INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Spheres in Power-law Liquids with Velocity Slip at Solid-Liquid Interface: Momentum and Heat Transfer Phenomena

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SHORT ABSTRACT

Fluid Flow in contact with solid particles occur in numerous applications such as fixed and fluidized bed reactors, pneumatic conveying, nuclear reactors, sedimentation, sewage sludge, coal combustion, airborne dynamics and suspension flows. On the other hand, velocity slip along the solid surface can arise in the case of aerosols, flow through porous materials, suspension, capillary flows, polymer flow through extruders and flow along smooth solid surfaces. Thus, the momentum and heat transfer from spheres can be affected by velocity slip at the fluid-solid interface as well as rheology of surrounding continuous liquid and adjacent spheres. Thus, in the present work, the momentum and heat transfer phenomena of a single spherical particle and those of assemblages of spheres in Newtonian and power-law liquids with linear velocity slip boundary condition at the fluid-solid interface are numerically analyzed. The effect of the velocity slip at fluid-solid interface is studied by the use of linear velocity slip model. While the effect of volume fraction of spheres in assemblages is deliberated by the use of free surface cell model. The flow behavior and heat transfer phenomena of single solid spheres and assemblages of spheres in Newtonian and power-law fluids are studied using a finite difference method based simplified marker and cell (SMAC) semi implicit algorithm. For computational simplicity sphere-in-sphere type computational domain has been chosen. Thus the governing continuity, momentum and energy equations are considered in spherical coordinates. The convective terms being discretized using the quadratic upstream interpolation for convective kinematics (QUICK) scheme; while the diffusive and non-Newtonian terms discretized using central differencing scheme. Further, the velocity slip effects on the streamline patterns, iso-vorticity contours, drag coefficients, surface vorticity, surface pressure, surface viscosity, isotherm contours, surface Nusselt number and average Nusselt number of single sphere and of assemblages of spheres in Newtonian and power-law fluids are extensively deliberated as functions of the Reynolds number, slip parameter, power-law index, Prandtl number and volume fraction of spheres. In summary, in the case of single sphere at $Re \leq 20$, there is no flow separation for all slip parameters and power-law indices in the present range of investigation. Regardless of value of the Reynolds number, there is no flow separation for all values of power-law index provided the slip parameter is ≤ 1. For $\lambda \geq 5$ and $Re > 20$, the recirculation wake length increases with increasing Reynolds number and slip parameter. Further, a crossover Reynolds number (at $Re \approx 5$) is found on C_d versus Re curve for all values of the power-law indices; however, this crossover Reynolds number is found to be weak function of the slip parameter. Regardless of the values of the slip parameter, below this crossover Reynolds number, the drag coefficients increased with the decreasing power-law indices, while the opposite trend is observed above this crossover Reynolds number. Furthermore, the drag coefficient of spheres in an assemblage increased with increasing slip parameter and/or volume fraction of spheres. The thermal boundary layer becomes thinner with increasing Reynolds number and/or Prandtl number and/or decreasing power-law indices. The average Nusselt number increases with increasing Reynolds number and/or Prandtl number and/or volume fraction of spheres and/or decreasing slip parameter and/or power-law index. Finally, on the basis of present numerical results, several correlations for C_d and Nu_{avg} of single and multiple spherical particles in Newtonian and power-law fluids with velocity slip at the interface are proposed.