Effects of Wheelspace Coolant Injection and Gap Geometry on Blade Endwall Heat/Mass Transfer

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An experimental investigation is performed with a linear cascade composed of five blades having the profile of the first stage rotor airfoil of a high-pressure gas turbine. Air injected through a slot located upstream of the cascade simulates the engine wheelspace coolant injection between the stator and the rotor. The injected flow enters the wind tunnel test section at a 45° angle to the bottom endwall, with an effective blowing rate of unity. The surface downstream of the gap is coplanar to the upstream surface in the baseline configuration, and is shifted to form a backward and a forward facing step for two additional configurations in order to simulate the effects of misalignment of the rotor and stator endwalls. Naphthalene sublimation measurements conducted at a Reynolds number of 600,000 based on true chord and cascade exit velocity provide local heat/mass transfer coefficients on the endwall and blade surfaces. The local mass transfer data obtained injecting naphthalene-free and a naphthalene-saturated air are reduced to derive detailed maps of cooling effectiveness on the surfaces downstream of the gap. An oil dot test shows the surface flow for the three geometrical configurations.

The combined analysis of the mass transfer and the flow visualization results provides an interpretation of how the secondary flow structure and the cooling effectiveness are affected in the three cases, giving guidance in optimizing the design of the endwall and blade cooling systems. The oil-dot visualization indicates that with injection, the line marking the intersection of the passage vortex and incoming flow moves downstream into the passage, suggesting that the incoming boundary layer is energized by injection and is able to penetrate

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further into the passage. The coolant exiting from the slot is drawn to the suction side of the blade and climbs up the suction surface of the airfoil, being pushed up by the action of the passage vortex system and leaving a well defined streak of cooling effectiveness on the blade surface. For the tested blowing rate, hardly any coolant reaches the pressure side of the blade. For the step-up configuration, the coolant penetrates further downstream in the pressure side of the passage. When the endwall is brought down to create a step-down configuration, the coolant penetrates less on the pressure side of the passage and more on the suction side of the passage and on the airfoil suction surface, providing a higher overall cooling effectiveness but reduced effectiveness on the pressure side of the passage.