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Computer simulations of natural convection of single phase nanofluids in simple enclosures: A critical review

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ABSTRACT

The objective of the present work is to show that the internal natural convection of single phase nanofluids in enclosures can be easily predicted theoretically with no need to perform a numerical simulation provided that a reliable Nusselt number correlation for clear fluids in these enclosures is available. Six common enclosures shapes for which nanofluid heat transfer has been the subject of investigation in recent publications are selected for the present study. Computer simulations are performed to find the Nusselt number and the heat transfer coefficient for natural convection of nanofluids in horizontal and tilted square, horizontal and vertical annulus, triangular enclosure and the Rayleigh-Bénard convection configuration. The results of numerical simulations are compared with the prediction of a theoretical approach which uses the Nusselt correlations available in the literature for clear fluids. This comparison clearly shows that most of the earlier single phase numerical simulations for natural convection of nanofluids in cavities are redundant and the same predictions could be obtained theoretically in a much simpler way. The study was performed for Al_2O_3 and CuO nanofluids. In addition, critical reviews of recent publications on numerical simulation of natural convection of single phase nanofluids are presented.

1. Introduction

With presenting the concept of nanofluid in 1995, Choi [1] attracted the attention of many researchers who were interested in increasing the heat transfer coefficient of liquids in many industrial applications. Accordingly, suspension of even low volume fractions of nanoparticles in liquids augment the thermal conductivity of the mixture [2]. Many of the researchers have studied the heat transfer characteristics of nanofluids in last decade experimentally as well as computationally. There have been concerns that if the nanofluids behave as a single phase fluid or it has to be treated as a two-phase mixture [3]. Using a single phase model for nanofluid simplifies the application of computer simulation technique as only the material properties in the Navier–Stokes and energy equations need to be modified with appropriate correlations. This simplicity has attracted the attention of researchers for investigating the heat transfer behavior of nanofluids. For example, according to Science Direct database, in 2009 more than thirty papers reported the results for computational study of the natural convection of nanofluids using a single phase approach in region with simple geometries. A review of the recent publications reveals that a few researchers have simply extended the earlier performed numerical heat transfer studies for clear fluids to nanofluids using the single phase model. In most of these papers, the natural convection of one type of nanofluid for a specific shape of enclosure was investigated, which requires little computational effort. In addition some researchers seem to not follow the new findings in the literature and continue to use some old non-reliable models for properties of nanofluids in their numerical simulations and present a wrong prediction for heat transfer of nanofluids.

The present study is intended to show that the existing correlations for clear fluids could be extended and used for prediction of the nanofluids heat transfer in many applications. Thus, there is no need for performing numerical simulation for analyzing the bulk heat transfer of nanofluids with the use of single phase models in simple configurations. Computational modeling, however, would be required if there is a need for information on the isotherm and streamline patterns due to the addition of nanoparticles to a base fluid. In addition, numerical simulation would be needed to quantify the distribution of the heat flux along thermally active boundary surfaces of the enclosure.

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