International Journal of Thermal Sciences 50 (2011) 61–72

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

Numerical investigation of cooling performance with the use of Al_2O_3/water nanofluids in a radial flow system

Yue-Tzu Yang*, Feng-Hsiang Lai

Department of Mechanical Engineering, National Cheng Kung University, Tainan 70101, Taiwan

ARTICLE INFO

Article history:
Received 8 March 2010
Received in revised form
26 August 2010
Accepted 30 August 2010
Available online 2 October 2010

Keywords:
Nanofluids
Radial flow
Laminar forced convection
Heat transfer enhancement
Heat flux

ABSTRACT

Simulation is conducted to investigate the forced convection flow of Al_2O_3/water nanofluid in a radial flow cooling system using a single phase approach. Computations are validated with experimental data available in the literature. Results show the same trend as revealed in some of the published works that the Nusselt number increases with the increase of Reynolds number and nanoparticle volume fraction, though the increase in pressure drop is more significant with the increase of particle concentration. Temperature-dependent thermophysical properties of nanofluids are found to have a marked bearing on the simulation. Under a fixed pumping power the nanofluid shows no higher heat transfer rate than water at heat flux $q'' \leq 3900\ \mathrm{W/m^2}$, while as the heat flux increases the enhancement using a nanofluid becomes more remarkable. Considerable improvements in the average Nusselt number and significant reductions in the thermal resistance under a given pumping power are revealed compared to that of pure water at some supplied heat fluxes. For 4% Al_2O_3/water mixture at $PP_{rel} = 0.5$, the average Nusselt number increases by about 4% and 10% respectively as the heat flux $q'' = 16{,}000\ \mathrm{W/m^2}$ and $q'' = 34{,}000\ \mathrm{W/m^2}$ is applied, while the thermal resistance can be reduced by 2.3% and 7%.

1. Introduction

Nanotechnology is considered by many researchers to be one of the significant forces that drive the next major industrial revolution of this century. A significant research effort has been committed to exploring the thermal transport properties of colloidal suspensions of nanosized solid particles (nanofluids). The presence of the nanoparticles in the fluids increased appreciably the effective thermal conductivity of the fluid and consequently enhanced the heat transfer characteristics. Nanofluids have a distinctive characteristic which is quite different from those of traditional solid-liquid mixtures in which milli-meter or micro-meter sized particles are involved. Thus, nanofluids are best for applications in which fluid flows through small passages because nanoparticles are small enough to behave similar to liquid molecules.

Experimental works [1,2] reported that with low nanoparticles concentrations (1–5 vol%), the effective thermal conductivity of the suspensions can increase by more than 20% for various mixtures. Xuan and Li [3] studied turbulent flow in a straight tube using a Cu/water nanofluid and revealed a 40% heat transfer enhancement. The forced convection flows of CNT (carbon nanotube) nanofluids through a horizontal tube were investigated by Ding et al. [4]. The results showed remarkable enhancement of the convective heat transfer and the enhancement depends on the flow conditions (Reynolds number), CNT concentration and the pH value, with the smallest effect of pH. Furthermore, for nanofluids containing 0.5 wt.% CNTs, the maximum enhancement was found to reach over 350% at Re = 800, which could not be attributed purely to the enhanced thermal conduction. Turbulent flow and heat transfer of three different nanofluids (CuO, Al_2O_3 and SiO_2) in an ethylene glycol and water mixture flowing through a circular tube under constant heat flux condition were numerically analyzed [5]. It was noted that at a constant Reynolds number, Nusselt number increases by 35% for 6% CuO nanofluids over the base fluid. The application of 6 nm copper-in-water and 2 nm diamond-in-water nanofluids in the micro-channel heat sinks was numerically discussed [6], and the Brownian motion was accounted in the mathematical model. Chakraborty and Roy [7] theoretically analyzed the influence of nanofluids on thermally developing and hydrodynamically developed electroosmotic transport in parallel plate microchannels. It was revealed that the influences of the nanofluids are much more conspicuous in the thermal entrance region, as compared to the thermally fully developed region. Moreover, appreciable effects of nanofluids are only observed for higher values of Peclet numbers, whereas their influences are virtually imperceptible for a lower Peclet number. Ho et al. [8] conducted experiments to investigate the cooling performance of

* Corresponding author. Tel.: +886 6 2757575x62172; fax: +886 6 2352973.
E-mail address: ytyang@mail.ncku.edu.tw (Y.-T. Yang).

1290-0729/$ – see front matter © 2010 Elsevier Masson SAS. All rights reserved.
doi:10.1016/j.ijthermalsci.2010.08.017