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EXPERIMENTAL TURBINE AERO-HEAT TRANSFER STUDIES IN ROTATING RESEARCH FACILITIES

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The present paper deals with the experimental aero-heat transfer studies performed in rotating turbine research facilities. Turbine heat transfer research had significant progress in the last few decades. Since the full scale operational conditions of a modern gas turbine dictate high temperatures in the excess of 2600 ^{o} F and typical pressure ratios from 20 to 50 , experimental forced convection heat transfer research in a rotating environment is a technically a challenging task.

The most significant parameters to simulate in a rotating aero-heat transfer facility can be listed as Reynolds number based on the blade chord for highly viscous flow phenomena, Mach number for compressibility and shock wave effects, intensity and scale of free stream turbulence, Strouhal number for the unsteady wake passing effects, free stream to wall temperature ratio, coolant to free stream temperature ratio, specific heat ratio and molecular Prandtl number of the operating gas and a rotation number for internal cooling work performed under rotational conditions.

The experimental rotating research rigs for gas turbine aero heat transfer research range from full scale gas turbine demonstrators to short duration facilities, from rotating coolant passage simulators to large scale/low speed turbine research facilities, from rotating disk cavity research rigs to tip leakage flow simulators using a moving surface for the generation of relative flow effects of tip leakage flows. While instrumented full scale gas turbine demonstrators are excellent candidates to generate very realistic gas turbine heat transfer data, the initial investment made to construct them, their extremely high operational costs and the technological challenges in performing reliable and high resolution aero-thermal measurements limit their current use.

The short duration facilities or blow down type rigs have been extremely popular choices mainly because of their relatively reduced cost of operation and excellent scaling available for Mach number and Reynolds number sensitive aero-thermal phenomena. Although they may not operate at full scale free stream to wall temperature ratios, they can generate an accurately measurable amount of heat transfer from the gas side to turbine blades in either a linear cascade or in a turbine stage where there is a highly realistic rotor operation. The heat transfer coefficients resulting from short duration rotating rigs are considered to be very high quality in terms of experimental uncertainties. Although heat transfer instrumentation in short duration facilities require relatively advanced thermal sensor making, signal transmission and signal processing abilities, the results generated in these facilities have extremely high technical value during and after a turbine design sequence. The most visible short duration heat transfer facilities were constructed and operated by Oxford University, Von Karman Institute for Fluid Dynamics, Ohio State University (Calspan in earlier days), MIT Gas Turbine Lab and Wright Patterson Air Force Base.

Large scale and low speed research facilities are also frequently used in aero-heat transfer research because of their low operating costs. They are highly reliable and safe to operate especially in university laboratories where the research assistants are usually graduate students. One of the first turbine research rigs was operated by Dr.R.Dring at United Technologies Research Center at Connecticut. The currently operational low speed, large scale turbine research rigs are at the Aero-heat Transfer Laboratory of the Pennsylvania State University, Purdue University and Texas A&M University. There are also a number of low-speed/large-scale aero-thermal facilities currently operational in Germany and Switzerland.

The current paper will provide a summary of presently operational turbine heat transfer research facilities. In addition to major rotating rigs, the research results from the Axial Flow Turbine Research Facility AFTRF at Penn State, operated by the author of this paper will also be included. Since the final status of any forced convection heat transfer problem is closely defined by the detailed structure of momentum transfer in a highly unsteady, rotating and turbulent viscous flow conditions, emphasis will also be placed on pertinent turbine aerodynamic features existing in rotating facilities.