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Experimental study of sensible heat storage/retrieval in/from a nanofluid enclosed between concentric annular tubes

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Abstract

In this work, an experimental study has been carried out to quantify an amount of sensible heat storage/recovery in a specific nanofluid (distilled water +Titanium dioxide). The experimental results show, especially, the influence of nanoparticles mass concentration on the heat storage/recovery performance for a fixed mass flow rate (Γ= 300 kg/h) of heat transfer fluid (HTF). This parameter contributes to the improvement of the heat transfer and therefore the enhancement of the sensible heat storage/retrieval.

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Keywords: Sensible heat storage; Heat transfer fluid; Nanoparticles; Nanofluid; Titanium dioxide; Nanoparticles mass concentration

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1. Introduction

The nanofluid discussed in this work concern fluid containing dispersed nano-meter sized particles (nanoparticles). The thermal conductivity of nanoparticles is greater than that of the base liquid, it is expected to increase the thermal conductivity of nanofluid to very low concentrations. Several experimental and theoretical results agree on improving the heat exchange with the addition of nanoparticles compared to base fluids [1-7]. Thus, the experimental study of Ding et al. [1] showed that the addition of low concentrations of nanoparticles (carbone nanotubes) leads to an increase in the convective heat exchange coefficient compared to the case of single-phase fluid. Khanafer et al. [2] presented a numerical research investigation of natural convection in a two-dimensional enclosure to determine convective heat transfer coefficient in nanofluids. In their study, the nanofluid was assumed to be single-phase in the enclosure and the effect of suspended nanoparticles on buoyancy-driven heat transfer process was analyzed. Furthermore, it was observed that the heat transfer rate increased as the particle volume fraction increased at any given dimensionless Grashof number. The Titanium dioxide nanoparticles were used in the numerical study conducted by Yurong et al. [3] in which convective heat transfer of nanofluid is flowing through a straight tube under the laminar flow. In this numerical investigation, both single phase method and combined Euler and Lagrange method were utilized. The obtained results are compared with the experimental data and show significant enhancement of heat transfer of nanofluids.

In 2013, an experimental comparison of heat transfer behavior between metal oxide nanofluid flows through helical coiled tube with uniform heat flux boundary condition was carried out by Kahani et al. [4]. According to this study, a significant enhancement to the heat transfer rate through the use of Al_2O_3 and TiO_2 nanoparticles at 1% volume concentration under laminar and turbulent flow, takes place. Recently, Haghighi et al. [5] experimentally investigated convective heat transfer of nanofluids in turbulent flow inside a circular tube. Additionally, they concluded that both heat transfer and pressure drop can be predicted with the help of conventional correlations developed for single phase fluids.

A literature review can show that the majority of studies have focused on the heat transfer improvement through the use of nanofluids [1-7] whereas, to our knowledge, the heat storage/recovery has practically never been studied. So, this work highlights the heat storage/retrieval capacity of the Titanium dioxide nanofluid during charging/discharging cycle.

Nomenclature

C_p	Specific heat capacity, ($J.kg^{-1}.K^{-1}$)
Q_{HTF}	Heat flux of the heat transfer fluid, (W)
r	Radial distance from the wall of HTF pipe, (m)
t	Time, (s)
T_{in}	Inlet temperature (see Fig. 1), (°C)
T_H	Mean temperature of hot water, (°C)
T_C	Mean temperature of cold water, (°C)
T_{out}	Outlet temperature (see Fig. 1), (°C)
ΔT	Temperature difference, (°C)
Δt	Time interval, (s)
Z	Axial distance from the bottom of annular space, (m)
V	Volume between concentric annular tubes, (m^3)
Γ	Mass flow rate, ($kg.h^{-1}$)
ϕ	Nanoparticles mass concentration, (%)
Φ	Heat flux density, ($W.m^{-2}$)
ρ	Density, ($kg.m^{-3}$)