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Thermal Performance of Concentric Pipe Heat Exchanger Using Nano-particle In Base Fluid

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Abstract — *Nanofluids are new kind of high potential heat transfer medium. This Project aims to experimentally investigate Thermal performance of concentric pipe heat exchanger using Nano fluid(CuO) with change in volume fraction(Concentration). The results obtained from nanofluids cooling in concentric tube heat exchanger are compared with those from base fluids.*

Keywords*-Nano fluid ;Concentric Pipe ;Heat Exchanger ;CuO.*

I. INTRODUCTION AND NANO FLUID

Past decade is a witness of the growth in a domain of nano technology [1, 2]. Gradually, nanotechnology has paved its way in various fields, such as heat transfer, medical science, and electronics [1].

A wide verity of industrial process involves the transfer of heat energy. The enhancement of heating or cooling in an industrial process may create a saving in energy, reduce process time, raise thermal rating, and improve working life of equipment. In conventional fluid, if the solid particles (2 mm) are added then it increases the thermal conductivity. But it leads to certain problems like layer formation, erosion, and low dispersion[3].

Low thermal conductivity of fluid is a challenge in heat exchanger development [4, 5].At present, researchers are using novel methods to improve the thermal properties of fluid for better heat transfer [4]. One of such method of improving the heat transfer efficiency of fluid is by addition of small size solid particles in fluid [4]. Generally slurries of different types of powders comprise of metallic, non-metallic and polymers are used by the researchers for the development of a fluid with better thermal conductivity [4]. Effect of such powder based slurries on heat transfer are evaluated by the researchers [6,7]. Research studies have indicated that compare to nano size particles, particles of micron size and millimeter size may pose serious problems in the functioning of heat exchangersand hence, it is preferable to use nano size particles in fluid [4,5]. Nano size particles have larger surface area due to which they are able to impart higher heat transfer in a fluid in which they are suspended [4,5]. Thermal conductivity of the fluid may increase with the addition of nano particles [8,9].

Suspensions of solid submicron- and nanometer-sized particles in various fluids (also called nanofluids) have been considered for applications as advanced heat transfer fluids[10].A nanofluid is a mixture of water and suspended metallic nanoparticles. Since the thermal conductivity of metallic solids are higher than that of fluids, it is expected that solid/fluid mixture will have higher effective thermal conductivity compared to the base fluid. Thus, the presence of the nanoparticles changes the transport properties of the base fluid thereby increasing the effective thermal conductivity and heat capacity, which ultimately enhance the -heat transfer rate of nanofluids.

Because of the small size of the nanoparticles (10-9m),Nano fluids incur little or no penalty in flow characteristics when used in low concentrations. Nano fluids are extremely stable and exhibit no significant settling under static conditions, even after weeks or months.

II. WHAT IS CONCENTRIC PIPE HEAT EXCHANGER?

The double-pipe heat exchanger is one of the simplest types of heat exchangers. It is called a double-pipe exchanger because one fluid flows inside a pipe and the other fluid flows between that pipe and another pipe that surrounds the first. This is a concentric tube construction. Flow in a double-pipe heat exchanger can be co-current (parallel) or counter-current. There are two flow configurations: co-current is when the flow of the two streams is in the same direction, counter current is when the flow of the streams is in opposite directions. In this double-pipe heat exchanger, generally a hot process fluid flowing through the inner pipe transfers its heat to cooling water flowing in the outer pipe.

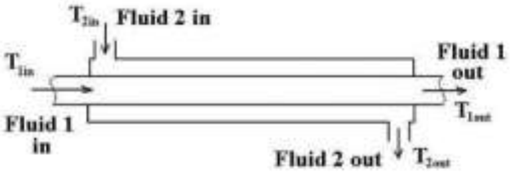


Fig.1:Parallel Flow Concentric Pipe Heat Exchanger

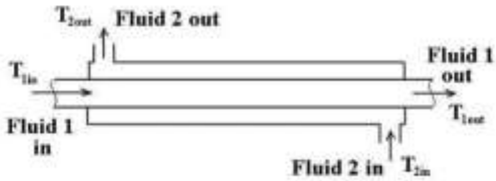


Fig.2:Counter Flow Concentric Pipe Heat Exchanger

III. ROLE OF FLUIDS IN HEAT ECHANGER

Heat exchangers are a device that exchange the heat between two fluids of different temperatures that are separated by a solid wall. The temperature gradient, or the differences in temperature facilitate this transfer of heat. Transfer of heat happens by three principle means: radiation, conduction and convection. In the use of heat exchangers radiation does take place. However, in comparison to conduction and convection, radiation does not play a major role. Conduction occurs as the heat from the higher temperature fluid passes through the solid wall. To maximize the heat transfer, the wall should be thin and made of a very conductive material. The biggest contribution to heat transfer in a heat exchanger is made through convection.

In Heat exchanger, generally there are two fluids. One is in hotter state at inlet and another is in colder state at the inlet. The effectiveness and efficiency of heat exchanger is depends on several parameters. One of the parameter is thermal conductivity of fluids which are used. As the thermal conductivity of fluids is higher, heat transfer is more. Generally water used as cold fluid because of easy availability and no cost. But sometimes a specific fluid is used as cold fluid which has higher thermal conductivity..

IV. WHY NANO FLUID REQUIRED?

As we have discussed earlier that thermal conductivity of solid is more than fluids. So, if we add solid particles to fluids, thermal conductivity of mixture (solid/fluid) increase and enhancement of heat transfer takes place. Nanofluids have been considered for applications as advanced heat transfer fluids for almost two decades. However, due to the wide variety and the complexity of the nanofluid systems, no agreement has been achieved on the magnitude of potential benefits of using nanofluids for heat transfer applications. Compared to conventional solid–liquid suspensions for heat transfer intensifications, nanofluids having properly dispersed nanoparticles possess the following advantages:[3,4]

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
- Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

Pak and Cho (1998) derived experimentally the turbulent friction and heat transfer behaviors of dispersed fluids (i.e., ultrafine metallic oxide particles suspended in water) in a circular pipe. Two different nanofluids particles, γ-alumina (Al_2O_3) and titanium dioxide (TiO2) with mean diameters of 13 and 27 nm, respectively, were used as suspended particles. In their flow loop, the hydrodynamic entry section and the heat transfer section was made using a seamless, stainless steel tube, of which the inside diameter and the total length were 1.066 cm and 480 cm, respectively. The hydrodynamic entry section was long enough (i.e., x/D = 157) to accomplish fully developed flow at the entrance of the heat transfer test section. They observed that the Nusselt number for the dispersed fluids increased with increasing volume concentration as well as Reynolds number. But at constant average velocity, the convective heat transfer coefficient of the dispersed fluid was 12% smaller than that of pure water.[11]

Xuan and Li (2003) built an experimental rig to study the flow and convective heat transfer feature of the nanofluid flowing in a tube. Their test section was a straight brass tube of the inner diameter of 10 mm and the length of 800 mm. Eight thermocouples were mounted at different places of the heat transfer test section to measure the wall temperatures and other two thermocouples were respectively located at the entrance and exit of the test section to read the bulk temperatures of the nanofluid. They investigated convective heat transfer feature and flow performance of Cu-water nanofluids for the turbulent flow. The suspended nanoparticles remarkably enhance heat transfer process and the nanofluid has larger heat transfer coefficient than that of the original base liquid under the same Reynolds number. They found that at fixed velocities, the heat transfer coefficient of nanofluids containing 2.0 vol% Cu nanoparticles was improved by as much as 40% compared to that of water. The Dittus–Boelter correlation failed to predict the improved experimental heat transfer behavior of nanofluids. The heat transfer feature of a nanofluid increases with the volume fraction of nanoparticles.[12]

Wen and Ding (2004) were first to study the laminar entry flow of nanofluids in circular tubes. A straight copper tube with 970 mm length, 4.5 mm inner diameter, and 6.4 mm outer diameter was used as the test section. The whole test section was heated by a silicon rubber flexible heater. Their results showed a substantial increase in the heat transfer coefficient of water-based nanofluids containing γ-Al2O3 nanoparticles in the entrance region and a longer entry length is needed for the nanofluids than that for water. They concluded that the enhancement of the convective heat transfer could not be solely attributed to the enhancement of the effective thermal conductivity. Particle migration is proposed to be a reason for the enhancement, which results a non-uniform distribution of thermal conductivity and viscosity field and reduces the thermal boundary layer thickness.[13]

V. EXPERIMENTAL SETUP

During this project we have used one experimental setup which is shown in Fig. 3. It is having both type arrangements; parallel as well as counter.

Fig.3:Experimental Setup

The following is a list of all equipments and their specifications which are used in the double pipe heat exchanger.

5.1 Pump:

Mfg. by	Eterna
Model	HL37
HP	0.5 HP
Power	0.37 kw
Discharge	11 – 46 LPM
Max. Suction	8.5 m
Voltage	180 – 240 volts
Frequency	50 Hz
Phase	Single
Ampere	3.8 A
Suction Dia.	25 mm
Delivery Dia.	25 M

Fig.4:Pump

5.2 Concentric Pipe Heat Exchanger:

Inner Tube	
Tube Material	Copper
Tube Diameter	15 mm
Tube Length	5.96 m
Outer Tube	
Tube Material	Galvanized Iron
Tube Diameter	38 mm
Tube Length	5.96 m

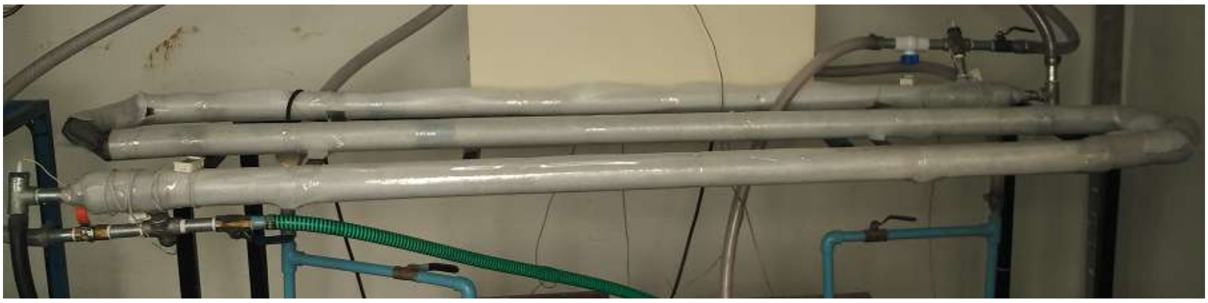


Fig.5:Concentric Pipe Heat Exchanger

5.3 Hot and Cold Fluid Tanks

Inner Material	SS – 304
Outer Material	SS – 304
Capacity	80 Liters
Heater	6 kw rating
Temperature Control	PID Thermostatic Type
Insulation	25 mm Glass Wool

Fig.6:Hot and Cold Fluid Tanks

5.4 Flow Measurement Device

Quantity	2 nos.
Range	1 – 10 LPM
Glass Tube	Borosilicate Glass
Float	Pre calibrated SS – 316
Valve	Integrated Needle Valve

Fig.7:Rotameters

VI. EXPERIMENTAL WORK

An Experiments are carried out on counter flow heat exchanger without and with adding the nano fluid in water with varying concentrations. Following observations are taken while doing experimental work.

6.1 Data without Nano Fluid:

Cold Water(Outer pipe)			Hot water(Inner pipe)		
Flow rate (LPM)	**Inlet Temp (°C)**	**Outlet Temp (°C)**	**Flow rate (LPM)**	**Inlet Temp (°C)**	**Outlet Temp (°C)**
M_C	T_1	T_4	M_H	T_2	T_3
5	34.2	39.2	1	62.5	38.3
6	36.5	40.9	2	57.2	40.8
10	30.5	40.8	3	57.6	41.6

Table.1:Experimental Data of Counter Flow Heat Exchanger without Nano Fluid

LPM	Avg. Heat	Area	LMTD	Uo
1-5	3894.19	0.7133	10.87	260.9
2-6	1947.38	0.7133	9.005	303.1
3-10	3199	0.7133	9.81	457.3

Table.2:Processing Data of Counter Flow Heat Exchanger without Nano Fluid

6.2 Data with Nano Fluid:

Volume Fraction	Cold Water(Outer pipe)			Hot water(Inner pipe)		
	Flow rate (LPM)	**Inlet Temp (°C)**	**Outlet Temp (°C)**	**Flow rate (LPM)**	**Inlet Temp (°C)**	**Outlet Temp (°C)**
Φ	M_C	T_1	T_4	M_H	T_2	T_3
0.01	5	35.2	38.9	1	61.2	36.2
0.02	6	37.1	42.3	2	67.3	37.9
0.03	10	38.2	42.7	3	69.4	48.0

Table.3:Experimental Data of Counter Flow Heat Exchanger with Nano Fluid

Φ	LPM	Avg. Heat	Area	LMTD	Uo
0.01	1-5	1657.75	0.7133	6.86	354.2
0.02	2-6	2910	0.7133	7.03	580.6
0.03	3-10	8048	0.7133	16.85	669.86

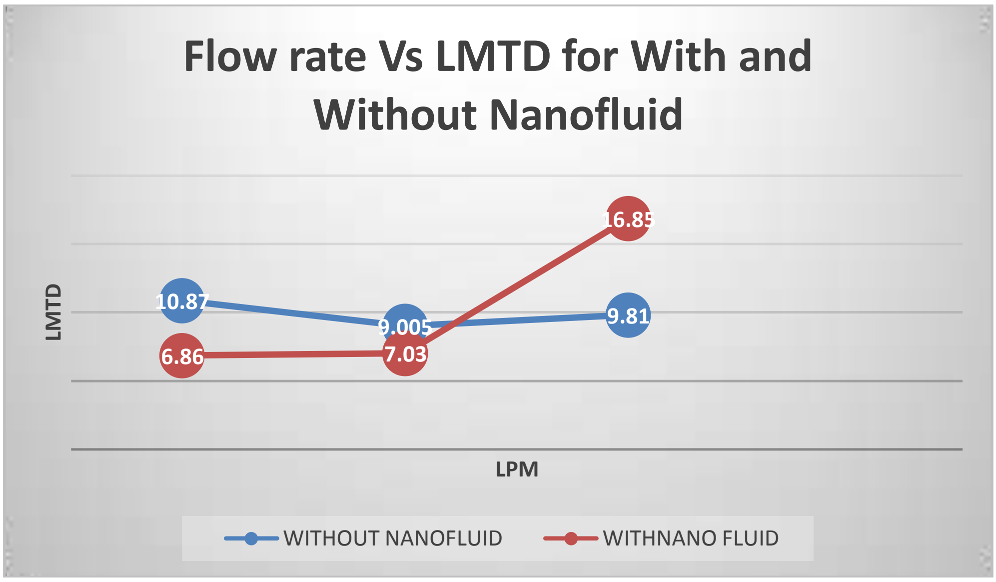
Table.2:Processing Data of Counter Flow Heat Exchanger with Nano Fluid

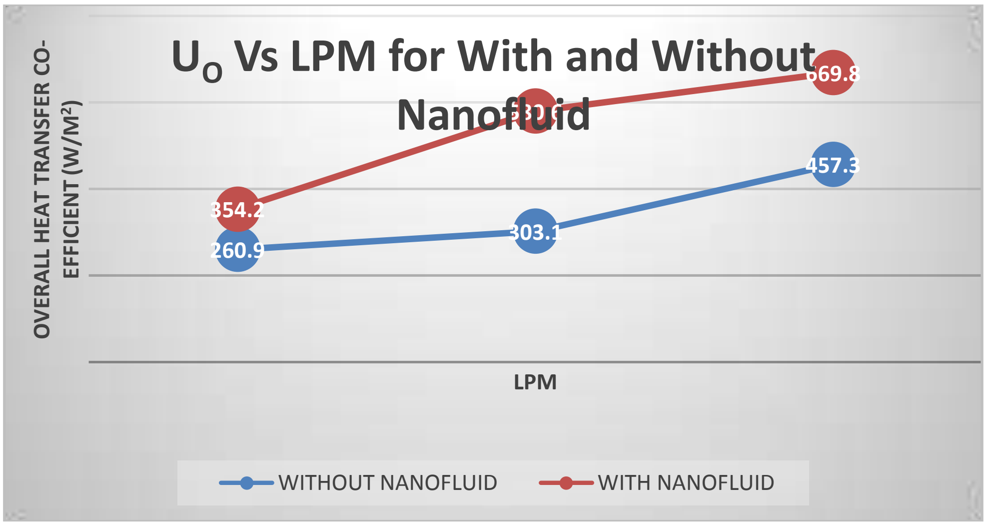
VII. RESULT AND CONCLUSION

From experimental observations and data processing, comparison has been carried out as below.

LPM	LMTD		U_O	
	WITHOUT NANOFLUID	**WITH NANOFLUID**	**WITHOUT NANOFLUID**	**WITH NANOFLUID**
1-5	10.87	6.86	260.9	354.2
2-6	9.005	7.03	303.1	580.6
3-10	9.81	16.85	457.3	669.86

Table 5: Comparative of with and without nanofluid





From the experimental investigation and above comparative analysis, it can be concluded that the heat transfer performance and flow characteristic of a water-nanofluid (CuO) flowing in a fabricated counter flow concentric tube heat exchanger. The interpretation of data indicates that better heat transfer rates and higher overall heat transfer coefficient can be derived with the help of nano particles in fluid media. Similar findings reported by Albadr et. al [10] in their study of Al_2O_3 nanoparticles. Data indicates that as we increase the flow rate of fluid media, heat transfer and its coefficient increases in nano particles based fluid media.

The experimental data indicates that as we increase the flow-rate, heat transfer in a fluid with nano particles increases where as in case of fluid without nano particles, there is not much deviation.

The value of Overall heat transfer co-efficient increases with increase in concentration of nano fluid in the base fluid.

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