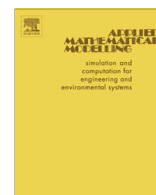




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Investigating the effect of various nanoparticle and base liquid types on the nanofluids heat and fluid flow in a microchannel

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ABSTRACT

In this paper, heat transfer and pressure drop of different nanofluid types in a two-dimensional microchannel is investigated numerically. To do this, an Eulerian–Eulerian two-phase model is used for nanofluid simulation and the governing equations are solved using a finite volume method. Nine different nanoparticles and three different base liquid types (water, ethylene glycol and engine oil) are considered. Heat transfer and pressure drop of different nanofluid types are compared at $Re = 100$ and 1% volume concentration for different nanoparticles and at constant inlet velocity for different base liquids. Numerical results show an almost equal pressure drop for all the nanoparticles dispersed in water, while, the heat transfer coefficient is highest for water–diamond and is the lowest for water– SiO_2 nanofluids. Also, the pressure drop for water-based nanofluid is very lower than the others and the heat transfer coefficient is the highest for water-based nanofluids.

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1. Introduction

One way to enhance the heat transfer rate is to increase the thermal conductivity of the flowing fluid. In the past years, it has been shown that nanofluids have higher thermal conductivities compared to the base liquids and also enhance the heat transfer rates (e.g. [1–4]). Also, the recent developments in the nanotechnology make a possibility to produce different types of nanoparticles for using in the nanofluids. Thus, different base liquid and nanoparticle types have been considered as a cooling fluid in thermal systems. A good review of such studies can be found in [5].

In the literature, there are many experimental and numerical studies governing the nanofluid heat transfer and pressure drop. In the experimental studies, most of the researchers have reported an increase in heat transfer rate with an increase in Reynolds number and volume concentration (such as [6–8]). Selvakumar and Suresh [6] carried out an experimental study for CuO–water nanofluid in a copper heat sink. Two volume concentrations of 0.1% and 0.2% were used in the study and the results showed a 29.63% increase in heat transfer coefficient for 0.2% nanofluid compared to the pure water. Ho and Chen [7] experimentally studied alumina–water nanofluid flow and heat transfer in a rectangular minichannel heat sink and reported a significant increase in heat transfer coefficient compared to the water-cooled heat sink. Effect of nanoparticle volume concentration and surfactants on the heat transfer performance of nanofluids flow in a parallel microchannel configuration was examined by Byrne et al. [8]. Their results showed the importance of using surfactants to have proper suspension of nanoparticles in the base fluid.

From numerical aspect, the nanofluid studies can be divided to homogeneous and two-phase methods. Most of the numerical solutions have been done using a homogeneous model: Maiga et al. [9] used a homogeneous method to investigate the water– $\gamma-Al_2O_3$ and ethylene glycol– $\gamma-Al_2O_3$ nanofluid heat transfer in a circular tube and reported better heat transfer

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Nomenclature

A	defined in Eq. (20)
B	defined in Eq. (19)
c_p	specific heat at constant pressure (J/kg K)
C_d	drag coefficient
d_p	nanoparticle diameter (m)
D_h	hydraulic diameter (m)
F_d	drag force (Pa/m)
$\bar{h}$	average heat transfer coefficient (W/m ² K)
h	heat transfer coefficient (W/m ² K)
h_v	volumetric heat transfer coefficient (W/m ³ K)
h_p	liquid-particle heat transfer coefficient (W/m ² K)
H	channel height (m)
k	thermal conductivity (W/m K)
L	channel length (m)
$\bar{Nu}$	average Nusselt number
Nu_p	particle Nusselt number
p	pressure (Pa)
P	non-dimensional pressure
Pr	liquid phase Prandtl number
Re	Reynolds number ($\rho_l u_{in} D_h / \mu_l$)
Re_p	particle Reynolds number
u, v	velocity components in the x and y directions, respectively (m/s)
U, V	non-dimensional velocity in the x and y directions, respectively
$\vec{V}$	velocity vector (m/s)
T	temperature (K)
x, y	axial and vertical coordinates, respectively (m)
X, Y	non-dimensional axial and vertical coordinates, respectively

Greek symbols

β	friction coefficient (kg/m ³ s)
Γ	defined in Eq. (18)
θ	non-dimensional temperature
μ	viscosity (Pa s)
ρ	density (kg/m ³)
φ	volume concentration
ω	defined in Eq. (20)

Subscripts

b	bulk
eff	effective
i	phase index (=l, p)
in	inlet
l	liquid phase
m	mean
p	particle phase
w	wall

enhancements for ethylene–glycol based nanofluids. Hung et al. [10] investigated the nanofluid flow and heat transfer in a rectangular microchannel heat sink (MCHS). Using a numerical homogeneous model, they studied the nanoparticle type, base liquid type, particle volume concentration, particle size and pumping power effects on heat transfer performance of the MCHS. Their simulation results showed better heat transfer performance for water–alumina nanofluids compared to the other nanoparticle types. Also, they found a lower overall thermal resistance (i.e., higher heat transfer rates) for water-based nanofluids. Hung and Yan [11] carried out another study similar to [10] for nanofluid flow in rectangular double-layered microchannel heat sinks and reported better heat transfer performance for water–alumina nanofluids. Mohammed et al. [12] studied the effect of different nanoparticle types on the nanofluid heat transfer and pressure drop. They used homogeneous model for nanofluid flow in a triangular microchannel heat sink and reported that water–diamond and water–Ag nanofluids have higher heat transfer and lower pressure drop, respectively. Bayat and Nikseresht [13] considered alumina nanoparticles dispersed in three different base liquids. Using the homogeneous model, they reported that ethylene–glycol

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