The demand for more power is rapidly increasing worldwide. Gas turbines provide 35% of the power demands within the United States. The overall efficiency of a gas turbine can be increased while simultaneously maximizing specific work output, by increasing the turbine inlet temperature. However, even with the advancements in modern materials in terms of maximum operating temperature, various components are already subjected to temperatures higher than their melting temperatures. An increase in inlet temperature would subject these components to even higher temperatures, such that more effective cooling would be necessary, whilst ideally using the same (or less) amount of cooling air bled from compressor. Improvements in the performance of these cooling techniques is thus required.

The objective of this study is to investigate the effects of coolant density on the jet structure for different multi-row film cooling configurations. Typical operating density ratio at engine conditions are between 1 and 2.5, while it is observed that a majority of the density ratios tested in literature are between 1 and 1.5. While these tests may be executed outside of engine-like conditions, it is important to understand how density ratio effects the flow physics and film cooling performance. The density ratio within this study is varied between 1.0 and 1.5 by alternating the injecting fluid between air and Carbon Dioxide, respectively.

In order to compare the results collected from these geometries, lateral and spanwise hole-to-hole spacing, metering hole diameter, hole length, and inclination angle are held constant between all testing configurations. The effect of fluid density upon injection is examined by independently holding either blowing, momentum flux, or velocity ratio constant whilst varying density ratio.

Particle Image Velocimetry (PIV) is implemented to obtain both streamwise and wall normal velocity measurements for the array centerline plane. This data is used to examine the interaction of the jet as it leaves the film cooling hole and the structure produced when the jet mixes with the boundary layer.

Similarities in jet to jet interactions and surface attachment between density ratios are seen for the cylindrical configuration when momentum flux ratio is held constant. When observing constant blowing ratio comparisons of the cylindrical configurations, the lower density ratio is seen to begin detaching from the wall at $M = 0.72$ with little evidence of coolant in the near wall region. However, the higher density cylindrical injection retains its surface attachment at $M = 0.74$ with noticeably more coolant near the wall, because of significantly lower momentum flux ratio and lower "jetting" effect. The fan-shape film cooling configuration demonstrates improved performance, in terms of surface attachment, over a larger range of all ratios than that of the cylindrical cases. Also, the fan-shaped film cooling configuration is observed to constantly retain a thicker layer of low velocity fluid in the near wall region when injected with the higher density coolant. The higher density fluid is seen to produce a thicker boundary layer when compared to that produced by the lower density injection, for both the cylindrical and fan-shaped configurations.

Major: Mechanical Engineering

Educational Career:
Bachelor's of Mechanical Engineering, BS, 2016, University of Central Florida

Committee in Charge:
Jayanta Kapat, Chair, Mechanical & Aerospace Engineering