The Development and Validation of Supersonic Testing Capabilities at The Royal Military College of Canada

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The Royal Military College of Canada has developed a transient vacuum in-draft wind tunnel for experimental studies of supersonic flow aerodynamics. The facility supports investigations of fundamental compressible-flow phenomena and the design of supersonic inlets. To achieve these conditions, fixed-length supersonic nozzles were designed using the Method of Characteristics under inviscid flow assumptions. Mach 2.5 and 3.5 nozzle contours were then corrected for viscous effects using steady RANS simulations to account for boundary layer growth. Structural analyses in `ANSYS Mechanical` were used to reduce material cost while maintaining adequate strength, and both nozzles were additively manufactured.

The nozzle designs were validated using two approaches. First, static pressure ports were used to estimate the local Mach number in the test section. Second, high-speed schlieren imaging was used to capture oblique shocks generated by wedges of known angle, allowing the Mach number to be inferred from oblique shock relations. Initial static-pressure-based estimates were 7% lower than the design value, while schlieren-based measurements agreed with the target Mach number. This discrepancy was traced to the assumption of constant total pressure between ambient conditions and the test section. Analysis of schlieren revealed weak Mach waves in the flow at 20° from the horizontal. Such waves would cause a 0.6% total pressure loss. By accounting for this loss, the measured and predicted Mach number agreed within measurement error.

With the facility now validated, experimental campaigns have begun. At Mach 2.5, supersonic inlet was tested using schlieren imaging to track shock structure and static pressure measurements in order to assess internal flow quality (Fig. 1a). At Mach 3.5, opposing wedges of different angles were used to generate intersecting shock systems for the study of supersonic instability mechanisms relevant to SCRAMJET intake flows (Fig. 1b).

(a) (b)

Figure 1: Schlieren imagery of (a) a Mach 2.5 intake (b) a Mach 3.5 shock-shock interaction.

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