INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Study of linear stability and heat transfer characteristics of water flows with density inversion

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SHORT ABSTRACT

The Ph.D. work is concerned with the study of convective flows of water near its density inversion. The linear stability and heat transfer characteristics of the water flows are studied. The study focuses on the temperature range in which water shows density inversion. First, the solutions of convection boundary layer flows are obtained using the perturbation method. The linear stability analysis of natural and mixed convection boundary layer flows is carried out for temporal and spatial stability. The global stability of mixed convection flows in the lid-driven cavity is also investigated.

The solutions of mixed convection boundary layer flow of water, with density inversion, about a vertical plate, are presented using the perturbation method. Aiding as well as opposing mixed convection flow configurations are considered. Both, varying wall temperature and heat flux conditions are analyzed in the study. The perturbation solutions are presented in terms of universal functions which are valid for arbitrary continuous variation of wall temperature or wall heat flux thermal conditions, and hence, the solutions of boundary layer flow with arbitrarily varying wall temperature or wall heat flux can be obtained. Similarity solutions for natural and mixed convection boundary layer flow over a vertical plate with power-law varying wall heat flux, are presented which are not available in the literature. The similarity solutions for mixed convection are presented for both assisting and opposing mixed convection configurations. The perturbation solutions are presented for velocity, temperature, velocity, and thermal boundary layer thicknesses, skin friction coefficient, Nusselt number for various flow parameters such as Richardson number and Reynolds number.

Moreover, linear stability analysis of natural convection boundary layer flows of water near its density inversion is performed. Both, the temporal and spatial stability analysis is carried out. The stability of natural convection is studied for isothermal and isoflux wall conditions. The critical value of the buoyancy parameter for natural convection over the isothermal plate is found to be 22.84, while, in the case of isoflux plate, it is found to be 75.48. Linear stability analysis is also carried out for mixed convection boundary layer flows over an isothermal vertical flat plate. The stability is studied for both temporal and spatial stability characteristics. The results are presented for neutral stability curves, Eigenvalue spectrum, critical Eigenfunctions, and critical convection parameters. Mixed convection flow is formulated in such a way that when the Richardson number varies from 0 to ∞, the convection varies smoothly from pure forced convection to pure natural convection through mixed convection. For Ri = 0 and Ri → ∞, from the mixed convection formulation, the results of forced and natural convection asymptotes are recovered accurately. Such formulation is carried out by choosing appropriate scaling parameters for non-dimensionalization.

The work is extended to study the bi-global linear stability of mixed convection flows of water with density inversion in a lid-driven differentially side heated square cavity. The stability characteristics show dramatic changes with variation of Richardson number. In the range of Richardson numbers 0 to 0.4, the critical Reynolds number is almost constant with a value of about 4550. In the range of 0.4 to 0.6, the critical Reynolds number decreases drastically to a value of 1325. For Richardson numbers 0.6 to 1, the critical Reynolds number increases to 2354.23. Beyond which the Reynolds number decreases with Richardson numbers. The drastic instability near Richardson numbers 0.4 to 0.5 is found to be due to the formation of thin recirculation under primary recirculation, which is highly unstable. In the range of Richardson numbers 0 to 0.4, the most unstable Eigenvalue has zero real part indicating a stationary mode that does not change with time. For Richardson number greater than 0.4, the most unstable Eigenvalue is a pair of complex conjugate Eigenvalues indicating a Hopf mode which is a time-dependent disturbance. For pure forced convection asymptote, the most unstable mode is found to be thermal mode.