CFD ANALYSIS AND ENHANCEMENT OF HEAT TRANSFER IN COMPACT SHELL AND TUBE HEAT EXCHANGER BY USING CAMPHOR-WATER

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Abstract

A heat exchanger is a device that allows heat from one fluid pass to another fluid without the fluids having to mix together or come into direct contact which is used in power generation, refrigeration and chemical process industries. For many years shell and tube heat exchangers employ forced convection to reduce the hot fluid temperature by increasing the cold fluid temperature. In this paper to use ANSYS software and experimental computations are to examine drop in temperatures by using camphor-water as a hot fluid and water as a cold fluid with varying inlet conditions like temperature and velocity. For that cross flow heat exchanger model was reinforced and analyzed. The outcomes from the experimental were compared with CFD values. While expected that the heat exchanger by using camphor-water gives more heat transfer rate than water.

Keywords: *heat exchanger, forced convection, and ANSYS.*

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1. INTRODUCTION

Heat exchanger is a component which permits transfer of heat from one stream to another stream and those streams are disunite by solid boundary. An uncomplicated design of shell and tube heat exchanger utilized in different applications like cooling, heating, condensation, boiling or evaporation. So that when deign this type of heat exchanger we must regard the type of material to be considered which effects the heat transfer coefficient. The optimal design of heat exchanger is constructed by estimating the both hot and cold fluid temperatures.

2. LITERATURE SURVEY

Xi'an, China [1] by providing the sealers in shell side heat transfer is improved. Heat transfer coefficient for shell side is increased by sealers between baffles and shell. Qiuwang Wang [2] A combined multiple shell-pass shell-and-tube heat exchanger ((CMSP-STHX)) is examine with segmental baffles of the conventional shell-and-tube heat exchanger. Under the same mass flow rate and overall heat transfer rate, the average overall pressure drop of the CMSP-STHX is lower. Varsha Gupta [3] the thermal analysis effected by the tube cross sections containing geometry square, triangle due to variations of the surface area. By increasing flat surface area of contact of fluid with its boundary than enhances the heat transfer rate. Parkpoom Sriromreun [4] by placing the zigzag shape baffles create co-rotating vortex flows having a great influence on the flow turbulence intensity which results in higher the heat transfer rate. Susheela Palanisami [5] an eco friendly mosquito repellent scattered with lemon grass oil. the mosquito repellent is less damage to our health than remaining which is available in the market. Mukul Kumar and YoshinoriAndo [6] by the chemical vapour deposition of camphor high-purity carbon nanotubes (CNTs) are prepared, which is environment-friendly hydrocarbon. Camphor-based CNT synthesis technique stands fairly good against the 12-principle protocol of green chemistry. Ravi kumar [7] by wet granulation technique using camphor as subliming agent sodium starch glycolate together with cross carmellose sodium as super disintegrants the Orodispersible tablets of haloperidol were produced. by explosing the granules to vacuum Camphor was sublimed. The tablets were produced by compress the porous granules. V.ajaykumar [8] in this paper enhance the heat transfer rate in shell and tube heat exchanger by using nano particles suspended in different fluids such as Water and Ethylene glycol. The thermo physical properties of nano fluid mixture were forecast by analytical method. Yonghua You [9] with trefoil-hole baffles the heat transfer rate is effectively enhanced on the shell side, meanwhile, the flow resistance increases substantially. A closer look at above research works reveals that the heat transfer rate in shell and tube heat exchanger is improved by using different fluids. But in this paper I choose camphor-water to improve the heat transfer rate.

3. SCOPE OF THE WORK

It is observed from the literature that the experimental data for different fluids in laminar and turbulent flow conditions are available. However, no experimental and CFD simulation results are available for camphor-water in laminar to turbulent flow conditions. In this paper I prepare and find out the thermo physical properties in addition additives of camphor to water. By using camphor-water the heat transfer rate is enhanced. Similarly by using CFD simulation software, it can reduce the time and operation cost compared to experimental calculations, in order to measure the optimum parameter and the behavior of this type of heat exchanger.

4. ESTIMATE THE PROPERTIES OF CAMPHOR-WATER

Camphor [$C_{10}H16O$], is a ketone or a keto-tetra hydro-cymene, obtained from the camphor tree, Cinnamomum camphora.

4.1 Sample Preparation

Camphor is triturated with alcohol and precipitated calcium phosphate, water is added gradually and filtered. By the filtration excess camphor and calcium phosphate are removed. By using this composition and above preparation method I prepare camphor water by using magnetic stirrer.

Table 1: Composition is used to prepare a camphor-water

Camphor	8g
Alcohol	5ml
calcium phosphate	5g
Distilled water	1000ml

Table 2: Properties of camphor-water

Temp (^{0}k)	Density (kg/m3)	Viscosity (m^2/s)	Spec. heat (Cp) j/kg.k	Thermal conductivity (w/m.k)
303	1000.3	$0.825*10^{-6}$	4189.72	0.6146
313	997.79	$0.652*10^{-6}$	4189.71	0.62976
323	992.77	$0.562*10^{-6}$	4192.19	0.64143

By using this magnetic stirrer I prepare camphor-water up to 20 litters and it is used in experimental setup as tube side fluid.

5. EXPERIMENTAL SETUP

The experiment is carried out under laminar flow by using camphor-water as tube side fluid and water as shell side fluid. The water is feed through shell side from the tank and camphor-water is passing through tube side as a hot fluid. By using electrical heater the camphor-water is heated with control device. By using flow meters the flow rate is measured and governed by adapting valves. By attachment of thermocouples at inlet and outlet, temperatures of fluid are measured. Fig1 shows the experimental setup.

Fig 1: Shell and tube heat exchanger

In this experimental setup tubes are orientated in 60 degree with 25% baffle cut is considered. At different velocities experiment is carried out in laminar flow and temperatures of hot and cold inlet temperatures are respectively 323k and 300k. Heat transfer coefficients of shell and tube side are calculated. These values are compared with numerical values.

Heat rejected in hot water (Q_h) = $m_h*c_{ph}*(T_{hi}-T_{ho})$ in watts:

Heat taken by cold water (Q_c) = $m_c*c_{pc}*(T_{co}-T_{ci})$ in watts

Logarithmic mean temperature difference

LMTD = $(\theta 2 - \theta 1)/ \ln(\theta 2/\theta 1)$

Where $\theta 2 = Thi - Tci$, $\theta 1 = Tho - Tco$

Overall heat transfer coefficient: U_0=Qs/ (Ao* LMTD).

5.1 Tube Side Fluid Temperature Variation

From the below figure the hot fluid inlet and outlet temperatures is directly proportional to mass flow rate i.e. on increasing the mass flow rate the temperature of hot fluid increases.

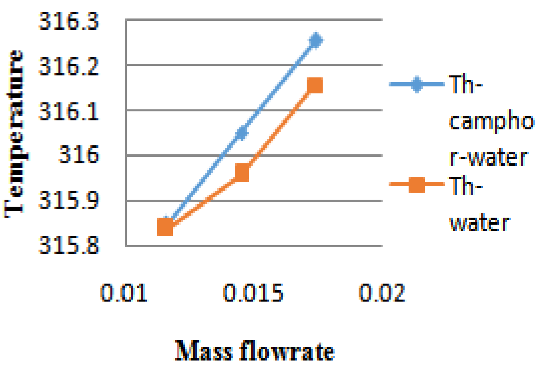

Chart -1: Tube side fluid temperature variation with mass flow rate

Above graph illustrates that camphor-water has acquired highest hot inlet & outlet temperatures compared to water.

5.2 Shell Side Fluid Temperature Variation

From the below figure the cold fluid inlet and outlet temperatures is inversely proportional to mass flow rate i.e. on increasing the mass flow rate the temperature of cold fluid decreases.

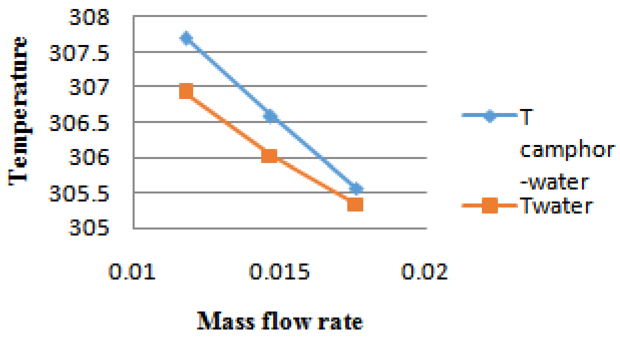

Chart -2: shell side fluid temperature variation with mass flow rate

From the above experimental setup as expected that camphor-water gives more heat transfer rate than water. For this experimental setup simulation will be done as follows.

6. SIMULATION

6.1 Problem Description and Modeling

The model is created by using CATIA software for numerical analysis. By using finite volume method analysis is done.

6.1.1 Geometry Modeling and Material Properties for the Analysis

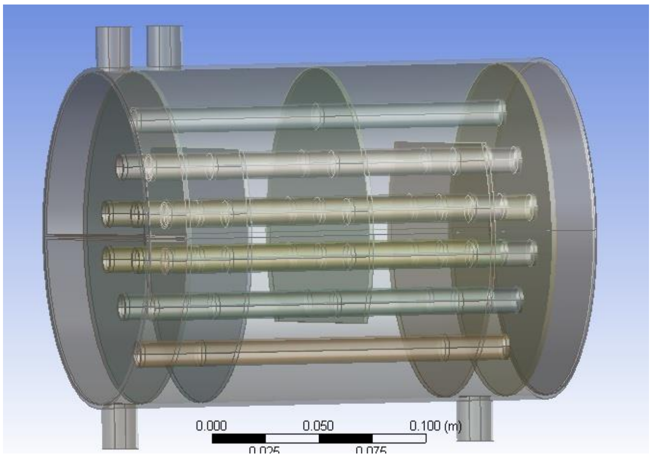

Fig2: Shell and tube heat exchanger model

6.1.2 Mesh Generation

Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. The computational zone was meshed with the structured and unstructured tetrahedral grid due to the complicated structure of shell and tube heat exchanger,. The grid system is generated by ANSYS Workbench.

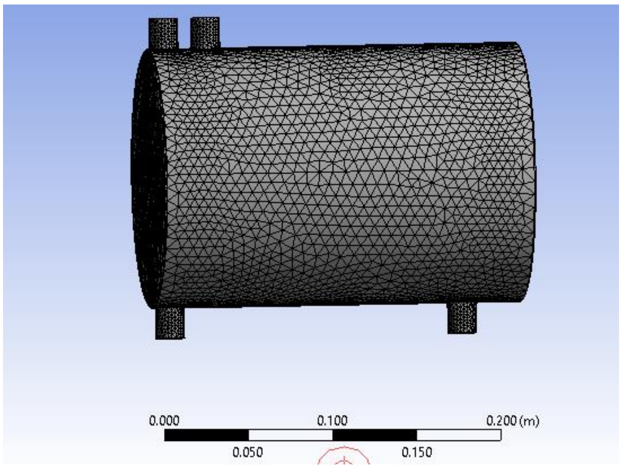

Fig 3: grid generation

6.1.3 Defining Material Properties

Table 2: Properties of materials

Material	Density (kg/m3)	Spec. heat (Cp) j/kg.k	Thermal conductivity (w/m.k)	Viscosity (m^2/s)
Copper	8978	381	387.6	-
Steel	8030	502.48	16.27	-
Camphor-water	1000.3	4189.72	0.6146	$0.825*10^{-6}$
water	997.5	4178	0.6129	$0.834*10^{-6}$

6.2 Numerical Solution

Boundary conditions are applied at inlet as velocity inlets and pressure outlets at outlet. The velocity at inlet of the cold fluid and hot fluid was varied as 0.066m/s,0.08315m/s,0.09978 m/s and 0.0660m/s, 0.08252 m/s, 0.0990 m/s respectively. Atmospheric pressure is considered at outlet. Inlet temperatures of hot and cold fluid are 323k and 300k. Remaining parameters are calculated by FLUENT software. After giving the boundary conditions to the inner and outer fluid, finally we have to run the calculations.

6.3 Results and Discussions

The observations of CFD simulation results are discussed below for the given boundary conditions. To determine the best fluid for shell and tube heat exchanger

i. By using ANSYS software results will be analyzed.
ii. Experimental calculations will be done to use as a cross check.
iii. ANSYS FLUENT is a use full tool for modeling laminar flow heat transfer.

The temperature, pressure & velocity variation in a cross flow heat exchanger for laminar flow is as shown in below profiles.

6.3.1 Temperature, Pressure & Velocity Profile for Cross Flow Heat Exchanger: At Velocity of 0.09 (Streamline Representation) for Tube Side

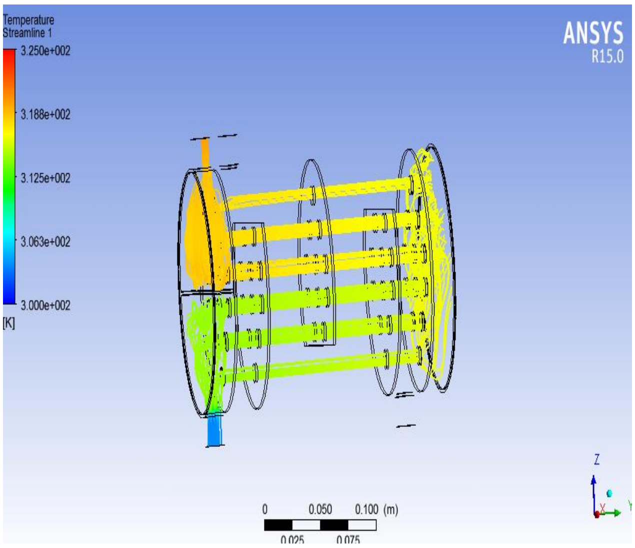

Fig4. Temperature variation

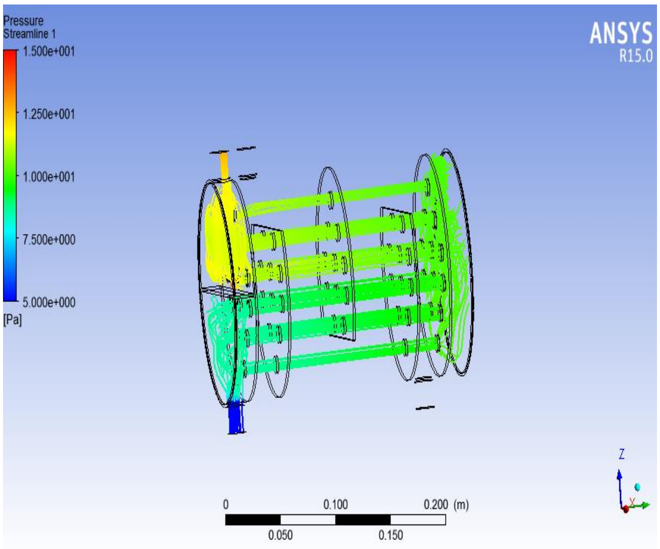

Fig5. Pressure variation

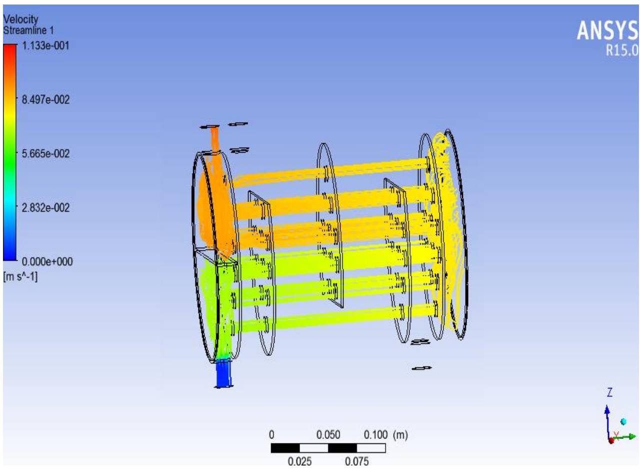

Fig6. Velocity variation

Figures show the fluid flow pattern in plain tube. At the inlet of constant mass flow rate, the temperature, pressure and velocity varies in the length direction. One can observe that the hot fluid temperature decreases by rejecting heat to cold fluid in length direction and also Pressure and velocity varies in length direction.

6.3.2 Temperature, Pressure & Velocity Profile for Cross Flow Heat Exchanger: At Velocity of 0.09 (Streamline Representation) for Shell Side

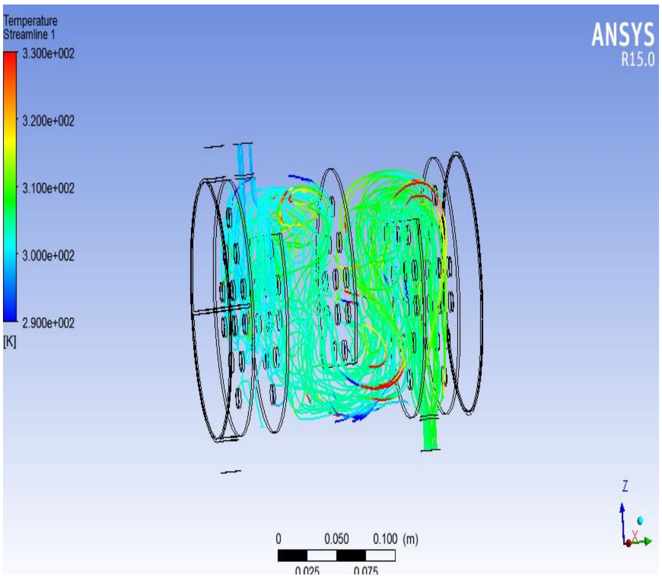

Fig7. Temperature variation

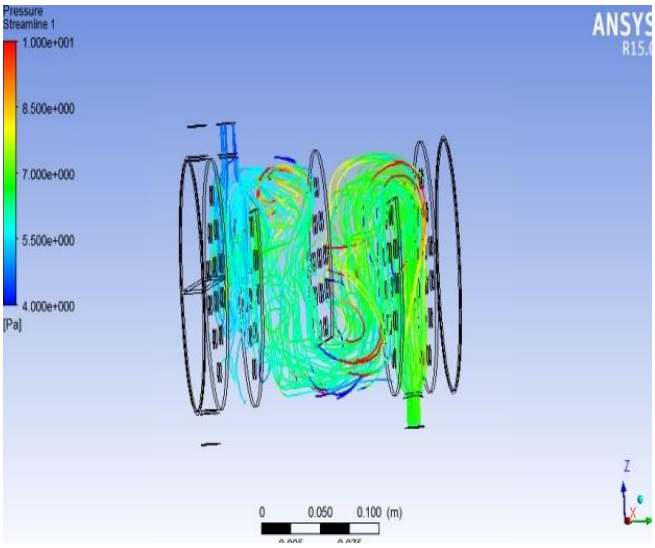

Fig8. Pressure variation

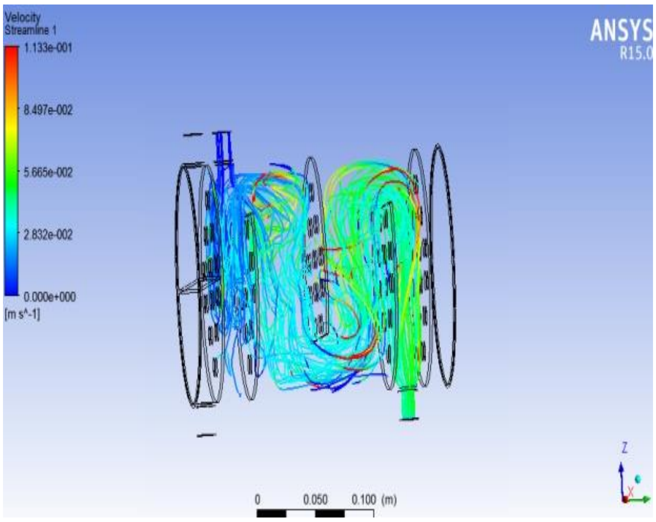

Fig12. Velocity variation

Figures show the fluid flow pattern in shell side along its length. By referring figure the temperature of fluid varies by restrain the fluid with inserting baffle at inner side of shell. The temperature of fluid increases at outlet than inlet by extracting heat from the hot fluid. Figure shows the pressure inside tube side increases in length directions similarly the figure shows velocity variation in length direction.

7. FLUENT VALUES VS. EXPERIMENTAL VALUES

7.1 Co-efficient of Heat Transfer (Q_A)

The below figure shows that co-efficient of heat transfer directly proportional to mass flow rate i.e. by increasing mass flow rate, the co-efficient of heat transfer increases.

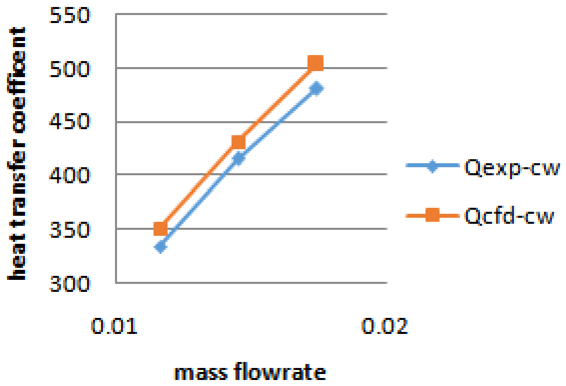

Chart 3: Overall heat transfer rate varies with mass flow rate

7.2 Overall Heat Transfer Co-efficient (U_o)

The below figure shows that of heat transfer co-efficient directly proportional to mass flow rate i.e. by increasing mass flow rate, the Overall heat transfer co-efficient increases.

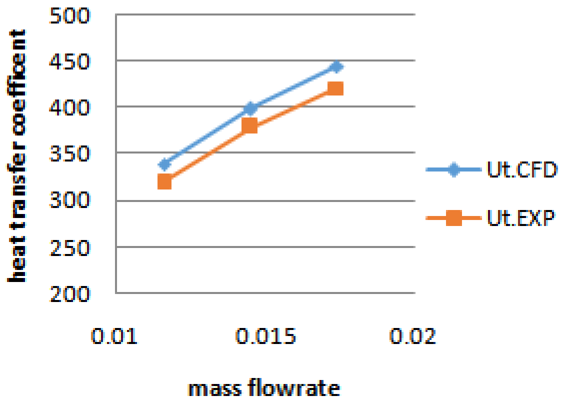

Chart 4: overalll heat transfer co-efficent varies with mass flowrate

7.3 Log Mean Temperature Difference (LMTD)

The below figure shown that logarithmic mean temperature difference directly proportional to mass flow rate i.e.by increasing mass flow rate, LMTD increases.

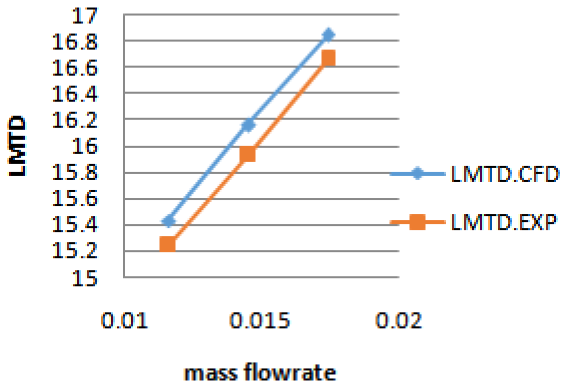

Chart 5: LMTD varies with mass flow rate

From the above graphical representation, it is resolved that the obtained values like Coefficient of heat transfer (Q_A), Overall heat transfer coefficient (U_O) and Logarithmic mean temperature difference (LMTD) are proved to be within 5% of error for laminar flow validation. So the analysis is terminated successfully.

Table 3: Comparison of experimental and FLUENT values of camphor water at different mass flow rates

Values	**Mass flow rates (Kg/s)**	**0.011**	**0.014**	**0.017**
Experimental	Overall heat transfer co-efficient (w/m k)	389.00	459.54	511.48
	Cold fluid outlet temp. (k)	3307.86	306.42	305.75
	Hot fluid outlet temp. (k)	316.53	316.40	316.45
	LMTD (k)	15.43	16.16	16.84
FLUEN	Cold fluid outlet	307.4	306.58	305.7

T	temp. (k)	1		4
	Hot fluid outlet temp. (k)	315.8 3	315.95	316.1 5
	LMTD (k)	15.23	15.924	16.65
% Error (LMTD)		1.23	1.45	1.08

8. CONCLUSION

In present study the experimental and CFD analysis for the heat transfer augmentation in a shell and tube heat exchanger by using camphor-water is investigated. The conclusions of investigation are as follows.

- In cross flow arrangement, considering laminar flow. At different mass flow rates by using camphor-water fluid acquired better heat transfer than water.
- By comparing the numerical and experimental results the LMTD of shell and tube heat exchanger at different mass flow rates is below 5%.
- In FLUENT the average temperature is used for calculations and for experimental, material properties are considered constant depend upon inlet temperature.

9. FUTURE WORK

Shell and tube Heat Exchanger has a wide range of application in many industries like in thermal power plants, petro chemical plants, for space heating. From the above investigation by changing physical parameters and inlet conditions by using camphor-water thermal properties of heat exchanger can be calculated.

- By using the different baffles, heat transfer augmentation for camphor-water can be studied.
- The performance of different tube shapes can also be studied under different combinations of baffle cuts.
- These variant angular baffles can be used for heat transfer augmentation studies.

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