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Thermo-hydraulic Performance of Shell and Tube Heat Exchanger by Enhancing Thermo-physical Properties Using Nano fluid

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ABSTRACT- Shell and tube type heat exchanger is widely used in industries to transfer heat from hot to cold fluids. We always looks for the maximum possible rate as well as minimum capital cost. The main objective is to transfer enthalpy at greater possible rate. Shell and tube heat exchangers are widely used in various fields like boilers, condensers, etc. They provide more surface area for heat transfer between two fluids in comparison with other type of heat exchanger. Fluids like Nano fluids have become the major area of research now-a-days for the purpose of minimum pumping power. This report give an outline of the proposed work and literature review of some of the important articles published in various journals and gives the effect of the heat transfer characteristics in shell and tube heat exchangers using Nano fluids. Some of the published articles include experimental work to explore heat transfer behavior of γ-Al_2O_3 Nano fluid in a shell and tube heat exchanger. Further, variables like stagnation point, separation point, heat transfer coefficient and shear stress were determined and compared for the heat transfer characteristics of an Al_2O_3/ethylene glycol Nano fluid and ethylene glycol fluid in a cross rectangular arrangement of tubes in a shell and tubes heat exchanger.

I. INTRODUCTION

Heat exchangers play a very important role in the field of energy conservation by taking heat from the fluid at higher temperature and use this considerable amount of heat for heating the other heat input system. Heat transfer rate can either be increased by increasing area of heat transfer or by increasing the thermal conductivity of fluids or temperature difference between cold and hot fluids. Increasing the heat transfer area is not possible everywhere because of space restrictions. Increasing the temperature difference is also restricted, because upper limit doesn't cross the metallurgical condition and lower limit is atmospheric condition. Therefore our main motive is to increase thermos-physical properties of cooling fluid.

The scientific aspects is concentrating both on improving the equipment design and on enhancing the thermal potential of the working fluid. A considerable amount of reduction in energy consumption could be made possible by improving the performance of heat exchanger systems.

Heat transfer rate in a heat exchanger are dependent on the thermos-physical properties of the fluids participating in the heat exchanger, the material of the heat exchanger and also the areas of the surfaces which is taking place in the process.

Nano fluids are the newly discovered fluid which is used for various industrial and automotive applications because of their magnificent thermal performance. Nano fluids consists of suspensions of nanoparticles with at least one of their principal dimensions smaller than 100nm.The Nano fluids, in comparison to base fluids like water/oil, possess enhanced thermo-physical properties such as thermal conductivity and convective heat transfer coefficient. Due to small and very large specific surface area of the Nano particles, Nano fluids have superior properties like thermal conductivity, stability, lesser clogging in flow passage, homogeneity etc. Hence, Nano fluids have a wide range of potential applications like electronics industries, automotive field, and nuclear applications where improved heat transfer or efficient heat transfer is required. Hence in the past few years, many experimental investigations on the thermal conductivity of Nano fluids have been reported which showed that Nano fluids shows relatively higher thermal conductivities than their base fluids even when the concentrations of suspended nanoparticles are very low and the Nano fluid thermal conductivity increase significantly with Nano particle volume concentration.

After studied the researched paper of Etemad and Farajollahi [2010], we concluded that the use of Nano fluid increases the heat transfer coefficient by enhancing the thermos-physical properties and as a result of which the heat transfer characteristics of the shell and tube heat exchanger increases in a significant amount. Etemad and Farajollahi [2010] studied on behavior of Nano fluid in a shell and tube heat exchanger. The objective of this paper is an experimental system was designed and constructed to investigate heat transfer behavior of γ-Al_2O_3 Nano fluid in a shell and tube heat exchanger. They measured the heat transfer characteristics under the turbulent flow condition. The experiments were done for wide ranges of Peclet numbers, and volume concentrations of suspended nanoparticles in base fluid. Based on the results found, the heat transfer characteristics of Nano fluids improve with Peclet number significantly. The addition of nanoparticles to the base fluid causes the significant improvement of heat transfer characteristics and results in larger heat transfer coefficient than that of the base fluid at the same Peclet number. The Nano fluid has an optimum volume concentration of Nano particles in which the heat transfer characteristics show the maximum enhancement.

The another research paper Khoddamrezaee et al. [2010] investigated heat transfer characteristics of an Al2O3/ethylene glycol Nano fluid and ethylene glycol fluid in a cross rectangular arrangement of tubes in a shell and tubes heat exchanger. The variables like stagnation point, separation point, and heat transfer coefficient and shear stress for Nano fluid and pure fluid were determined and compared. From the results they concluded that by using of Nano fluids, the stagnation and separation points of flow were delayed and the heat transfer coefficient and shear stress increased.

The paper of khoddamrezaee et al. [2010] it is found that even by the use of Nano fluid sheer stress increases but at the same time heat transfer coefficient also increases. In our research work we had concluded that the Nano fluid used in our research work increases he heat transfer coefficient.

The peer of researched of Lotfi et al. [2012] it is found that the use of multi walled nanotubes enhanced the heat transfer rate**.** Hence we have taken multi walled tube in our researched work**. Lotfi et al. [2012]** conducted an experimental investigation on heat transfer enhancement of multi-walled carbon nanotube (MWNT)/water Nano fluid) in a horizontal shell and tube heat exchanger. The test section of the heat exchanger has 14 tubes with 7mm inside diameter and lenght580mm. The coolant flows in shell with 101mm diameter. The carbon Nanotubes were prepared by the use of catalytic chemical vapor deposition (CCVD) method over Co–Mo/Mg On a catalyst. From the results it is found that the presence of multi-walled Nanotubes enhanced the heat transfer rate the heat exchanger.

The researched paper of Arunachalam and raza, [2012] it is concluded that the use of Nano fluid **enhanced the** overall heat transfer coefficient. The nanoparticle which we had taken in our researched work is titanium oxide in order to make the Nano fluid along with the water as a base fluid. **Arunachalam and Raja, [2012]** studied heat transfer character of Alumina/water Nano fluid in a shell and tube heat exchanger with the aid of coil insert. They studied behavior of Peclet no, or Alumina/water Nano fluid concentration on the heat transfer and pumping power. The concentration of Nano particle was taken as 0.5, 1 and 1.5 (in percent) was prepared and made solution with base fluid water. An increase in the concentration of the nanoparticles in the base fluid caused a significant enhancement in the all over heat transfer coefficient compared with water, they used wire coil insert raises the all over heat-transfer-coefficient for the give Peclet number and it was raised by 12.6, 20 25 (all in percent) for Alumina/water Nano fluid when the percentage of volume concentrations was 0.5, 1, 1.5 at Pe of three thousand, compared to those of distilled water. There was similar rise of thirteen percent in the pumping work for wire coil insert, when compared to that of the pumping power find with distilled water. Moreover the researched of Leong et al. [2012] it is found that the use of Nano fluid enhanced the overall and convective heat transfer coefficient. From the conclusion of this research paper we had used the TiO_2 as nanoparticle in order to prepare the Nano fluid along with the base fluid is taken as water. **Leong et al. [2012]** investigated the application of Nano fluids as working fluids for a biomass heating plant with shell and tube heat recovery exchangers. The results showed that the overall and convective heat transfer coefficient improved with the application of Nano fluids compared to ethylene glycol or water based fluids.

Another researched paper we have studied Albadr et al. [2013] and we concluded that the use of Nano fluid gives the significantly higher heat transfer characteristics. Hence the idea of using Nano fluid is adopted and the nanoparticle which we used in order to make the Nano fluid is taken as titanium oxide. **Albadr et al. [2013]** experimentally studied horizontal shell and tube heat exchanger for forced convective heat transfer and flow characteristics of a counter flow under turbulent flow conditions for water as base fluid and different volume concentrations of Al2O3 Nano fluid. They found that nanoparticles dissolved in distilled water increases both thermal conductivity and viscosity of the Nano fluid. Friction factor increases with the increase in volume concentration of nanoparticles. Particle volume concentration of 2% the use of Aluminum oxide Nano fluid gives significantly higher heat transfer characteristics.

The researched work of santhoshCibi [2013] it is investigated that the use of Nano fluid enhanced the thermal conductivity. **SanthoshCibi, et al., [2013]** studied on convective of heat transfer increment with graphite Nano fluids by the use of Shell and tube heat exchanger. They mainly focus during their research study the graphite Nano fluids performed great in Shell and tube heat exchanger for laminar flow. They used Graphite Nano powders for the experiment and stirrer with the base water by varying its concentration in the range of 0.025, 0.05, and 0.075 (in percent) by volume. During the experiment they observed that when the concentration of the graphite was rises with different concentrations, the heat-transfer-co-efficient rises gradually with the concentrations. They also concluded that the performance of graphite on K (thermal conductivity) value of Nano fluids was much better than heat transfer-coefficient of Nano fluids, and also with graphite rise concentration and flow performance of the coldest fluid.

Kirubadurai and Ramesh [2014] studied on heat-transfer behavior of Shell-Tube heat exchanger using Silicon Nitride- Water Nano fluid. They did the work on new Nano fluid system which they emerge by silicon nitride to amalgamate Nano fluid for shell-tube heat exchanger. During the study the results showed that the Nano fluid provides better thermal properties. They also concluded that the most of these parameter of heat-transfer was not taken for study in past time, hence they performed on it and it require the simultaneously study of Nano fluid for heat transfer provides valuable information for the optimization of heat-transfer improvement. And they find the efficiency raises up to eleven percent with nanoparticles with water.

The another researched paper of Tiwari[2015], they found that use of Nano fluid increases the overall and convective heat transfer coefficient **.Tiwari[2015]** studied on "thermal Performance of Shell and Tube Heat Exchanger using Nano fluids "in this paper, an attempt is made to experimentally investigate the thermal performance of a shell and tube heat exchanger using Nano fluids. The cold water based Nano fluids flow in tube side and water as hot fluid flows on shell side. Use of nanoparticles in water based Nano fluid as coolant in shell and tube heat exchanger improves the effectiveness by a considerable amount, while the convective and overall heat transfer coefficient increases even further with the addition of 3% Al_2O_3nanoparticles in water based fluid.

II. MATERIAL AND COMPONENT USED

1. Nano fluid: it is comprises of TiO_2 **(**Titanium oxide as nanoparticle and water as a base fluid. The specification of the Nano fluid is discussed below:

Figure 1: Nano Fluid

Table 1: Specifications of Nano fluid

1.	Size of Nano particle	18nm
2.	Name of Nano particle	Titanium oxide (TiO2)
3.	Concentration	0.2% TiO2
4.	Base fluid	Water
5.	Method of preparation	Two step method

2. Shell and tube type of the heat exchanger: Shell and tube Heat Exchanger used in this experiment is a single pass multi tube Heat Exchanger. Shell of this heat exchanger is made up of mild steel having one meter effective heat transfer area and tube inside the shell is of also one meter in length and material of construction of tube is copper, having excellent conductivity.

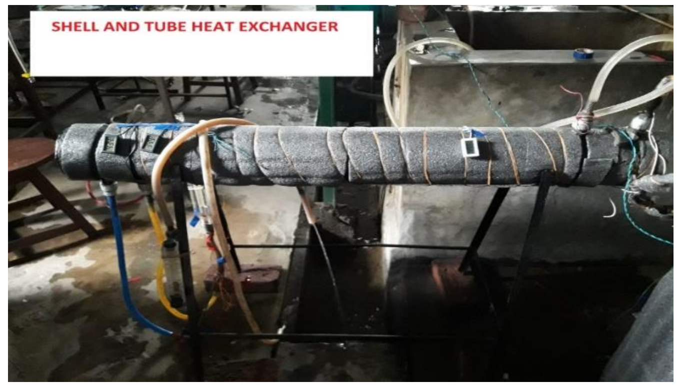
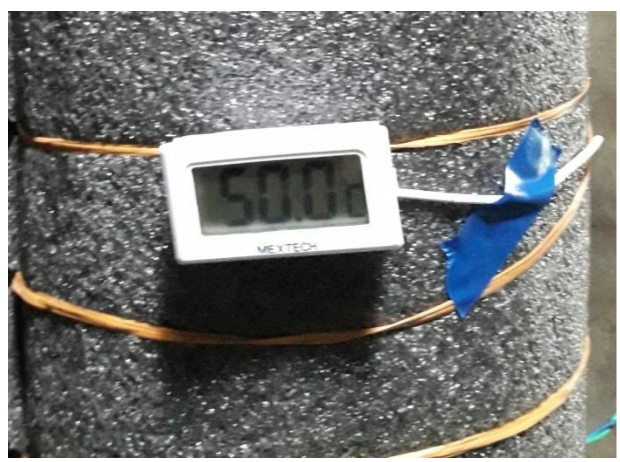


Figure 2: Shell and Tube Heat Exchanger

3) Temperature Indicator

Temperature Indicators are required to indicate the inlet and exit temperature of hot and cold fluid. There are four temperature indicators are required for this setup, two at the inlet of the and two at the exit of Heat Exchanger.



specifications of Temperature Indicator

1.	Manufacturer	Divinext
2.	Type	Battery operated

3.	Measuring Range	-50ºC to +110ºC
4	Indicator	Digital display

4) Thermostat

Thermostat is device which is used in this Experiment to fix the hot reservoir temperature. In this setup heating coil is connected with the thermostat, if temperature differs from the set point temperature then power supply automatic OFF and ON so that set temperature is constant

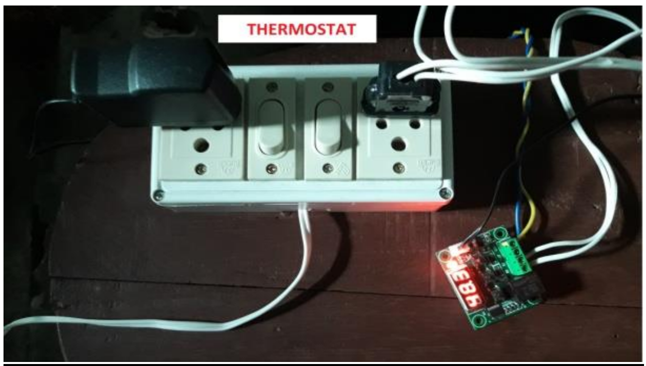


Table 4.6 Specifications of Thermostat

1.	Manufacturer	Robocraze W1209
2.	Material of construction	Epoxy
3.	Temperature range	-50ºC to +110ºC
4.	Temperature control mode	ON/OFF (Automatic)
5.	Control accuracy	0.1sec
6.	Supply voltage	DC 12V

METHODOLOGY

1)Design of shell

The shell thickness of 3/8 inch for the shell inner diameter of 12-24 inches can be satisfactorily used up to 300 psi of operating pressure.

Shell of Heat Exchanger.

2)Design of tube

The tube of outer diameter 3/4 and one inch are very commonly used to design a compact heat exchanger. The most efficient condition for heat transfer is to have maximum number of tubes in shell to increase turbulence.

NOMENCLATURE

$C_{p(hot)}$ Specific heat of hot fluid
$C_{p(cold)}$ Specific heat of cold fluid
m_h Mass flow rate of hot fluid.
m_c Mass flow rate of cold fluid
t_c Inlet temperature of cold fluid
t_h Inlet temperature of hot fluid
C_h Heat capacity of hot fluid
C_c Heat capacity of cold fluid
C_{min} Minimum heat capacity
ε Effectiveness of heat exchanger
ε_1 Effectiveness of heat exchanger without nano fluid
ε_2 Effectiveness of heat exchanger with nano fluid
$\Delta\varepsilon$ Change in effectiveness of heat exchanger with and without nano fluid
LPM Mass flow rate in litre per minute

3.2 Design of shell and tube Heat Exchanger.

The design of shell and tube heat exchanger includes the determination following parameter

1. Heat transfer area;
2. Number of tubes;
3. Tube length and its Diameter;
4. Number of shell and passes;
5. Type of heat exchanger (fixed tube sheet, removable bundle etc.);
6. Tube pitch;
7. Number of baffle its, size and type;
8. Shell and tube side pressure drop.

Deign procedure

Step 1.

Calculation heat transfer area(A) required: $A = \frac{Q}{U_O.LMTD.F_T}$ …….. (1)

Where,

Q= amount of heat exchanged between hot and cold fluids it can be calculated from energy balance equation.

Energy balance equation is:

Step 2.

Q =$m_hC_{p(hot)}(t_{h(inlet)}-t_{h(exit)})$ =$m_cC_{p(cold)}(t_{c(exit)}$ $_{–}t_{c(inlet)})$ ………… (2)

Step 3. Calculate the number of tubes (n_t) required to provide the heat transfer area (A); n_t= $\frac{A}{Ï€doL}$ ……… (3)

Step 4

Calculate tube side velocity, u$= \frac{4m(n_{/n_t})}{\pi\rho d_i^2}$ ……………… (4)

If u$< 1m/s$,fix $n_p$so that R_e= $\frac{4m(n_{/n_t})}{Ï€d_iÎ¼}$ â%o¥10^4 ……………. . (5)

Where, m, $\rho, and\ \mu$ are mass flow rate, density and viscosity of tube side fluid. However, this is subject to allowable pressure drop in the tube side of the heat exchanger.

Step 5.

Select the type of baffle (segmental, doughnut etc.), its size (i.e. percentage cut, 25% baffle are widely used), spacing and number. The baffle spacing is generally chosen to be within $0.2D_s$ to D_s.

Step 6.

Determine the tube side film heat transfer coefficient (h_o) from

$j_h = \frac{h_oD_e}{k}(\frac{cÎ¼}{k})^{-1/3}(\frac{Î¼}{Î¼_w})^{-0.14}$ …………………(6)

We may take $\frac{Î¼}{Î¼_w} = 1.0$ ………………….. (7)

Select the outside tube (shell side) dirt factor (R_{do}) and inside tube (tube side) dirt factor (R_{di})

Calculate the overall heat transfer coefficient ($U_{o,cal}$) based on the outside tube area neglect the tube wall resistance including dirt factor:

$$U = \left(\frac{1}{h_o} + R_{do} + \frac{A_o}{A_i}\left(\frac{d_o - d_i}{2k}\right) + \frac{A_o}{A_i}\left(\frac{1}{h_i}\right) + \left(\frac{A_o}{A_i}\right)R_{di}\right)^{-1}$$

……………… (8)

Step 7.

If 0< $\frac{U_{o,cal\_}U_{o,assm}}{U_{o,assm}} < 30\%$, go the next step 8 step .Otherwise go to step 5, calculate heat transfer area (A) required using $U_{o,cal}$ and repeat the calculation from step 5.

Step 8.

Calculate % overdesign. Overdesign represent extra surface area provided beyond that required to compensate for fouling .Typical value of 10% or less is acceptable.

% Overdesign = $\frac{A - A_{reqd}}{A_{reqd}}$

(9)

A=designed area of heat transfer in the heat exchanger; A_{reqd}= required heat transfer area.

Step 9.

Calculate shell side pressure drop (âˆ† P_S): (i) pressure drop for flow across the tube bundle (friction loss) (âˆ† P_s) and (ii) return loss (âˆ† P_{rs}) due to change of direction of fluid.

Total shell side pressure drop: âˆ† P_S = âˆ† P_s + âˆ† P_{rt} (10)

If the tube-side pressure drop exceeds the allowable pressure drop for the system , decreases the number of tube pass or increases number of tube per pass.

NANO FLUID

Nanofluids are the newly investigated heat transfer fluids used for various industrial applications because of their magnificant thermal performance. Nanofluids comprises of suspensions of nanoparticles with at least one of their dimensions smaller than 100nm with the base fluids.

Preparation Method

Nanofluids can be prepared by mixing nanoparticles with base fluids base fluids may be taken as water or oil. Nanoparticles may be metals such as copper, Cu; Aluminum, Al etc. The metal carbides such as silicon carbide (SiC) may also be used as nanoparticles.

There are two methods of preparation of Nanofluids

1. One step method
2. Two step method

One step method

A one step method is a system for producing nanofluids by particle-source evaporation and deposition of the evaporant into a base fluid. The base fluid (e.g water, ethyl glycol etc.) is placed in a rotating cylinder drum having an adjustable heater-boat-evaporator and heat exchanger-cooler apparatus. As the drum rotates, a thin layer is formed on inside surface of the drum a heater-boat-evaporator having an evaporant material (particle source) placed within its boa evaporator adjustably positioned near a portion of rotating thin liquid layer, the evaporant material being heated thereby evaporating part of evaporant material absorbed by the liquid film to form nanofluids

Two step method

In two step method, solid is decomposed into the particle of nano size and then prepared particle mixed with the base fluid using the ultrasonic or by means of magnetic stir. An ultrasonic vibrator or higher shear mixing device is generally used to stir Nanopowders with host fluids. Continuous use of ultrasonication or stirring restrict the coagulation of nanoparticles in the base fluid The dispersion of nanoparticles in the base fluid is quite difficult because of its hydrophobic character of its surface. Experimental study investigation of surfactant in stability by **Shiva et al.[IHMTC2017-09-0788]** Clear that MWCNT into ethylene glycol with surfactant increases the stability of nanofluid. Once the Nanofluids are prepared the different techniques can be used to analyze the stability of Nanofluids such as sedimentation visualization technique Zeta potential measurement, spectroscopy or turbidity test.

mh(LPM)	(Th)inlet ºC	(Th)exit ºC	mc(LPM)	(Tc)inletºC	(Tc)exitºC	ε(%)calculated
1	50	40.7	2	32.1	36.5	51.95
1	50	40.1	3	32.1	35.4	55.30
1	50	39.4	4	32.1	34.7	59.21
1	50	38	5	32.1	34.5	67.03
1	50	37	6	32.1	34.2	72.62

RESULT AND DISCUSSION

This includes calculation of effectiveness of shell and tube heat exchanger with normal cold water and hot water and compare this effectiveness with use of nanofluid (0.2%TiO_2, Titanium oxide) and plot their graph.

Effectiveness of Heat Exchanger without use of nanofluid

The heat exchanger effectiveness ε, is defined as the ratio of actual heat transfer to the maximum heat transfer as given below,

$$\varepsilon = \frac{\text{Actual heat transfer}}{\text{Maximum possible heat transfer}}$$

$$= \frac{Q}{Q_{max}}$$

$$= \frac{C_h(T_{hi} - T_{he})}{C_{min}(T_{hi} - T_{ci})} = \frac{C_c(T_{ce} - T_{ci})}{C_{min}(T_{hi} - T_{ci})}$$

Here, $C_h = m_h c_{ph}$

$C_c = m_c c_{pc}$

$C_{min} = \text{Min}(C_h, C_c)$

Calculation:

For the first reading,

Obtained data are

T_{hi} =50ºC

T_{he} =40.7ºC

T_{ci} =32.1

T_{ce}=36.5

m_h=1.0 LPM

m_c=2.0 LPM

So, C_h<C_m

Now using Equation

$$\varepsilon = \frac{50 - 40.7}{50 - 32.1} = 51.95\%.$$

Calculation of effectiveness without nanofluid for all the readings for shell and tube heat exchanger for single pass and parallel flow on excel sheet, and arranged in tabulated form and draw their graph

Graph between effectiveness and mass flow rate of cold fluid, keeping mass flow rate and inlet temperature of hot fluid as fixed.

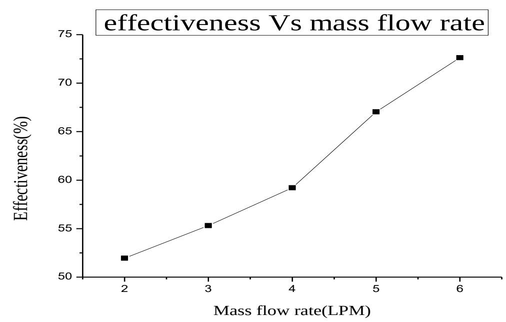


Fig. 6.1

Figure 6.1 shows the variation of effectiveness with the mass flow rate of cold fluid. When mass flow rate of cold fluid increases then effectiveness increases gradually up to four litre per minute then rapid increase beyond four litre per minute.

Table 6.2 shows the inlet and exit temperature of hot and cold fluid irrespective of their mass flow rate. Last column of the table shows the calculated effectiveness which is calculated with the help of excel sheet.

Table: 6.2

mh (LPM)	(Th) inlet ºC	(Th)exit ºC	Mc (LPM)	(Tc) inletºC	(Tc) exitºC	ε(%) calculated
2	50	42	2	32.1	40.1	44.69
2	50	41.2	3	32.1	37.9	49.16
2	50	40.3	4	32.1	36.9	54.18
2	50	39.2	5	32.1	36.4	60.33
2	50	38.3	6	32.1	36	65.36

Graph between effectiveness and mass flow rate of cold fluid, keeping mass flow rate and inlet temperature of hot fluid as fixed.

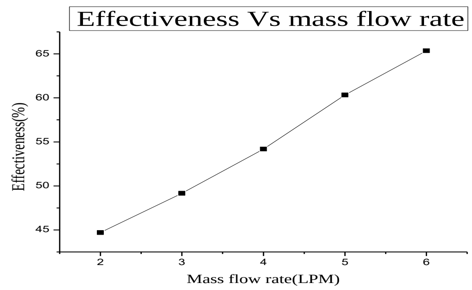


Fig. 6.2

When the mass flow rate of hot fluid increases from one litre per minute to two litre per minute then effectiveness is decreases. Fig. 6.2 indicates that effectiveness increases gradually with slightly variation up to 6 litre per minute.

Effectiveness of Heat Exchanger with use of nanofluid (0.2% TiO_2)

Now titanium oxide 0.2% concentration used for nano fluid preparation and this nanofluid used as coolant and calculate the effectiveness of shell and tube heat exchanger for single pass and parallel flow.

Effectiveness of Heat Exchanger with use of nanofluid

The heat exchanger effectiveness (ε) is defined as the ratio of actual heat transfer to the maximum heat transfer. Thus

$$\varepsilon = \frac{\text{Actual heat transfer}}{\text{Maximum possible heat transfer}} = \frac{Q}{Q_{max}}$$

$$\varepsilon = \frac{C_h(T_{hi} - T_{he})}{C_{min}(T_{hi} - T_{ci})} = \frac{C_c(T_{ce} - T_{ci})}{C_{min}(T_{hi} - T_{ci})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where, $C_h = m_h c_{ph}$

$C_c = m_c c_{pc}$

$C_{min} = \text{Min}(C_h, C_c)$

Calculation:

For the first reading with nanofluid,

Obtained data are

$T_{hi} = 50^oC$

$T_{he} = 40.1^oC$

$T_{ci} = 32.1$

$T_{ce} = 36.8$

$m_h = 1.0$ LPM

$m_c = 2.0$ LPM

So, $C_h < C_m$

Now using Eqn. 2, we get

$$\varepsilon = \frac{50-40.1}{50-32.1} = 55.3072\%.$$

Calculation of effectiveness with nanofluid for all the readings for shell and tube heat exchanger for single pass and parallel flow heat exchanger on excel sheet, and arranged in tabulated form and draw their graph. Table 6.3 shows the inlet and exit temperature of hot and cold fluid irrespective of their mass flow rate.

Table 6.3

mh(LPM)	(Th)inlet ºC	(Th)exit ºC	mc(LPM)	(Tc)inletºC	(Tc)exitºC
1	50	40.1	2	32.1	36
1	50	39.3	3	32.1	35
1	50	38.2	4	32.1	34
1	50	37.6	5	32.1	33
1	50	36.8	6	32.1	33

Graph between effectiveness and mass flow rate of cold fluid (nanofluid TiO_2 0.2% volume), keeping mass flow rate and inlet temperature of hot fluid as fixed.

Figure 6.3

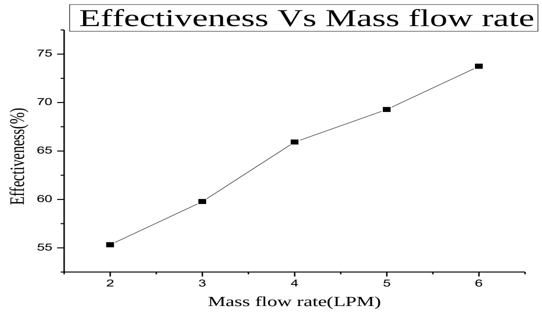


Figure 6.3 shows the effectiveness variation with mass flow rate of cold fluid (nano fluid, 0.2% TiO_2) as the mass flow rate of cold fluid increases then effectiveness also increases with slightly varies in between the flow condition Table 6.4 shows the inlet exit temperature of hot and cold fluid irrespective of their mass flow rate. Last column of this table shows calculated effectiveness of heat exchanger irrespective of flow conditions.

Table:6.4

mh(LPM)	(Th)inlet ºC	(Th)exit ºC	mc(LPM)	(Tc)inletºC	(Tc)exitºC	ε(%)calculated
2	50	40.5	2	32.1	37.1	53.07
2	50	39.8	3	32.1	36.4	56.98
2	50	38.6	4	32.1	35.8	63.68
2	50	38.1	5	32.1	35	66.48
2	50	37.4	6	32.1	34.6	70.39

Graph between effectiveness and mass flow rate of cold fluid (nanofluid TiO_2 0.2% volume), keeping mass flow rate and inlet temperature of hot fluid as fixed.

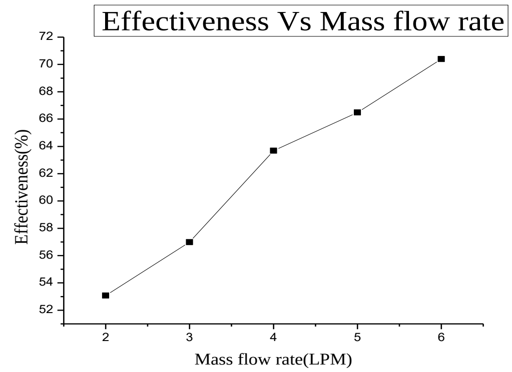


Fig 6.4, Figure 6.4 shows the variation of effectiveness with mass flow rate, as effectiveness increases when mass flow rate increases up to 3 litre per minute gradually increases, then rapidly increases up to four litre per minute then again gradually increases beyond four litre per minute.

Comparison of Effectiveness (ε)

In this paragraph we will compare the calculated effectiveness of heat exchanger with nanofluid and without nanofluid

For the comparison of effectiveness following variables kept constant for each set of observation.

1. Mass flow rate of cold fluid (LPM)
2. Mass flow rate of hot fluid (LPM)
3. Inlet temperature of cold fluid (ºC)
4. Inlet temperature of hot fluid (ºC)

m_c = Mass flow rate of cold fluid (LPM)
m_h = Mass flow rate of hot fluid (LPM)
ε_1 = Effectiveness without nano fluid (in %)
ε_2 = Effectiveness with nanofluid (in %)

Table 6.5 comprise effectiveness with and without use of nano fluid irrespective flow condition. Last rows of this table shows the net increase in effectiveness when we use the nanofluid as a cold fluid

Table:6.5

m_c	2	3	4	5	6
m_h	1	1	1	1	1
ε_1	51.95	55.30	59.21	67.03	72.62
ε_2	55.30	59.77	65.92	69.27	73.74
$\Delta\varepsilon$	3.35	4.46	6.70	2.22	1.11

comparison of effectiveness of heat exchanger.

Table 6.6 consist effectiveness of heat exchanger with simple cold water and nano fluid irrespective flow condition.

Table 6.6

m_c	2	3	4	5	6
mh	2	2	2	2	2
ε1	44.69	49.16	54.18	60.33	65.36
ε2	53.07	56.98	63.68	66.48	70.39
Δε	8.37	7.82	9.49	6.14	5.02

Figure 6.6 shows the comparison of effectiveness without nanofluid and with nanofluid. Red colour curve shows effectiveness without nano fluid and black colour shows with use of nano fluid. This figure also shows effectiveness with nanofluid is higher while comparing with simple cold water.

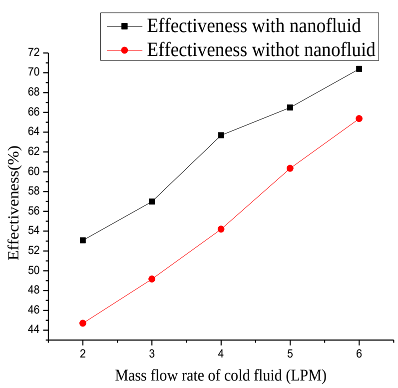


Figure 6.6 shows comparison of effectiveness of heat exchanger.

Figure 6.6 shows the variation of effectiveness with the mass flow rate, as the mass flow rate of cold fluid (*either water or nanofluid*) increases, the effectiveness also increases with little variation. This graph also shows effectiveness with use of nanofluid is higher when compare it wih simple cold water.

Conclusion

Based on the study thermo-hydraulic performance of shell and tube heat exchanger using nano fluid, the following conclusion is observed.

Heat transfer rate enhanced by shell and tube heat exchanger by using TiO_2-water nanofluid (0.2% TiO_2) was experimentally and numerically investigated. The obtained result indicated that nano particle (TiO_2) played an important role in improving fluid mixing and heat transfer enhancement. Observation based on experimental data and numerical calculation the use of TiO_2-water nanofluid resulted up to 9.5% higher thermal performance than the use of base fluid (water). As the mass flow rate of cold fluid increases the effectiveness also increases.

Hence from the entired observation it is found that the effectiveness with use of nanofluid is higher than that of the simple cold water.

FUTURE SCOPE

Many operating and design parameter have been covered in this research. However there are many other issue that may be investigated. Recommended future studies as follows,

- Use of nanofluid in place of base fluid (water) to achieve higher effectiveness.
- If uses in power plant it reduces the pump work for the same amount of heat transfer with the base fluid (water).
- Use of nanofluids, minimum global warming potential and eco-friendly.
- It will reduce size of heat exchanger for the same amount of heat transfer with the base fluid (water).
- There is always chance of development of some new experimental or new numerical methods which can give the new scope in this field.

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