International Communications in Heat and Mass Transfer 38 (2011) 742–748

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

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

Enhancement of heat transfer using CuO/water nanofluid and twisted tape with alternate axis ☆

Khwanchit Wongcharee [a], Smith Eiamsa-ard [b,*]

[a] Department of Chemical Engineering, Faculty of Engineering, Mahanakorn University of Technology, Bangkok 10530, Thailand
[b] Department of Mechanical Engineering, Faculty of Engineering, Mahanakorn University of Technology, Bangkok 10530, Thailand

ARTICLE INFO

Available online 22 March 2011

Keywords:
Heat transfer enhancement
Friction factor
Twisted tape
Nanofluid
Alternate axis
CuO

ABSTRACT

Heat transfer, friction and thermal performance characteristics of CuO/water nanofluid have been experimentally investigated. The nanofluid was employed in a circular tube equipped with modified twisted tape with alternate axis (TA). The concentration of nanofluid was varied from 0.3 to 0.7% by volume while the twisted ratio (y/W) of TA was kept constant at 3. The experiments were performed in laminar regime (Reynolds number spanned $830 \leq Re \leq 1990$). The uses of nanofluid together with typical twisted tape (TT), TA alone and TT alone were also examined. To evaluate heat transfer enhancement and the increase of friction factor, the Nusselt number and friction factor of the base fluid in the plain tube were employed as reference data. The obtained results reveal that Nusselt number increases with increasing Reynolds number and nanofluid concentration. By the individual uses of TA and TT, Nusselt numbers increase up to 12.8 and 7.2 times of the plain tube, respectively. The simultaneous use of nanofluid and TA improves Nusselt number up to 13.8 times of the plain tube. Over the range investigated, the maximum thermal performance factor of 5.53 is found with the simultaneous employment of the CuO/water nanofluid at 0.7% volume and the TA at Reynolds number of 1990. In addition, the empirical correlations for heat transfer coefficient, friction factor and thermal performance factor are also developed and reported.

1. Introduction

Heat transfer enhancement using nanofluids has gained significant attention over the past few years. Nanofluids are potentially applicable as alternative coolants for many areas such as electronics, automotive, air conditioning, power generation and nuclear applications [1]. Several published researches have concluded that the use of nanofluid effectively improved the fluid thermal conductivity which consequently enhanced heat transfer performance. Several types of nanoparticles have been employed for nanofluid preparation, including metals such as gold (Au), copper (Cu) and silver (Ag) and also metal oxides such as TiO_2, Fe_3O_4, Al_2O_3 and CuO [2–8]. Due to their significantly lower cost, metal oxides are more attractive for heat transfer enhancement application compared to metals. Among the spherical metal oxides, CuO shows an outstanding performance in the improvement of thermal conductivity as shown in Table 1.

Recently, nanofluids were used simultaneously with other heat transfer enhancing devices [1,9,10]. Chandrasekar et al. [1], reported the heat transfer and friction factor characteristics of Al_2O_3/water nanofluid in a circular pipe under laminar flow with wire coil inserts. It was found that Nusselt number increased by 12.24% at $Re = 2275$ by the use of the nanofluid with concentration of 0.1% volume compared to that of the base fluid (distilled water). By the uses of two wire-coil inserts with pitch ratios of 2 and 3 together with the nanofluid, Nusselt numbers were further enhanced by 21.5% and 15.9% respectively. Sundar and Sharma [9] studied the turbulent heat transfer and friction factor of Al_2O_3 nanofluid in circular tube with twisted tape inserts. Their results revealed that when nanofluid (0.5% volume) and twisted tape (twist ratio of 5) were used simultaneously, heat transfer coefficients at Reynolds numbers of 10,000 and 22,000 were higher than those of water in a plain tube by 33.51% and 42.17% respectively. Pathipakka and Sivashanmugam [10], numerically studied heat transfer behaviour of nanofluids in a uniformly heated circular tube fitted with helical inserts in laminar flow. Al_2O_3 nanoparticles in water of 0.5%, 1% and 1.5% concentrations and helical twist inserts of twist ratios 2.93, 3.91 and 4.89 were employed for the simulation. Compared to the base fluid, the maximum heat transfer enhancement of 31.29% was found with the use of helical insert of twist ratio 2.93 together with nanofluid with volume concentration of 1.5% at Reynolds number of 2039.

According to the above literature, it is evident that the simultaneous use of nanofluid and twisted tape efficiently further improved heat transfer rate with respect to the individual use of twisted tape or nanofluid. However, only the combined effect of nanofluid and typical twisted tape was reported [9,10]. On the other hand, several

☆ Communicated by W.J. Minkowycz.

* Corresponding author.
E-mail address: smith@mut.ac.th (S. Eiamsa-ard).

0735-1933/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2011.03.011