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Studies on convection with anisotropic thermal diffusion in tilted domains

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Abstract

Thermal convection plays an important role in the natural processes such as geophysical flows, ocean currents, circulation of the earth's mantle, and engineering processes involving heat exchangers, electronic equipment cooling, solar energy collectors, electric oven, melting and solidification process, etc. Primarily, the thermal convection studies are focused on the effects of boundary conditions, aspect ratios, Rayleigh number, and Prandtl number. Rayleigh-Bénard convection is one of a kind of natural convection which has been widely studied due to its importance in practical applications. This thesis details effect of anisotropic thermal diffusion on thermal convection inside tilted domains. A kinetic theory-based lattice Boltzmann method with multiple relaxation time collision formulation (LB-MRT) is employed. This approach uses double distribution functions to simulate the thermal convection inside the two-dimensional domains and three distribution functions to simulate the mixed convection inside a cylindrical cavity with an axisymmetric domain. The mathematical formulations of 2D LB-MRT and LB-MRT with an axisymmetric approach for anisotropic thermal diffusion and domain tilt are explained. A detailed discussion on the validation, parallel computation and performance is given. The benchmark studies of differentially heated 2D cavities, Rayleigh Bénard convection in a square cavity, and natural convection in diagonally 'flipped-L' shaped enclosures are performed. Further, Rayleigh-Bénard convection in tilted rectangular, square, 'L' shape, and diagonally 'flipped-L' shape cavities are studied. The steady Rayleigh-Bénard convection is observed for 'L' shape and diagonally 'flipped-L' shape cavities at low Rayleigh numbers. However, for higher Ra numbers, unsteadiness in the flow structure is observed. This unsteady behavior of the flow is then characterized by using the time-dependent signal of spatially averaged Nusselt number on the hot wall. The effect of anisotropic thermal diffusion on the Rayleigh-Bénard convection inside a cylindrical cavity using the axisymmetric approach is studied. The Rayleigh number is limited up to $Ra = 10^4$ to produce axisymmetric flow structures without azimuthal velocity. Further, the effect of a domain tilt on the convection is discussed. Next, the effect of mixed convection with an anisotropic thermal diffusion on the bubble breakdown with a rotating top and the stationary bottom lid is investigated. The code is first validated for fluid flow inside the lid-driven cylindrical cavity without thermal effects. The validation is also carried out for the convection inside the hot rotating top-lid cavity. The effect of mixed convection on the Bodewadt boundary layer thickness and the temperature boundary layer thickness is investigated. The simulation studies are performed for various Reynolds numbers, Richardson numbers, and Rayleigh numbers. It is concluded that the Bodewadt boundary layer thickness and the temperature boundary layer thickness are directly proportional to the Richardson number. For anisotropic thermal diffusion the Bodewadt boundary layer thickness remains constant and temperature boundary layer thickness increases for certain Richardson number with an increase in the ratio of thermal diffusivity values. The bubble breakdown vanishes with an increase in the Richardson number at a constant Reynolds number. Lastly, major conclusions from the present thesis work are discussed and the future directions are given.

About speaker: Amitkumar completed schooling from Pimpri-Chinchwad area in the Pune city, Maharashtra, India. He had 4 years of training and work experience in a paint-shop at Tata Motors, Pune. He completed his Bachelor degree in Mechanical Engineering from Pimpri Chinchwad College of Engineering (affiliated to the Savitribai Phule Pune University). Later, he completed his M.Tech. degree in Hydro Power Engineering from Maulana Azad National Institute of Technology, Bhopal and joined for the Ph.D. program. His research interests are in computational fluid dynamics, convective heat transfer, multi-phase fluid flow, lattice Boltzmann method, and high performance computing.

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