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Experimental study of overall heat transfer coefficient in the application of dilute nanofluids in the car radiator

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HIGHLIGHTS

► Overall heat transfer coefficient in the car radiator measured experimentally.
► Nanofluids showed greater heat transfer performance comparing with water.
► Increasing liquid and air Re increases the overall heat transfer coefficient.
► Increasing the inlet liquid temperature decreases the overall heat transfer coefficient.

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ABSTRACT

Heat transfer of coolant flow through the automobile radiators is of great importance for the optimization of fuel consumption. In this study, the heat transfer performance of the automobile radiator is evaluated experimentally by calculating the overall heat transfer coefficient (*U*) according to the conventional ε-NTU technique. Copper oxide (CuO) and Iron oxide (Fe_2O_3) nanoparticles are added to the water at three concentrations 0.15, 0.4, and 0.65 vol.% with considering the best pH for longer stability. In these experiments, the liquid side Reynolds number is varied in the range of 50–1000 and the inlet liquid to the radiator has a constant temperature which is changed at 50, 65 and 80 °C. The ambient air for cooling of the hot liquid is used at constant temperature and the air Reynolds number is varied between 500 and 700. However, the effects of these variables on the overall heat transfer coefficient are deeply investigated. Results demonstrate that both nanofluids show greater overall heat transfer coefficient in comparison with water up to 9%. Furthermore, increasing the nanoparticle concentration, air velocity, and nanofluid velocity enhances the overall heat transfer coefficient. In contrast, increasing the nanofluid inlet temperature, lower overall heat transfer coefficient was recorded.

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1. Introduction

Replacement of nanofluids as a heat transfer media and its relevant advantages over the conventional heat transfer fluids were over emphasized in the recent investigations. Different experimental studies were performed to analyze and verify their advantages in various heat exchange systems like shell and tube heat exchangers [1], double tube heat exchangers [2,3], plate heat exchangers [3], heat pipes [4,5], microchannel heat sink [6], electronics cooling [7], building air conditioning [8,9], and the like. Another application is implementation of nanofluids instead of the conventional fluids in car radiators which is recently under studied. The radiator is an important accessory of vehicle engine. Normally, it is used as a cooling system of the engine and generally water is heat transfer medium. This air cooler configuration is louvered fin and flat tube and due to its complicated geometry less experimental studies can be found in the open literature.

Choi [10] reported a project to target fuel savings for the automotive industries through the development of energy efficient nanofluids and smaller and lighter radiators. A major goal of the nanofluids project is to reduce the size and weight of the vehicle cooling systems by greater than 10% despite the cooling demands of higher power engines. Nanofluids enable the potential to allow higher temperature coolants and higher heat rejection in the automotive engines. It is estimated that a higher temperature radiator could reduce the radiator size approximately 30%. This translates into reduced aerodynamic drag and fluid pumping and fan requirements, leading to perhaps a 10% fuel savings. It is

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interesting idea in these years which humans involved in the energy and fuel shortage crisis. According to this idea, scarce experimental and theoretical studies were performed to analyze the application of nanofluids in the car radiator.

Leong et al. [11] attempted to investigate the heat transfer characteristics of an automotive car radiator using ethylene glycol based copper nanofluids numerically. Thermal performance of an automotive car radiator operated with nanofluids has been compared with a radiator using conventional coolants. Vajjha et al. [12] have been numerically studied a three-dimensional laminar flow and heat transfer with two different nanofluids, Al_2O_3 and CuO, in the ethylene glycol/water mixture circulating through the flat tubes of an automobile radiator to evaluate their superiority over the base fluid. Convective heat transfer coefficient in the developing and developed regions along the flat tubes with the nanofluid flow showed considerable improvement over the base fluid.

Khan et al. [13] have experimentally studied forced convection cross-flow heat transfer of hot air over an array of cold water carrying elliptic tubes. Their experimental investigation was restricted to water as the coolant. Cuevas et al. [14] have studied the heat transfer performance of a louvered fin and flat tube heat exchanger. Mixture of ethylene glycol and water was circulated through the tubes at a supply temperature of 90 °C. This fluid was cooled with ambient air at temperature of 20 °C. The thermohydraulic performance (calculation of heat transfer coefficient and friction factor) of the heat exchanger has been compared with the classical correlations given in the literature. Avramenko et al. [15] made theoretical estimation of the heat transfer enhancement in laminar flow of a nanofluid over a flat plate. For 1% concentration of nanoparticles, the respective increase in the Nusselt number reaches up to 5%.

Peyghambarzadeh et al. [16] have recently investigated the application of Al_2O_3/water nanofluids in the car radiator by calculating the tube side heat transfer coefficient. They have recorded the interesting enhancement of 45% comparing with the pure water application under highly turbulent flow condition. In the other study, Peyghambarzadeh et al. [17] have used different base fluids including pure water, pure ethylene glycol, and their binary mixtures with Al_2O_3 nanoparticles and once again it was proved that nanofluids improves the cooling performance of the car radiator extensively. In the two latter studies, tube side heat transfer coefficient was calculated according to the temperature measurement at the thin walls of the radiator flat tubes. It is very hard to accurately measure the temperature at the wall and therefore, the data may have not adequate accuracy.

In this study, the application of CuO/water and Fe_2O_3/water nanofluids in the car radiator is investigated through the measurement of overall heat transfer coefficient; *U*. Using this method, there is no need to measure the wall temperature. Furthermore, variable liquid and air flow rates, different nanoparticle concentrations, and various liquid inlet temperatures are applied to have more understandings about the radiator cooling efficiency.

2. Experimental

2.1. Set up and procedures

As shown in Fig. 1, the experimental set up used in this research includes flow lines, a reservoir tank, two heaters, a centrifugal pump, a liquid flow meter, a variable speed forced draft fan, an air flow channel, a PID controller for temperature adjustment, five thermoresistances for temperature measurement and a cross flow heat exchanger which is an automobile radiator. The test section is a cross flow heat exchanger inside the air flow duct which is consisted of serpentine finned-tube exchanger, shown in Fig. 2. Water flows upward through the 34 vertical non circular tubes with stadium-shaped cross section. The fins and the tubes are made with aluminum.

The pump gives a constant flow rate of 10 l/min, the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line. The working fluid fills 25% of the feed tank which has 30 L total volume (height of 35 cm and diameter of 30 cm). The total volume of the circulating liquid is constant in all the experiments. Five layer insulated tubes (Isopipe 0.75 in

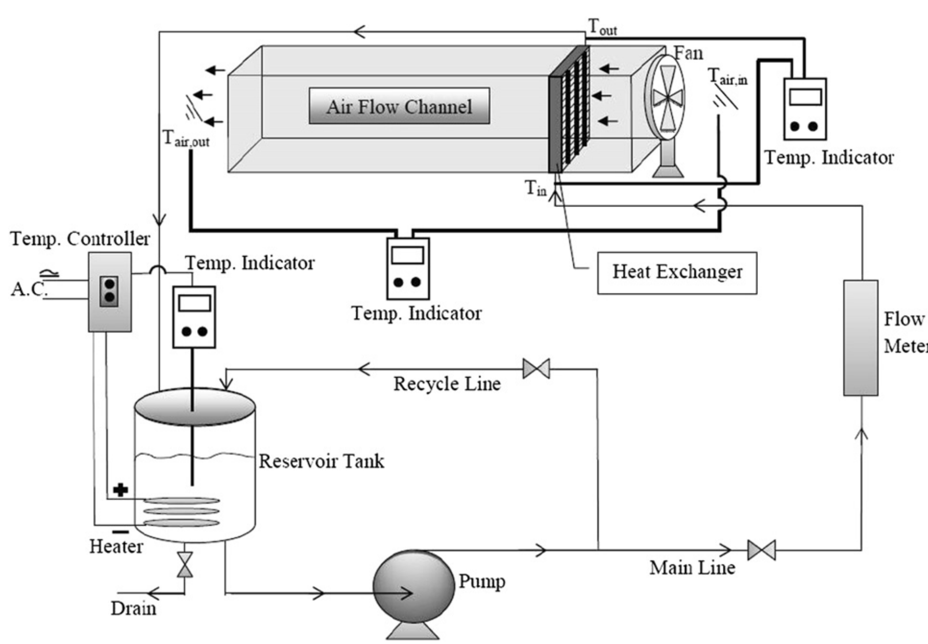

Fig. 1. The cooling loop set up for the simulation of automobile cooling system.

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