Experimental Investigation of Heat Transfer of Cuo/Water-Mono Ethylene Glycol Nanofluid in a Counterflow Heat Exchanger with Twisted Tape

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ABSTRACT

In this work, the heat transfer attribute of Copper oxide/Water - Mono Ethylene Glycol nanofluids is scrutinized experimentally. A melange of water and mono-ethylene glycol was presumed as base fluid with varying proportions by volume. By ultrasonication, the solid nanofluids derived are utilized in the testings. The nanoparticle volume fraction of 0.05%, 0.10%, 0.15% by volume respectively are considered in this study to find out enhanced attributes of heat transfer of base fluid with nanofluid compared with regular coolant. It has been found that the major benefaction in transfer improvement is nanofluid flow scale and nanoparticles volume fraction whereas the escalation in heat transfer due to temperature at inlet of coolant is nether. The temperature of the hot fluid is maintained at 90ºC. Furthermore, this scrutinization denotes that the nanofluid depicts a great ability as heat transfer fluid. Utilization of nanofluid enables to design concise heat exchangers thus reducing the weight of the entire system and cost of production and transportation.

Keyword : *- Copper oxide; Mono ethylene glycol; ultrasonifiation; nanofluid; heat exchanger.*

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1. INTRODUCTION

Ashkan Alimoradi et al. in his work studied the various geometrical parameters which influence the heat transfer ability and entropy generation of the heat exchanger [1], Jian-Zhong Lin et al. investigated on flow and heat transfer characteristics of nanofluids containing rod-like particles in a turbulent pipe flow and Reynolds number, particle volume concentration and particle aspect ratio were derived [2], Amitkumar S. Puttewar et al. designed and evaluated shell and helical coil heat exchanger by c onsidering the various parameters such as flow rate of cold water, flow rate of hot water, temperature, effectiveness and overall heat transfer coefficient [3], Ming Pan et al. worked on improving heat recovery in retrofitting heat exchanger networks with heat transfer intensification, pressure drop constraint and fouling mitigation [4], Ya pingchen et al. investigated on performances of trisection helical baffled heat exchangers for oil/water–water heat transfer [5], Zhang-Jing Zheng et al. worked on Optimization of porous insert configurations for heat transfer enhancement in tubes based on genetic algorithm and CFD [6], Mehdi Bahiraei et al. worked on improving the energy efficiency of shell and tube heat exchanger equipped with helical baffles using nanofluid [7], K.Sivakumar et al. analyzed the performance of heat transfer and effectiveness on laminar flow with effect of various flow rates [8], Amol andhare et al. studied the the convective heat transfer coefficients of a helical coil heat exchanger are investigated experimentally [9], Shive Dayal Pandey et al. did experimental analysis of heat transfer and friction factor of nanofluid as a coolant in a corrugated plate heat exchanger [10]. Only a little moderations has been done in NFs among other prominent potentials. With further research in NF, this prominency is predestined. There is a need for variation in the nanoparticle magnitude to obtain experimental data from fluids. Further works has to be explored in determining the attributes such as particle form, distribution and motion of particle in HT. These attributes will yield a wider application of NFs as HT.

2. EXPERIMENT SETUP

The setup to conduct the experiment is employed is presented in fig. 1 and 2. The test equipment holds of two fluid tanks namely hot fluid tank and cold fluid tank. The hot fluid inlet conceals a twisted strip of copper. The cold fluid inlet gets extended into a large galvanized tube through with the hot fluid inlet follows. The inner tube is made of copper whereas the outer tube is cast iron

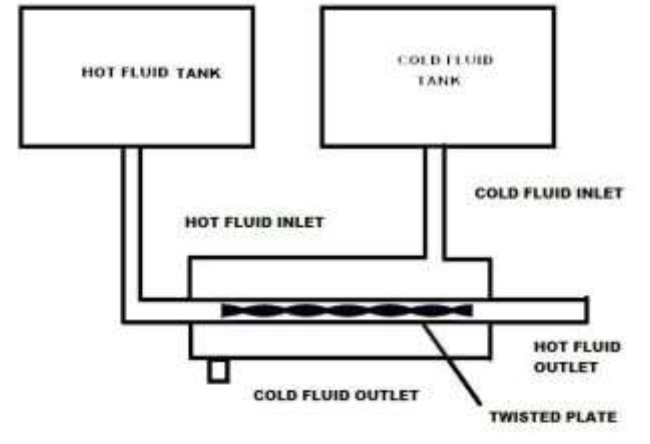

Fig -1 Experimental Setup

The inner diameter of the copper tube is 22 mm and the outer diameter is 25 mm. For Cast Iron tube, 54 is the outer diameter and 50 is the inner diameter. The cold fluid flows in the outer shell while the flow of NF is through the inner shell i.e. tube. Insulations has been made on the galvanized iron tube for proper heat transfer. There are 4 thermocouple been placed at four transition points for proper temperature measurement. The volume of the storage tanks been used can hold around 25 litres. The hot fluid tank gets its heat from an external electrical heater attached along with the setup. The temperature measurement from thermocouple can be read with the help of digital temperature indicator.

3. TEST PREPARATION

The heater is switched on and the water is heated up to an initial temperature of about 65 degree celsius. The flow rates of the hot water as well as the cold water tubes are adjusted. The respective flow rate is maintained until a steady state condition is reached. The inlet and the outlet temperature of the cold and hot fluids are noted. The transit of hot and cold fluids are also observed. The experiment is repeated for different Copper oxide concentrations.

4. PROCESSING OF EXPERIMENTAL OBSERVATIONS

First, the volume of the galvanized pipe used is determined. With the diameter and length of the tube known, we can calculate the volume (1) and similarly for the diameter and length of copper tube, we can also determine with the same formula the volume. Here, D is the diameter of tube and L is the length of the tube.

$$V_{GI} = \pi / 4 \times D^2 L \tag{1}$$

$$V_{Cu} = \pi / 4 \times D^2 L \tag{2}$$

The nanoparticle concentration used for testing process can be found with the volume concentration along with mass and density of water and Mono- Ethylene Glycol (MEG) can be found by the equation 3, for different concentrations: 0.0, 0.05, 0.1 and 0.15.

$$\text{Volume concentration}/100 = \frac{\text{Mass of CuO / Density of CuO}}{\frac{\text{Mass of CuO}}{\text{Density of CuO}} + \frac{\text{Mass of water MEG mixture}}{\text{Density of Water MEG mixture}}} \qquad (3)$$

To determine the temperature handling force of heat exchangers, Logarithmic Mean temperature difference is found. Here the inlet and the outlet temperatures of hot fluid are T_1 and T_2 respectively and the inlet and outlet temperatures of the cold fluid are t_1 and t_2 respectively.

$$\text{LMTD}_{0.00} = \frac{(T_1\text{-}t_2) - (T_2\text{-}t_1)}{\text{Ln}\,(T_1\text{-}t_2) / (T_2\text{-}t_1)} \qquad (4)$$

The heat given by hot water Q_h and cold water Q_c can be determined by equations 5&6. Here, m_{h1} and m_{c1} are mass flow rate of hot/cold fluid respectively, C_{ph1} and C_{pc1} are specific heat of hot/cold fluid respectively, and T_{h1} and T_{c1} are change in temperature of hot/cold fluid respectively.

$$Q_h = m_{h1}\, C_{ph1}\, T_{h1} \qquad (5)$$

$$Q_c = m_{c1}\, C_{pc1}\, T_{c1} \qquad (6)$$

The average heat transfer for all both the hot water and cold water if the heat given by hot water Q_h and cold water Q_c are determined by the formula.

$$Q_{avg} = (Q_{h1} + Q_{c1}) / 2 \qquad (7)$$

The maximum heat transfer can be obtained by the m_{min} and C_{pmin}

$$Q_{max} = m_{min}\, C_{pmin}\, (T_{hi} - T_{ci}) \qquad (8)$$

For Overall heat transfer, by formula

$$U_0 = Q_{avg} / \text{LMTD}\, A_0 \qquad (9)$$

Effectiveness can be calculated for Q_{avg} and Q_{max}

$$\text{Effectiveness } (\epsilon) = Q_{avg} / Q_{max} \qquad (10)$$

5. RESULTS AND DISCUSSION

By varying the mass flow rate of hot and cold fluids with Cu0, observations are made and tabulated in table 1.

Table -1 Experimental Results

S.NO.	VOLUME CONCENTRATION	AVERAGE HEAT TRANSFER	MAXIMUM HEAT TRANSFER	LMTD	OVERALL HEAT TRANSFER COEFF.	EFFECTIVENESS
1.	0.0	324.7	823.57	18.98	380.8	0.394
2.	0.05	384.65	864.8	19.49	438.58	0.44

3.	0.1	426.05	988.43	22.49	451.85	0.461
4.	0.15	502.57	1050.2	22.98	487.07	0.47

Turbulence has been yielded due to the placement of twisted copper strip inside the hot pipe. As a result, counter flow heat exchanger effectiveness was higher than the results without the twisted tape in parallel flow.

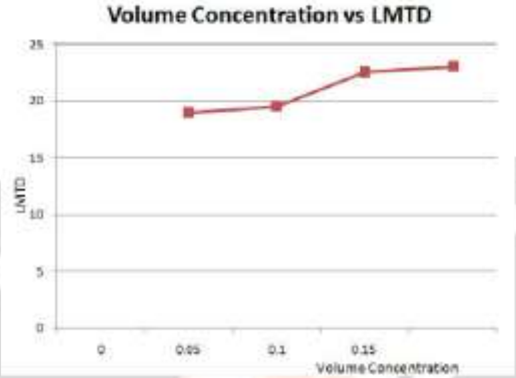

Fig -2 Volume Concentration vs LMTD

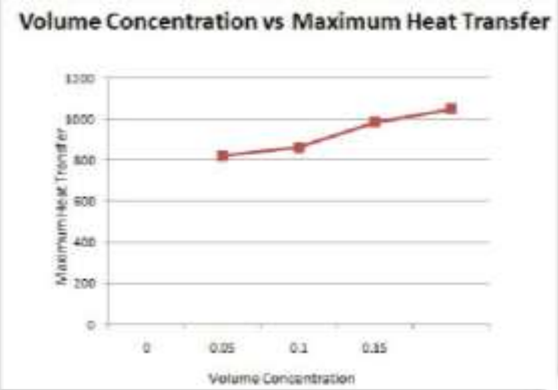

Fig -3 Volume Concentration vs Maximum heat transfer

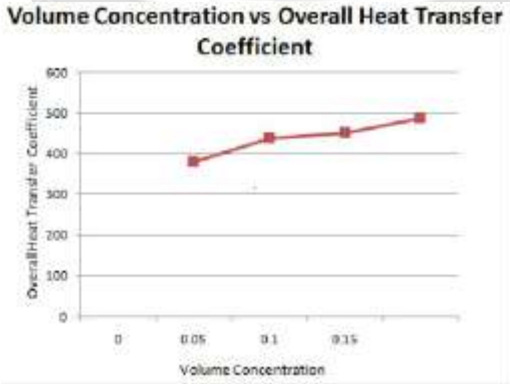

Fig -4 Volume Concentration vs OHTC

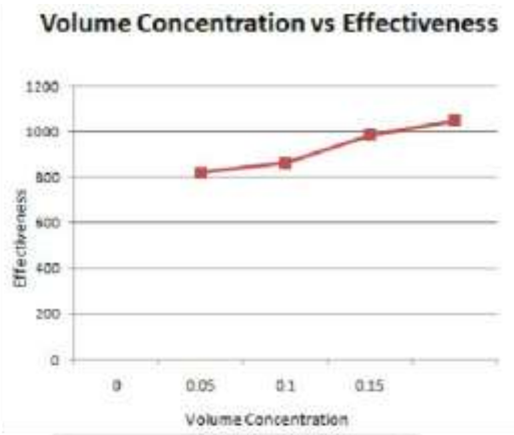

Fig -5 Volume Concentration vs Effectiveness

6. CONCLUSIONS

In the investigation conducted various heat transfer properties such as log mean temperature difference, overall heat transfer coefficient, mass heat transfer coefficient and effectiveness of Cu0/Water. Mono ethylene glycol at various volume concentrations of nanofluid particles and following outcomes are been made:

- All of these four transfer properties have seen a significant increase with the addition of CuO nanoparticle in water and mono ethylene glycol base fluid of which indicates that the use of nanoparticles in heat transfer applications are preferable.
- The Log Mean Temperature Difference is said to be increased to about 21.01% with the addition of 0.15% nanoparticles.
- The Maximum heat transfer coefficient has seen a rise of 27.5% with inclusion of 0.15% of CuO nanoparticle.
- In a similar manner, the overall heat transfer coefficient also seen an increase of 27.9% upon addition of 0.15% CuO.
- The effectiveness has seen an increase of about 20/5% when 0.15% CuO added in base fluid.
- It can be thus concluded that nanoparticle directly influence the heat transfer property of base fluid and thus can be used for practical industrial applications where transfer of heat is involved.

7. FUTURE SCOPE

The investigation can be elaborated with the use of hybrid nanofluids containing two or more nanoparticles. The experiment can be carried out using more insert elements such as trapezoidal twisted plates and baffle.

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