International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Experimentation on Double Pipe Heat Exchanger Using Water and Nanofluid

J. Emeema[1], C. Lakshmi Sindhuja[2], K. Laxman[3]

[1]Department of Mechanical Engineering, Vidya Jyothi Institute of technology, Aziz Nagar, Hyderabad, Telangana, India, Emeema[at]gmail.com

[2]Department of Mechanical Engineering, Vidya Jyothi Institute of technology, Aziz Nagar, Hyderabad, Telangana, India, lakshmisindhuja.c[at]gmail.com

[3]Department of Mechanical Engineering, Kommuri Prathap Reddy Institute of technology, Hyderabad, Telangana, India, laxman.lkr[at]gmail.com

Abstract: ***Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures. The hot and cold fluids do not mix with each other. Heat exchangers are widely used in steam power plants, oil and gas industries, radiators in cars; chemical processing, air conditioning systems etc., Heat exchangers are broadly classified according to the nature of heat exchange process & relative direction of motion of fluids (Parallel flow and Counter flow). In this experiment, heat transfer parameters like heat flow rate, Logarithmic mean temperature difference, overall heat transfer coefficient, and effectiveness through the Heat Exchanger were determined using water and nanofluid for parallel flow and counter flow directions on a Double Pipe or Concentric Tube Heat Exchanger. The results obtained from the experiment were graphically depicted for comparison and conclusions.***

Keywords: Heat transfer rate, Effectiveness, Overall heat transfer Coefficient, Logarithmic mean temperature difference, Number of transfer units

1. Introduction

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single or multicomponent fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control a process fluid.

Typical heat exchangers that we come across in our daily lives include condensers and evaporators used in air conditioning units and refrigerators. Boilers and condensers in thermal power plants are examples of large industrial heat exchangers. Heat exchangers are used in automobiles in the form of radiators and oil coolers. Heat exchangers are also widely used in chemical and process industries. Other applications of heat exchangers are found in cryogenics, dairy industries, petroleum industries, nuclear power plants, surface condensers in power plants etc.

There are different types of heat exchangers depending on the applications. A simplest type of heat exchanger consists of two concentric pipes of different diameters called the double pipe heat exchanger in which one fluid flows through the smaller pipe while the other fluid flows through the annular space between the two pipes as shown in Figure 1.

In a double pipe heat exchanger, two types of heat flow arrangements are possible. Parallel flow, in which both the hot and cold fluids enter the heat exchanger at the same end and move in the same direction and counter flow, in which both the hot and cold fluids enter the heat exchanger at opposite ends and flow in opposite directions as shown in Figure 2.

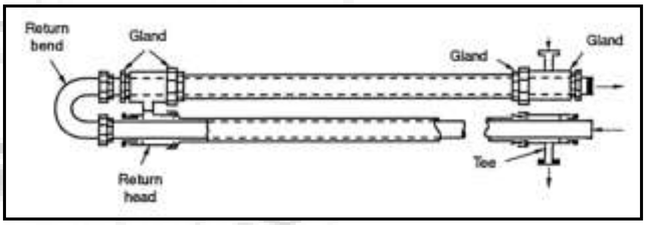


Figure 1: Double pipe heat exchanger

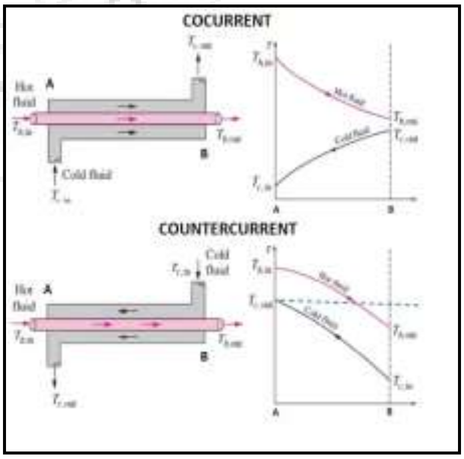


Figure 2: Parallel flow (co-current) and counter flow (counter-current) directions

Figure 3: Experimental set-up

There are different kinds of fluids that are considered for the effective heat exchange in a heat exchanger depending upon the application. Nanofluid is a new kind of heat transfer medium, containing nanoparticles (1–100 nm) which are uniformly and stably distributed in a base fluid. These distributed nanoparticles, generally a metal or metal oxide greatly enhance the thermal conductivity of the nanofluid, increases conduction and convection coefficients, allowing for more heat transfer. 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.

2. Heat Transfer Parameters and Equations Affecting the Performance of Heat Exchanger

2.1. Logarithmic mean temperature difference (LMTD)

LMTD is a logarithmic average of the temperature difference between the hot and cold fluids at each end of the double pipe heat exchanger

$LMTD = (\Delta T_A - \Delta T_B) / \ln x (\Delta T_A / \Delta T_B)$
ΔT_A =Temperature difference between two streams at end A
ΔT_B =Temperature difference between two streams at end B

2.2. Heat transfer rate or heat flow rate(Q):

Q is the exchanged heat flow rate between hot & cold fluids in Watts.

2.3. Overall heat transfer coefficient (U):

U is the overall heat transfer coefficient which considers both conduction & convection effects of heat transfer.
U is based on the surface area of the heat exchanger.
U_0 = overall heat transfer coefficient based on the outer surface area (A_0)
U_i= overall heat transfer coefficient based on the inner surface area (A_i)

2.4. Equation for heat transfer

$Q = U_0 A_0 LMTD$

This holds both for parallel flow & counter flow arrangements.

2.5. Effectiveness

Effectiveness of a heat exchanger is defined as the ratio of actual heat transfer rate to the theoretical maximum possible heat transfer rate.

$\mathcal{E} = Q / Q_{max}$
$Q = \dot{m}_h \times c_{ph} (T_{hi} - T_{ho}) = \dot{m}_c \times c_{pc} (T_{ci} - T_{co})$ W
$Q_{max} = C_{min} (T_{hi} - T_{ci})$ W
Where
$\dot{m}_h$=mass flow rate of hot fluid, kg/s
C_{ph}= specific heat of hot fluid, kJ/kg K
$\dot{m}_c$=mass flow rate of cold fluid, kg/s
C_{pc}= specific heat of cold fluid, kJ/kg K
C_{min} = minimum value of C_h & C_c
C_h= heat capacity rate of hot fluid, kW/K
C_c= heat capacity rate of cold fluid, kW/K
$C_h = \dot{m}_h \times C_{ph}$ & $C_c = \dot{m}_c \times c_{pc}$

2.6. Number of transfer units (NTU)

$NTU = (U_0 \times A_0)/C_{min}$

3. Experimentation

Experiment was conducted using water and nanofluid in both parallel and counter flow directions on the double pipe heat exchanger. The experimental setup is shown in Figure 3.

Experiment using water as working fluid:

The mass flow rates of hot and cold fluids were kept constant throughout the experiment. The working fluid inlet temperature was varied for different readings ranging from 50^0C to 75^0C for hot fluid and from 35^0C to 40^0C for cold fluid in both parallel and counter flow directions.

Experiment using nanofluid as working fluid:

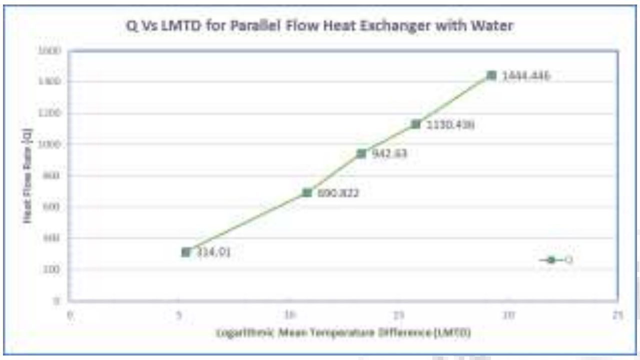
The Nano particle considered for the experiment was aluminum oxide ($Al_2 O_3$). To prepare the nanofluid, 50g of aluminum oxide was mixed in 15 liters of water to get the required concentration.

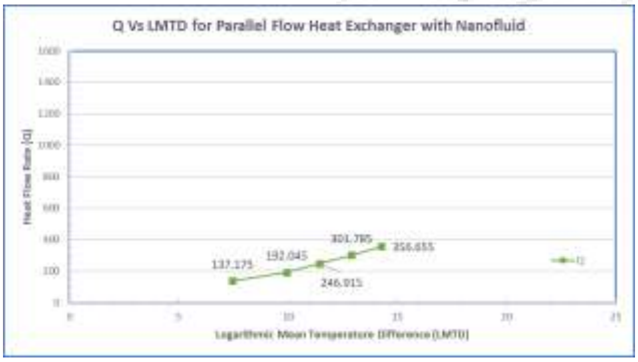
The mass flow rates of both hot and cold nanofluids were kept constant throughout the experiment. The nanofluid inlet temperature was varied for different readings ranging from 45^0C to 70^0C for hot nanofluid and from 30^0C to 35^0C for cold nanofluid in both parallel and counter flow directions.

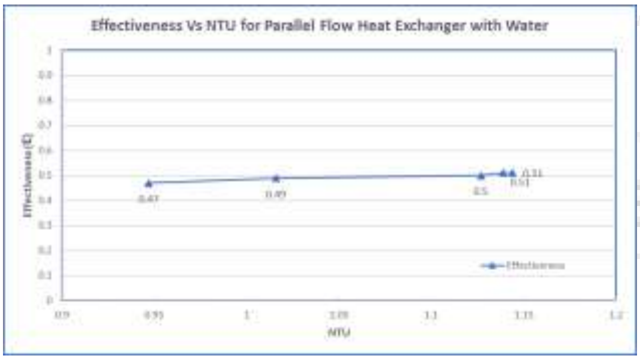
From the readings obtained from experimentation, various Heat transfer parameters that affect the performance of Heat Exchanger like Heat Flow rate (Q), Logarithmic Mean Temperature Difference (LMTD), Overall Heat transfer coefficient (U), Effectiveness (Ɛ), Number of transfer units (NTU) have been calculated and plotted graphically.

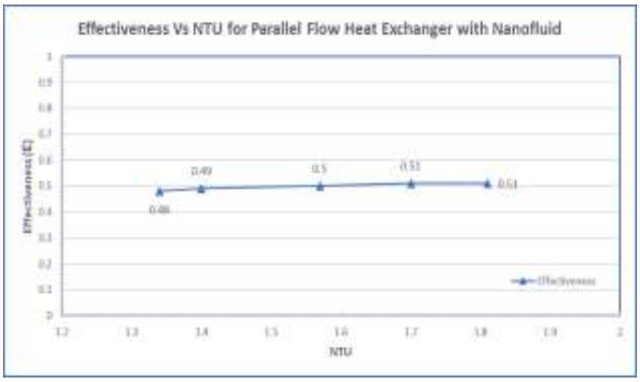
4. Heat Transfer parameters in graphical form

4.1. Parallel Flow Direction

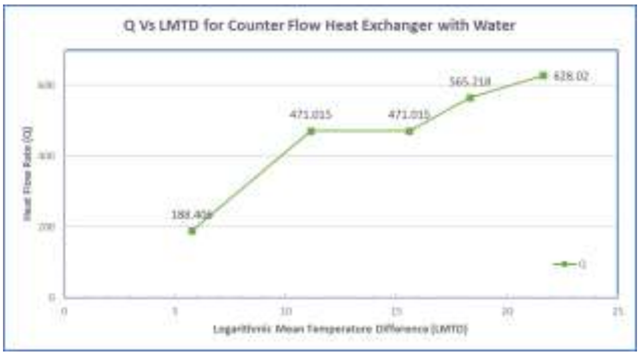


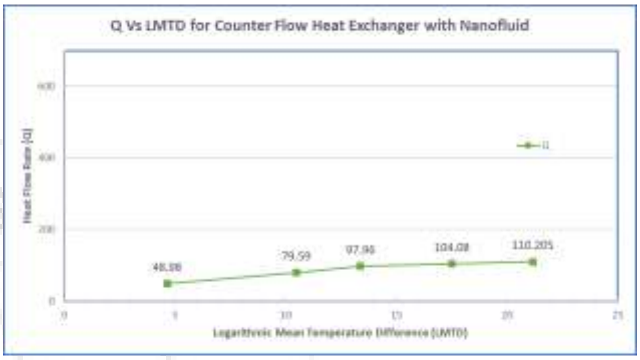


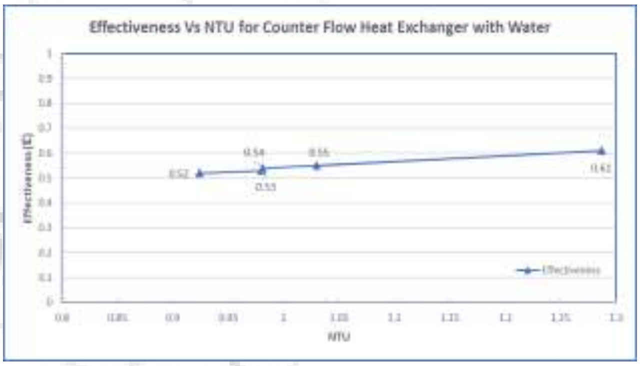


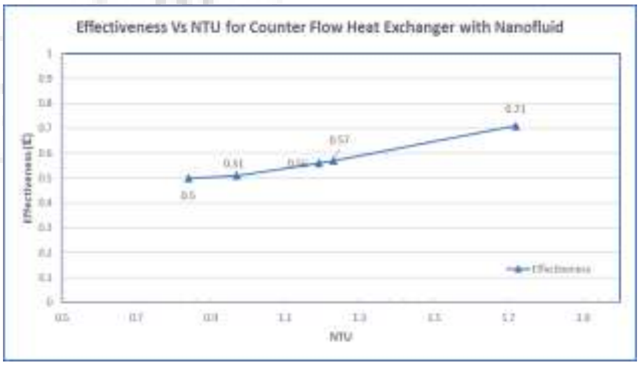


4.2. Counter Flow Direction









5. Results and Discussions

Graphs Q vs LMTD and Effectiveness (Ɛ) vs NTU have been plotted for water and nanofluid in both parallel flow and counter flow directions.

The following observations have been made.

A very small change in effectiveness was observed in both directions for nanofluid.

Heat flow rate Q decreased in both parallel and counter flow directions for nanofluid.

This is because water shows higher heat transfer rate Q than nanofluid, at lower inlet temperature (around 60^0C – 70^0C). This can be attributed to high specific heat capacity and low density of water. When the inlet temperature increases, the heat transfer rate of nanofluids gradually increases due to Brownian motion of nanoparticles. The density of water decreases at high temperature resulting in increased random motion of nanoparticles and more number of particles meet the surface leading to increase in heat flow rate (Q).

6. Conclusion

The heat flow rate Q was found to be decreasing for the concentration of nanofluid and the range of inlet fluid temperatures considered in this experiment. So, this experimentation forces us to think of ways of altering the operating parameters appropriately, to increase the heat transfer rate Q through the Heat Exchanger.

7. Future Scope of Work

- To discover ways of increased heat flow rate with nanofluids even at lower inlet temperatures.
- The concentration of nanofluid can be increased to get better results for effectiveness and heat flow rate.
- Experiment can also be carried out with other nanofluids, with different concentrations and different inlet temperatures.

References

[1] http://web.iitd.ac.in/~pmvs/courses/mel709/classification-hx.pdf
[2] https://en.wikipedia.org/wiki/Heat_exchanger
[3] http://www.mechnol.com/classification-of-heat-exchangers.html
[4] http://www.engineersedge.com/heat_transfer/parallel_counter_flow_designs.htm
[5] https://en.wikipedia.org/wiki/Nanoparticle
[6] https://en.wikipedia.org/wiki/Nanomaterial
[7] https://scholar.google.co.in/scholar?hl=en&as_sdt=0,5&as_vis=1&q=use+of+nanofluids
[8] http://www.sciencedirect.com/science/article/pii/S0142727X99000673