Cavity Purge Flows in High Pressure Turbines

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Abstract

Turbomachinery forms the principal prime mover in the energy and aviation industries. Due to its size, improvements to this fleet of machines have the potential of significant impact on global emissions. Due to high gas temperatures in stationary gas turbines and jet engines, areas of flow mixing and cooling are identified to benefit from continued research. Here, sensitive areas are cooled through cold air injection, but with the cost of power to compress the coolant to appropriate pressure. Further, the injection itself reduces output due to mixing losses. A turbine testing facility is central to the study, allowing measurement of cooling impact on a rotating low degree of reaction high pressure axial turbine. General performance, flow details, and cooling performance is quantified by output torque, pneumatic probes, and gas concentration measurement respectively. The methodology of simultaneously investigating the beneficial cooling and the detrimental mixing is aimed at the cavity purge flow, used to purge the wheelspace upstream of the rotor from hot main flow gas. Results show the tradeoff between turbine efficiency and cooling performance, with an efficiency penalty of 1.2 %-points for each percentage point of massflow ratio of purge. The simultaneous cooling effectiveness increase is about 40 %-points, and local impact on flow parameters downstream of the rotor is of the order of 2° altered turning and a Mach number delta of 0.01. It has also been showed that flow bypassing the rotor blading may be beneficial for cooling downstream. The results may be used to design turbines with less cooling. Detrimental effects of the remaining cooling may be minimized with the flow field knowledge. Stage performance is then optimized aerodynamically, mixing losses are reduced, and the cycle output is maximized due to the reduced compression work. The combination may be used to provide a significant benefit to the turbomachinery industry and reduced associated emissions.

Keywords
turbomachinery; axial turbine; cavity purge; purge flow; wheelspace; rim seal; spanwise transport; radial transport; effectiveness; cooling; efficiency