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HEAT TRANSFER ENHANCEMENT USING CuO-WATER NANOFLUID

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Abstract- *Nanofluid is nanometer sized particle which basically are colloidal mixtures of nanometric metallic compound in a base fluid such as water, ethylene glycol, oil etc. Nanofluids have been the subject of intensive study worldwide since pioneering researchers recently discovered the anomalous thermal behavior of this fluids. So suspended nanoparticle is used in base fluids for increasing the thermal conductivity rate. In this study CuO nanoparticles were used to prepare the nanofluids. A NFU type heat exchanger made of stainless steel was used. For the experiment five different volume concentrations of nanofluid were considered which were 0.01%, 0.025%, 0.075%, 0.1%, 0.2% at different flow rates of 12.5, 11.5, 9.5 and 7.5 lpm. A significant change in heat transfer coefficient have been observed with the change in concentration. The maximum value of heat transfer coefficient was found to be 10399 w/m^{2}k when the concentration was 0.2% at 12.5 lpm. For concentrations of 0.01%, 0.045%, 0.075%, 0.1% and 0.2% at 9.5 lpm the heat transfer coefficients were found to be 500, 2978, 5790, 7220 and 8777 W/m^{2}K respectively. This study has shown that using copper-oxide (CuO-Water) as nanofluid has* significantly *increased the heat transfer coefficient.*

Keywords: Nanofluid, nanoparticles, heat exchanger, heat transfer enhancement

1. INTRODUCTION

Recent technological developments in the field of electronics, transportation, medical and HVAC systems have resulted in a pressing need for a performance enhanced cooling system. Heat transfer means of flowing fluid in either laminar or turbulent regime or a stagnant fluid, in one of the most important process in many industrial and civil applications. The literature has revealed that the low thermal conductivity of the common base fluids is a primary limitation in enhancing the performance and the compactness of many devices. When nanoparticles such as CuO, TiO_2, SiO_2 are added to the base fluids, anomalous but understandable behavior results. Amazing capability of nanofluids in heat transfer enhancements has encouraged researcher in recent decades to develop concepts and technologies advocated by manufacturers of ultra-compact, miniaturized and intrinsic electronic chips. The uplifting demand for higher speed, multiple functioning, more powerful and smaller sized boards has almost doubled number of transistors on electronic chips with production of localized heat flux over 10 MW/m^2 and total power exceeding 300 W. Promising to fulfill this critical need, technologies like "Nanofluid with tunable thermal properties" emerged by Phillip et al [1]. According to Philip et al, the observed reversible tunable thermal property of Nanofluid with advantage of 300% increase in thermal conductivity of the base fluid may find many technological applications for this fluid in nano electromechanical system (NEMS) and micro electromechanical system (MEMS) based devices. Hea et al.[2] explains that on one hand micro/macro particle bring about little thermal enhancement to the base fluid while on the other hand, abrasion, channel clogging and higher pressure drop are comparably higher than those of nanofluids. Hea et al.[2] also highlighted nanofluids by excellent stability and higher thermal conductivities. In study of nanofluids researchers like Jayhooni et al. [3] concluded that up to an optimum point there exist a direct ascending trend of conductivity of nanofluid with increase of concentration of particles and decrease of particle size. Nanofluids can be considered as the future of heat transfer fluids in various heat transfer application. They are expected to give better thermal performance than conventional fluids due to the presence of suspended nanoparticles which have high thermal conductivity and heat transfer rate. Studies on effective thermal conductivities of nanofluid were investigated under macroscopically and stationary conditions by Choi and Eastman [4], Lee et al. [5], Xuan and Roetzel [6], Li Q. and Xuan Y [9], developed an effective thermal conductivity model for CuO/water and CuO/Ethylene glycol nanofluids taking into account the thermal conductivity of the solid and liquid, their relative volume fraction, particle size and interfacial properties. Wang et al. [11] measured thermal conductivities of carbon nano tubes (CNT) in water, CuO in water, SiO_2 in water, and CuO in ethylene glycol by transient hot-wire method and reported 11.3% improvement in the thermal conductivity of water-based CNT nanofluids with 0.01% volume

concentration.
This experiment aimed to design and construct a set up for enhancing heat transfer using CuO-water nanofluid.

2.EXPERIMENTAL SETUP

The experimental apparatus, shown in Fig 1, consists of nanofluid, heat exchanger (NFU), rota meter, thermometer, tank, heater, pump, pipe and various fittings. At first, the experimental setup were needed to design. The heat exchanger was made of stainless steel. The ratio of the heat transfer surface area of a heat exchanger to its volume is called the area density β. The U-tube heat exchanger used was of low surface area density because of its size which was only 0.3 m long and had a diameter of 0.15m. Its surface area density was only 0.6 m^2/m^3. Copper oxide nanofluids of five different volume concentrations of 0.01%, 0.045%, 0.075%, 0.1% and 0.2 % were prepared for measuring the temperature dependent thermal conductivity and viscosity of all the nanofluids concentration considered in the present work.

Fig 1 : Experimental setup

2.1 Nano fluid

There are two fundamental methods to obtain nanofluids one is Single-step direct evaporation method. In this method, the direct evaporation and condensation of the nano particulate materials in the base liquid are obtained to produce stable nanofluids and in two-step method, first the nanoparticles are obtained by different methods and then are dispersed into the base liquid. In the present investigation, to prepare stable nano fluid neither surfactants nor acid are added in the CuO nanofluids, because with the addition of surfactants the thermo physical properties of nanofluids are affected. Addition of acid may damage the tube material because corrosion takes place after a few days with the prolonged usage of such nanofluids in practical applications. Copper oxide nanofluids of five different volume concentrations of 0.01, 0.045, 0.075, 0.1 and 0.2 % are prepared for measuring the temperature dependent thermal conductivity and viscosity of all the nanofluids concentration considered in the present work.

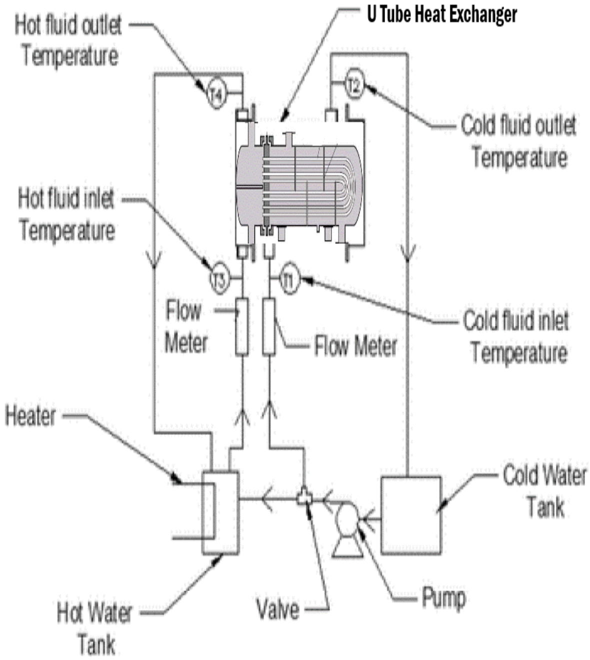

Fig 2 : Schematic diagram of experimental apparatus

2.2 Experimental Procedure

The overall experiment procedure is shown in a nutshell by the following Fig:3

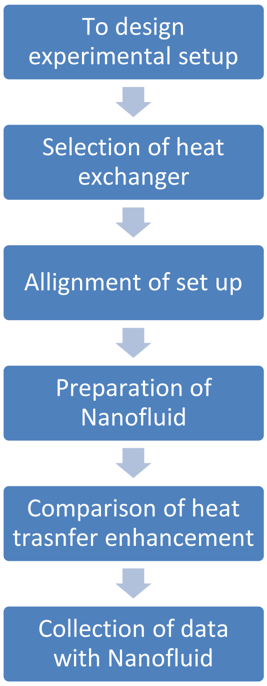

Fig 3 : Flow chart of the study

At first, there is the designing of the experimental setup. This design was made considering all the pros and cons of the experiment.
After that there comes the selection of nanoparticle. There was various types of nanoparticles. Among those

CuO was selected for the study. The nanoparticle used here was copper oxide which was mixed with water to form nanofluid. Then comes the selection of heat exchanger. From various heat exchangers, NFU type heat exchanger made of stainless steel was used in this study. When every selection was completed, the experimental set up was aligned with necessary piping system and required equipment. In the meanwhile, nanofluids were prepared using nano sized copper particle and water as base fluid. After the preparation nanofluids were used to conduct the experiment and the data were collected. Changing the concentration of nanoparticle and flow rates, the data was collected under different conditions. At last of the flow chart there is the comparison of the heat transfer enhancement.

3. DATA REDUCTION

For the experiment five different volume concentrations of nanofluid were considered which were 0.01%, 0.025%, 0.075%, 0.1% and 0.2% at different flow rates of 12.5, 11.5, 9.5 and 7.5 lpm. The weight of the nanoparticles required for preparation of the nanofluid of a particular volume fraction was calculated by using the following relation

% of volume concentration, $\varphi = \frac{\frac{w_{CuO}}{\rho_{CuO}}}{\frac{w_{CuO}}{\rho_{CuO}} + \frac{w_{bf}}{\rho_{bf}}}$ …… (1)

Here,
ρ_{CuO}=6300 kg/m^3 and ρ_{bf}=1000kg/m^3

Specific Heat of Nanofluid was calculated by,

$$C_{p,nf} = (1-\varphi)(\rho.C_p)_{bf} + \varphi(\rho.Cp)p)/((1-\varphi).\rho_{bf} + \varphi$$

……………. (2)

Overall heat tansfer coefficient was calculated by

$U = \frac{Q}{AF\delta T_m}$ …………………………………... (3)

And the log mean temperature difference was calculated by,

$\delta T_m = \frac{\delta T_1 - \delta T_2}{\frac{\delta T_1}{\delta T_2}}$ ……………………………. (4)

Thermal Balance
$Q_c = m_c C_{pc}(T_{c,out} - T_{c,in})$ (5)
$Q_h = m_c C_{ph}(T_{h,in} - T_{h,out})$ (6)

Correction factor can be obtained from Kakac et al. [10] chart using two parameters P and R.
Here,
$P = \frac{t_2 - t_1}{T_2 - t_1}$ and $R = \frac{T_1 - T_2}{t_2 - t_1}$

4 .RESULTS AND DISCUSSIONS

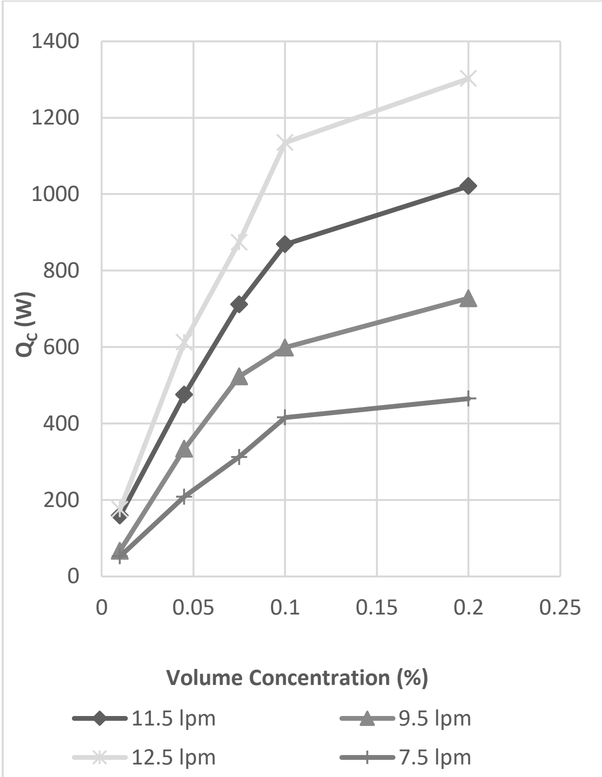

Fig 4 : Effect of volume concentration on heat transfer rate

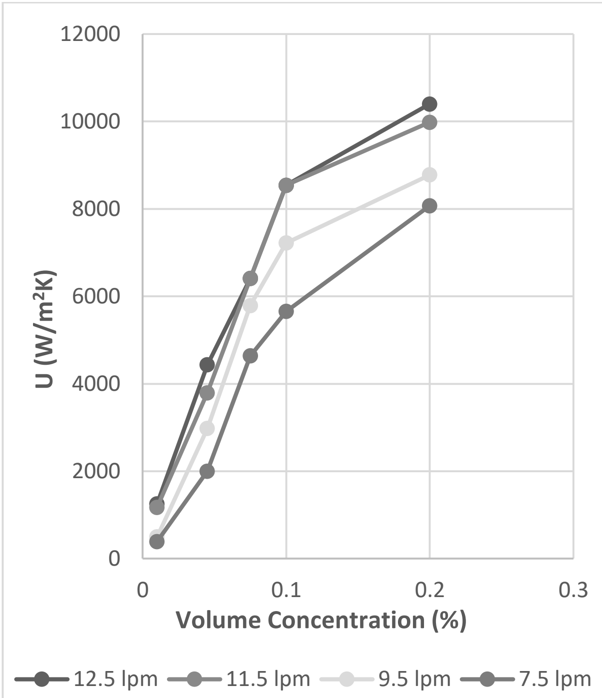

Fig 5: Effect of volume concentration on overall heat transfer coefficient

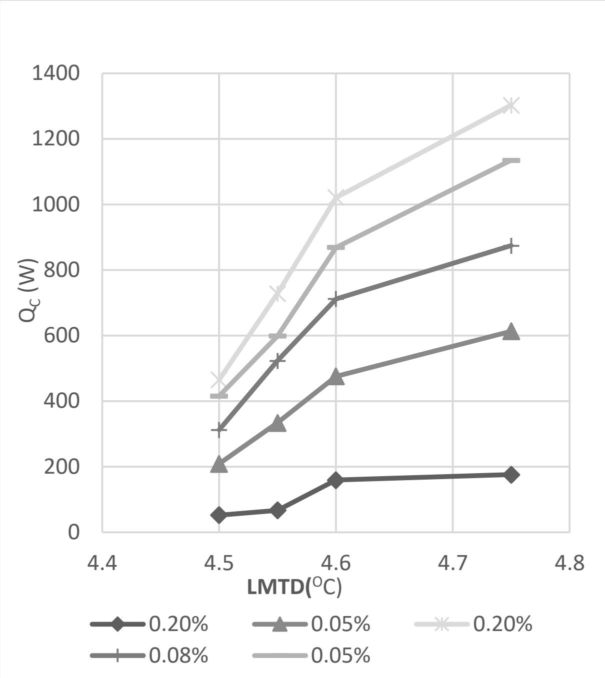

Fig 6 : Effect of LMTD on heat transfer rate

From the mentioned graphs it can be seen that for the same flow rate, heat transfer has increased with the increase of volume concentration. Since nanoparticles has greater thermal conductivity than the base fluid, with the increase in volume concentration the thermal conductivity of nanofluid has increased gradually that resulted in the increase in heat transfer rate. When for the same volume concentration different flow rate is considered, heat transfer has increased again with the increase of flow rate. It is known that heat transfer rate is dependent directly on the mass flow rate and also the temperature difference. That is why there was the increase in heat transfer rate with the increase of mass flow rate. Again for the same flow rate, overall heat transfer coefficient has increased with the increase of volume concentration. With the increase of volume concentration, heat transfer rate increases. Thus the overall heat transfer coefficient also has increased since it is directly proportional with the heat transfer rate. At the same concentration, it is seen that overall heat transfer coefficient has increased with the increase of flow rate. As heat transfer rate increases with the flow rate, the coefficient has increased here. For the same volume concentration, heat transfer rate has increased with the increase of LMTD. For the same LMTD, heat transfer rate has increased with the increase of volume concentration since more nanoparticles generates more thermal conductivity. For the same volume concentration, overall heat transfer coefficient has increased with the increase of LMTD. For the same LMTD, overall heat transfer coefficient has increased with the increase of volume concentration. Since with the increase of concentration heat transfer rate increases and also at the same LMTD, overall heat transfer coefficient is directly proportional to the heat transfer.

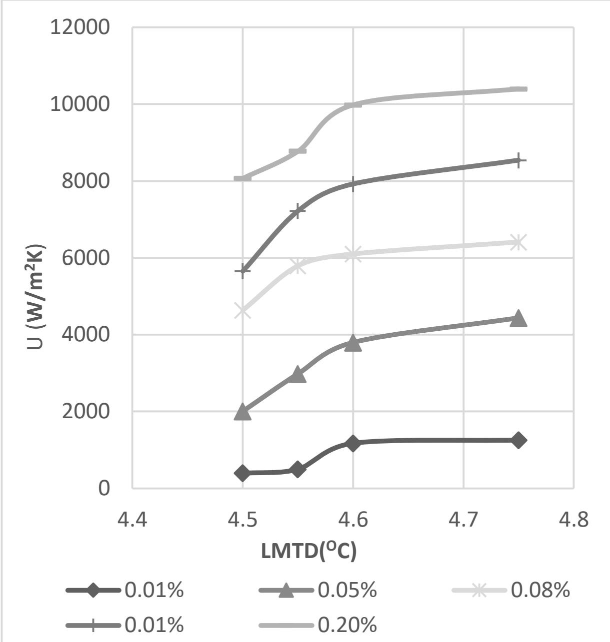

Fig 7 : Effect of LMTD on overall heat transfer coefficient

5. CONCLUSIONS

An experimental study was carried out to investigate if the heat transfer rate actually increases with use of nanoparticles or not. For the sake of the experiment we chose nanoparticle concentrations of 0.01%, 0.025%, 0.075%, 0.1%, 0.2% at different flow rates of 12.5, 11.5, 9.5 and 7.5 lpm. The experimental results can be summarized as follows:

- For the same flow rate, heat transfer has increased with the increase of volume concentration
- With the increase in volume concentration the thermal conductivity of nanofluid has increased gradually that resulted in the increase in heat transfer rate
- For the same volume concentration different flow rate is considered, heat transfer has increased again with the increase of flow rate.
- For the same flow rate, overall heat transfer coefficient has increased with the increase of volume concentration.

So after investigating all the experimental data, mathematical analysis and graphical analysis we can finally state that the heat transfer rate has increased in noticeable numbers after using the nanofluid (CuO) in the water which we used as base fluid.

6. ACKOWLEDGEMENT

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7. REFERENCES

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7. NOMENCLATURE

Symbol	Meaning	Unit
P	Power	(W)
p	Pressure	(N / m^2)
Q	Volumetric flow of waste gas	(Nm^3/s)
m	Mass flow rate	(kg/h)
s	Specific heat	(kJ/kg-k)
$\Delta\Theta$	Temperature difference	(K)
ρ	Density	(kg/m^3)
g	Gravity	(m/s^2)
Q_c	Amount of heat	(kJ)
φ	Volume concentration	(kg/m^3)
δTm	Temperature difference	(K)
A	Area of the heat exchanger	(m^2)
F	Correction factor	
C_p	Specific heat	(J/kg.K)
$LMTD$	Log mean temperature difference	ºC
W_{CuO}	Mass of the nanoparticle	(gm)
W_{bf}	Mass of the base fluid	(gm)
U	Overall heat transfer coefficient	(W/m^{2}K)
ρ_{CuO}	Density of CuO	(Kg/m^3)
ρ_{bf}	Density of base fluid	(Kg/m^3)
bf	Base fluid	
nf	Nano fluid	
CuO	Copper Oxide	