Increasing demand for gas turbine performance has elevated the turbine inlet temperature well beyond the melting range of the hot-gas-path component materials. Extensive cooling combined with thermal barrier coating is practiced in these regions to combat the high convective heat transfer coefficients thereby sustaining component durability. Film cooling (a type of external cooling) uses pressurized air (coolant), typically bled from the last few compressor stages to establish thermal protection for the component. This is accomplished by ejecting the coolant through the component surface via discrete holes, covering the surface from the hot mainstream gas. Secondary flows generated at the airfoil-endwall junction interact with the coolant in the presence of the pitchwise pressure gradient and mainstream flow acceleration, resulting in a non-uniform coolant distribution on the endwall. Excess usage of coolant can severely impact the engine thermal efficiency.

A deeper understanding of the endwall secondary flow and coolant film interaction can improve the efficiency of existing endwall film cooling configurations. In view of this, an experimental and numerical study was performed to investigate the secondary flow and coolant film interaction in a high subsonic annular cascade with a maximum isentropic throat Mach number of \( \approx 0.68 \). Endwall thermal protection was established using discrete cylindrical holes with a streamwise inclination angle of 30° and no compound angle relative to the mean approach velocity vector. The surface flow visualization on the inner endwall provided the location of the saddle point and the three dimensional separation lines. The predicted streamlines showed that the horseshoe vortex was confined to approximately 1.5% of the airfoil span for the no film injection case and intensified with low momentum film injection. At high momentum film injection, the injected coolant weakened the horseshoe vortex. It was seen that increasing the average blowing ratio improved the film effectiveness. The discharge coefficients calculated for each film cooling hole indicated significant non-uniformity at lower blowing ratios and the strong dependence of discharge coefficients on the mainstream static pressure and location of the three-dimensional separation lines. Near the airfoil suction side, a region of coalesced film cooling jets providing close to uniform film coverage was observed, indicative of the mainstream acceleration and the influence of the endwall separation lines.