International Journal of Heat and Mass Transfer 76 (2014) 350–356

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

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

Thermal conductivity variation for methanol based nanofluids

R.M. Mostafizur [a], M.H.U. Bhuiyan [a], R. Saidur [a,*], A.R. Abdul Aziz [b]

[a] Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Department of Chemical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 5 December 2013
Received in revised form 15 April 2014
Accepted 16 April 2014
Available online 21 May 2014

Keywords:
Nanoparticles
Methanol
Nanofluids
Thermal conductivity
Volume fraction

ABSTRACT

Nanofluids refer to mixtures of solid nanoparticles suspended in base fluids. Nanofluids have gained popularity in heat transfer applications due to its attractive thermal characteristics. Thermal conductivity is one of the main parameters to which the applicability of nanofluids is attributed, as it affects the heat transfer coefficient. Three types of nanoparticles, namely Al_2O_3, SiO_2 and TiO_2 were suspended in methanol solution at five volume fractions (0.005%, 0.01%, 0.05%, 0.1% and 0.15%) in this work. Thermal conductivity was measured at five different temperatures (1, 5, 10, 15 and 20 °C) using a KD_2 pro thermal conductivity meter. Thermal conductivity increases with the increase of volume fraction of nanoparticles for all types of nanoparticles investigated in this work. Enhancements between 1–8% occurred in thermal conductivities for every 0.05 vol% increase in nanoparticle volume fraction with Al_2O_3 having the highest enhancement. Thermal conductivity also increased between 0.5–3.9% for every 5 °C increment in temperature with SiO_2 showing the least change. This study demonstrates that favorable thermal conductivity values and can be obtained for a specific type of nanoparticle at a specific temperature and volume fraction. Finally, a new correlation has been proposed for thermal conductivity of methanol based nanofluids in terms of volume concentration based on the experimental data.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

"Nanofluids" is a term corresponding to a new class of fluids with enhanced thermo-physical properties produced by suspension of fine nanoparticles (in the size range of 1–100 nm) in a base fluid [1]. Recently, researchers have used these nanoparticles for various applications in the field of heat transfer. The first decade in the research on nanofluids primarily focused on measuring and modeling fundamental thermo-physical properties such as thermal conductivity, density, viscosity and heat transfer coefficient. Nowadays, researchers are trying to explore the performance of nanofluids in a wide variety of applications. As conventional cooling fluids such as water and air shows inadequate capability to dispatch the heat from industrial equipment, researchers have been searching for a suitable means of efficient cooling [2]. Many studies have recommend using nanofluids in various industrial applications such as power generation, chemical process, microelectronics, transportation, air condition and micro-sized applications [3,4]. Thus, a lot of experimental work and theoretical models have been developed by the researchers to improve the thermal properties of nanofluids [5–8].

Thermal conductivity is one of the most important parameters for investigating the heat transfer enhancement of nanofluids [9]. Higher-thermal-conductivity materials are mostly used in heating or cooling applications whereas lower-thermal-conductivity materials are mainly used for insulation purpose. One of the most promising methods for improving the thermal conductivity of the fluids is to add solid particles into the base fluids in a suspension [9]. However, if the suspended particles size is of millimeter or micrometer, the fluid appears unsteady and sedimentation, clogging and corrosions are developed [6]. To remove these problems, nanofluids with enhanced thermal performance execute a high-class heat transfer fluids. Numerous experimental data and theoretical models have explored the enhancement in thermal conductivity [8,10–12]. They showed that addition of small volume percentage of solid particles dramatically changes the thermal conductivity of the base fluids. However, the experimental results showed that thermal conductivity of nanofluids is influenced by other parameters such as nanoparticle materials, shape, size and base fluid properties as well as operating temperature [6].

A great number of works have experimentally measured the thermal conductivity for different types of nanoparticles suspended in base fluids such as water, oil, ethylene glycol, organic

---

* Corresponding author. Tel.: +60 3 79677611; fax: +60 3 79675317.
E-mail addresses: mostafiz.rahman@live.com (R.M. Mostafizur), mhub2k2@yahoo.com (M.H.U. Bhuiyan), saidur@um.edu.my (R. Saidur), azizraman@um.edu.my (A.R. Abdul Aziz).

http://dx.doi.org/10.1016/j.ijheatmasstransfer.2014.04.040
0017-9310/© 2014 Elsevier Ltd. All rights reserved.

Nomenclature

a	original particle radius (nm)
d_{np}	diameter of nanoparticle (nm)
E_k	thermal conductivity enhancement
h	nanolayer thickness (nm)
k_{bf}	thermal conductivity of base fluid (W/m K)
k_{nf}	thermal conductivity of nanofluid (W/m K)
k_{np}	thermal conductivity of nano-particle (W/m K)
n	empirical shape factor
T	temperature (K)
w_{bf}	weight of base fluid (g)
w_p	weight of nanoparticle (g)

Greek symbols

ϕ	particle volume fraction (%)
ψ	sphericity
ρ_{bf}	density of base fluids (kg/m^3)
ρ_p	density of nanoparticles (kg/m^3)

Subscripts

bf	base fluid
nf	nanofluid

solvents, ionic liquids, etc. The commonly used nanoparticles include metals, metal oxides, metal carbides, nitrides, nanotubes and other compounds [9,13]. Turgut et al. [14] experimentally found that the thermal conductivity increased with an increase in particle volume fraction. They observed a 7.4% increase in thermal conductivity compared with the base fluid (water) for 3% volume fraction of TiO_2 nanoparticles at 13 °C. Zhang et al. [15] also measured thermal conductivities of different nanofluids for a temperature range of 5 °C to 50 °C using transient hot-wire method. They used Au–toluene, Al_2O_3–water, TiO_2–water, CuO–water and CNT–water nanofluids with the average particle diameters of 1.65, 20, 40, 33 and 150 nm respectively. There results were accurately predicted by Hamilton and Crosser equation for spherical nanoparticles.

Pang et al. [16] found 14.29% and 10.74% increments thermal conductivity of methanol-based nanofluids for the concentration of 0.5 vol% at 293.15 K for SiO_2 (particle size 10–20 nm) and Al_2O_3 (particle size 40–50 nm) nanoparticles respectively. Moreover, Pang et al. [17] experimentally found increments of up to 6.5% in the thermal conductivity of 10 wt% NaCl, 40 vol% CH_3OH mixed with 0.1 vol% concentration of Al_2O_3. Firouzfar et al. [18] used methanol–silver nanofluids in a thermosyphon heat exchanger to compare the energy savings with that of pure methanol. Their results showed that methanol–silver nanofluids showed energy savings of about 8.8–31.5% for cooling and 18–100% for reheating in an air conditioning system.

Methanol was used as a working fluid of a heat pipe for a temperature range of 200–500 K [19]. Different type of heat pipes like conventional, vapor–dynamic thermosyphons, sorption and micro/miniature heat pipe [20] have recently been used for heat transfer applications. The methanol based nanofluids were also used as a working fluids in HVAC systems [18]. Therefore, the thermo-physical properties of methanol based nanofluids should be designated for heat transfer applications. The main objective of this study is to measure the thermal conductivity of methanol-based nanofluids considering different values of temperatures and volume fractions.

2. Experiment

2.1. Chemicals and materials

In this study, methanol (CH_3OH) was used as a base fluid to prepare the nanofluids using Al_2O_3, SiO_2 and TiO_2 nanoparticles. Table 1 shows the thermo-physical properties of these nanoparticles obtained from literatures [21,22] and properties of pure methanol were taken from manufacturer material data sheet. The nanoparticles were procured from Sigma Aldrich (Malaysia).

2.2. Preparation of nanofluids

The nanoparticle volume fraction was calculated using the Scherrer's equation [23] as follows:

$$\text{Volume concentration, } \phi = \left(\frac{w_p/\rho_p}{w_p/\rho_p + w_{bf}/\rho_{bf}}\right) \quad (1)$$

Then the two-step method was applied to prepare the methanol-based nanofluids at different volume fractions. Firstly, the nanoparticles were suspended into the base fluid (methanol) followed by shaking in the incubator for 30 min at 150 rpm. The mixture was dispersed afterwards using an ultra-sonication homogenizer so that, the nanoparticles are uniformly and evenly distributed. The sonication process was maintained for 2 h at the frequency of 20 Hz and power equals to 500 W.

2.3. Thermal conductivity measurement

The thermal conductivity measurement by steady-state methods is not suitable for liquids, because it needs a longer time and the heat loss during this period cannot be quantified, which may lead to large errors in results. Moreover, natural convection might take place during this period causing an additional error in the results. In this study, thermal conductivity was measured by using a KD_2 pro thermal conductivity meter (Made in Decagon, USA). This device measures thermal conductivity by transient hot wire method over the range of 0.02–2.00 W/m K. The accuracy of the equipment is ±0.001% for measurement within the mentioned range. Thermal conductivity of Al_2O_3–methanol, SiO_2–methanol and TiO_2–methanol at various volume fractions (0.005%, 0.01%, 0.05%, 0.1% and 0.15%) was measured at temperatures of 1, 5, 10, 15 and 20 °C, respectively. All the data were recorded for three times and the corresponding average values were analyzed for result. The measured values of methanol-based nanofluids were then compared with those obtained by the existing models. One of the most common models for the thermal conductivity measurement had been proposed by Hamilton and Crosser [24]. This model considered the nanoparticle shape factor and is expressed as follows:

Table 1
Thermo physical properties of nanoparticles & chemicals.

Parameter	Al_2O_3	SiO_2	TiO_2	Methanol
Molecular mass (g/mol)	101.96	60.08	79.87	32.04
Average particle diameter (nm)	13	5–15	21	–
Purity (%)	99.5	99.5	99.5	99.8
Density (kg/m^3)	4000	2200	4260	792
Thermal conductivity (W/m K)	40.0	1.2	8.4	0.204

Download English Version:

https://daneshyari.com/en/article/7056791

Download Persian Version:

https://daneshyari.com/article/7056791

Daneshyari.com