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COMPARISON OF THE PERFORMANCE OF DIFFERENT TYPES OF NANOFLUIDS TO IMPROVE THERMAL EFFICIENCY OF HEAT EXCHANGER

H. A. Raha[1], **G. Dhar**[2], **M.A. Razzaq**[3], **J.U. Ahamed**[4], **S. Istiaque**[5]

Department of Mechanical Engineering, Chittagong University of Engineering and Technology,
Chittagong-4349, Bangladesh
a.rrazq@cuet.ac.bd[3,*]

Abstract*-Using nanofluid (Al_2O_3/water and CuO/water), the thermal performance of heat exchanger under turbulent condition has been examined in this analysis. Heat transfer rate, overall heat transfer coefficient, , LMTD have been calculated for getting the information about the thermal performance of heat exchanger. A NFU type heat exchanger has been used in this experiment. Nanoparticle, thermometer, rotameter, pump have been used for the experimental purposes. Al_2O_3, CuO and different composition of Al_2O_3-CuO nanoparticles have been mixed with base fluid to make nanofluid suspension. Magnetic stirrer has been used to prepare the nanofluid. To find the best composition of nanoparticles, experiment has been done for a constant flow rate. Four thermometers have been used to measure the temperature of fluid. A rotameter also has been used for flow regulation. The result shows that 30% Al_2O_3 and 70% CuO includes heat transfer rate of 1250 W and overall heat transfer coefficient of 1934 W/m^{2}K. Effectiveness is also higher for this hybrid nanofluid which is around 4.3%.*

Keywords: Overall heat transfer coefficient, Hybrid nanofluid, Effectiveness, Heat exchanger.

1. INTRODUCTION

Ordinary fluids, which are used to enhance heat transfer rate, such as oil, water and ethylene glycol are hardly satisfying the necessaries of modern industry, transportation, nuclear, electronic engineering and so forth with the development of industry. Theoretical and experimental analysis were performed on the characteristics of liquid suspensions having multi or micro size particles. Moraveji and Razvarz [1] performed an analysis on a heat pipe's thermal efficiency using Al_2O_3 nanofluid at different weight concentration and demonstrated that, comparing to pure water, the thermal performance of the pipe is increased by using nanofluid. Reddy and Rao [2] experimentally searched on the condition of heat transfer coefficient as well as friction factor in a heat exchanger adding TiO_2 nanofluid. The base fluid was the mixture of pure water as well as ethylene glycol in this analysis. The experiment was performed using and without using helical coil inserts. They demonstrated that the heat transfer coefficient increases due to the increment of Reynolds number as well as volume concentration of nanoparticles. Vermahmoudi et al. [3] performed an experimental investigation on a heat exchanger, which was finned, to find out the overall heat transfer coefficient of Fe_2O_3-water nanofluid. They demonstrated that the overall heat transfer coefficient increases due to the increase of air Reynolds number, flow rate and volume concentration of nanoparticles. Goodarzi et al. [4] showed that heat transfer of working fluid increases due to the enhancement of Reynolds number or the percentage of nanoparticles performing an analysis on the thermal performance of a counter flow double pipe heat exchanger. Akhtari et al. [5] carried out an experimental as well as numerical analysis in double pipe and shell and tube exchangers to find out heat transfer of α Al_2O_3-water nanofluid. In this case they showed that, comparing with pure water, 13.2% and 21.3% increment of heat transfer coefficients occur in double pipe and shell and tube heat exchanger respectively. Using a biological nanofluid Sarafraz and Hormozi [6] performed an analysis on forced convective heat transfer enhancement. In the experiment they used a double pipe heat exchanger and revealed consequences of inlet bulk temperature, flow rate and nanofluid concentration on heat transfer coefficient. Sarafraz et al. [7] carried on an study on the pressure drop behavior and heat transfer coefficient of COOH-CNT/water nanofluids. They performed this study in a double pipe heat exchanger and showed that for the appearance of carbon nanotube thermal conductivity enhances up to 56%.

The result of rising of friction factor with curvature ratio is exhibited by Aly [8] performing a numerical study on heat transfer and pressure drop behavior of Al_2O_3/water flow. The flow had been continued into parallel and cross flow concentric tube heat exchangers. They also demonstrated that as the nanoparticles volume concentration increased the pressure drop penalty is negligible. Sozen et al. [9] performed an experiment to examine the consequences of using nanofluid on a parallel flow performance concentric tube heat exchanger (PFCTHE) and a cross flow concentric tube heat exchanger (CFCTHE). The nanofluid is from alumina and fly ash. In this experiment they showed that due to the fly ash nanofluid which is used as working fluid increases the efficiency by 31.2% and 6.9% for PFCTHE and CFCTHE respectively. Chavda et al. [10] experimentally investigated the parallel/counter flows of a nanofluid in a double pipe heat exchanger. Hashmi and Akhavan-Behabadi [11] agreed that using helical tube insert is a more effective method without using of straight tube to enhance the convective heat transfer coefficient. They revealed that 78.4% increment in heat transfer coefficient in helical coil at 82.2% Reynolds number comparing to the straight tube. Kumar et al. [12] carried on an experiment in shell and tube heat exchanger. The exchanger was helically coiled and the study was done under turbulent condition using Al_2O_3/water nanofluid with varying nanoparticles concentration. They revealed that the Nusselt number increases 56% higher than distilled water for 0.8 volume % Al_2O_3 nanoparticles.

From the study it is clear that alumina shows higher thermal property. So Al_2O_3 and CuO nanoparticles have been used in this experiment. By combining of these two nanoparticles the thermal performance of heat exchanger seems to be increased. In this study the thermal performance of heat exchanger using 1% volume fraction of Al_2O_3, CuO, 30% Al_2O_3 and 70% CuO, 70% Al_2O_3 and 30% CuO, 50% Al_2O_3 and 50% CuO with base fluid has been analyzed.

2. EXPERIMENTS

2.1 Preparation of Nanofluid:

The CuO and Al_2O_3 nanoparticles having an average size of 50 nm and 40 nm respectively with density 6.3 gm/cm^3 for CuO and 3.6 gm/cm^3 for Al_2O_3 have been used for investigation in the present experimental work. Copper oxide and aluminium oxide nanofluid of 1% volume of fraction have been prepared for the measurement of the temperature dependent thermal conductivity. The nanoparticles accumulation takes place when nanoparticles have been suspended in the base fluid. The sample of CuO and Al_2O_3 nanofluid have been subjected to magnetic stirring process for 48 hours but no ultrasonic vibration. Thus there were particle settlement but the fluids have been stirred adversely before use.

Materials with a nominal composition of 70 wt% Al_2O_3 and 30 wt% CuO, 50 wt% Al_2O_3 and 50 wt% CuO and 30 wt% Al_2O_3 and 70 wt% CuO have been prepared by mechanical mixing. These have been mixed in a planetary ball milling machine for 2 hours to produce a homogenous mixture.

On the other hand, to prepare a solution of 1% volume fraction the composition of Al_2O_3 and CuO nanoparticles and their corresponding weight is given below.

Table 1: Different Composition of Al_2O_3 and CuO Nanoparticles and their Corresponding Weights.

Composition of Al_2O_3 and CuO nanoparticles	Weight of Al_2O_3 nanoparticles (Grams)	Weight of CuO nanoparticles (Grams)
70 wt% Al_2O_3 and 30 wt% CuO	7	3
50 wt% Al_2O_3 and 50 wt% CuO	5	5
30 wt% Al_2O_3 and 70 wt% CuO	3	7

2.2 Experimental Setup:

In this experiment NFU-type heat exchanger has been used. Four thermometers have been used that indicate the temperature. A centrifugal pump has been used to flow the nanofluid through the heat exchanger. Flowmeter has been used to regulate the flow of water. Heater has been used to heat the water to flow hot water through the heat exchanger.

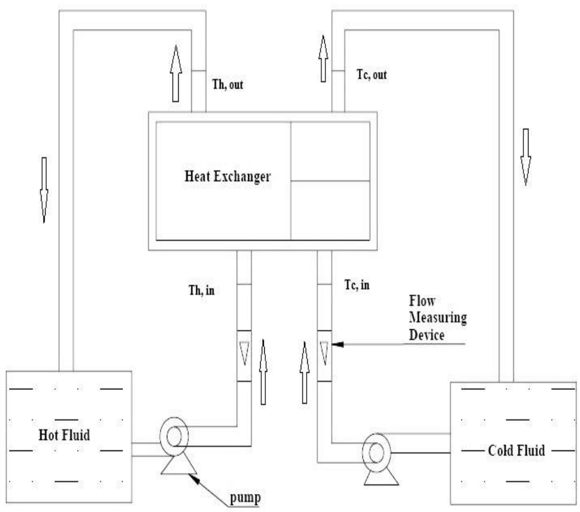

Fig. 2.1: Schematic Diagram

2.3 Experimental Procedure:

This experiment includes a heating tank, a nanofluid reservoir tank, a shell and tube heat exchanger, a nanofluid cooling system, by pass line, thermometers, pump and flow meter. In this experiment nanofluid has been flown through the tube and water has been flown through the shell of the NFU-type heat exchanger. The hot reservoir is thermally insulated and two valves control flow rates. Water and nanofluids flow meters have been calibrated via weighting collected water and nanofluids around a specific time interval. There are mainly four thermometers have been used in the entrance and exit pipes of heat exchanger. Two of the thermometers are used to measure the temperature of nanofluid at the entrance and exit of tube side, and the other two has been applied to assess the temperatures of water at the entrance and exit of shell side. There are two loops (nanofluid and water flow loops) exist in the experiment.

Fig.2.2: Experimental setup

3. DATA REDUCTION EQUATIONS

Density of nanofluid,

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_{bf} \tag{1}$$

Specific heat of nanofluid,

$$C_{p,nf} = \frac{\varphi(\rho C_p)_p + (1-\varphi)(\rho C_p)_{bf}}{(1-\varphi)\rho_b + \varphi\rho_p} \tag{2}$$

Where,

φ = Volume concentration
ρ_p = Density of nanoparticles
ρ_{bf} = Density of base fluid
$C_{p,bf}$ = Specific heat of base fluid, J/KgK
$C_{p,p}$ = Specific heat of nanoparticles, J/KgK

Log mean temperature difference (LMTD),

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}} \tag{3}$$

Here,

$$\Delta T_1 = T_{h,in} - T_{c,in} \tag{4}$$
$$\Delta T_2 = T_{h,out} - T_{c,out} \tag{5}$$

Overall heat transfer coefficient,

$$U = \frac{\dot{Q}}{AF\Delta T_m} \tag{6}$$

Here,

U = Overall heat transfer coefficient, W/m^{2}K
$\dot{Q}$ = Actual heat transfer rate
A = Area of the heat exchanger, m^2
F = Correction factor

Correction factor can be obtained from Kakac et al. [13] chart using two parameters P and R.

Here,

$$P = \frac{t_2 - t_1}{T_2 - t_1} \tag{7}$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} \tag{8}$$

Effectiveness,

$$\varepsilon = \frac{\dot{Q}}{\dot{Q}_{max}} \tag{9}$$

Where,

$$\dot{Q} = \dot{m}_c C_{pc}(T_{c,out} - T_{c,in}) = \dot{m}_h C_{ph}(T_{h,out} - T_{h,in}) \tag{10}$$

$$\dot{Q}_{max} = C_{min}(T_{h,in} - T_{c,in}) \tag{11}$$

Here,

$\dot{m}_c, \dot{m}_h$ = Mass flow rates
$T_{c,in}, T_{h,in}$ = Inlet Temperatures
$T_{c,out}, T_{h,out}$ = Outlet temperatures
C_{min} = The smaller of $\dot{m}_c C_{pc}, \dot{m}_h C_{ph}$

4. RESULT AND DISCUSSION

Figure 4.1 and Figure 4.2 shows that 30% Al_2O_3 and 70% CuO hybrid nanofluid shows better thermal performance than the other nanofluid in a constant flow rate (18 L/min). The figures clearly show that utilization of nanofluid increase the heat transfer rate as well as overall heat transfer coefficient than the fresh water. Since the nanoparticle has greater thermal conductivity than the base fluid so heat transfer rate as well as overall heat transfer coefficient also increased in accordance with the conductivity of the fluid. The figures also show that in case of hybrid 30% Al_2O_3 and 70% CuO nanofluid heat transfer rate and overall heat transfer coefficient are higher, it may cause because of the following reasons –

1. The nanoparticle whose mean radius is smaller between Al_2O_3 and CuO may get inserted into the other particle and form a grain of larger surface area. Due to this increasing surface area heat transfer rate as well as overall heat transfer coefficient increase.

2. If the mean radius of the particles is nearly same, then the particles get diffused which also increase the surface area as well as heat transfer rate.

As the smaller dimensions of nanoparticles, it is a natural tendency to have a zigzag motion of nanoparticles in basefluid which is called Brownian motion. Due to the presence of Brownian motion, energy transfer in the direct nanoparticle-nanoparticle contact arises from the particle collision that is a partial cause of the enhancement of thermal conductivity.

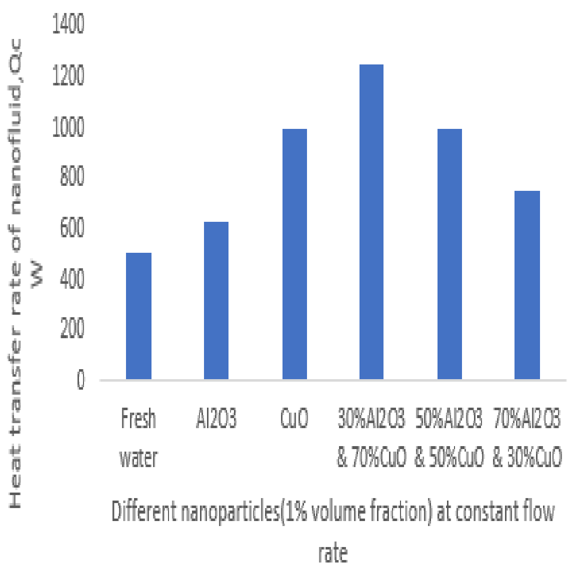

Fig.4.1. Heat transfer rate of different nanofluid at constant flow rate.

In nanofluid the liquid molecules make layers at the solid surfaces which are known as interfacial layer. These interfacial layers show different thermophysical properties. It shows higher thermal conductivity than liquid which helps in heat transfer enhancement as well as heat transfer coefficient that is experienced in this analysis.

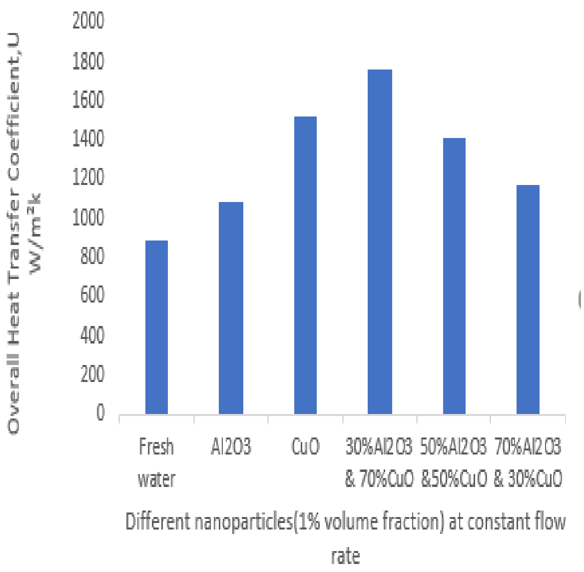

Fig.4.2. Overall heat transfer coefficient of different nanofluid at constant flow rate.

In figure 4.3 it is clear that using hybrid nanofluid of 30%Al_2O_3 and 70% CuO shows higher effectiveness. On the other hand using nanofluid the effectiveness increases comparing to the base fluid.

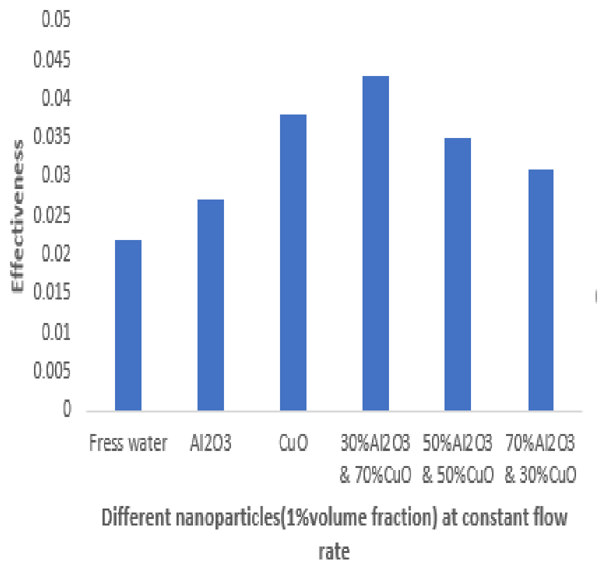

Fig.4.3. Effectiveness of different nanofluid at constant flow rate

5. CONCLUSIONS

In this present world nanotechnology is the talk of the town. The significance of using nanotechnology to the heat transfer process can bring a new era to the world. As this technology is spreading itself to almost all engineering section, we can use it to the heat transfer devices for increasing the device's efficiency. It will ensure the longer time of these devices. As we know the application of these devices, any kind of positive and advanced modification can tremendously change the process of industry like steam power plant, thermal power plant etc. So this study would surely help us to know about the properties of nanoparticles and would show us how it is useful in heat transfer. The outcomes of this experimental analysis are

a. Comparing to the conventional fluid like water nanofluid shows better heat transfer characteristic. In case of hybrid nanofluid, better heat transfer rate is shown. In this experiment, it is shown that 30% Al_2O_3 and 70% CuO have higher heat transfer rate and overall heat transfer coefficient than Al_2O_3, CuO, 70% Al_2O_3 and 30% CuO, 50% Al_2O_3 and 50% CuO water base nanofluid.
b. For the constant flow rate, effectiveness is also higher for 30% Al_2O_3 and 70% CuO which is around 4.3%.

6. REFERENCES

1. Mostafa Keshavarz Moraveji, Sina Razvarz, "Experimental investigation of aluminum oxide nanofluid on heat pipe thermal performance", *International Communications in Heat and Mass Transfer* 39 , pp. 1444–1448, 2012.
2. M. Chandra Sekhara Reddy, Veeredhi Vasudeva Rao, "Experimental investigation of heat transfer coefficient and friction factor of ethylene glycol

water based TiO2 nanofluid in double pipe heat exchanger with and without helical coil inserts", *International Communications in Heat and Mass Transfer* 50, pp. 68–76, 2014.
3. Y. Vermahmoudi, S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, "Experimental investigation on heat transfer performance of Fe2O3/water nanofluid in an air-finned heat exchanger", *European Journal of Mechanics B/Fluids* 44, pp. 32–41, 2014.
4. M. Goodarzi, A.Sh. Kherbeet, M. Afrand, E. Sadeghinezhad, M. Mehrali, P. Zahedi, S. Wongwises, M. Dahari, "Investigation of heat transfer performance and friction factor of a counter flow double-pipe heat exchanger using nitrogen-doped, graphene-based nanofluids", *International Communications in Heat and Mass Transfer*, Vol. 76, pp. 16–23, 2016.
5. M. Akhtari, M. Haghshenasfard, M. R. Talaie, "Numerical and Experimental Investigation of Heat Transfer of α-Al2O3/Water Nanofluid in Double Pipe and Shell and Tube Heat Exchangers", Volume 63, Issue 12, pp. 941-958, 2013.
6. M.M. Sarafraz, F. Hormozi, "Intensification of forced convection heat transfer using biological nanofluid in a double-pipe heat exchanger", Experimental Thermal and Fluid Science, Vol. 66, pp. 279–289, 2015.
7. M.M. Sarafraz, F. Hormozi, V. Nikkhah, "Thermal performance of a counter-current double pipe heat exchanger working with COOH-CNT/water nanofluids", Experimental Thermal and Fluid Science, Vol. 78, pp. 41–49, 2016.
8. W.I.A. Aly, "Numerical study on turbulent heat transfer and pressure drop of nanofluid in coiled tube-in-tube heat exchangers", Energy Conversion and Management, Vol. 79, pp. 304–316, 2014.
9. A. Sözen, H. İbrahim Variyenli, M. Bahadır Özdemir, M. Gürü, İ. Aytaç, "Heat transfer enhancement using alumina and fly ash nanofluids in parallel and cross-flow concentric tube heat exchangers", Journal of the Energy Institute, Vol. 89, Issue 3, pp. 414–424, 2016.
10. N.K. Chavda, J.R. Patel, H.H. Patel, A.P. Parmar, "Effect of nanouid on heat transfer characteristics of double pipe heat exchanger: Part-i: Effect of aluminum oxide nanouid", *International Journal of Research in Engineering and Technology*, Vol. 3, Issue 12, pp. 42-52, 2014.
11. S.M. Hashemi, M.A. Akhavan-Behabadi. "An empirical study on heat transfer and pressure drop characteristics of CuO–base oil nanofluid flow in a horizontal helically coiled tube under constant heat flux", *Int. Comm. Heat Mass Transfer* 39 pp. 144–151, 2012.
12. P.C. M. Kumar, J. Kumar, S. Suresh, "Heat transfer and friction factor studies in helically coiled tube using Al2O3/water nanofluid", *Eur. J. Sci. Res*. 82, pp. 161-172, 2012.
13. https://www.google.com/search?q=alumina+nanoparticles&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiM0-HXofTaAhUFv18KHc7nCMEQ_AUICigB&biw=1517&bih=681imgrc=-b5Wx8Oh9kObmM;SEM image of alumina nanoparticles.