first phase. It will include, at minimum, four different circumferential positionings of the first stator row relative to the second stator row. In addition, the second phase will include an analysis to describe the experimental phenomena of both phases, which will improve the current ability to predict turbine midspan airfoil heat transfer.

REFERENCES

1. Lokay, V. I.; and Trushin, V. A.: Heat Transfer from the Gas and Flow-Passage Elements of a Rotating Gas Turbine. Heat Transfer - Soviet Research, Vol. 2, No. 4, July 1970.
2. Dunn, M. G.; and Holt, J. L.: The Turbine Stage Heat Flux Measurements. Paper No. 82-1289, AIAA/ASME 18th Joint Propulsion Conference, 21-23, June 1982, Cleveland, Ohio.
3. Dring, R. P.; Joslyn, H. D.; Hardin, L. W.; and Wagner, J. H.: Turbine Rotor-Stator Interaction, Trans. ASME, Jour. Eng. for Power, Vol. 104, October 1982, pp. 729-742.
4. Graziani, R. A.; Blair, M. F.; Taylor, J. R.; and Mayle, R. E.: An Experimental Study of Endwall and Airfoil Surface Heat Transfer in a Large Scale Turbine Blade Cascade. Trans. ASME, Jour. Eng. for Power, Vol. 102, No. 2, April 1980, pp. 257-267.

OBJECTIVES

- Turbine rotor heat transfer data
- Rotor-stator interaction (ΔX)
- Comparison with cascade data
- Second stator heat transfer data
- Stator-stator interaction (ΔCirc)
- Quasi-steady and/or unsteady boundary layer analysis

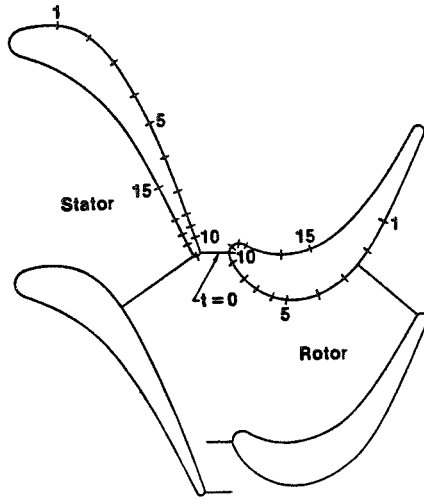


FIGURE 1. TURBINE STAGE AT 15% GAP (Ref. 3)

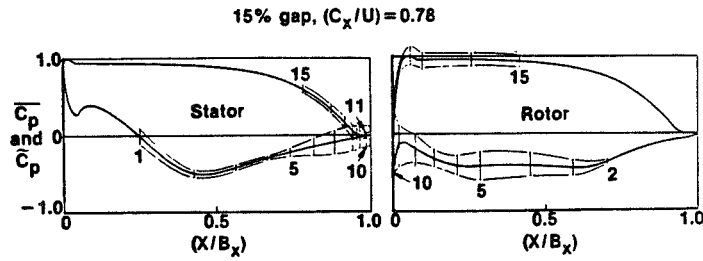


FIGURE 2. UNSTEADY PRESSURE ENVELOPES (Ref. 3)

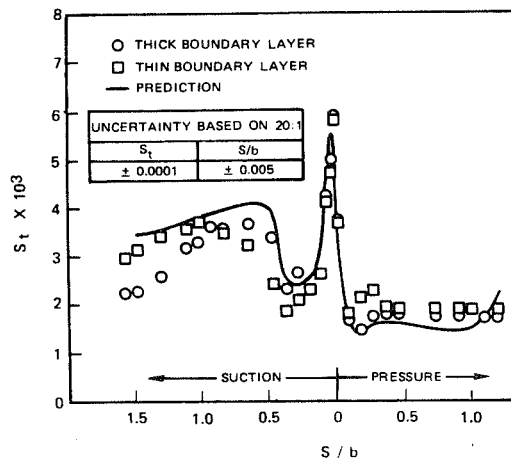


FIGURE 3. MEASURED AND PREDICTED MIDSPAN HEAT TRANSFER DISTRIBUTIONS (Ref. 4)