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EXPERIMENTAL INVESTIGATION ON THERMAL PERFORMANCE OF SHELL AND TUBE HEAT EXCHANGER USING HYBRID NANOFLUID

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ABSTRACT

An experimental investigation was carried out to study the heat transfer performance of a shell and tube heat exchanger using hybrid nanofluids as the working fluid. It is aimed at analysing the thermal performance withthe effect of various concentrations on shell and tube heat exchanger. The particles used in these experiments were magnesium and aluminium with 700 nm in size. The base working fluid was pure distilled water. The effects of volume fraction of the solid nanoparticles added to the working fluid on the performance of shell and tube heat exchanger are considered. Experiments were performed under three mass flow rates and for five different volume fraction such as 0.4kg/s, 0.3kg/s, 0.2kg/s and 5%, 10%, 15%, 20%, and 25%. Effects of volume fraction to investigate the thermal performance of shell and tube heat exchanger were compared and discussed. From the comparison of the thermal performance using both distilled water and nanofluids, it is found that adding of nanoparticle in distilled water is a key effect of the heat transfer enhancement. Experimental results show that adding magnesium and aluminium nanoparticles into the base fluid (distilled water) can apparently improve the thermal performance of the shell and tube heat exchanger.

Keywords: heat transfer, Nanofluid, Nanoparticles

I. INTRODUCTION

Heat exchanger have been employed in heat transfer related applications for many years like power plant solar energy, heat recovery systems, light water nuclear reactors, air craft cooling, electronics cooling, spacecraft thermal control, transportation systems, automotive industry, permafrost stabilization, and bio-related applications[1]. In recent years, the idea of utilizing nanoparticles within the working fluid of a heat exchanger has become a subject of significant importance [2–4]. There are a number of studies on thermal performance of the nanofluids[4–6]. The nanoparticles within the fluid changes its thermal performance. It has been investigated that the thermal conductivity of the nanofluids increases with a decrease in particle diameter with given concentration level [7–11]. However, there are some experimentations which do not confirm this improvement in the thermal conductivity [12]. The ability of heat transfer of heat exchanger is regulated by moving properties of the working fluid for heat transfer applications. The rate of heat transfer had been enhanced by incorporating the nano filler or additives to their working fluids to alternate the fluid thermal properties and flow patterns [13]. Choi [14] was the first who called the nanoparticles incorporated to fluid “nanofluid” in 1995 and then the research of this field of novel research working fluid had been investigated. Nanofluids are novel kind of fluids consisting of diffuse and suspended nanometre sized particles or fibres in fluids. They have concluded that thermal performance such as the anomalously high thermal conductivity at very low volume fraction and the significant improvement of forced convective and boiling heat transfer rate [15]. To attain the enhancement of the thermal characteristic, the selection of nano fluids plays a vital role in heat transfer devices. A broad range of nanoparticles such as titanium, gold, CuO, diamond, silver, copper and nickel oxide have been used to enhance the thermal characteristic of heat exchanger. Oztop and Abu-Nada [16] used $TiO_{2,}$ $Al_2O_3$and CuO as a nano fluids and water as base fluid, Yang et al. [17] investigated that thermal charateristic of a horizontal micro-grooved heat pipe using CuO as nano particle and water as nano fluid and Kole and Dey [18] studied Cu distilled waternanofluids as working fluid. Many research activities have been dedicated to the heat transfer enhancement applications by using nanofluids with advancement of nanotechnology and thermal engineering. In heat conduction and heat convection, nanofluid has extremely good performance in heat transfer applications such as heat pipes, heat exchanger, and power plant to enhance their heat transfer performance. Recently, most of the investigations on the effect of using nanofluids with electronic devices have been carried out experimentally [19]. In the nano-fluids, thermal characteristic were obtained in numerous experimental investigations. [20-26]. However, the magnesium and aluminium nano-fluid filled on shell and tube heat exchanger thermal performance has not been investigated. Therefore, the purpose of present study is to investigate the effect of nanofluid on shell and tube heat exchanger and its thermal performance.

II. MATERIALS AND METHODS

2.1. Experimental setup

A tank comprising the dimensions of 500 x 400 x 270 mm and made with mild steel material is containing pure distilled water and is heated with electrical heating coil with maximum capacity of 1000W is used to heat water which is to be pumped. Water is heated up to 75°C and temperature is measured using thermocouple. Shell comprising arrangement of tubes that having the dimensions of shell are 300 x 420 x 200 mm having the coil diameter is 280mm, diameter of pipe is ¾ inch, and length is 240mm and made up of mild steel because it is easy to bend.Then GI pipes with 1 inch diameter carrying nano fluid to tubes of shell. Shell will allow base fluid (water) to flow through it. Water releases heat to hybrid nano-fluid which circulated through the tubes and measuring the temperature using the thermocouple.Flow meter is installed between tank and heat exchanger and it is controlled by open type ball valve.

Figure.1.Experimental setup

2.2. Fluid preparation

Magnesium/Aluminium with water nanofluid (particle size=700nm) of required nano particle volume fractions were prepared by adding the nanoparticle to ultrapure water (Millipore). The nanofluid was subjected to ultrasonic pulses using an ultrasonicator for 3 hours to get stable suspension and uniform dispersion. The nano particles of various volume fractions 5%, 10%, 15%, 20%, 25% were considered in this study

Table.1.Mechanical properties of nano particle and base fluid used in the experimentation

Mechanical properties	Magnesium	Aluminium	Water
Thermal conductivity [w/mk]	171.3	204.2	0.6513
Specific Heat [J/kg K]	1013	846	4183
Density [kg/m^3]	1746	2707	985

Figure.2.Magnesium powderFigure.3.Aluminium powder

III. RESULTS AND DISCUSSION

3.1 Effect of the volume fraction on heat transfer rate

The variation of heat transfer rate with respect to different volume fraction of hybrid nano fluid with three mass flow rate (0.4, 0.3, and 0.2 kg/s) is shown in Figure.4. By using hybrid nano fluid, the higher thermal performance had been achieved. From the experimental investigation, it is observed that there is an enhancement in heat transfer rate, when volume fractions were increased in hybrid nano fluids. By increasing the mass flow rates, there is an occurrence of atomization in molecules that leads to high heat transfer rate. This can be certified that improvement in heat transfer rate is due to incorporation of hybrid nano particles.

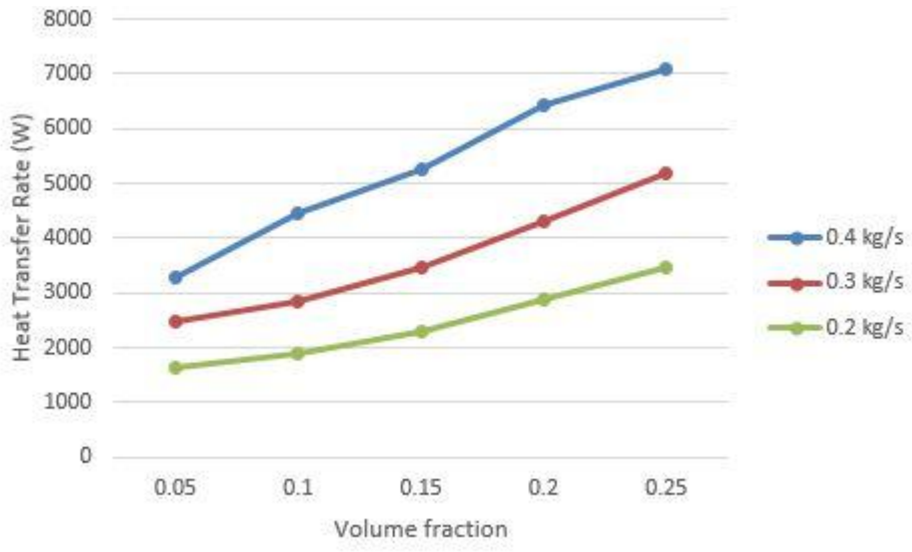

Figure.4.Effect of volume fraction on heat transfer rate with different mass flow rates

3.2 Effect of the volume fraction of nanoparticles on thermal resistance

Figure.5. illustrates that the influence of thermal resistance with respect to different volume fraction of hybrid nano fluid with three mass flow rates (0.4, 0.3, and 0.2 kg/s). From the experimental investigation, it is observed that there is a decrement in thermal resistance, when volume fractions were increased in hybrid nano fluids. The increase of the volume fraction causes the decrease inthe thermal resistance of the hybrid nanofluid due to the increase in viscosity of the nanofluid. This leads to formation of the liquid film that involves in evaporative heat transfer which results in reduction in thermal resistance of the hybrid nanofluid.

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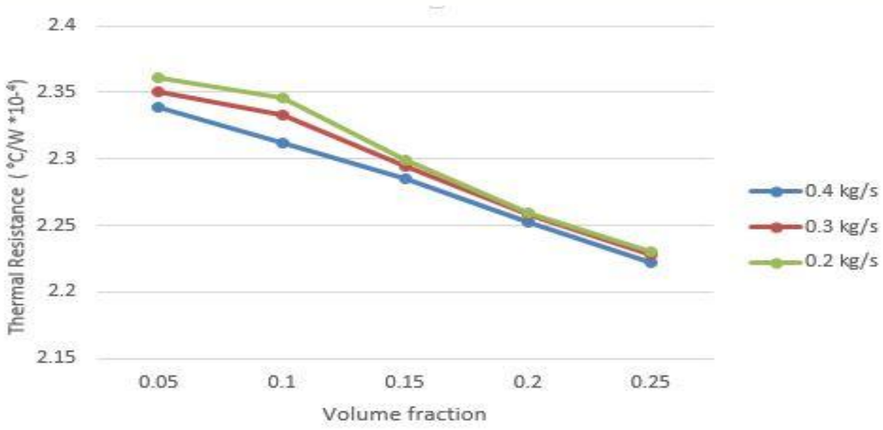
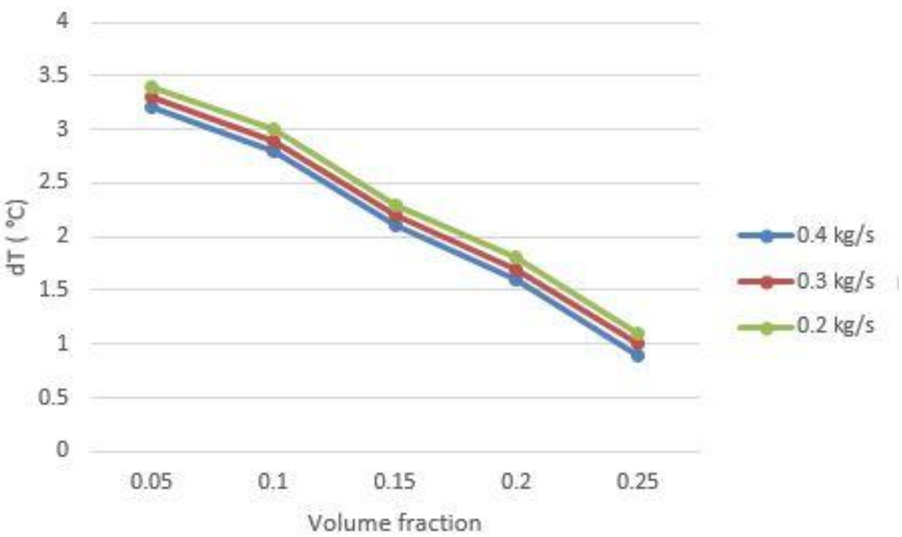


Figure.5.Effect of volume fraction on thermal resistance with different mass flow rates

3.3 Effect of volume fraction on temperature difference

Figure.6. presents effect of volume fraction on temperature difference with different mass flow rates (0.4, 0.3, and 0.2 kg/s). The temperature difference is reduced drastically by increasing the volume fraction due to increase in thermal conductivity property. The thermal conductivity property is enhanced for sake of volume concentration of hybrid nano fluid transfers more heat. This leads to drastic reduction in temperature difference.



IV. CONCLUSIONS

The effect of particle volume fraction on thermal performance of the hybrid nanofluid has been established. The experimental results may be concluded as below:

1. The experimental investigation can be certified that improvement in heat transfer rate is due to incorporation of hybrid nano particles.
2. The experimental result concluded that hybrid nanoparticles were incorporating with a small amount of base fluid which enhances the thermal conductivity.
3. Thermal performance carried out using hybrid nanofluids is found that incorporation of nanoparticles suspended in nanofluids is a significant effect of the heat transfer improvement for the shell and tube heat exchanger.
4. The variation of volume fraction, heat transfer rate, thermal resistance, temperature difference were studied.
5. It can be seen that, the temperature difference of the hybrid nanofluid shell and tube exchanger tended to decrease with increasein the volume fraction of hybrid nano fluid.

V.FUTURE SCOPE

In many applications, nanofluids have novel thermo physical properties that make them potentially effective in heat transfer, engine cooling/vehicle thermal management, chiller, refrigerator, pharmaceutical processes, microelectronics, fuel cells, hybrid-powered engines, domestic and heat exchanger, in machining, grinding and in boiler flue gas temperature reduction.

Nanofluids are primarily used for their enriched thermal properties as coolants in heat transfer equipment such as electronic cooling system (such as flat plate), radiators, and heat exchangers. Heat transfer over flat plate could be analysed by using hybrid nanofluids.

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