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Experimental Investigation of Pipe in Pipe Tube Heat Exchanger Using Sio_2 Nanofluid

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Abstract - Pipe in pipe tube heat exchanger system was design and constructed to investigate the behavior of the nanofluid SiO_2 with respect to the base fluid. Heat transfer characteristics were measured. Experimental setup consists of outer M.S pipe, inner aluminum pipe, SiO_2 nanofluid with 2% vol concentreat ,100nm size and water is a base fluid. Based on results heat transfer characteristics of the nanofluid improve the performance of the heat exchanger. By adding the nanopartical in the base fluid which increases the heat transfer characteristics and results in larger the heat transfer coefficient as compare to base fluid. In this paper we see the how nanofluid affects in the heat transfer.

Key Words: heat transfer characteristics, Nanofluid, pipe in pipe tube heat exchanger, Effectiveness .

1. INTRODUCTION

Pipe in pipe tube heat exchanger is a mechanical device, used to transfer of heat between two fluids at different temperatures. This types of heat exchanger widely used in industries. Now a day for heat transfer enhancement, nanofluid is used. The first time nanofluid was defined in 1995, when Choi, working in a research project at Argonne National Laboratory. Nanofluid is the mixture of nanopartical and base fluid. Nanopartical have the highly thermal conductivity, so it increases the thermal property of the base fluid (water or glycol). This exchanger used in food industries, petroleum industries, oil industries, thermal power plant and chemical industries etc. For increasing heat exchanger performance now a day's nanofluid is widely used in heat transfer devices. Now companies trying to find high heat transfer in compact heat exchanger. So by using nanofluid with various concentrations will increases the heat transfer rate at compact heat exchanger. So nanofluid is helpful for designing the heat exchanger which transfers more heat in compact size as compare to conventional heat heat exchanger. In this pipe in pipe tube heat exchanger SiO2 nanofluid with 100nm size at 2% vol. concentration is used.

1.1 Materials Selection

By studying the research, the many different nanofluid is used in heat exchanger like CuO, Al_2O_3 , ZnO etc. Base fluid mostly used for preparation of the nanofluid are water , ethylene glycol , engine oil etc. from the above study we have select the pipe in pipe tube heat exchanger with SiO_2 nanofluid.

Table -1: Thermal properties of water and SiO_2 nanofluid

Sr. No.	Property	water	SiO_2
1	density(Kg/m^3)	998	2220
2	Specific Heat (J/kg-k)	4187	745
3	Thermal conductivity (W/m.K)	0.58	1.4
4	Viscosity (Pa.s)	0.0019	-

Table -2: Material Specification

Sr. No.	Quantities	Materials	Size
1	Working fluid	Water and SiO_2	100nm
2	Upper pipe	M.S	Φ76.2mm(3inch)
3	Inner pipe	Aluminum	Φ25.4mm(1inch)
4	Piping	PVC	½ inch

2. EXPERIMENTAL SETUP

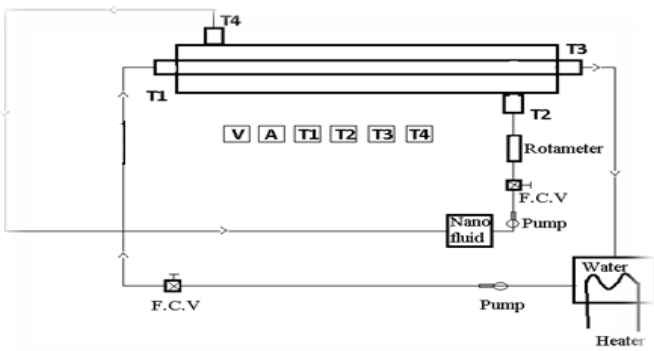

Fig -1: Line diagram of the setup

The pipe in pipe tube heat Exchanger consists of two pipes. Outer pipe made up of M.S having outer diameter 76.2mm and inner diameter 74.2 mm and 1m long. Inner pipe made up of aluminum having inner diameter 23.4mm and outer diameter 25.4mm and 1050mm long. On the inlet of one pipe valve is provided to open and close alternatively for parallel and counter flow operation. Two tanks are used for store cold and hot fluid. Two pumps is used for pumping the fluid in the heat exchanger it pump maximum 10.lpm of fluid. 2500 W one immersion heater is used, to heat the fluid. For flow measuring one rota meter is used to measure the cold fluid flow. Four K type thermocouple is used for measuring temperature of the inlet and outlet of the both fluids. For temperature indicating digital temperature indicator is used.

Fig -1: Experimental setup

2.1 Analysis of pipe in pipe tube Heat Exchanger

The analysis of the heat exchanger as following [7]:

i) Hot fluid heat transfer rate $Q_h = m_h \times C_{ph} \times (Th_i - Th_o)$

ii) Cold fluid heat transfer rate $Q_c = m_c \times C_{pc} \times (T_{Co} - T_{Ci})$

Where (Th_i, Tho) is the inlet and outlet temperature of the hot fluid. And (T_{Ci}, T_{Co}) is the inlet and outlet temperature of the cold fluid. m_h and m_C is the mass flow rate of hot and cold fluid.

$$Q_{avg} = \frac{(Qh + Qc)}{2}$$

iii) Effectiveness of the Heat Exchanger

$$\mathcal{E} = \frac{\dot{m}hCh\,(Thi - Tho)}{\dot{m}cCc\,(Thi - Tci)}$$

iv) Density of nanofluid calculated

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

v) Specific heat of the nanofluid

$$C_{pnf} = \frac{\phi \times C_{pnp} + (1-\varphi) \times \rho_{bf} \times C_{pbf}}{\rho_{nf}}$$

Where ρ_{nf}, C_{pnf} is the density and specific heat of the nanofluid respectively. Φ is the weight concentration of the of the nanopartical in volume of the base fluid. C_{pnp} and C_{pbf} is the specific heat of the nanopartical and base fluid respectively.

3. RESULTS AND DISCUSSION

In order to study of pipe in pipe tube heat exchanger, the nanopartical increase the thermo physical properties of the base fluid. By using nanofluid we will increase the heat transfer characteristics of the exchanger. Nanofluid gives the good result than water. Also the increases or decreases of the mass flow rate, is affect on heat transfer rate.

Table -3: Observation table

$\dot{m}$(lpm)	T_{wi}	ΔT_w	T_{ci}	ΔT_N	Qw_{avg}	Qn_{avg}	$\mathcal{E}_w$	$\mathcal{E}_w$
10	60	13.6	32	14.9	7000.66	7856.04	0.25	0.34
10	60	13.7	32	14.9	7101.15	7923.03	0.27	0.35
9	60	14.9	32	16.7	7285.37	8219.79	0.28	0.38
9	60	15.1	32	16.9	7473.79	8279.82	0.30	0.385
8	60	15.5	32	17.6	7415.16	8451.70	0.34	0.44
8	60	15.9	32	17.5	7415.17	8452.97	0.35	0.45

Results are shown in graphical forms, as they following:

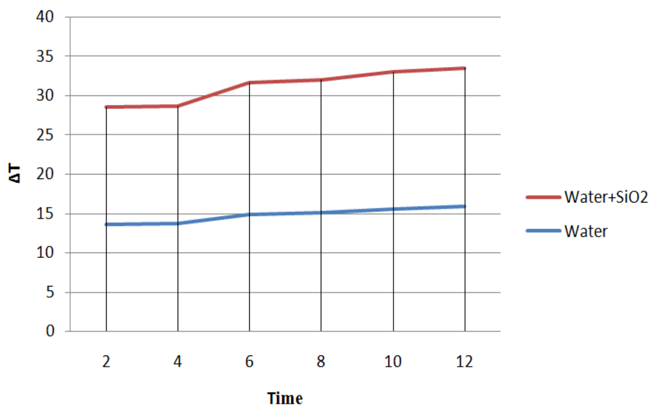

Chart -1: Time vs. temperature difference

It is the combine graph of water vs. SiO_2 nanofluid. This graph clearly shows that the difference between nanofluid and water. In this we see that time increases at specific interval there is increases the temperature difference. So we see that as compare to water nanofluid gives more temperature difference.

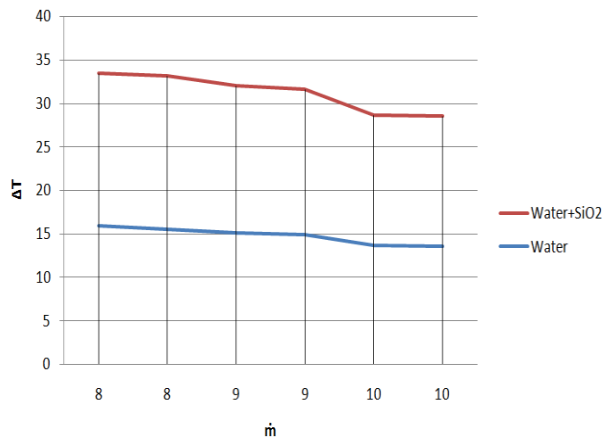

Chart -2: Mass flow rate vs. temperature difference

Chart 2. Shows that comparison between mass flow rate vs. temperature difference of the water and nanofluid. Nanofluids have more thermal conductivity than water. That means it will conduct more heat than water. In the graph we see that if we decrease the mass flow rate of the nanofluid or cold water there is increases the temperature difference of the heat exchanger. Means that if we vary the flow of the fluid there is affect on the outlet temperature of the heat exchanger.

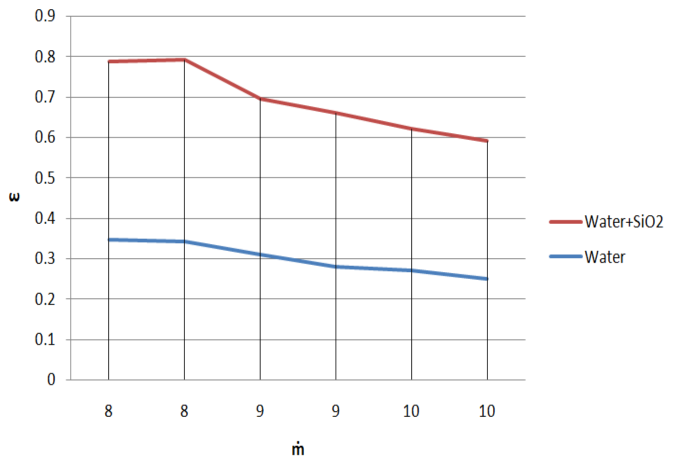

Chart -3: Mass flow rate vs. Effectiveness

The chart shows that the effectiveness of the water and nanofluid. And we see the combine result of the mass flow rate vs. effectiveness of the heat exchanger of water and nanofluid. Effectiveness of the heat exchanger is depends on temperature difference of the hot water and temperature difference of the inlet hot and inlet nanofluid fluid. So as we discus above if we vary the mass flow rate there is also vary the temperature difference of the hot water and nanofluid. Means that if we vary or reduce the mass flow rate of the working fluid, there is vary or increase the effectiveness of the heat exchanger. Effectiveness of the heat exchanger should be lies in between 0 to 1

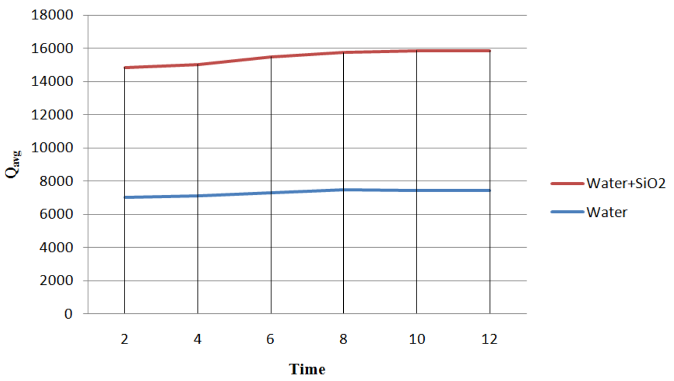

Chart -4: Time vs. average heat transfer rate

The chart 4 shows that water and nanofluid combine result of time vs. average heat transfer rate. Heat transfer rate of the heat exchanger is depends on the temperature difference of the fluid. So chart 4 shows that if we increases the time at a specific interval there is increases the average heat transfer tare of the heat exchanger.

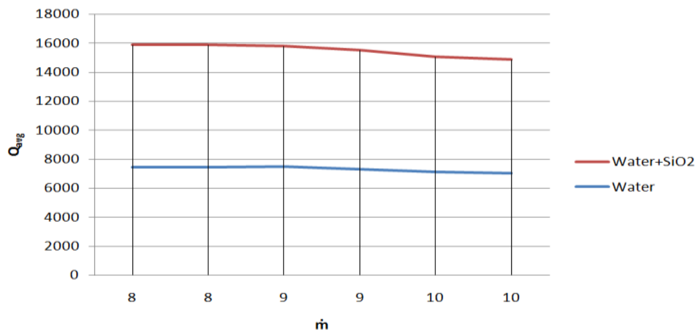

Chart -5: Mass flow rate vs average heat transfer rate

It is seen that effect of mass flow rate on average heat transfer rate of the heat exchanger. From chart 5 we see as we decrease the mass flow rate, there is average heat transfer rate of the nanofluid increases.

3. CONCLUSIONS

Heat transfer rate is directly proportional to Reynolds number. Pressure drop increases with increase in volume concentration. Spherical shaped nano-material give better heat transfer rate than other shapes. From the Experimental investigation we observed that thermal conductivity of the nanofluid is greater than water.

Inlet Temperature of the hot and cold fluid will also affect on the heat transfer rate. Also by varying the mass flow rate we can control the heat transfer rate and effectiveness of the heat exchanger. Increasing the time is also increases the heat transfer rate. By using SiO_2 nanofluid as a cooling fluid in the pipe in pipe tube heat exchanger Effectiveness of the heat exchanger increased by 23.10% as compare to the water.

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