



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS



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Near-field Examination of Sonic/Supersonic Nozzle Flows

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This thesis presents a numerical study on compressible flow within and downstream sonic/supersonic nozzles. It is a close look at the effects of thermodynamics and geometry configuration on the gas flow inside and downstream the ducts. An in-house CFD solver is developed to accommodate the complex flow structure that accompanies the underexpanded jet and impose the proper boundary conditions, in order to simulate the flow field. More focus is drawn to the phenomenon of Mach disk that occurs in case of highly underexpanded flow, its location and height are thoroughly studied and analysed. In order to more comprehend the factors that influence the freejet, it seemed only plausible to understand the alteration in jet structure with varying upstream geometries. Therefore, nine nozzle shapes are examined in terms of Mach disk location and height, and the resulting sonic line at the nozzle throat. This investigation provides an understanding to the influence of sonic nozzle geometry, and settling chamber over the jet structure, regardless of the viscosity effects. Hence, the inviscid Euler equations are employed for this purpose. Further, an optimisation algorithm is deployed to construct a supersonic nozzle wall shape that produces a radially-uniform flow at the exit, and for the maximum distance downstream of the exit. Three different nozzle shapes are obtained depending on the mathematical representation of the nozzle wall, the wall shape is found to significantly impact the flow field and its characteristics within and downstream the nozzle. The most feasible nozzle is then fabricated and used in physics-related experiments. The growth of shear layer is also examined, and it is linked to the nozzle wall shape and gas properties. Moreover, a novel arrangement for an altitude compensating nozzle is proposed to address the problem of operation under different pressure ratios. The idea is to replace the conventional nozzle with a set of parallel rings that would eventually form a supersonic nozzle with bleeding slots. This arrangement is found to be effective in eliminating the low-momentum part of the boundary layer, and maintaining a radially-uniform flow at the nozzle exit, in addition to its ability to alter the nozzle area ratio so that it operates at different altitudes. It is concluded from the simulations results that sonic and supersonic freejets are widely governed by the thermodynamics properties of the fluid, and the geometrical constraints imposed on the flow. Freejets are found to be sensitive to these factors, and the CFD solver used herein can be a valuable tool to evaluate the complex structure of such flows and a significant addition to the ocean of supersonic flow.