Master's Thesis Defense Announcement
Mechanical and Aerospace Engineering Department
The University of Texas at Arlington

DESIGN AND DEVELOPMENT OF SUPERSONIC FREE JET FACILITY

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Abstract

High-speed wind tunnels are essential facilities for conducting research and testing in external and internal flows. This thesis details the design and development of a blow-down supersonic free-jet facility with a 3-inch square nozzle in the Mach number range of 1.5−2.5 and unit Reynolds number ranging 50−200× 106/m. Key aspects of the facility development include the detailed design of the gas supply system, control valve selection, plenum, nozzle, test section, and the selection of an exhaust silencer. CAD designs for all the components of facility were generated in this effort.

A new analytical approach was developed to design supersonic contoured nozzles for wind tunnel applications. In the proposed nozzle design method, a streamline inside a reference nozzle is selected as the desired contoured nozzle wall. The reference nozzle is a simple, inviscid, sharp-cornered minimum-length nozzle generated using Method of Characteristics (MoC). Several streamlines are generated within the reference nozzle and specific criteria for selecting a streamline as the contoured nozzle wall are discussed. The criteria are based on the centripetal acceleration of the gas and the curvature of the sonic line. The nozzle wall profile obtained through this process is then corrected for viscous effects using integral boundary layer analysis. This approach simplifies the complexities of the conventional supersonic contoured nozzle design method proposed by J.C. Sivells. A comparative numerical study of the nozzle-exit profiles generated by conventional approach and the new streamline-based approach is carried out using ANSYS Fluent. For the numerical study, the $k-\omega$ SST model using a pressure-based solver is considered. Both nozzle design approaches generated flow conditions that are in good agreement with the targeted flow properties at M=1.5,2 & 2.5. For the selected case studies, the streamline nozzle design method slightly outperformed the Sivells method in terms of quantifiable performance parameters, such as core flow area size, flow distortion, and flow angularity.

Finally, the expansion of the free-jet test-rhombus to a constant-area test section is discussed. The pressure gradient developed in the constant-area test section due to Fanno flow and the shock-train length inside the test section during sub-atmospheric operations is of interest. These parameters were studied using sub-scale experiments in a smaller free jet. The results were scaled up using non-dimensional parameters for the designed 3-in square free-jet facility to better understand the flow conditions in the test-section and the operational envelope of the facility.