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Investigation of heat transfer enhancement in an enclosure filled with nanofluids using multiple relaxation time lattice Boltzmann modeling☆

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ABSTRACT

This work investigates the heat transfer performance in an enclosure including nanofluids with a localized heat source. The velocity field is solved by multiple relaxation time lattice Boltzmann modeling (MRT) which has superior numerical advantages to single relaxation time lattice Boltzmann modeling (SRT); however, heat transfer is simulated separately using SRT-lattice Boltzmann modeling. The hydrodynamics and thermal fields are then coupled together using the Boussinesq approximation. The main objective of this study is to investigate the influence of several pertinent parameters such as Rayleigh number, solid particle volume fraction of nanoparticles, and the geometry as well as location of the localized heat source on the heat transfer performance of nanofluids. The results obtained from lattice Boltzmann modeling clearly indicate that heat transfer augmentation is possible using nano-fluids in comparison to conventional fluids, resulting in the compactness of many industrial devices.

1. Introduction

Using nanofluids as a working fluid is an effective approach to meet some challenges associated with the conventional microfluids such as abrasion, clogging, rapid sedimentation and high pressure drop. Furthermore, nanofluids have distinguished thermal features such as high thermal conductivity and high surface to volume ratio, resulting in their perfect thermal performance. That's why nanofluids could be considered a practical approach to alleviate the repercussions of global warming, reduce the carbon footprints in our world and, more importantly, tackle our addiction to fossil fuels. Consequently, nanofluids can be widely used in the heat removal industry; for example, heat removal from electrical circuits. This is why intensive researches focus on the heat transfer augmentation utilizing nanofluids and their potential in cooling industry has been carried out recently [1], [2], [3], [4].

The discrepancies found in the literature as to whether the dispersion of nanoparticles in the base liquid improves the heat transfer performance or not, intrigued us to become more resolute to attack this problem using a mesoscopic method called multiple relaxation time (MRT) lattice Boltzmann modeling [5]. This work could also be an auspicious start to solve the nanofluid flow using a two-phase approach in which multiple relaxation time lattice Boltzmann is employed. Escobar and Amon [6] show that every continuum approach to heat transfer fails in micro/nano-scale phenomena and Fourier law is no longer applicable and Boltzmann equation is used to describe the phonon transport as the main carriers of the energy. Consequently, lattice Boltzmann modeling would enable us to model phonon transport in the two phase simulation. Furthermore, there is a lack of fundamental understanding as to what would be the best arrangement for the localized heat source in order to get the best thermal response out of the system. The present study is an attempt to address this shortcoming. Thermal lattice Boltzmann modeling falls into three categories, namely, the multispeed algorithm [7], the internal energy model [8] and the passive scalar model [9]. Shu et al. [10], have simulated the natural convection in a square enclosure using the Taylor series expansion and the least square method which is based on the lattice Boltzmann method (LBM). Mezhrab et al. [11], used hybrid lattice Boltzmann to simulate the convective heat transfer where the mass and momentum equations are solved using the multiple-relaxation model due to d'Humières et al. [12], whereas the diffusion–advection equation for the temperature is solved using the finite-difference technique.

To the best knowledge of the authors, no studies have been done before to investigate the heat transfer in an enclosure including nanofluids using multiple relaxation times (MRT), which has superior numerical features compared to that of the single relaxation time (SRT), such as: capability of modeling the high Rayleigh number flow field (convective-controlled flow field) and multiphase flow with high density ratio, as well as high numerical stability. Furthermore, we've taken advantages of using lattice Boltzmann modeling with respect to its simplicity of programming, the capability of being employed for

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