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Experimental investigation on heat transfer characteristics and pressure drop of BPHE (brazed plate heat exchanger) using TiO_2–water nanofluid

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ABSTRACT

In this research, the effect of using TiO_2–water nanofluid on heat transfer enhancement and pressure drop in a Brazed Plate Heat Exchanger used in domestic hot water system is investigated experimentally. TiO_2 nanoparticles with 20 nm diameter and 99+% purity are used for making the nanofluid at 0.3%, 0.8% and 1.5% weight concentration of suspended nanoparticles, in such experiments. This study is done on the brazed plate heat exchanger under turbulent flow condition. The effects of Reynolds number and weight concentration of nanoparticles on the heat transfer characteristics are investigated experimentally. This results in a significant increase in convective heat transfer coefficient through adding nanoparticles to distilled water. The results show that, the convective heat transfer coefficient and the overall heat transfer coefficient of TiO_2–water nanofluid is increased with enhancement of Reynolds number and at a specified Reynolds number, heat transfer characteristics is enhanced by increasing weight concentration of nanoparticles in brazed plate heat exchanger. The maximum enhancement of the nanofluid convective heat transfer coefficient at 0.3%, 0.8% and 1.5% weight fraction of nanoparticles are about 6.6%, 13.5% and 23.7% respectively. Also the maximum enhancement of the nanofluid overall heat transfer coefficient at mentioned weight concentrations of nanoparticles are about 2.2%, 4.6% and 8.5% respectively. Finally, the nanofluid pressure drop at various levels of nanoparticles is measured experimentally. According to these results, increment in system pressure drop is negligible compared to the heat transfer improvement.

1. Introduction

Nowadays Heat exchangers have a comprehensive application in industries. The brazed plate heat exchanger is a compact heat exchanger with high efficiency, operability at higher pressure, small size and low cost rather than most other compact heat exchangers, which are used in refrigeration and heat pump systems, process water heating and domestic hot water system that shown in Fig. 1. Due to the limitation of fossil energy sources, reducing the thermal energy used to produce hot water in buildings – which comprise a large portion of domestic energy consumption – may lead to economization in energy. Some experimental studies on enhancement of plate heat exchanger heat transfer by changes in its physical specification such as the effect of changes in plate configuration and the effect of increment in plate roughness were performed by researchers [1–3]. Due to the poor heat transfer properties of common fluids used in heat exchangers such as water, mineral oil and ethylene glycol, it is obvious that improvement of these properties will lead to increased efficiency. Solids such as metals and metal oxides are more thermal conductive compared with common heat transfer fluids like water. The idea of increasing the thermal conductivity of fluids by adding and suspending nanoparticles in a base fluid has been offered by Choi [4] for the first time. Some thermo-physical properties of base fluid such as convective heat transfer coefficient and thermal conductivity, enhanced significantly by adding and suspending metal or metal oxide nanoparticles in it. These fluids are named "nanofluids". Some researches about the effects of using nanofluids on heat transfer are mentioned as follows:

An experimental investigation on the convective heat transfer of Al_2O_3–water and TiO_2–water nanofluids in a horizontal circular tube was done by Pak and Cho [5]. They found that, the nanofluids Nusselt number increased with enhancement of Reynolds number and volume fraction of nanoparticles. Also they offered the first empirical correlation for predicting the nanofluid Nusselt number in a turbulent tube flow. The convective heat transfer and flow

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Nomenclature

Q	heat transfer rate (W)
U	overall heat transfer coefficient (W/m^2 K)
h	convective heat transfer coefficient (W/m^2 K)
$\dot{m}$	mass flow rate (kg/s)
u	fluid flow velocity (m/s)
C_p	specific heat (J/kg K)
k	thermal conductivity (W/m K)
N	number of corrugated plates
T	temperature of the fluid flow (°C)
A	heat transfer area of heat exchanger (m^2)
b	gap between two plates (m)
W	width of channel (m)
L	length of plates (m)
L_p	port to port length (m)
D_h	hydraulic diameter of channel (m)
P_c	corrugation pitch (m)
Δx	plate thickness (m)
ΔT_{LMTD}	logarithmic mean temperature difference (°C)
Δp_t	total pressure drop (pa)
Δp_{ch}	channel pressure drop (pa)
Δp_p	ports pressure drop (pa)
Re	Reynolds number ($\rho UD/\mu$)
Pr	Prandtl number ($C_p\mu/k$)
Nu	Nusselt number (hD/k)
f	friction factor

Greek symbols

μ	dynamic viscosity (Pa s)
ρ	mass density (kg/m^3)
φ	volume concentration
β	chevron angle of BPHE

Subscripts

o	outer edge
i	inner edge
c	cold
h	hot
np	nanoparticle
m	metal plate
f	fluid
bf	base fluid
nf	nanofluid
w	water

Abbreviations

HTC	heat transfer coefficient
BPHE	brazed plate heat exchanger

characteristics of Cu–water nanofluid inside a straight tube under constant heat flux boundary condition investigated, experimentally by Li and Xuan [6,7]. They reported that the convective heat transfer of nanofluid substantially increased compared with distilled water. Yang et al. [8] studied the convective heat transfer coefficient of graphite–water nanofluid in a horizontal tube heat exchanger. Based on their results, the convective heat transfer coefficient enhanced with increasing the volume fraction of graphite nanoparticles and Reynolds number. Heris et al. [9,10] in two experimental researches studied the convective heat transfer coefficient of Al_2O_3–water and CuO–water nanofluids inside a circular pipe with constant wall temperature. The results of their experiments showed that the convective heat transfer coefficient increased with enhancement of Peclet number and volume fraction of nanoparticles, such that this enhancement by using Al_2O_3 nanoparticle was more than Cuo nanoparticle. The effect of CuO–water nanofluids at 4% volume concentration of nanoparticles on the performance of a miniature plate heat exchanger investigated, both numerically and empirically by Pantzali et al. [11]. According to their reports, heat transfer raised about 18% by using the nanofluid in comparison with distilled water. Duangthongsuk and Wongwises [12,13] studied on the heat transfer and flow characteristics of TiO_2–water nanofluid with 0.2% volume concentration of nanoparticles in a double tube heat exchanger. Their experiment results indicated that the convective heat transfer coefficient of nanofluid enhanced rather than the distilled water and this enhancement was about 6–11% more than the base fluid. Farajollahi et al. [14] investigated Heat transfer of γAl_2O_3–water and TiO_2–water nanofluids in a shell and tube heat exchanger, experimentally. They used the mentioned nanofluids at 0.3%, 0.5%, 0.75%,

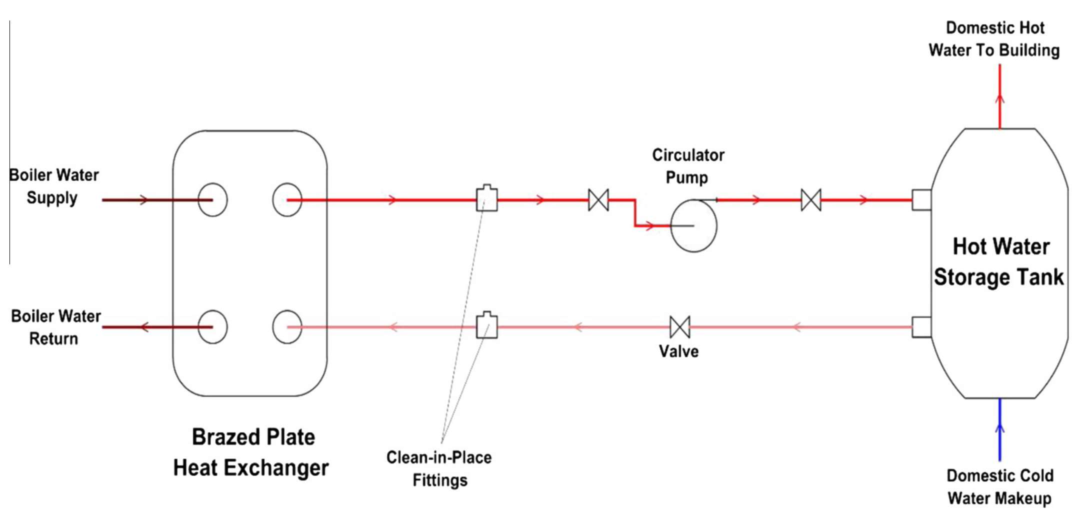

Fig. 1. Schematic of the domestic hot water system using BPHE.