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Heat transfer enhancement using nanofluids in an automotive cooling system ☆

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ABSTRACT

The increasing demand of nanofluids in industrial applications has led to increased attention from many researchers. In this paper, heat transfer enhancement using TiO_2 and SiO_2 nanopowders suspended in pure water is presented. The test setup includes a car radiator, and the effects on heat transfer enhancement under the operating conditions are analyzed under laminar flow conditions. The volume flow rate, inlet temperature and nanofluid volume concentration are in the range of 2–8 LPM, 60–80 °C and 1–2% respectively. The results showed that the Nusselt number increased with volume flow rate and slightly increased with inlet temperature and nanofluid volume concentration. The regression equation for input (volume flow rate, inlet temperature and nanofluid volume concentration) and response (Nusselt number) was found. The results of the analysis indicated that significant input parameters to enhance heat transfer with car radiator. These experimental results were found to be in good agreement with other researchers' data, with a deviation of only approximately 4%.

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1. Introduction

The main reason solid particles less than 100 nm are added to a liquid is to improve its thermal properties; this new fluid is then defined as a nanofluid. Solid metallic or nonmetallic materials dispersed in base fluids such as water, ethylene glycol and glycerol have become a topic of interest in recent years [1–7]. There are various applications of thermo fluid systems, including automotive cooling systems [8,9]. Base fluids (water, ethylene glycol and glycerol) have been used as conventional coolants in an automobile radiator for many years; however, these offered low thermal conductivity, which has prompted researchers to find fluids that offer higher thermal conductivity compared to that of conventional coolants. This resulted in nanofluids being used instead of these base fluids [10,11]. Forced convection heat transfer to cool circulating water from an automobile radiator was carried out by Peyghambarzadeh et al. [12]. The effects of different amounts of Al_2O_3 nanoparticles on the heat transfer performance of the automobile radiator were determined experimentally. The range of flowrate changed from 2 to 6 LPM with the changing inlet temperature of the fluid for all the experiments. The results showed a 40% increase in heat transfer by nanofluids compared to water. A numerical study of laminar heat transfer (CuO and Al_2O_3) with ethylene glycol and water inside the flat tube of a car radiator was carried out by Vajjha et al. [13]. A CFD model of the mass flow rate of air passing across the car radiator was introduced by Trivedi and Vasava [14]. The airflow simulation was created using the commercial software ANSYS 12.1 with the geometry defined using SolidWorks software, and this was followed by meshing, which created the surface mesh as well as the volume mesh accordingly. The results were compared and verified according to the known physical situation and existing experimental data. The results obtained serve as a database for future investigations. New correlations for the viscosity and thermal conductivity of nanofluids as a function of particle volumetric concentration and temperature developed from the experiments are used throughout this paper. The convective heat transfer coefficient and shear stress with the nanofluid showed marked improvement over the base fluid and showed higher magnitudes in the flat regions of the tube. The results showed that the increase in the nanofluid volume fractions due to the increase in the friction factors and convective heat transfer coefficient also increased the pressure loss. Numerical analysis of mixed convection flows in a U-shaped groove's tube in a radiator was conducted by Park and Pak [15]. The Modified SIMPLE algorithm for irregular geometry was developed to determine flow and temperature field. The results were used as fundamental data for tube design, suggesting optimal specifications for radiator tubes. Two liquids, water and an ethylene glycol–water mixture, were used as coolant fluid in a meso-channel heat exchanger and were studied numerically by Dehghandokhta et al. [16]. The results of numerical analysis were compared with the experimental data for the same geometrical and operating conditions to predict heat transfer rate, pressure and temperature drops in the coolants, and there was

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Nomenclatures

C	Specific heat [W/kg·°C]
D	Diameter [m]
E	Energy [W]
f	Friction factor
htc	convection heat transfer coefficient [W/m^2·°C]
k	Thermal conductivity [W/m·°C]
Nu	Nusselt Number [$htc \cdot D/K_{nf}$]
P	Pressure [N/m^2]
Pr	Prandtle Number [$C \cdot \mu/K_{nf}$]
Re	Reynolds Number [$\rho_{nf} D_h \cdot u/K_{nf}$]
u	Velocity [m/s]
μ	Viscosity [N·s/m^2]
ρ	Density [kg/m^3]
τ	Shear stress [N/m^2]
ϕ	Volume concentration

Subscripts

f	liquid phases
p	solid particle
nf	nanofluid
h	hydraulic

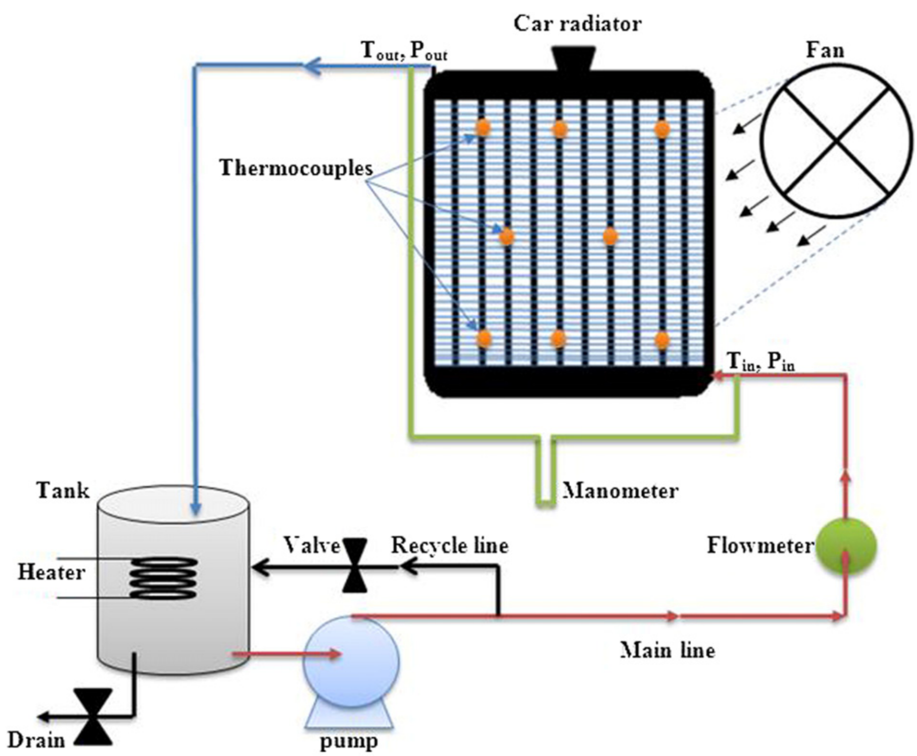
good agreement. Additionally, results showed that the heat exchanger enhanced the heat transfer rate by approximately 20% compared to a straight slab of the same length, and the enhanced heat exchanger has a good potential application as a car radiator with reasonably enhanced heat transfer characteristics compared to an ethylene glycol–water mixture as the coolant. The applications of copper–ethylene glycol nanofluids in a car cooling system have been studied by Leong et al. [17].

In this paper, the Nusselt number of TiO_2 and SiO_2 nanopowders suspended in water was evaluated experimentally. The test rig setup included the car radiator and the effects on heat transfer enhancement during operation were analyzed under laminar flow conditions. It should be noted that few studies have reported experimental data on the use of TiO_2 and SiO_2 nanofluid in an automotive cooling system. Furthermore, the effects of volume flow rate, inlet temperature and nanofluid volume concentration on the Nusselt number for the car radiator were studied. The regression equations for input (volume flow rate, inlet temperature and nanofluid volume concentration) and output (Nusselt number) parameters were found.

2. Experimental work

2.1. Experimental setup and procedure

The test rig shown in Fig. 1a was used to measure the heat transfer coefficient in the automotive radiator. This experimental setup includes



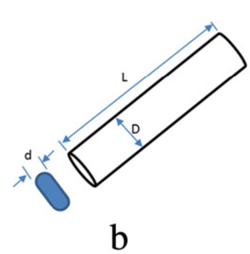


Fig. 1. a—Schematic diagram of the experimental setup, and b—Flat tube of the radiator.

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