Experimental Investigation of Shell and Tube Heat Exchanger using Nano-fluids

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Abstract— **- Heat exchangers are most widely used for heat transfer applications in industries. Shell and Tube heat exchanger is one such heat exchanger, provides more area for heat transfer between two fluids in comparison with other type of heat exchanger. Shell and Tube heat exchangers are widely used for liquid-to-liquid heat transfer applications with high density working fluids. This study is focused on use of shell and tube heat exchanger for nano-fluid as a working fluid. A nano-fluid is a mixture of nano sized particles of size up to 100 nm and a base fluid. Typical nano-particles are made of metals, oxides or carbides, while base fluids may be water, ethylene glycol or oil. The effect of nano-fluid to enhance the heat transfer rate in various heat exchangers is experimentally evaluated recently. The heat transfer enhancement using nano-fluid mainly depends on type of nanoparticles, size of nano-particles and concentration of nanoparticles in base fluid. This research work deals with experimental investigation of shell and tube heat exchanger with evaluation of convective heat transfer coefficient, overall heat transfer coefficient, exchanger effectiveness. The main objective of this work is to find effects of these parameters on performance of plate heat exchanger with parallel flow arrangement.**

Index Terms— ***heat transfer rate, Shell and tube heat exchanger, Nano-fluid, flow arrangement..***

I. INTRODUCTION

"A heat exchanger is equipment which transfers the energy from a hot fluid to a cold fluid with maximum possible rate."

Heat exchanger is a device which transfers the heat from hot fluid to cold fluid. In typical heat exchanger generally conventional fluids (such as water, mineral oil and ethylene glycol) are used as a working fluid. For decades, efforts have been done to enhance heat transfer, reduce the heat transfer time, minimize size of heat exchanger and finally increase the heat transfer and efficiency. These efforts include passive and active methods such as creating turbulence, increasing heat transfer area, increasing thermal conductivity of working fluid, etc.

Since solid particles have higher thermal conductivity, when they are dispersed in the fluids, it will result in higher heat transfer characteristics. There are many types of solid particles such as metallic, nonmetallic and polymeric. However due to large size, micro and macro-sized particles will face some problems in using of these suspensions. To reduce these problems, nano-sized particles are used in these suspensions. These suspensions are called as nano-fluids where nano-sized particles are suspended in a base fluid.

1.1 Shell and tube Heat Exchanger:-

Shell and tube heat exchangers are the most widely used unfired heat transfer equipments in the chemical industries in their various processes. They are also used in coal and gas based, nuclear, ocean thermal and geothermal properties.

1.1.2 Benefits of Shell and tube Heat Exchanger:-

• STHEs are flexible in size. They can vary from less than one square meter to thousand square meters and even more.

• They are mechanically strong enough to withstand normal shop fabrication stresses, the adversity of transportation and erection and the stresses of normal and abnormal conditions.

• They can be cleaned easily. Mechanical and chemical both leaning programs can be employed.

• Components which are most liable to failure, like tubes and gaskets can be easily replaced.

• Various good thermal and mechanical design methods are widely available.

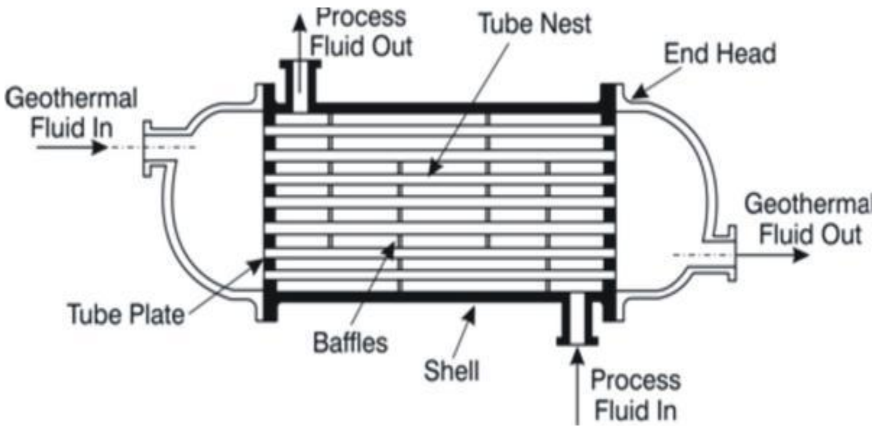

Fig -1: **Typical Shell and Tube Heat Exchanger**

1.3 Nano-fluids:-

Nanofluids, a name conceived by Dr.Choi, in Argonne National Laboratory, to describe a fluid consisting of solid nanoparticles with size less than 100nm suspended on it with solid volume fractions less than 4%. Nanofluids are suspension of nano-sized particles in base fluids. The size of these nanofluids varies from 1 to 100nm.

- *Base fluid:* water, organic liquid
- *Nano-particle size:* 1-100 nm
- *Nano-particle materials:* oxides (Al2O3, ZrO_2, SiO_2, CuO), metals (Au, Cu), carbon nanotubes.

Material	Thermal conductivity, ($W/m^2.K$)
Metallic solids Cu	401
Al	237
Ag	428
Au	318
Fe	83.5
Non-metallic solids Al_2O_3	40
CuO	76.5
Si	148
SiC	270
CNTs	~3000(MWCNTs) ~ 6000(SWCNTs)
BNNTs	260~600

Table -1: Thermal conductivity of nanofluids

1.3.1 Preparation of Nano-fluids:-

Preparation of nanofluids is done by applying nano-size particles into the base fluid. The nanofluids does not simply refer to a liquid-solid mixture, some special requirements are necessary for preparation of nanofluids such as even suspension, stable suspension, durable suspension, low agglomeration of particles and no chemical change of the liquid.
Some effective methods for preparation of suspension are: to change the PH value of suspension, to use surface activators or dispersant and to use ultrasonic vibration. The aim of all these techniques is to change surface properties of suspended particles and to suppress the formation of particle cluster in order to obtain stable suspensions. Nanofluid can be produced by mainly two techniques:

I. single-step method and

II. two-step method.

1.3.2 Thermal Application Nano-fluids:-

• Nanofluids can be used in transport system such automotive and automobile radiators.
• They can be utilized in metal cutting in metal processing.
• They can be also used as efficient coolant in data centers and electronics cooling systems.
• They can be used as energy storage media such as fabricating advanced phase change materials for thermal energy storage.
• In solar absorption, nanofluids could enhance the absorption property of the conventional working fluid in the solar collectors.

2. TECHNICAL SPECIFICATION

2.1 Design data of component of SHTX:-

2.1.1 Design data of shell

Fig -2 : Shell

Parameter	Value
Shell material	MS
Shell length	735mm
Shell	100mm
Shell ID	84mm

Table -2 : Design data of shell

2.1.2 Design data of flange

Fig -3 : flange

Parameter	Value
No. of flange	2
No. of tube sheet for flange	2 (each 4")

Table -3 : Design data of Flange

2.1.3 Design data of Shell cover

Fig -4 : Shell cover

Parameter	Value
No. of Shell Cover	2
Each size	4”

Table -4 : Design data of Shell cover

2.1.3 Design data of Tube

Fig -5 : Tube arrangement

Parameter	Value
Tube material	Copper
Tube OD	15mm
Tube ID	13mm
Tube length	2.79 foot
Tube thickness	1.62mm

Table -5 : Design data of tube

3. METHODOLOGY

3.1 Proposed Experimental set up:-

The figure shows the schematic diagram of proposed experimental setup of shell and tube heat exchanger. As shown in figure a hot fluid is flowing through the tube and cold fluid is flowing through the shell side. Here, the energy of hot fluid is transferred to the cold fluid and cold fluid is being heated. The temperature indicators are provided for measurement of inlet and outlet temperatures of both hot and cold fluid. By knowing several parameters we can calculate various properties of heat transfer. Some calculation of shell and tube heat exchanger having water as hot and cold fluid both is given in below section. By these calculations we can numerically validate the design of heat exchanger.

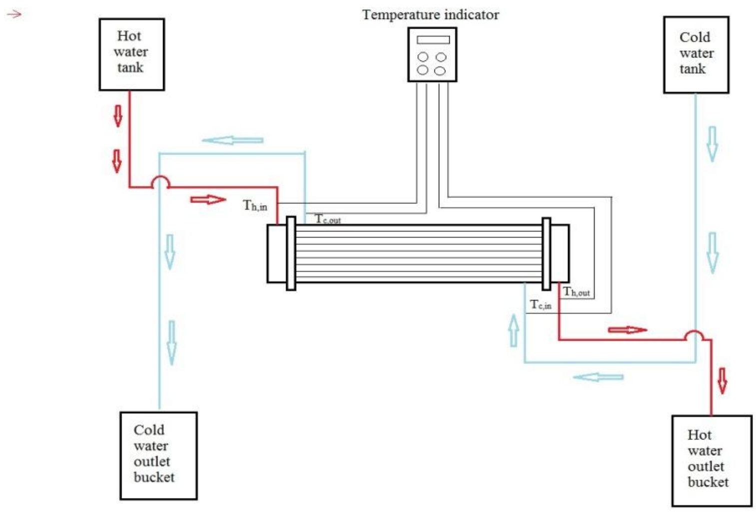

Fig -6 : Schematic diagram of experimental setup

4. EXPERIMENTAL SETUP

Fig -7 : Experimental model

The figure shows the experimental setup of shell and tube heat exchanger. As shown in figure a hot fluid is flowing through the tube and cold fluid is flowing through the shell side. Here, the energy of hot fluid is transferred to the cold fluid and cold fluid is being heated. The temperature indicators are provided for measurement of inlet and outlet temperatures of both hot and cold fluid. By knowing several parameters we can calculate various properties of heat transfer. The tanks for hot and cold fluid were provided at the height of 4 meters. Fits of all the experiments were carried out by using water as a working fluid and then after experiments were carried out for Al2O3 of 2% and 4% concentration respectively.

The mass flow rates for each fluid during each experiment were measure manually. We took a vessel of 1 litre volume and calculated the time taken for fill that vessel and calculated the mass flow rate. In order to measure the temperature of the fluids, a total four thermocouples were used in with two were located at the inlet and outlet of the tube bundle and two were located at the inlet and outlet of the shell. Many temperatures are measured for each fluid (water and nanofluid). The initial temperatures which were approximately same for every fluid were taken into account. By various calculations, overall heat transfer coefficient, LMTD, inside heat transfer coefficient, nusselt number, Reynold number etc were calculated from measured temperature. The results were then compared to each other.

4.1 Experimental Results:-

4.1.1 Experimental result for water as a working fluid

Experimental result for water as working fluid	
Hot Fluid	Hot water
Hot water inlet temperature	60.8 ^{o}C
Hot water outlet temperature	52 ^{o}C
Hot water mass flow rate	0.123 kg/s
Cold fluid	Cold water
Cold water inlet temperature	37.6 ^{o}C
Cold water outlet temperature	44 ^{o}C
Cold water mass flow rate	0.0952 kg/s

Table -6: Experimental result for plain tube heat exchanger

Experimental results for 2 vol. % Al2O3/water as a Working Fluid	
Hot Fluid	Nano fluid
Hot water inlet temperature	61.8 ^{o}C
Hot water outlet temperature	50.2 ^{o}C
Hot water mass flow rate	0.109 kg/s
Cold fluid	Cold water
Cold water inlet temperature	35.4 ^{o}C
Cold water outlet temperature	44.4 ^{o}C
Cold water mass flow rate	0.0952 kg/s

Table -7: Experimental results for 2 vol. % Al2O3/water as a Working Fluid

Experimental results for 4 vol. % Al2O3/water as a Working Fluid	
Hot Fluid	Nano fluid
Hot water inlet temperature	62 ^{o}C
Hot water outlet temperature	50.4 ^{o}C
Hot water mass flow rate	0.1071 kg/s
Cold fluid	Cold water
Cold water inlet temperature	34.6 ^{o}C
Cold water outlet temperature	45.2 ^{o}C
Cold water mass flow rate	0.0952 kg/s

Table -8: Experimental results for 4 vol. % Al2O3/water as a Working Fluid

4. RESULT AND ANALYSIS

Many experiments were done with water and nanofluid as a working fluid and temperatures were measured. Among them, approximate same values were taken into account for calculations as given above. By calculations it is observed that the heat transfer is enhanced on nanofluids as compared to water and it was increased with increase in concentration and temperature.

The experiment results are shown below

Working fluid	LMTD (°C)	U (W/m^2k)	h_i (W/m^2k)	Nu	Re
Water	15.57	88.7275	207.31	4.19	10761.57
2% vol. Al_2O_3	16.0649	103.78	313.6482	6.23	7979.54
4% vol. Al_2O_3	16.29	107.697	352.3223	6.75	7568.95

The comparison of obtained experimental LMTD for water and nanofluids is shown in figure 5.2. It is observed that LMTD increases with increase in temperature and concentration. The other experimental comparisons for U vs. hi, U vs. LMTD and U vs. Nu are shown in figure 5.3, 5.4 and 5.5 respectively. The blue line indicates changes in water properties, red line indicates changes in 2% vol. Al2O3 and green line indicates changes in 4% vol. Al2O3 properties.

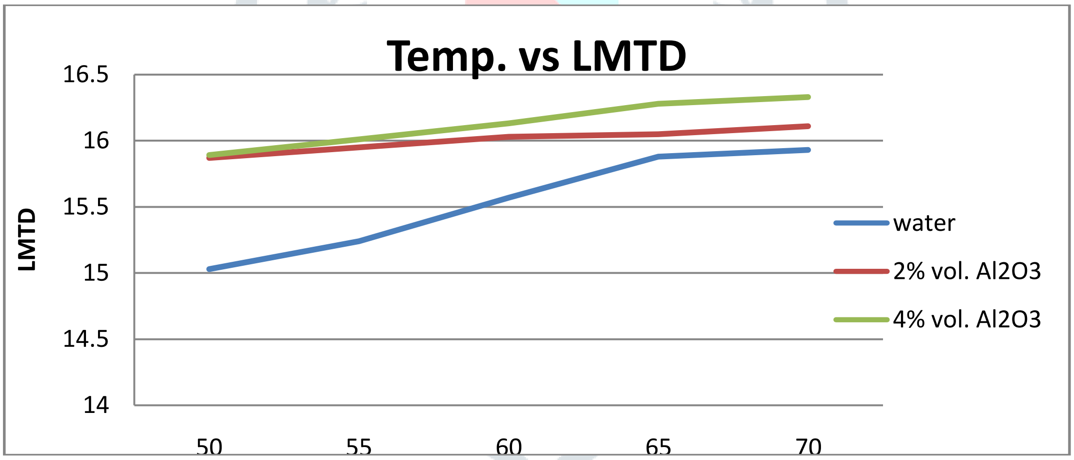

Fig -7 : Experimental LMTD of water and nanofluids at various temperatures

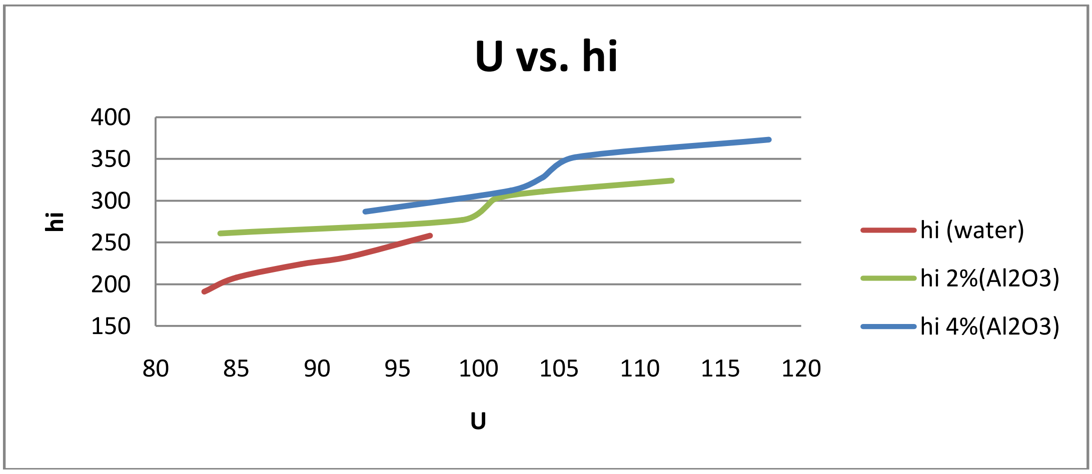

Fig -8 : Experimental h_i at various U for water and nano fluids

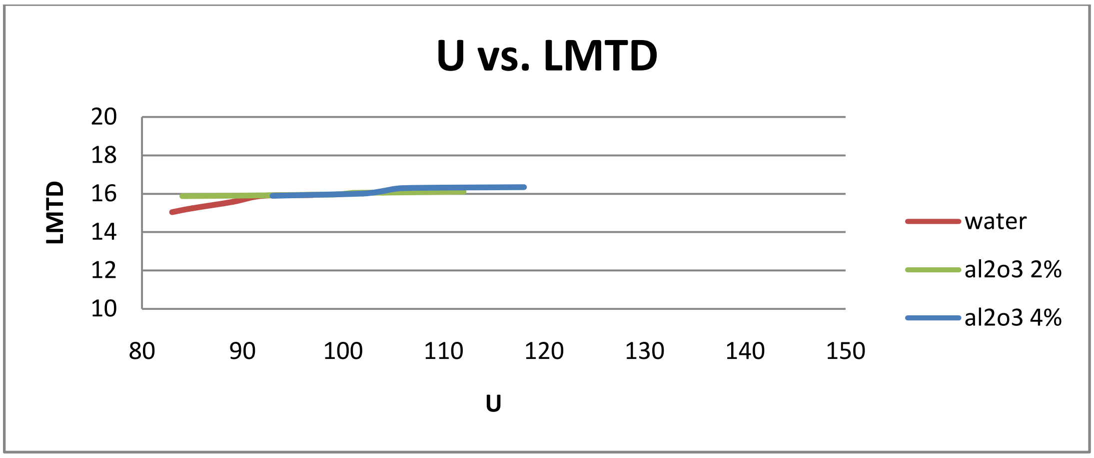

Fig -9 : Experimental LMTD at various U for water and nanofluids

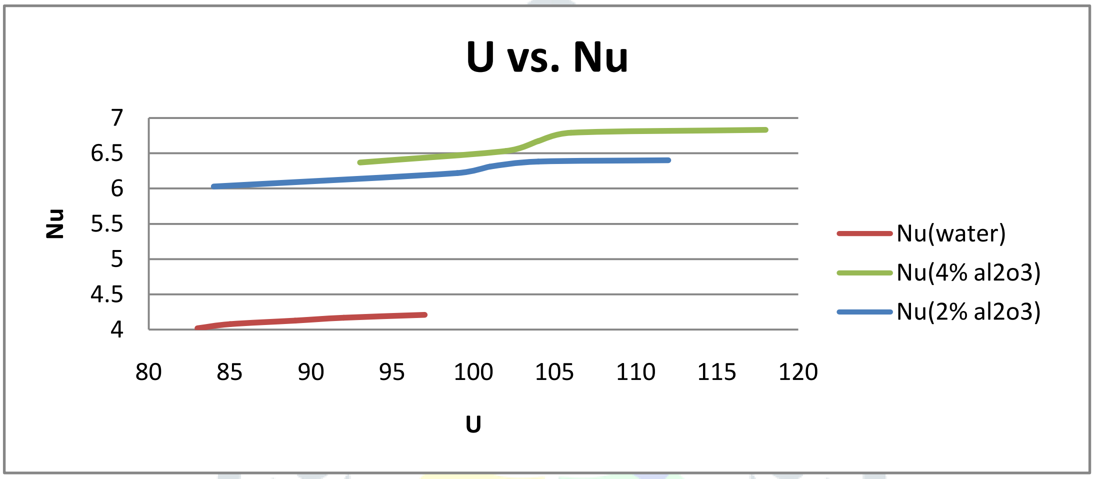

FIG -9 : EXPERIMENTAL NU AT VARIOUS U FOR WATER AND NANOFLUIDS

5.CONCLUSION

Generally, in industrial applications, conventional fluids are used as working fluid in heat exchangers. It is concluded that the heat transfer capacity of nanofluids is higher than that of conventional fluids. Hence, by using nanofluid as a working fluid in heat exchangers we can enhance the heat transfer capacity. In this research, initial experiments were done by using water as a working fluid and experimental LMTD, overall heat transfer coefficient, inside heat transfer coefficient, Reynold number and nusselt numbers were calculated from eq. of Durga Prasad [18].

Nanofluids of 2% and 4% vol. concentration Al2O3 were introduced into the heat exchanger and the experimental calculations are estimated from eq. of Durga Prasad[18]. It is observed that nanofluids showed better performance than that of water. Some concluded points from experiments are as follows.

- It is observed that nanofluids shown better performance than that of water.
- It is concluded that inside heat transfer coefficient is increased by 23% as of water. And it increased with concentration of nano particles.
- LMTD and overall heat transfer coefficient was also increased.
- Experiments showed a significant increase in experimental nusselt number.
- It is observed that the enhancement was increased with increased in volume concentration and temperature.
- Al2O3 with 4% of volume concentration shoved better performance than that of Al2O3 with 2% of volume concentration and water.

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