Stability of high-speed, three-dimensional boundary layers
Doctoral Dissertation Defense

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Abstract

The state of hypersonic boundary layers has a number of important implications for the design of hypersonic vehicles, including thermal protection, drag, and fuel mixing. The transition process may take a number of paths to turbulence stemming from several classes of instability in the boundary layer. In particular, the crossflow instability arises and is dominant in the boundary layers over a number of common hypersonic geometries such as swept surfaces and cones at nonzero angle of incidence.

The crossflow instability is studied experimentally in a low-disturbance, Mach 6 wind tunnel in the boundary layer on a yawed cone. A three-dimensional traversing mechanism is used in conjunction with constant-temperature hot-wire anemometry to create a series of 2D contours of streamwise mass flux in the boundary layer at a series of axial locations along the cone. Stationary crossflow waves are documented up to and through their saturation point. Mass flux fluctuations are observed in two distinct frequency bands centered at 33 kHz and 110 kHz. The low-frequency band corresponds to traveling crossflow waves and its amplitude is shown to decrease throughout the measurement region. The high-frequency band corresponds to secondary crossflow instability and quickly saturates. Further, the crossflow instability in a hypersonic boundary layer bears remarkable similarity to its counterpart in incompressible flows.

Alex Craig is a PhD candidate in the Department of Aerospace Engineering working under the supervision of Professor William Saric. His research interests are in the areas of hydrodynamic stability, boundary layer stability and transition, and hypersonic flows. He is currently seeking a position as a post-doctoral researcher.