Turbulent heat transfer in nanoparticulate multiphase channel flows with a high Prandtl number molten salt fluid

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ABSTRACT

The growing interest in energy efficient and sustainable technologies has created significant demand for novel heat transfer and thermal energy storage materials, such as nanofluids. The importance of nanoparticle science cannot be underestimated, since the motivation for the manipulation, through nanoparticle addition, of the properties of existing thermofluids (e.g. molten salt) arises from their poor thermal properties which represent a major limitation to the development of more energy-efficient processes. In this work, special consideration is given to investigate the role of particle dynamic forces[1], processing and heat transfer of nanofluids in three-dimensional flows, using an advanced computational modelling approach to simulate such flows using direct numerical simulation (DNS) coupled with Lagrangian particle tracking (LPT)[2].

The heat transfer behaviour of a nanofluid within a turbulent wall-bounded flow is investigated numerically, with the fluid phase properties chosen to represent a molten salt thermofluid flow typical of those present in solar thermal power plants. The configuration is a fully developed channel flow with uniform heating from both walls. The continuous phase is modelled using DNS with the open source spectral element-based solver, Nek5000. Predictions of a statistically steady turbulent channel flow at shear Reynolds number $Re_\tau = 180$ and high turbulent Prandtl number $Pr_t = 5.0$ are first obtained and validated[3]. An LPT routine is implemented to simulate the dispersed phase, and is capable of accommodating one-, two- and four-way coupling between the fluid and discrete phases[4]. In order to investigate the effect of particles on the turbulent heat flux and temperature field, nanoparticle response to temperature variations and turbulence are obtained and the associated statistics are presented.

The advantage of the model developed is its ability to study in detail phenomena such as interparticle collisions, agglomeration, turbophoresis[4] and thermophoresis, with the approach also of value in investigations of the heat transfer performance and long-term thermal stability of nanoparticle dispersions which as yet have not been considered in detail. The outcome of this study allows conclusions to be reached regarding the implications for solar thermal energy storage systems using nanoparticle-seeded molten salts.

Keywords: Direct numerical simulation, Lagrangian particle tracking, nanofluids, turbophoresis, thermophoresis.

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