INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:
Numerical Study of Flow Alteration Techniques and High Temperature Effects at Supersonic/Hypersonic Speeds

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SHORT ABSTRACT

The present work is focused on the numerical investigation of various flow problems like excessive wave drag force, shock wave boundary layer interaction as well as high temperature effects and subsequent implementation of flow alteration techniques to mitigate their adverse effects. Therefore, a finite-volume based multi-species reacting gas unstructured solver is developed in-house. It solves coupled 2-D axisymmetric Navier-Stokes equations along with the species continuity equations. Additionally, perfect and frozen versions of this solver have also been wielded to highlight the role of high temperature effects in the flowfield alteration as well as to simulate low enthalpy flowfield.

The initial study deals with the examination of real gas effects for the cases of unsteady shock tube flow and steady flow over a cylinder/sphere. The study portrays the limitation of the different governing parameters like driver to driven pressure ratio and freestream Mach number in deciding the flow features including shock propagation speed, shock stand-off distance and shock shape for both the cases in the presence of high-temperature effects.

Further, the investigation is continued to assess the energy deposition based flow alteration technique for drag reduction of hypersonic flow past a blunt body using perfect gas, frozen and reacting flow solvers. The study shows that deposited energy offers more power effectiveness in case of perfect gas flow while degradation in power is seen for frozen as well as reacting gas flow models which is attributed to the specific heats variation with temperature. In further studies, the aerodynamics of drag reduction using steady-state counter jet is investigated. Here, a new non-dimensional number is suggested which is jet to freestream momentum ratio through rigorous theoretical and numerical examinations. It is found that the jet to freestream momentum ratio is the vital deciding number which governs the various flow characteristics of steady-state opposing jet based drag reduction technique.

Later, efforts are also given towards mitigating the boundary layer separation in the presence of shock wave boundary layer interaction using pressure feedback technique (PFT). The studies showed significant reduction of separated region size using cooled pressure feedback channel. Later, the blunt leading edge is integrated along with the cooled PFT to improve its effectiveness. It is found that the integrated arrangement reduced the value of critical blunt radii (inversion and equivalent) without altering the entropy layer. The investigations are extended to study the passive control of SWBLI using the leading edge bluntness alone for perfect and reacting gas models. For precise computation of blunt critical radii, the in-house developed solvers are integrated with the gradient-based optimization algorithm. Here, lower critical radii values are noted for reacting gas flow as compared to perfect gas flow due to the assistance offered by the real gas effects. Further, it is concluded that only perfect gas simulations are sufficient to predict the critical radii to ensure separation control.