INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: DEVELOPMENT OF A FINITE VOLUME FRAMEWORK FOR CONVECTIVE-RADIATIVE FLOWS ON UNSTRUCTURED GRIDS

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This thesis presents the development of a low-Mach number flow solver on unstructured meshes and its application for convective-radiative heat transfer. Extensive discussions are presented on the circumstances in which variable-density flows can no longer be treated using an incompressible assumption (Boussinesq approximation). This includes problems involving large temperature difference natural convection and those coupled with radiative heat transfer. It is very well known that the Boussinesq approximation does not hold good at large temperature difference. However, studies in the present thesis show that even for small temperature difference, a low enough Planck number (significant influence of radiative heat transfer) may cause the Boussinesq approximation to fail. Three low-Mach number algorithms are presented and discussed in brief. Further, the importance of discrete conservation of mass and energy in obtaining robust solutions of non-Boussinesq flows has been discussed in detail. Importantly, the use of an algorithm that discretely conserves both mass and energy as opposed to calculating either one using the EOS allows the use of a larger time step on a given mesh without compromising on the solution accuracy. On similar lines, one may be able to use a finer mesh for a given time step in obtaining stable and accurate solutions for such problems. A balanced force algorithm for buoyancy driven flows at large temperature difference is presented and its importance is highlighted for practical problems including turbulent flows. It is shown that at large temperature difference buoyancy driven flows the discrete balance between pressure and buoyancy forces allows for larger allowable time step and therefore more cost-effective solutions for such flows. Furthermore, it is seen that the balanced formulation was necessary to compute accurately the turbulent natural convection problems in an acceptable turn-around times. The investigations highlight the need and ability of the force balancing in devising a robust and accurate algorithm to solve non-Boussinesq fluid flows. Applications of the flow solver for practical problems in enclosures in both laminar and turbulent regimes have been carried out. In particular, studies have been carried out for non-Oberbeck-Boussinesq buoyancy-driven turbulent flows in the presence of radiation. The results from the present work may serve as an ideal test case for benchmarking.