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Experimental and numerical investigation of nanofluid forced convection inside a wide microchannel heat sink

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ABSTRACT

This paper aims to study the laminar convective heat transfer of an alumina-water nanofluid flow inside a wide rectangular microchannel heat sink (94.3 mm, 28.1 mm and 580 μm; length, width and height, respectively) both numerically and experimentally. For experimental study, a microchannel is made using a silicon wafer with glass layers. For the numerical study, a two-phase Eulerian–Eulerian method using the finite volume approach is adopted in this study. Comparing the experimental and numerical results show that two-phase results are in better agreement with experimental results than the homogeneous (single-phase) modeling. The maximum deviation from experimental results is 12.61% and 7.42% for homogeneous and two-phase methods, respectively. This findings show that the two-phase method is more appropriate than the homogeneous method to simulate the nanofluid heat transfer. Also, the two-phase results show that the velocity and temperature difference between the phases is very small and negligible. Moreover, the average Nusselt number increases with an increase in Reynolds number and volume concentration as well as with a decrease in the nanoparticle size.

1. Introduction

Development in the microfabrication technologies leads to production of very small scale electronic devices. The allowable temperatures for this kind of devices should be in a definite range to assure their performance. The microchannel heat sink (MCHS) that has been introduced by Tuckerman and Pease [1] is a suitable choice for cooling such electronic devices. But, due to the development in the microfabrication technology, the devices are getting smaller and smaller while the generated heat flux inside them increases. Therefore, an efficient cooling system is necessary to maintain their temperature in a safe range. Recent developments in nanotechnology show that the nanofluid is an efficient coolant for electronic devices [2].

According to the literature, there are many numerical and experimental studies regarding nanofluid heat and fluid flow on the macro and microscale. From the numerical aspect, most of the studies have been done using the homogeneous (single-phase) modeling for the nanofluid (e.g. [3–7]). In this method, the nanofluid is considered a homogeneous mixture of nanoparticles and the base liquid.

Compared to the plentiful literature for homogeneous modeling results for nanofluids, there is limited research in this area using the two-phase method. In the two-phase method, the nanoparticles and the base liquid are considered as separate phases and then the heat and momentum transfer between these phases is modeled using different models. Generally, in this method, the two-phases are considered with different velocity and temperatures. Behzadmehr et al. [8] used a two-phase mixture model to study the turbulent nanofluid convection inside a circular tube. Comparing with an experimental study they reported that the two-phase results are more precise than the homogeneous modeling results. However, they considered thermal equilibrium conditions for the phases. Mirmasoumi and Behzadmehr [9] used the same method as [8] to study the mixed convection of the nanofluid in a tube. Also, Mirmasoumi and Behzadmehr [10] and Akbarinia and Laur [11] investigated the nanoparticles size effect on the mixed convective heat transfer of a nanofluid using the two-phase mixture method.

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