An Experimental Investigation Of Heat Transfer Characteristics Of Al2O3 Nanofluid Using Shell And Tube Heat Exchanger

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Abstract- *This study describes the investigation of heat transfer characteristics of Al2O3 Nanofluid using shell and tube heat exchanger. For this α- Al2O3 nanoparticles having size 30nm is used to prepare three different concentration of (0.3%,0.5%, and 0.7%) nanofluid . In experiment effect of three different concentration and volume flow rate on different parameters like Heat transfer rate, Convective heat transfer coefficient, Overall heat transfer coefficient, LMTD have been assessed experimentally. The result indicates that the Nu and Overall heat transfer coefficient of heat exchanger enhanced with the application of AL2O3 nanofluids.*

Keywords- Heat transfer, Nanofluid, Thermal Conductivity etc.

I. INTRODUCTION

Shell and tube heat exchanger is widely used in different heavy-duty applications like refrigeration and air conditioning, in the thermal power plant as a condenser and as a heater, in a process plant for heating etc. But to some extent shell and tube heat exchanger faces the problem of poor heat transfer rate. So to improve heat transfer rate there are lots of ways like to use fin, increase number of tube passes, provide baffles etc. All these solutions reach their far implication. So one can also manipulate with thermal properties of working medium of the heat exchanger. In present study effect of using Al_2O_3 Nanofluid as a working medium inside the heat exchanger has been investigated experimentally.

Barzegarian et.al. [2] have been carried out experiment under a laminar flow condition using three different concentration of nanoparticles (0.03%,0.14%,0.3%) . Nanofluid has been prepared using Sodium dodecyl Benzene Sulphonate (SDSB) as a surfactant to improve stability of nanoparticle inside base fluid. Result revealed that the Nu & overall heat transfer coefficient increases with Re because for laminar flow as we fix concentration level value of Pr become fix and Nu is directly proportional to Re. Again result shown that at particular Re the value of Nu & overall heat transfer coefficient increased with the increase in concentration. Value of friction factor decreased with the increase in Re and for given Re its value is maximum for 0.3% concentration. Azmi et.al [3] research presents the effect of increment of Alumina nanoparticles dispersed in 60:40 water to ethylene glycol based nanofluids towards heat transfer enhancement. Research has been carried out using three different volumetric concentrations of 0.2%, 0.4%, 0.6% for Re less than 20,000. Result shown that the Heat transfer coefficient and Nu increased with the increase in Re. An enhancement of 14.6% was observed for a concentration of 0.6%.

II. EXPERIMENTAL APPARATUS

The Figure 1 shows the layout of the experimental setup, used to investigate the heat transfer characteristics of the Al_2O_3 Nanofluid. Set up comprises of shell and tube heat exchanger, two flow loops namely Hot water loop and cold nanofluid loop, two submersible pump, and K-type of thermocouple to measure inlet, outlet temperature of fluid and surface temperature of tube.

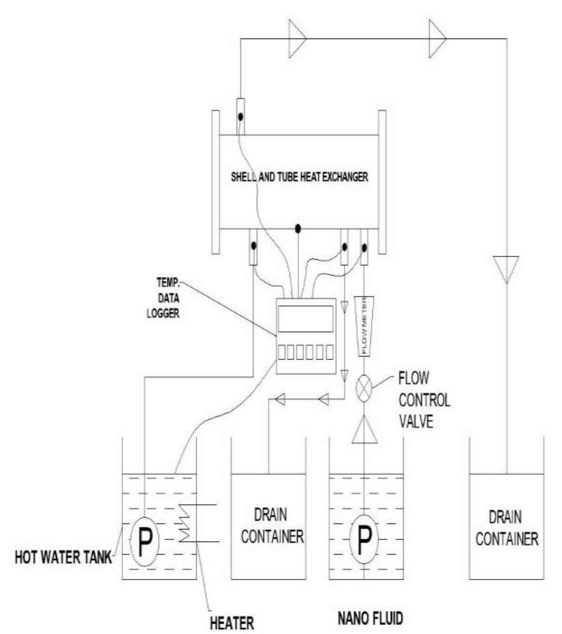

Fig.1 – Experimental Setup

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III. NANOFLUID PREPARATION

The water based Al_2O_3 nanofluid is devloped for three concentration level of 0.3, 0.5 and 0.7 vol% by dispersion of Al_2O_3-alpha nanoparticles with 30 nm mean diameter and 99.5% purity purchased from AUTUS NANOLAB. Since the surfactant reduces the fluid adhesion, it is expected to make the suspended fluids such as nanofluids more soluble and stable. For this purpose, Polyvinylpyrrolidone (PVP) was utilized as surfactant to make Al_2O_3-water nanofluid at mentioned volume concentrations of suspended nanoparticles. For better dispersing of nanoparticles in distilled water, decrement of nanofluid sedimentation and also the particle agglomeration, all solutions (consist of water, nanoparticles and surfactant) were stirred and then sonicated in an ultrasonic homogenizer for 60 min at 30Khz frequency.

IV. DATA REDUCTION

Thermophysical Properties of nanofluids:

To perform experiment accurate determination of thermal properties is desirable. Some of the theoritical models are available to calculate different properties like density, specific heat, viscosity ,Thermal conductivity etc. are described as below,

The density of nanofluids can be determined by using the Pak and Cho expression.

$$\rho_{nf} = (1-\emptyset_v)\rho_{bf} + \emptyset_v\rho_{np} \qquad (1)$$

The specific heat is calculated from Xuan and Roetzel equation,

$$\rho_{nf}C_{pnf} = (1-\emptyset_v)\rho_{bf}C_{pf} + \emptyset_v\rho_{np}C_{pnp} \qquad (2)$$

Einstein proposed an expression for determining the dynamic viscosity of dilute suspensions that contain spherical particles.

In the model, the interactions between the particles are neglected. The associated expression is as follows. This expression is valid for concentration level below 5%.

$$\mu_{nf} = (1+2.5\emptyset_v)\mu_{bf} \qquad (3)$$

Maxwell model has been used for calculation of thermal conductivity

$$\boldsymbol{K_{nf} = \frac{K_{np} + 2K_{bf} + 2\emptyset_v(K_{np}-K_{bf})}{K_{np} + 2K_{bf} - \emptyset_v(K_{np}-K_{bf})}} \qquad (4)$$

Thermal Parameters:

Heat gain by nanofluid is calculated using the below equation,

$$Q = \dot{m}_n C_{pnf}(t_{no} - t_{ni}) \qquad (5)$$

Overall heat transfer of nanofluid is the calculated using following equations,

$$Q = UA\,\theta_m \qquad (6)$$

Where $\theta_m = \frac{(\theta_1-\theta_2)}{ln\left(\frac{\theta_1}{\theta_2}\right)}$ (7) $\theta_1 = (t_{wi} - t_{no})$ (8)

$$\theta_2 = (t_{wo} - t_{ni}) \qquad (9)$$

Convective heat transfer coefficient of nanofluid is calculated using the below equation,

$$Q = h_i A_s (t_W - t_b) \qquad (10)$$

V. DATA VALIDATION

Before performing experiment with nanofluid, initially the experimental set up is validated for its accuracy by performing some experiments with distilled water. The experimental Nusselt number values are then compared with Saider –tate correlation,Hausen Correlation and Shah correlation for laminar Flow

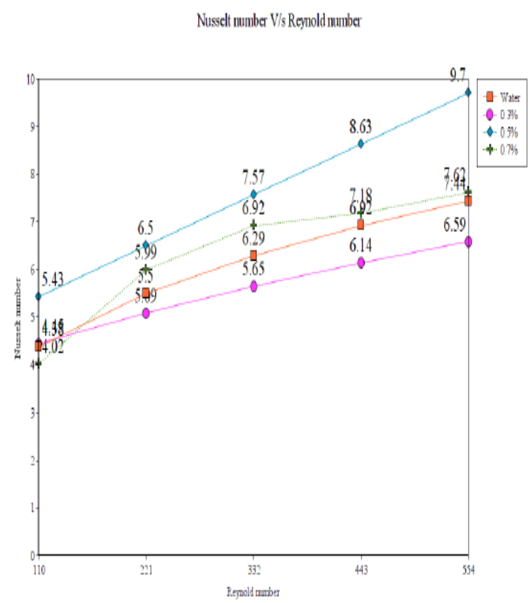

Fig.2 – Variation of Nu with Re

A good agreement with a average deviation of 7.144 % is obtained between experimental nusselt number and with Nusselt number obtained by Saider-Tate correlation.

VI. RESULT AND DISCCUSION

Based on experiment it is seen that the Heat transfer rate of nanofluid augments with enhancement of volume flow rate of nanofluid and concentration. Compared to water Maximum enhancement of 51.48% was obtained for 0.7% concentration level.

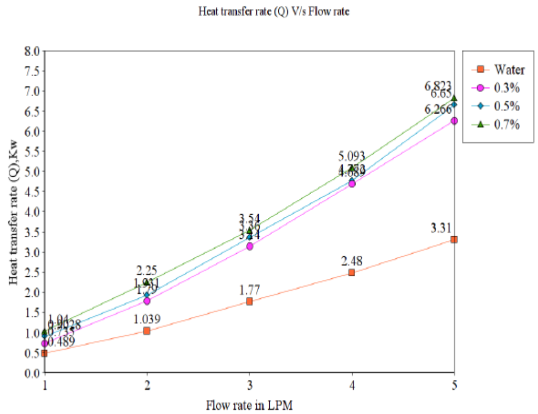

Fig.3 – Variation of Heat transfer with flow rate

It can be seen from Fig 4 that the variation of the overall heat transfer coefficient of the nanofluid with respect to different volume flow rate for various volumetric concentration. It increases with the increase in concentration ratio due to fact that the overall heat transfer coefficient is inverse of thermal resistance and Thermal resistance decreases because of high heat transfer rate of nanofluid. Hence overall heat transfer coefficient Increases. Compared to water average enhancement of 64.89% was obtained for 0.7% concentration level.

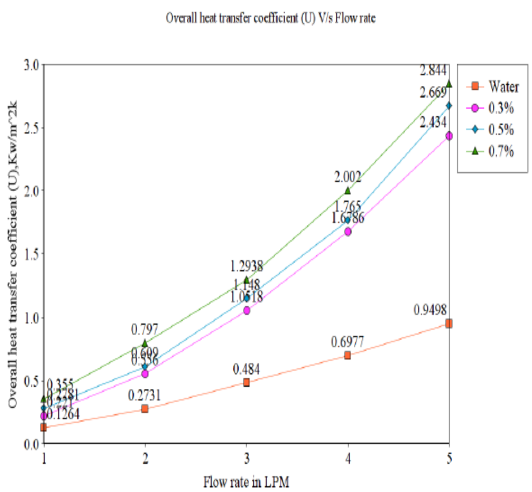

Fig.4 – Variation of Overall Heat transfer coefficient with flow rate

Results clearly indicate that the convective heat transfer coefficient of nanofluid increases with volume flow rate for each concentration. For all three nanofluids, the convective heat transfer coefficient increases significantly as the concentration of nanoparticle increases in the base fluid at a constant volume flow rate. For flow rate of 5 LPM the convective heat transfer coefficient for 0.7% volume concentration is 2.95% higher than 0.5% volume concentration.

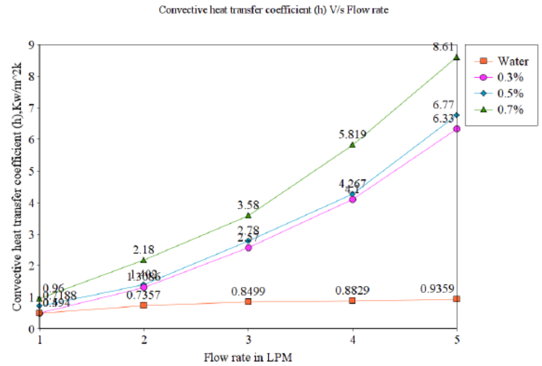

Fig.5 – Variation of Covective Heat transfer coefficient with flow rate

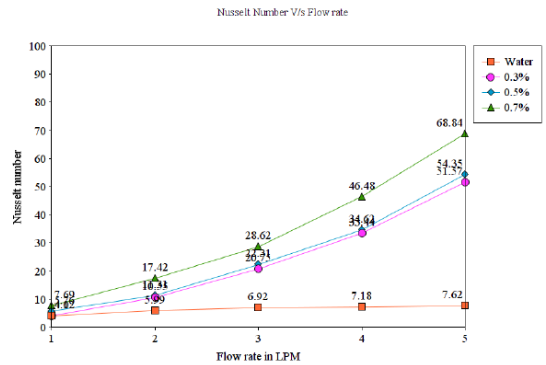

Fig.6 – Variation of Nu with flow rate

The non dimensional Nu increases with the increasing in concentration level. Beside the increase in thermal conductivity chaotic movement of particle, Brownian motion and reduction in thermal boundary layer plays major role in enhancement of Nu. For 5 LPM and $\emptyset_v$=0.3% the enhancement is found to be 85.224%and enhancement in Nu is found to be 87.97% and 88.96% for $\emptyset_v$=0.5%, 0.7% respectively.

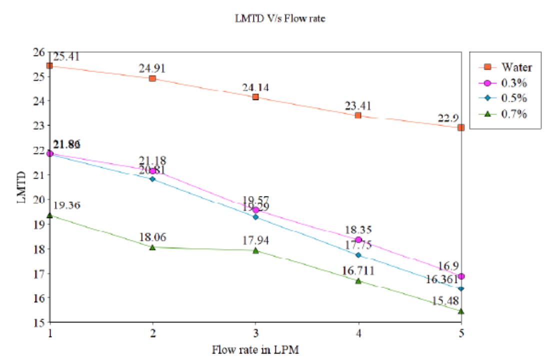

Fig.7 – Variation of LMTD with flow rate

It is seen that the LMTD decreases with the increase in volume concentration and volume flow rate .This is because the LMTD is inversely proportional to the convective heat transfer coefficient. For volume flow rate of 5 LPM and at $\emptyset_v$=0.7% the reduction in LMTD is found to be 47.93% compared with water.

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