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Lattice Boltzmann simulation of natural convection in tall enclosures using water/SiO_2 nanofluid ☆

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ABSTRACT

Natural convection in enclosures using water/SiO_2 nanofluid is simulated with Lattice Boltzmann method (LBM). This investigation compared with other numerical methods and found to be in excellent agreement. This study has been carried out for the pertinent parameters in the following ranges: the Rayleigh number of base fluid, $Ra = 10^3$–10^5, the volumetric fraction of nanoparticles between 0 and 4% and aspect ratio (A) of the enclosure between 0.5 and 2. The thermal conductivity of nanofluids is obtained on basis of experimental data. The comparisons show that the average Nusselt number increases with volume fraction for the whole range of Rayleigh numbers and aspect ratios. Also the effect of nanoparticles on heat transfer augments as the enclosure aspect ratio increases.

1. Introduction

There is no need to say that Lattice Boltzmann methods (LBM) are in high pace development and have become a powerful method for simulation fluid flow and transport problems in single and multiphase flows [1,2]. Also this method has been utilized in a wide range of applications [3–7]. In this work, the method is applied for natural convection in enclosures using water/SiO_2 nanofluid. As diverse industrials including microelectronics, transportation, and manufacturing become more advanced, cooling technology is one of the most important challenges. For example cooling systems for electronic devices [8], chemical vapor deposition instruments (CVD) [9], furnace engineering [10], solar energy collectors [11], phase change material [12], non-Newtonian chemical processes [13,14], and domains are affected by electromagnetic fields [15,16]. Moreover, this problem has important applications in building energy systems [11] and architecture, e.g. an innovative technique to improve the heat transfer is using the nano-scale particles in the base fluid. Fluids with nanoparticles suspended in them are called nanofluids. This is because nanofluids have fascinating features .One of them is that nanofluids have anomalous high thermal conductivity at very low nanoparticles concentration [17] and considerable enhancement of forced convective heat transfer [18].

So many investigators have experimentally studied flow and thermal characteristics of nanofluids. Especially, in order to understanding buoyancy-driven heat transfer of nanofluids in a cavity several investigations have been theoretically and experimentally conducted. Putra et al. [19] conducted the experiment for observation on the natural convective characteristics of water based on Al_2O_3. They reported that natural convective heat transfer in a cavity is decreased with the increment of the volume fraction of nanoparticles. Kim et al. [20] analytically researched the convective instability driven by buoyancy and heat transfer characteristics of nanofluids with theoretical models which are used to estimate properties of nanofluids and indicated that as the thermal conductivity and shape factor of nanoparticles decrease, the convective motion in a nanofluid sets in easily and their results were similar with Putra et al. experimental investigation. Khanafer et al. [21] numerically investigated buoyancy-driven heat transfer enhancement in a two-dimensional enclosure utilizing nanofluids. Their paper shows the Nusselt number for the natural convection of nanofluids is increased with the volume fraction. Wen and Ding [22] showed that the local heat transfer coefficients increased 41% and 46% at $Re = 1050$ and 1600, respectively in the presence of nanoparticle volume fraction of 0.016. Jung et al. [23] reported that the heat transfer coefficient increased 32% by dispersing 1.8% nanoparticles in a micro-rectangular channel with Al_2O_3/water nanofluid. Abu-Nada et al. [24] investigated the influences of nanoparticle on the natural convection heat transfer enhancement in horizontal annuli with various nanoparticles and volume fractions. They reported an enhancement of heat transfer in horizontal annuli. A theoretical study on a heated cavity was reported by Hwang et al. [25]. They observed that the heat transfer coefficient of Al_2O_3/water nanofluids is reduced when there is an increase in the size of nanoparticles and a decrease in average temperatures. Khodadadi and Hosseinizadeh [26] investigated which nanoparticles within conventional phase change materials such as water. Their findings demonstrate that nano-enhanced phase change material

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