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Experimental Investigation on Heat Transfer Enhancement of Three Tube Heat Exchanger using Aluminium Oxide (Al_2O_3)/Water Nano fluid

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ABSTRACT

Enhancement of heat transfer can be done by increasing the heat transfer area, heat transfer coefficient, thermal conductivity of the metal and thermal conductivity of the fluid. In general the thermal conductivity of the fluid is less than the thermal conductive of the solid. The thermal conductivity of the fluid can be increased by suspending the metal particles in the basic fluids. Experiments were conducted for water and different volume concentration of Alumina (Al2O3) /water Nano fluid. It is found that the enhancement of Overall heat transfer coefficient by using multi passes and nano fluid (0.1%, 0.3% and 0.5% volume concentrations) is increased. The Effectiveness of the heat exchanger was increased by 13.88%, 21.65% and 30.41% for different volume concentrations of Alumina (Al2O3) and also observed that Nano fluid performs better than the water with three tube heat ex-changer.

Keywords:— *Heat exchanger, three tube exchanger, Nano fluid, effectiveness. Volume concentration.*

I. INTRODUCTION

The conversion of energy provided by nature into useful work and to exchange or transfer the energy from one fluid to another either by conduction, convection or radiation or with all modes of heat transfer is necessary. Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while preventing them from mixing with each other. There are various ways of heat exchange methods from one fluid to another fluid. The heat transfer in a heat ex changer can be enhanced by increasing the heat transfer area, heat transfer coefficient, thermal conductivity of the metal and thermal conductivity of the fluid. Usually, the thermal conductivity of the fluid is less than the thermal conductivity of the solid. Heat exchangers have a wide spectrum of applications in industrial and commercial areas. To increase the efficiency of the heat exchangers, various methods like installing baffles, adding additives etc. have been employed. The base fluid usually used is water which has a lower thermal conductivity when compared to metals. So by dispersing the Nano sized metallic particles in the base fluid, the thermal conductivity increases considerably. J. Vadasz, et al [1] did theoretical investigation of heat transfer enhancement (experimentally) using Nano-fluids suspensions at the macro-scale level. L. Syam Sundar et al, [2] conducted experiments to determine the thermos-physical properties like thermal conductivity and viscosity of Al_2O_3 Nano fluid at different volume concentrations and temperatures. Kamaldeep Singh, et al, [3] did experimental work at different temperature ranges with varying volume concentration (0.1%, 0.2%,0.5%). Al_2O_3 Nanoparticle in dispersed in the base fluid and the behavior of thermo physical properties of Nano fluid are studied and compared with the base fluid. Alpesh V Mehta, et al. [4] did experimental investigation and indicated that particle size, volume fraction and properties of the Nano-particles influence the heat transfer characteristics of Nano fluids.

This paper shows the work on Mini heat exchanger using Al_2O_3- Water Based Nano fluid. The present work has been done on the three tube heat exchanger with Nano fluid (Al_2O_3) as coolant and observed the performance of the exchanger with Nano fluid and water.

Nanofluid Preparation and Evaluation of Thermo-Physical Properties:

For the preparation of Nano fluid, Al_2O_3 Nanoparticles having an average particle size of 100nm are purchased from Reinste Nano Ventures Pvt. Ltd. Nano fluid with a required volume concentration of 0.1%, 0.3%, 0.5% was then prepared by dispersing a specified amount of Al_2O_3 Nanoparticles in water by using a ultrasonic vibrator (Toshiba, India) generating ultrasonic pulses of 100W at 36 ± 3 kHz. To get a uniform dispersion and stable suspension which determine the final properties of Nano fluids, the Nano fluids are kept under ultrasonic vibration continuously for 2-3 hour. Surfactants were used for the stability of the Nano fluids. [5,6,7 and 8].

Figure : 1 Ultra Sonicator

Figure : 2 Nano Power

Figure : 3 Sample of Nanofluid

The amount of Nanoparticles required for preparation of Nano fluid with different volume fractions and the thermo physical properties of Nano fluid are estimated by using the following correlations. Volume of Nanoparticles is

$$\frac{\emptyset}{100} = \frac{\text{VloumeofAlumina}}{\text{VloumeofAlumina+Vloumeofwater}}$$

Density of Nano fluid is $\rho = \varphi\rho - (1 - \varphi)\rho$, Here ρ_{nf} is density of Nano fluid, φ is Volume fraction of Nanoparticle, ρp is density of Nanoparticle and ρw is density of base fluid. Specific heat of Nanofluid is $C_{P,nf} = (1 - \emptyset)(Cp)_{bf} + \emptyset(Cp)p$, Where ρ, Cp are density and specific heat. Subscripts nf, p and w indicate Nanofluid, Nanoparticle and water respectively. The correlation used for estimating the dynamic viscosity of Nanofluid, μnf is $\mu nf = \mu w(1+39.11\ \phi+533.9\ \phi 2)$ μw is dynamic viscosity of water. Wasp's thermal conductivity $k_p+2k_w-2\varphi(k_w-k_p)$ model is used to estimate effective thermal conductivity of Nano fluid.

$$Knf = Kw\left[\frac{k_p+2k_w-2\varphi(k_w-k_p)}{k_p+2k_w+\varphi(k_w-k_p)}\right]$$

Knf is thermal conductivity of Nano fluid, k_p is thermal conductivity of Nano particle and k_w is thermal conductivity of water[9, 10, and 11].

2. Experimental Setup and Procedure

Three concentric tubes having different diameters (2.5cm, 3.86cm and 4.60cm respectively) are arranged co-axially with the central axis of the heat exchanger as shown in the Figure 3. The hot water flows in the outer most and inner most pipes and cold water flows in the middle pipe connected with proper inlets and outlets. The above arrangement can have the advantage of both parallel flow and counter flow at a time. Hot water flows in to the heat exchanger though the electric heat, which is used to rise the water temperature and water temperature measured with the thermocouples(0°C to 100°C) at inlet and outlet of pipe. The flow rates are regulated with the help of control valves and by bypass valves and two rotometers (5-25 LPM) are also connected at to measure the flow rate. Pressure gauges are connected to measure the pressure variation in the flow at each inlet and outlet of the pipes. Four thermometers are used to measure the temperatures at inlet and outlet of the heat exchanger. One pump is used to pump the Nano fluid in to the heat exchanger and exit is connected to the radiator having a fan, which is used to cool the Nano fluid for re-circulation in to the heat exchanger.

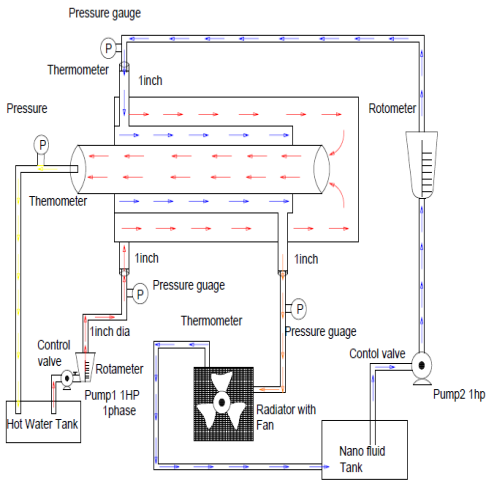

Figure : 4 Schematic diagram of Three Tube Heat Exchanger

2.1 Heat Transfer Analysis

The amount of heat transfer from the hot fluid to cold can be calculated by using the inlet and outlet temperatures. Heat transfer from the hot fluid is

$$\cdot Q = mnf\ Cnf(Tnf, out\ \_\ Tnfin) = mh\ Ch(Th\ in\ \_\ Th\ out) = UA\ (\Delta T)m \ldots\ldots\ldots\ldots [1]$$

The amount of heat gain by the Nano fluid is

Log mean temperature difference for three tube heat exchanger is derived

$$\text{mathematically}\Delta T_m = \frac{\sqrt{\left(T_{h_i}-T_{h_o}\right)^2+\left(T_{nf_o}-T_{nf_i}\right)^2}}{\log_e \frac{\left(T_{h_i}-T_{h_o}\right)-\left(T_{nf_o}+T_{c_i}\right)+\sqrt{\left(T_{h_i}-T_{h_o}\right)^2+\left(T_{nf_o}-T_{nf_i}\right)^2}}{\left(T_{h_i}+T_{h_o}\right)-\left(T_{nf_o}+T_{nf_i}\right)-\sqrt{\left(T_{h_i}-T_{h_o}\right)^2+\left(T_{nf_o}-T_{nf_i}\right)^2}}} \ldots\ldots\ldots\ldots [2]$$

$$\text{Effectivenessofheatexhanger} = \frac{\text{actualheattransferrate}}{\text{maximumheatransferrate}} = \frac{\dot{Q}}{Q_{max}} = \frac{C_{nf}(T_{nf,out}-T_{nf,in})}{C_{min}(T_{h,in}-T_{nf,in})} \ldots\ldots\ldots\ldots [3]$$

III. Results and Discussions

Experiment is conducted on the three tube heat exchanger with various flow rates at hot fluid and cold fluid side with water and Nano fluid. The following Results are observed and discussed.

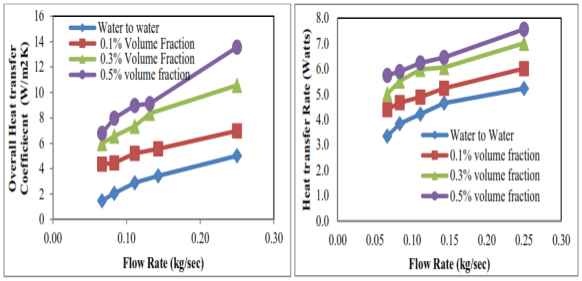

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Figure : 5 Compression of Overall heat transfer coefficient and heat transfer rate for different volume fractions

It is observed that there is increase in overall heat transfer Coefficient with Nano fluid as compared with water. Overall heat transfer coefficient is also increases with increase of volume fraction of Nanoparticle. If volume fraction of Nanoparticle increase means that more Nanoparticles have a contact with the surface area. Because of high contact area more amount heat can transfer to the cold fluid. There are variations in the values of heat gained by the cold water of the Nano fluid with various mass flow rates as shown in the table. Average heat gain by the cold fluid with various volume fraction of Nano fluid is 25%.

3.1 Comparison of Effectiveness and Percentage Increase of Effectiveness

It is observed that the effectiveness of water to Nano fluid increases when compared to water to water experiment because the thermal conductivity of metal oxide Nano fluid is more.

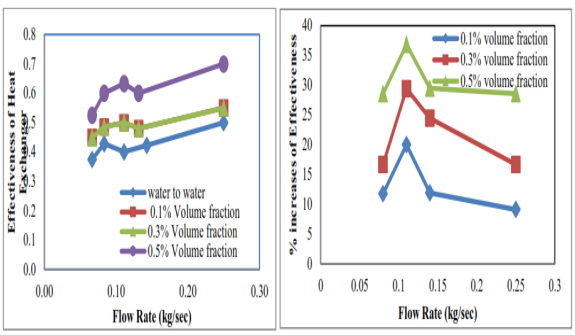

Figure : 6 Comparison of effectiveness and percentage increase of effectiveness with water and Nano fluid

As the mass flow rate decreases, the effectiveness of water to water and water to Nano fluid experiment decreases. When we compare the different volume fractions of the Nano fluid, it is seen that the heat effectiveness also increases. Effectiveness of heat exchanger is increased with increase of volume fraction of (0.1%, 0.3%, and 0.5%) of Nanoparticle in the range of 13.88%, 21.65% and 30.41%.

IV. CONCLUSIONS

The experimental investigation carried on three tube heat exchanger with Nano fluid by varying different mass flow rate and different volume fraction of Nano fluid. Form the experimental study the following conclusions are drawn as follows. Overall heat transfer coefficient is increased with Nano fluid when compared with only water. Three tube heat exchanger is having the arrangements of parallel and counter flow at a time, and the use Nano fluid is the main reasons for increase of overall heat transfer coefficients. Heat gain by the cold fluid is enhanced with different volume fractions of Nano fluid as compared with water. Nanoparticles can occupy the more surface area, because of the size of the Nanoparticles. Nanoparticle size is considered less than 100 nm for the present work. The effectiveness of water to Nano fluid is more when compared to water to water. This is due to the high thermal conductivity of metal oxide Nano fluids. Effectiveness of heat exchanger is increased with increase of volume fraction of (0.1%, 0.3%, and 0.5%) of Nanoparticle in the range of 13.88%, 21.65% and 30.41%.

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