International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 09 | Sep 2020 www.irjet.net p-ISSN: 2395-0072

PERFORMANCE ANALYSIS OF SHELL AND TUBE PARALLEL-FLOW HEAT EXCHANGER USING NANOFLUIDS

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Abstract - *A heat exchanger is a system used to transfer heat between two or more fluids. Heat exchangers are used in both cooling and heating processes. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. A Nano fluid is a fluid containing nanometer-sized particles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in Nano fluids are made of metals, oxides, carbides, or carbon Nano tubes. High specific surface area and therefore more heat transfer surface between particles and fluids. The overall objectives of the project is to fabricate a shell and tube heat exchanger with hot fluid stationary and cold fluid running through it inside a copper tube coil. The temperature difference between the two ends of the copper tubes is measured and readings are taken. The same physical parameters are used to analyses the performance of the heat exchanger in CFD, and further the static fluid is changed from water to aluminium oxide Nano fluid, and the performance of Nano fluids in heat exchangers is studied using CFD. The overall results provide the efficiency differences using the analysis report.*

***Key Words*: Heat exchanger, Copper tube coil, Nanoparticles, Nano fluids**

1.1 INTRODUCTION

There are several industries that use large boilers for their manufacturing process. Mostly the boilers in the food industries overcome these maintenance problems. The hot water in the Boiler is reduced to the room temperature to get released to the environment without any hazardous impact over the nature or the atmosphere of the industry. The traditional cooling system provides the cooling of the hot fluid to a greater extent. But recent advancements in nanoparticles which has molecular structure fabricated according to the need provide greater support for this heat transfer application. Those nanoparticles are fabricated again into fluids to apply wherever fluid applications are needed. These Nano fluids provide greater efficiency in heat transfer process. Comparatively recyclable process but expensive in terms of fabrication with water, it provides faster heat transfer.

1.2 PROJECT NEED

The vast field of thermal engineering involves heat exchangers, power plants; nuclear reactors etc. among them the heat exchangers find a brief usage in all thermal aspects. Every field involving thermal energy as power source, have heat exchangers in its process flow. Further, the heat exchangers are of different types based on their mode of heat transfer. But most common type of heat exchanger is conduction type heat exchanger. The idea of using Nano fluids as cooling medium is a recent research study that has been made by researchers all over the world. The yield provided with this research paved the way for further industrial usage of the Nano fluids. Although the fabrication cost of such Nano fluids are high, it provides convenience of recycle and reuse. Also the efficiency when compared with water is at a higher plane. The idea of using aluminium oxide Nano particles is feasible, due to the availability and lower cost comparing to other Nano particles. The oxides present in the fluids greatly improve the thermal conductivity of the medium, resulting in rapid heat absorption and dissipation. The overall objective of the project is to analyse the aluminium oxide Nano fluids as a flowing medium with conventional heat exchanger and also analysis comparison with water flowing medium. The analysis report finds helpful for researchers or others when involved in the field of using Nano fluids as coolant in real-time.

2.1 PROCESS EXPLANATION

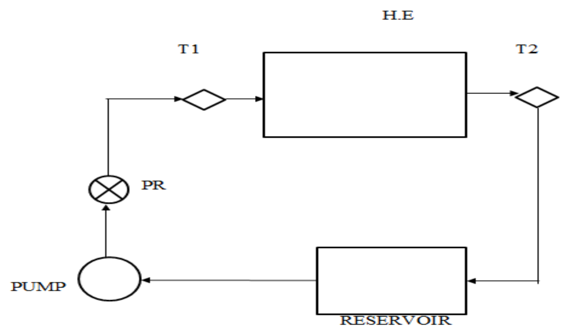

Fig 1

RESERVOIR - inlet coldwater reservoirs.

T1 & T2 - temperature sensors.

P.R - pressure regulator valve.

H.E - shell and tube heat exchanger

2.1. PROCESS EXPLANATION:

The overall objective of the project is to compare the simulation (CFD) result. With the real time project results. In real time, the container holds the copper tube with a heat exchanger setup which allows cold water to flow inside the copper tube. The head transfer process occurs between hot water and cold water through conduction between the walls of copper tube, as copper is an efficient thermal conduct. The hot water of 70 degree Celsius is poured inside the heat exchanger barrel which is thermally insulated by FRP to avoid heat losses. Two drain tubes are available in the heat exchanger barrel, one over the barrel and the other lowest side of the barrel the barrel is of height 1200 mm and diameter of 580 mm. the copper tube enforced and coiled inside the barrel is 10mm dia and of 2mm wall thickness. The copper tube has 11 turns which is welded by 9m of copper tubes together. The overall draft of the copper coil is shown below.

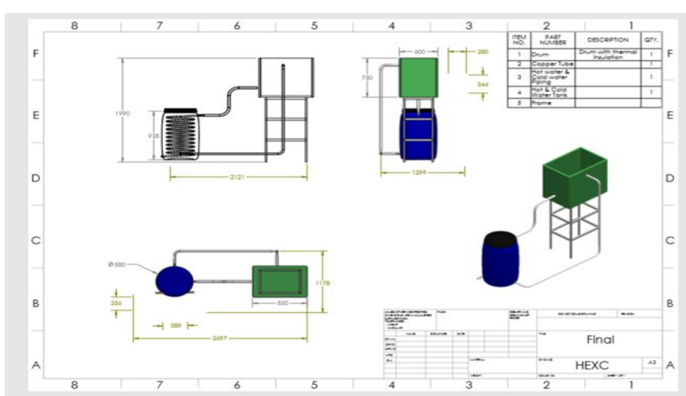

Fig: 2

2.2 PROCESS FLOW:

The hot water (L1) is fed into the boiler through the pump. The temperature of the L1 is measured using thermometer as 70 degree Celsius. The FRP insulation reduces the heat loss due to convection over the surface of walls of the barrel. The lower drain pipe is made sure. The cold water (L2) is kept in a reservoir of the room temperature of 25 degree Celsius. The temperature sensor setup is implemented or attached to the inlet and outlet of copper tube, to measure the temperature difference between complete cycles, and also to measure the overall heat transfer of the process. A pressure regulator is also coupled with the variable hose pipe of 10 mm dia hose pipe which regulates the flow rate of the fluid medium.

2.3PROCESS WORKING :

The hot water from source is made to flow in the coil and maintained at 70 degree Celsius. The hot water from the reservoir of 25 degree is poured inside the barrel. The pump outlet is connected with variable hose provided with a pressure regulator of 10mm dia. the pressure regulator regulates the flow rate of the fluid flow through the copper tube. The heat is transferred from the stagnant hot water to the flowing cold water through the copper tube. The flow is considered as a parallel flow stagnant. Again the water out from the copper tube is fed into the reservoir in a height higher than that of the pump. The outlet water from the reservoir is allowed to flow to the pump by means of gravity. The pump increases the pressure and again circulates the water to the copper tube. The temperature difference is measured between the two ends of the copper tube by temperature sensors. The same process is done by using CFD analysis and fed with same temperatures, coil dimensions, and other physical parameters. Another simulation is done by using aluminium oxide Nano fluid as flowing medium. The temperature differences and efficiency differences are collected as a report. With the same physical parameters used for the hot water fluid flow, the Nano fluid simulation is carried out .The simulation results are combined with the results obtained from the real time result. The results deviation from the real time heat exchanger and the CFD analysis is done with water as flowing medium , and also the comparison between the CFD analysis of both water and aluminium oxide Nano fluids as flowing medium. The effect of using aluminium oxide Nano fluids is studied.

2.4 SPECIFICATIONS

Dimensions of copper tube:

1. Diameter of copper tube : 10mm
2. Thickness of copper tube : 2mm

Dimensions of the coil:

1 Height of the coil : 800mm
2 Diameter of the coil : 395mm
3 Pitch : 49.56
4 No. of turns : 11

Dimensions of Drum:

1. Height : 1000mm
2. Diameter : 515mm

Properties of Aluminium oxide (Nano fluid): Properties of water :

(Properties for the volume fraction of 1%)

PROPERTIES	VALUES
Thermal conductivity	0.63065 W/m k
density	1025.24 Kg/m^3
heat capacity	4051.06 J/kg K
viscosity	0.0009147 kg/MS

TABLE 1

PROPERTIES	VALUES
Boiling Point	100 deg
Density	997 kg/m^3
Specific latent heat	40.8kg/mol
Specific heat capacity	4.2 J/g deg

TABLE 2

3) CALCULATIONS:

The following calculation is to determine the overall heat transfer between the static cold water and dynamic hot water

$Q = m*c_p*(T3-T_1)$

T1 = inlet temperature (˚c)

T2 = temperature on the 5th coil (˚c)

T3 = outlet temperature (˚c)

Q = UA*(LMTD)

The overall heat transfer between the liquids is taken by the above stated LMTD equation

LMTD = $\frac{\Delta T1 - \Delta T2}{ln\frac{\Delta T1}{\Delta T2}}$

Q1 = Heat Transfer from hot water

Q2 = Heat Transfer from cold water

Q = Overall Heat transfer

U = Overall heat transfer coefficient

A = Surface area of the copper tube

LMTD = Logarithmic Mean Temperature Difference

m = mass flow rate of the water (kg/s)

ρ = density of the fluid (kg/m^3)

v = volume of the fluid (m^3)

TYPE OF FLOW:

$m = \rho A_c C$ kg/s

A_c = area of cross section of the tube (mm2)

C = velocity of the fluid inside the coil (mm /sec)

For m = 0.012678 kg/s:

$C = m / (\rho A_c) = 442.196$ mm /s

$Re = (C*L_c) / \mu = (442.197 * 8) / 0.4415 = 8012.6$ (Re = Reynolds number)

L_c = characteristic length of the coil (inner dia = 0.8cm)

μ= kinematic viscosity of water at 65 deg (0.4415 mm^2/s)

Re > 2300, therefore the flow is turbulent

For m = 0.96 kg/s of water:

C = 3400 mm/s for (ρ = 997 kg/m^{3,} μ= 0.4415 mm^2 /s)

Re =(C*L_c) / μ = 57688

Re > 2300, therefore the flow is turbulent

EFFICIENCY ($\eta_{H.E)}$ OF THE HEAT EXCHANGER:

Assuming it as parallel flow

For m = 0.012678 kg/s

T_{hi} = 70˚c

T_{ho} = 57˚c

T_{ci} = 30˚c

T_{co} = 39˚c

LMTD = $\frac{\Delta T1-\Delta T2}{ln\frac{\Delta T1}{\Delta T2}}$ **= (**40 – 21) / ln (40/21) = 308.29 K

Q = U*A_c*(LMTD) J/s

Applying LMTD value in the above equation

Q = 0.6922 J/sec

Q_{max} = m*c_p*ΔT = 2.129 J/s

$\eta_{H.E}$ = Q/ Q_{max} = 32.5

NANO FLUID AS COLD FLUID:

For m = 0.012678 kg/s

T_{hi} = 70˚c

T_{ho} = 36˚c

T_{ci} = 30˚c

T_{co} = 59˚c

LMTD = $\frac{\Delta T1-\Delta T2}{ln\frac{\Delta T1}{\Delta T2}}$ **= (**70-30) / ln (70/30) = 303.79 K

Q = U*A_c*(LMTD) J/s

Applying LMTD value in the above equation

Q = 1.784J/sec

Q_{max} = m*c_p*ΔT = 2.129 J/s

$\eta_{H.E} = Q/ Q_{max}$ = 56 %

RESULT:

For mass flow rate = 0.01246788kg/s

RESULT	T1 (°C)	T2 (°C)	T3 (°C)
SIMULATION (water)	70	65	58
SIMULATION (aluminium oxide)	70	57	34
REAL TIME (water)	70	63	60

TABLE 3

Re > 2300 , therefore the flow is turbulent

$\eta_{H.E} = Q/ Q_{max}$ = 32.5 % when water as cold fluid

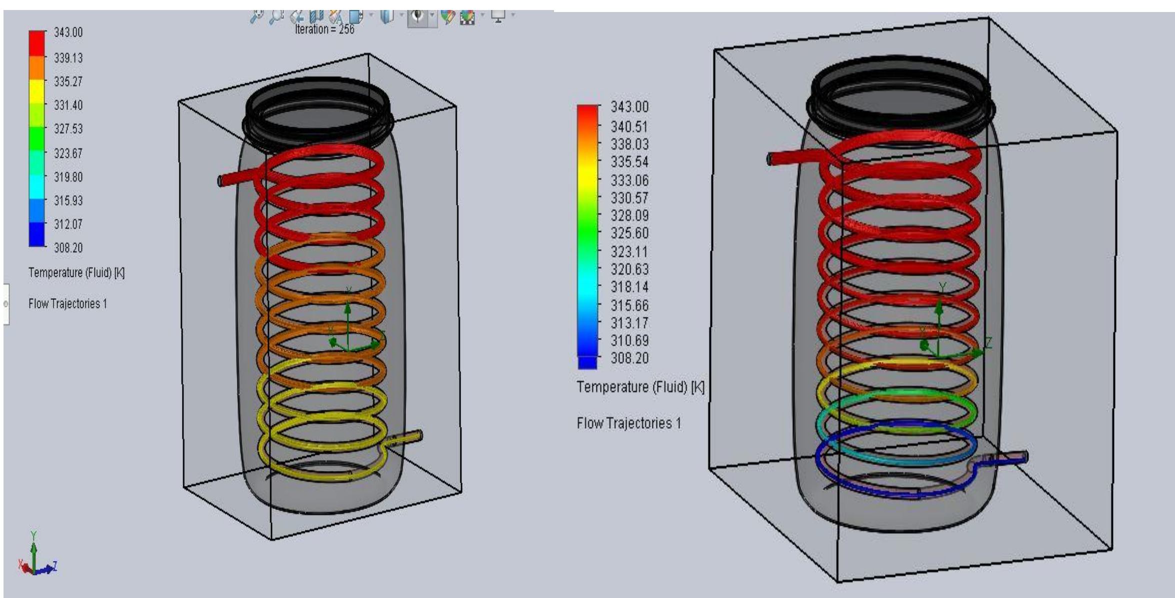

Fig 1 (Water as cooling medium) fig 2 (Al_2O_3 as cooling medium)

For mass flow rate = 0.96kg/s

RESULT	T1 (°C)	T2 (°C)	T3 (°C)
SIMULATION (water)	70	37	35
SIMULATION (aluminium oxide)	70	35	35
REAL TIME (water)	70	42	38

TABLE 4

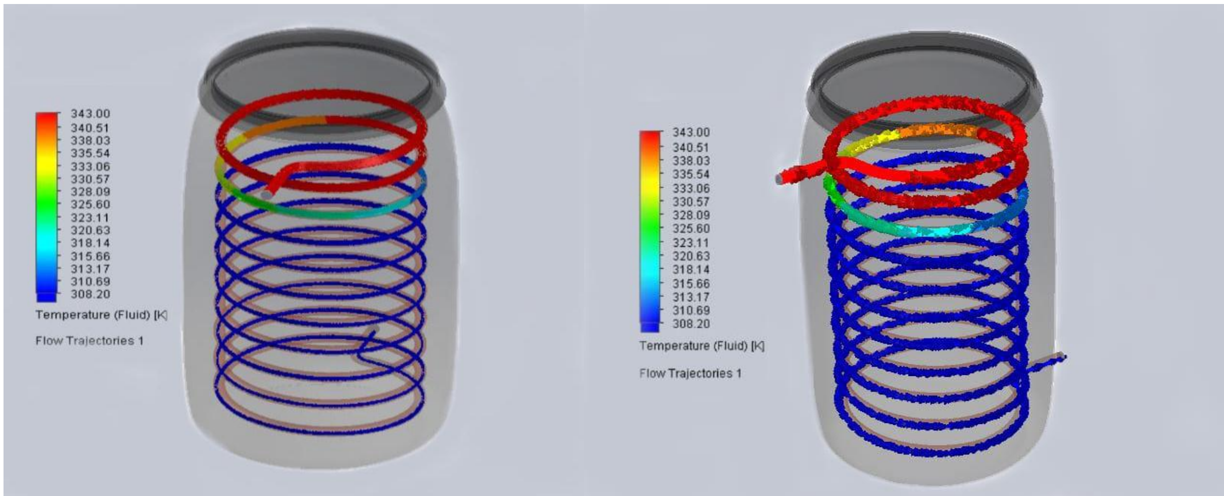

Fig3 (Water as cooling medium) fig 54 (Al2O3 as cooling medium)

CONCLUSION:

The overall results provide the conclusion that the heat transfer is enhanced when using aluminum oxide Nano fluoids as a substitute for water as cooling medium. When water used as coolant medium in the heat exchanger, the heat transfer rate is low which when compared to the trial when aluminium oxide as cooling medium. Further when the flow rate is increased the rate of cooling also increases. This analysis results provides greater information about using aluminium oxide Nano fluids as a cooling medium in industry boilers, with greater recyclability. The increased time efficiency provides greater utility of such Nano fluids in industries. Also the flow rates can be increased to enhance the cooling effect.

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