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Analysis of Parallel Flow and Counter Flow Heat Exchanger using Fluent Techniques

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ABSTRACT

In present day shell and tube heat exchanger is the most common type heat exchanger widely use in oil refinery and other large chemical process, because it suits high pressure application. Efficiency of heat exchanger and its dimensions are ones of the most important parameters to consider in engineering design. The size of heat exchanger can be more compact by introducing the fins to The aim of the study is design tube and box heat exchanger with various pattern of tubes and examine the flow and temperature field at inlet and outlet point of tube and container using ANSYS programming tool. The process in solving simulation consists of modeling and meshing the basic geometry of shell and tube heat exchanger using CFD package ANSYS. Three types of heat exchangers are planned in this examination with various structures of cylinders increase the heat transfer rate between the heat exchanger surface and the surroundings.

The purpose of this study is to simulate experimental study with computational fluid dynamics study for validation the Geometrical model is developed from literature for simulation. Geometrical model creation and meshing is done by ANSYS Workbench. That's why it is important to design the heat exchanger in such a way that it can give best performance so that optimum effectiveness can be achieved.

By using ANSYS software, the thermal analysis of Shell and Tube heat exchangers is carried out by varying the layout. Comparison will make between the Experimental results of heat interaction and effectiveness will be calculated for different tube materials. ANSYS. With the help of the available numerical results, the design of Shell and Tube heat exchangers will be altered for better efficiency.

KEYWORDS:Heat Exchanger, parallel flow, counter flow, ANSYS, CATIA, Effectiveness

1. INTRODUCTION

A heat exchanger is a gadget intended to productively exchange or "trade" heat starting with one issue then onto the next. Any fluid can be utilized to exchange heat, whether it be liquid, oil or moving air.it can be used for both heating and cooling process. The fluids in the exchanger can either be separated by a solid wall or be in direct contact. Due to the increase in demand of machines top notch heat exchangers are also needed to increase the life and efficiency of the machines. They have a wide range of applications such as:

- Space heating
- Refrigeration
- Air conditioning
- Power stations
- Chemical plants
- Petro-chemical plants

- Natural gas processing
- Sewage treatment

1.1. CLASSIFICATION BASED ON FLOW CONFIGURATION:

Based on flow configuration heat exchangers are of 4 types namely counter flow, concurrent flow, cross flow and hybrids as multi pass flow or cross counter flow.

1.2 COUNTER FLOW: In this type of heat exchanger the two fluids flow in opposite direction but parallel to each other. This is the most efficient arrangement as it allows the maximum change in the temperature of both the fluids.

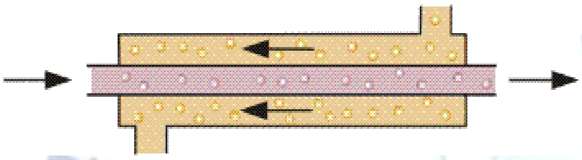


Figure 1: COUNTER FLOW

1.3 CONCURRENT FLOW: This type provides a constant wall temperature, but it is a less efficient arrangement. In this the fluids flow in the same direction and are parallel to each other.

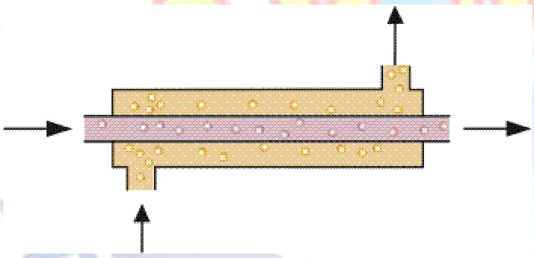


Figure 2: COCURRENT FLOW

1.4 CROSS FLOW: In this type of exchanger the fluids flow at an angle of 90° with each other. The efficiency of cross flow lies between that of counter and concurrent flow.

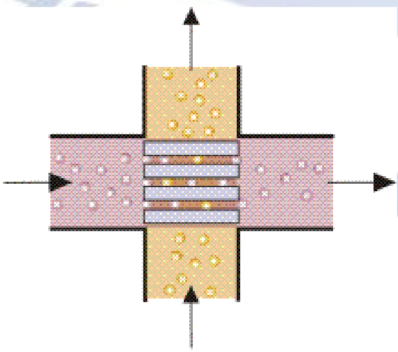


Figure 3: CROSS FLOW

1.5 HYBRID FLOW: These type of heat exchangers is mostly used for practical industrial purposes. Some common types of hybrid are combination of cross/counter flow and multi pass flow heat exchanger.

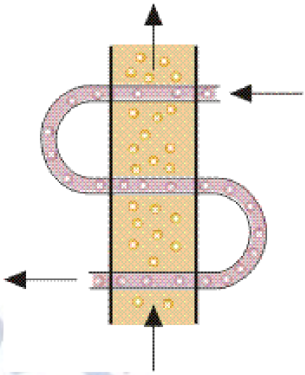


Figure 4: CROSS/COUNTER FLOW

2. LITERATURE REVIEW

Darvid, A.N., Smith, K.A., Merril, E.W. and Brain studied A wide range of researches are already done to study the flow characteristics and heat transfer in helical heat exchangers. The enhancement of the heat transfer in the helically coiled tubes is due to the centrifugal forces. A secondary flow field is produced due to the curvature of the tube with a circulatory motion, which causes the fluid particles to move towards the core region of the tube. The secondary flow enhances heat transfer rates by reducing the temperature gradient across the cross-section of the tube. Thus there is an additional convective heat transfer mechanism occurs, perpendicular to the main flow, which does not exist in straight tube heat exchangers.[1]

K.S. Bharuka, D.Y. Kasture studied the characteristics of heat transfer in a double pipe helical heat exchanger and found that the overall heat transfer coefficients increases with increasing inner Dean number. However, this increase is a function of the ratio of the mass flow rates.[2]

Timothy J. Rennie studied the heat transfer characteristics for a double pipe helical heat exchanger for both counter and parallel flow with both the boundary conditions of constant heat flux and constant wall temperature. The results from the simulations were within the range of the pre-obtained results. The overall heat transfer coefficients were determined for dean numbers ranging from 38 to 350. He observed that the overall heat transfer coefficients varied directly with the inner dean number but the fluid flow conditions in the outer pipe had a major contribution on the overall heat transfer coefficient. So, he concluded that during the design of a double pipe helical heat exchanger, the design of the outer pipe should be given the highest priority in order to get a better overall heat transfer coefficient. [3]

Vimal Kumar, Burhanuddin Faizee, MonishaMridha and K.D.P. Nigam conducted an experiment on tube-in-tube heat exchanger and observed that with the increase in operating pressure in the inner tube, the overall heat transfer coefficient increases and the friction factor value in the inner-coiled tube was in agreement with the literature data.[4]

3. METHODOLOGY

3.1 Methodology adopted

Here the analysis is done using ANSYS 14 software.

- Geometrical modelling
- Meshing
- Solution:
- Material selection
- Defining zones
- Boundary conditions
- Solution methods
- Solution initialization
- Iteration
- Plot results and contours
- Calculation of various parameters

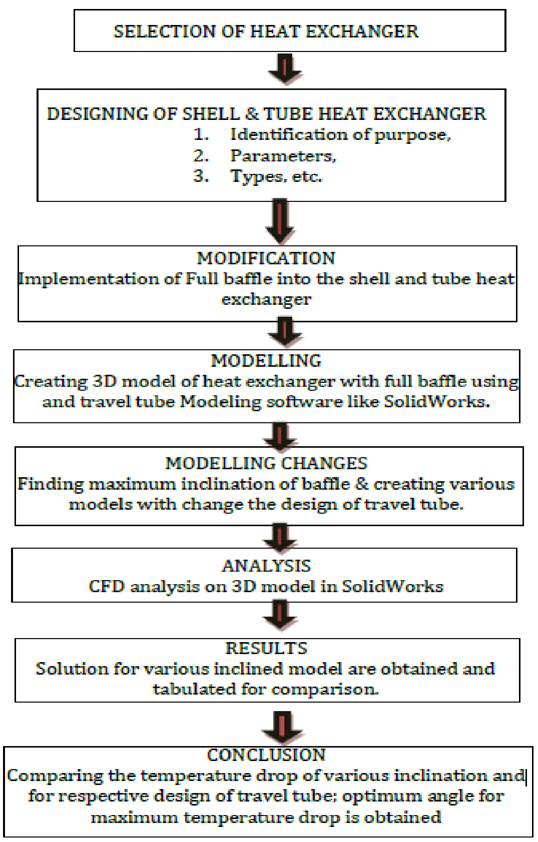


Fig 5: chart for methodoly

4. MODELING OF HEAT EXCHANGER

In this project, there are two types of heat exchangers are modelled in ansys and Catia. This are

Table 1: Tube in tube Heat exchangerdetais

Heat exchanger length, *L*	400 cm
Shell inner diameter, *Di*	200cm
Tube outer diameter, do	20mm
Tube bundle geometry and pitch Triangular	40mm

Table 2: Tube and shell heat exchanger details

Heat exchanger length, *L*	400 cm
Shell inner diameter, *Di*	40cm
Tube outer diameter, do	20mm
Tube bundle geometry and pitch Triangular	40mm
Number of baffles. *Nb*	25
Central baffle spacing, *B*	30mm

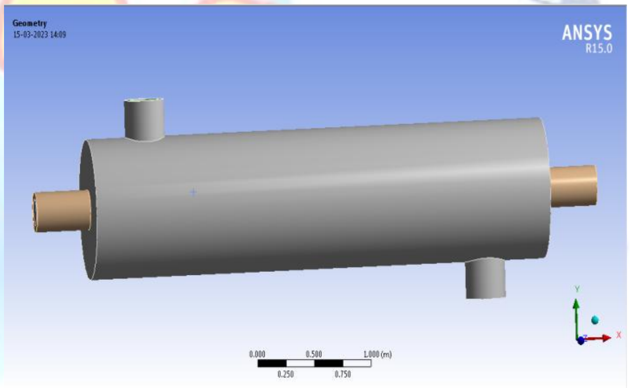


Fig 6: Tube in tube Heat exchanger

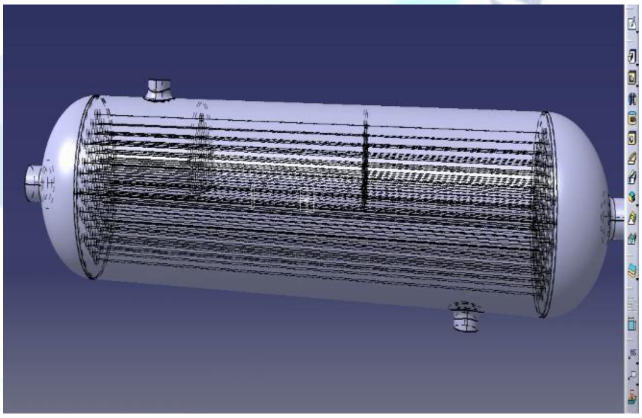


Fig 7: Tube and shell heat exchanger

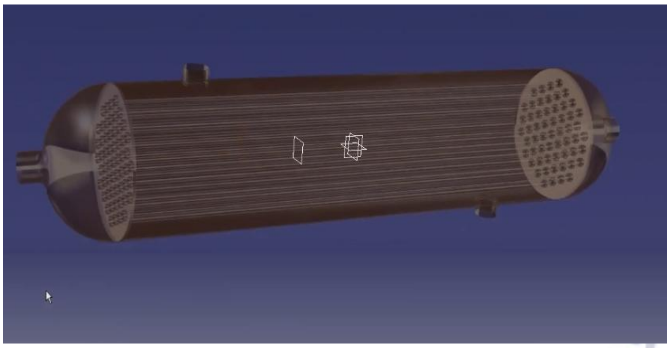


Fig 8: Tube and shell heat exchanger inner view

Table 3: Experimental cases

S.no	Type heat exchanger	Material	Hot water inlet temperature	Cold water inlet temperature	Mass flow rate
1	Tube in tube	Copper	370k	25^0c	Mass flow rate for two fluids is 1kg/sec
2			480k		
3	Tube in shell	Copper	370k	25^0c	
4			480k		

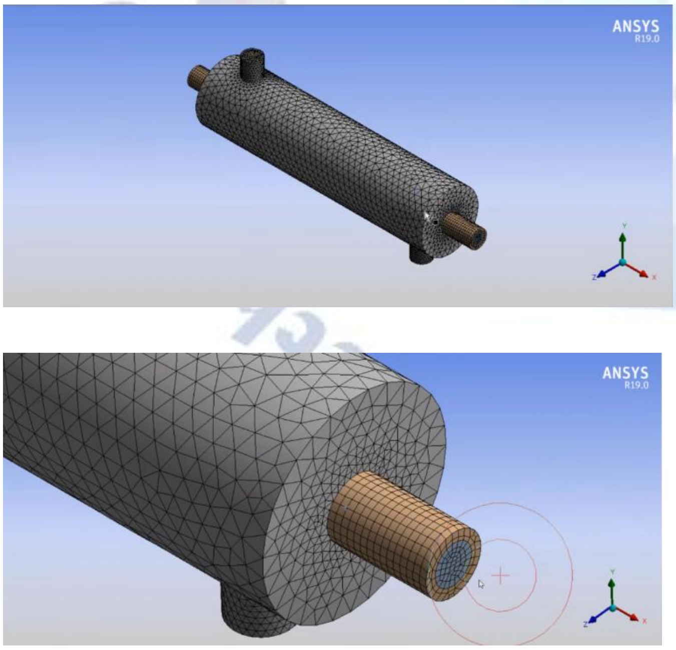


Figure 9: Meshed model of tube in tube heat exchanger

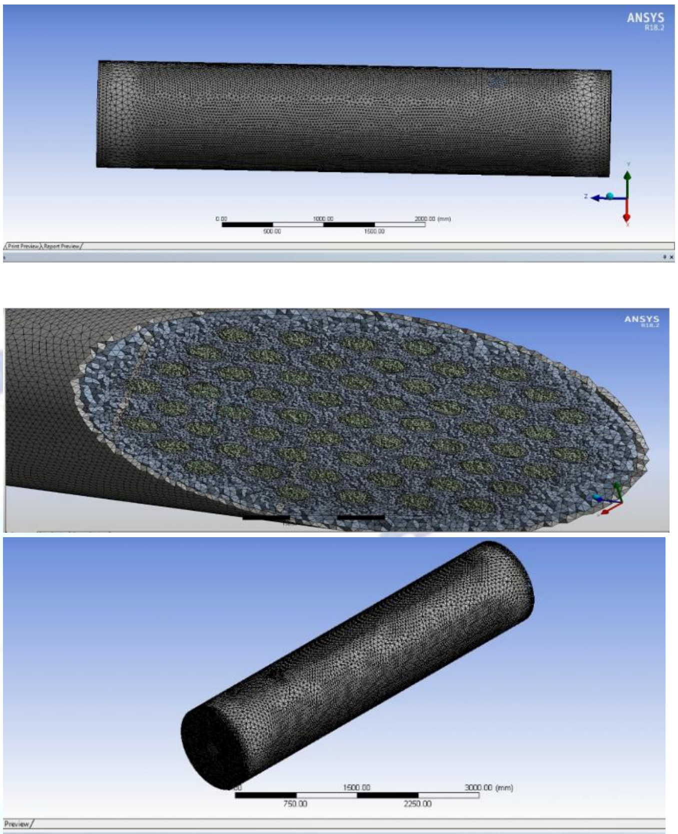


Figure 10: Meshed model of tube in tube heat exchanger

5. RESULTS AND DISCUSSION

5.1 PARALLEL FLOW CONDITION

Parallel flow condition at hot water temperature of 370k of mass flow rate of 1 kg per sec and inlet wtare temperature of 298K having mass flow rate of 1 kg per second.

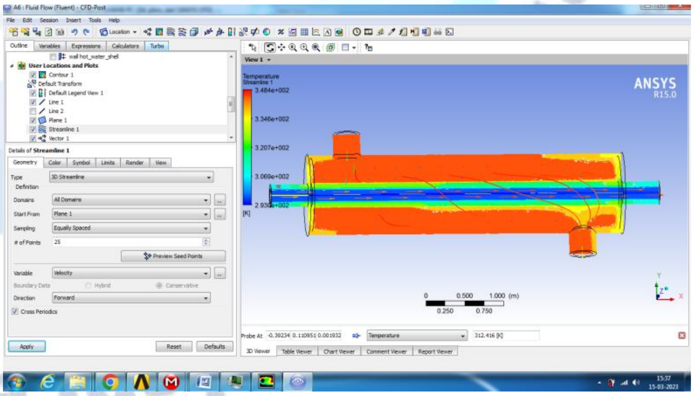


Fig 11: Tube and tube type heat exchanger of hot in let 370k

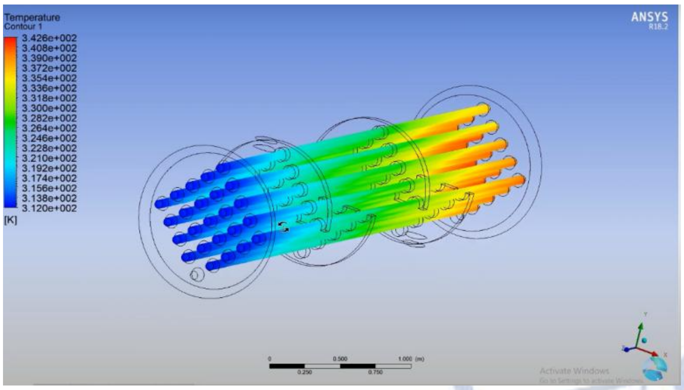


Fig 12: shell and tube type heat exchanger of hot in let 370k

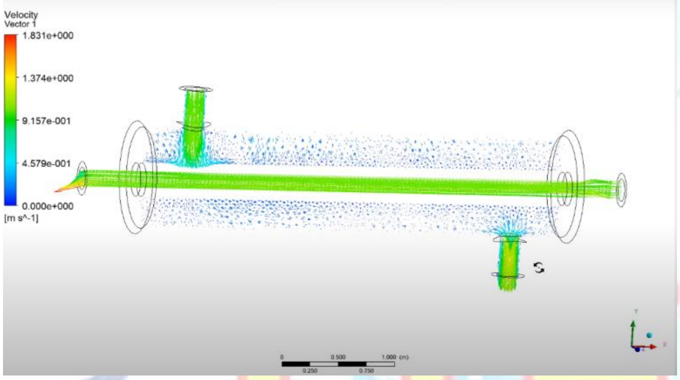


Fig 13: velocity of fluid for tube and tube heat exchanger

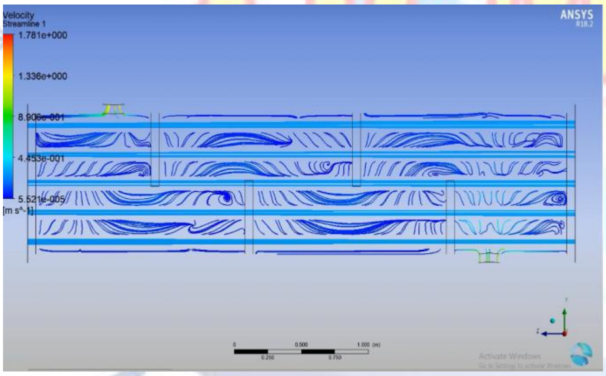


Fig14: velocity of fluid for shell and tube heat exchanger

Parallel flow condition at hot water temperature of 480k of mass flow rate of 1 kg per sec and inlet wtare temperature of 298K having mass flow rate of 1 kg per second.

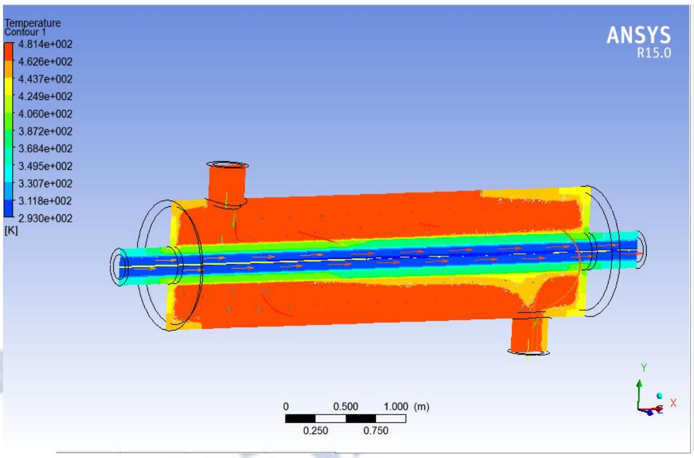
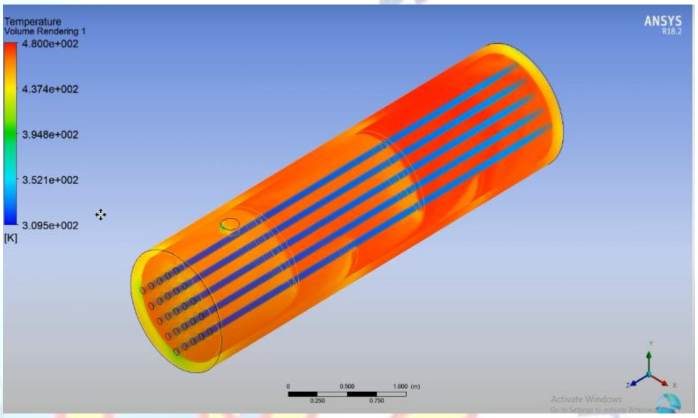


Fig 15: Tube and tube type heat exchanger of hot in let 480k



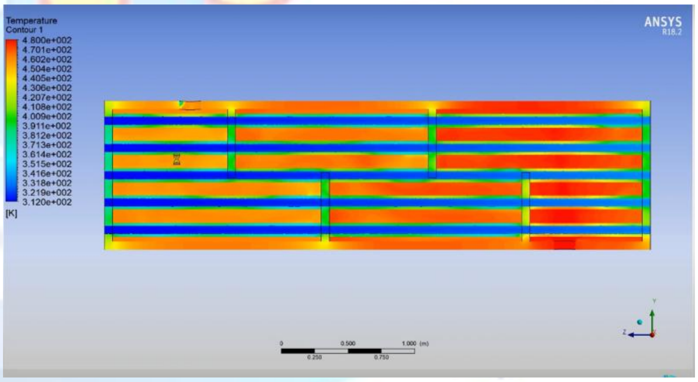
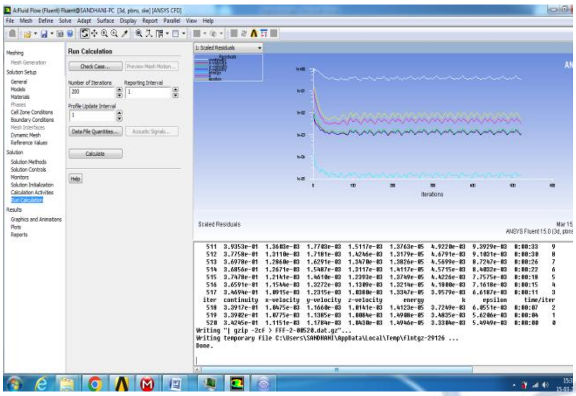
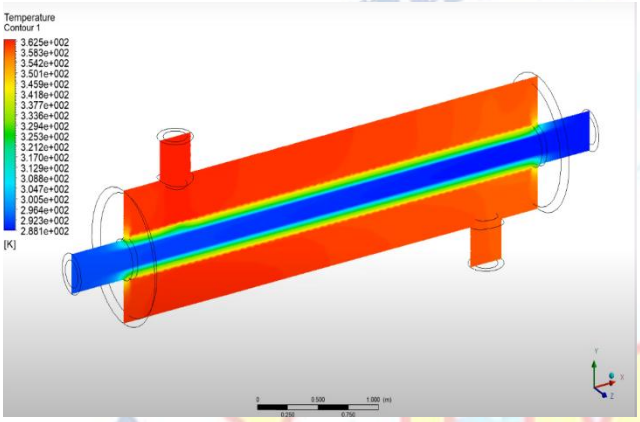


Fig 16: shell and tube type heat exchanger of hot in let 480k

5.2 COUNTER FLOW CONDITION

Counter flow condition at hot water temperature of 370k of mass flow rate of 1 kg per sec and inlet wtare temperature of 298K having mass flow rate of 1 kg per second.





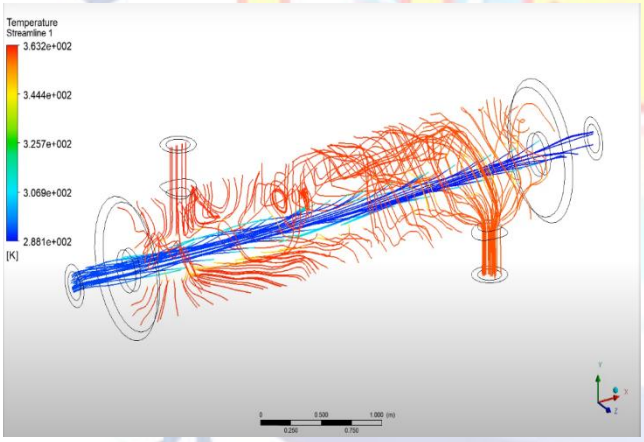


Fig 17: Tube and tube type heat exchanger of hot in let 370k for counter flow case

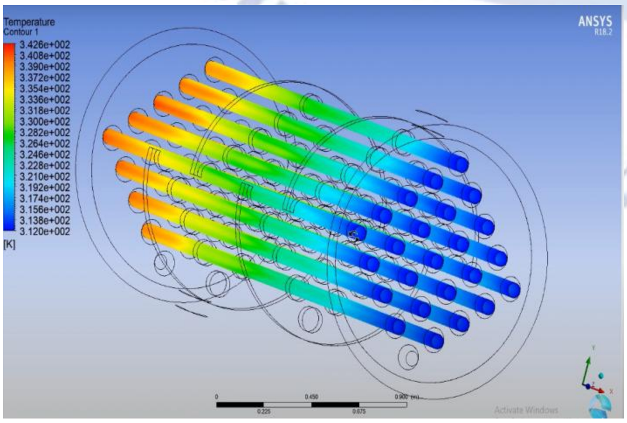
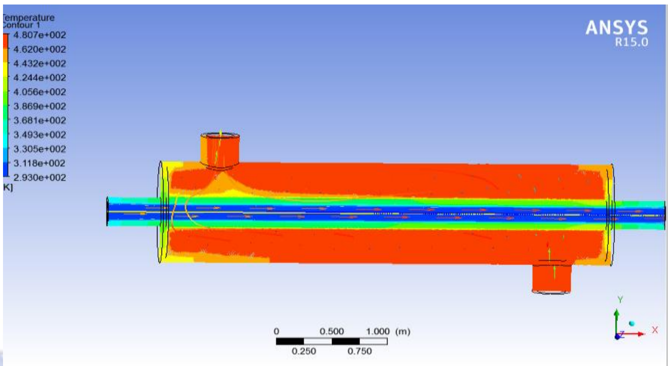


Fig 18: shell and tube type heat exchanger of hot in let 370k for counter flowcase



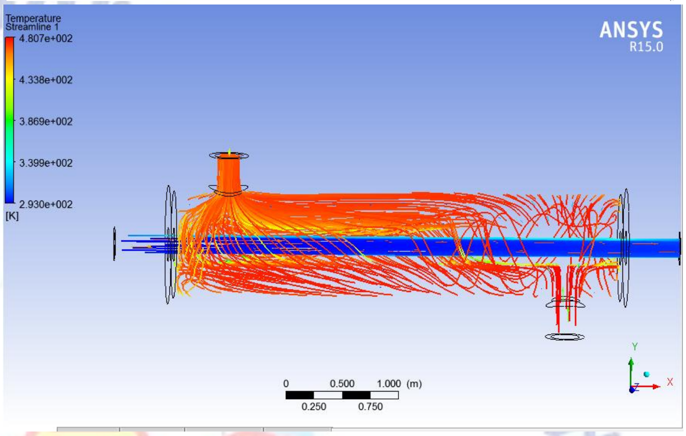


Fig 19: Tube and tube type heat exchanger of hot in let 480k for counter flow case

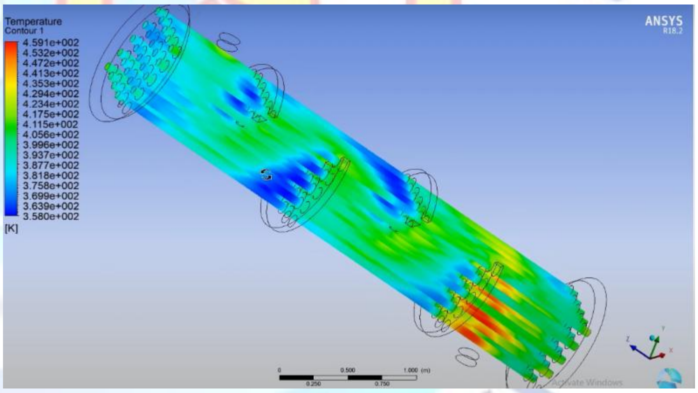
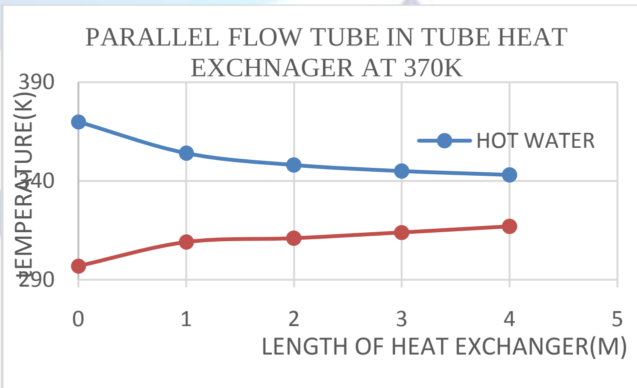
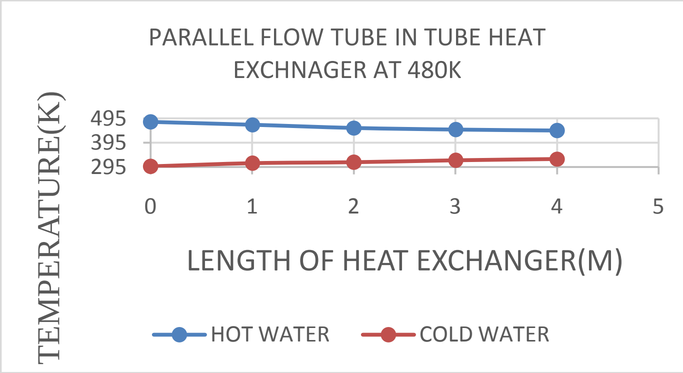


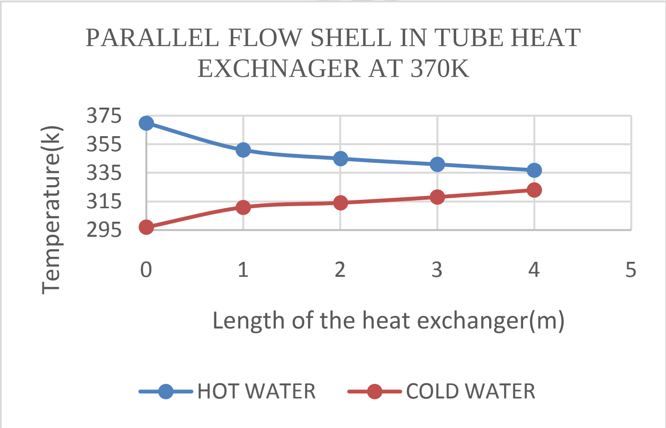
Fig 20: shell and tube type heat exchanger of hot in let 480k for counter flow



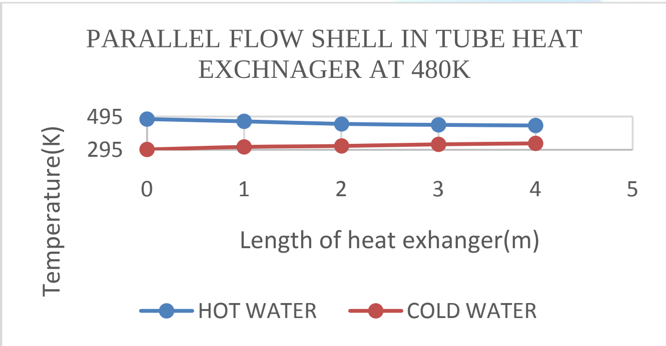
Graph 1: Parallel flow tube in tube heat exchanger at 370k



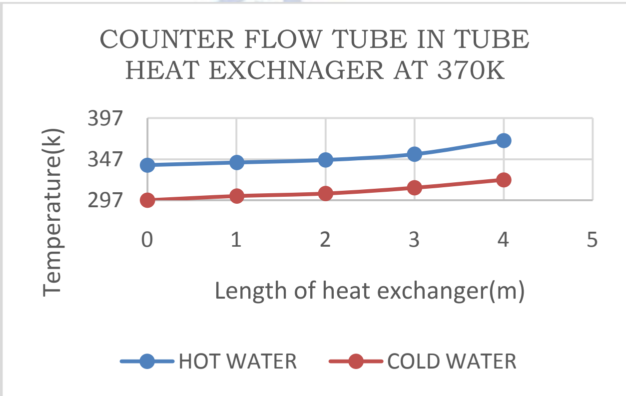
Graph 2: Parallel flow tube in tube heat exchanger at 480k



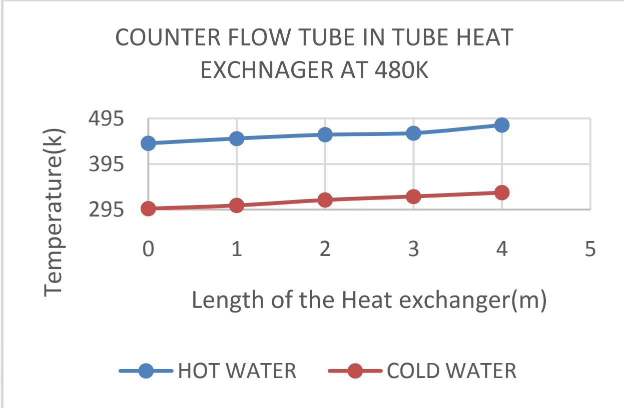
Graph 3: Parallel flow shell in tube heat exchanger at 370k



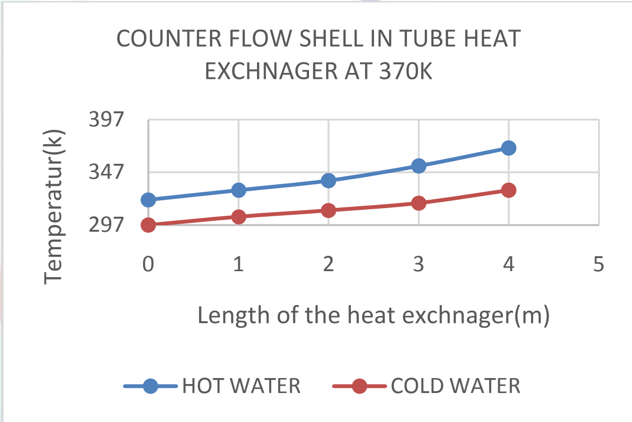
Graph 4: Parallel flow tube in tube heat exchanger at 480k



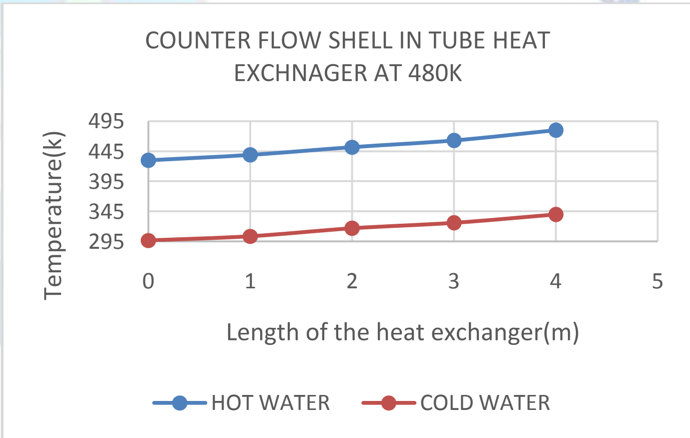
Graph 5: Counter flow tube in tube heat exchanger at 370k



Graph 6: Counter flow tube in tube heat exchanger at 480k



Graph 7: Counter flow shell in tube heat exchanger at 370k



Graph 8: Counter flow tube in tube heat exchanger at 480k

5.3 EFFECTIVENESS THE THERMAL ENERGY STO RAGE TANK:

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

$$\varepsilon = \frac{Q_{actual}}{Q_{max\ possible}}$$

Q_{actual} = Heat lost by hot fluid = Heat gained by cold fluid

$Q_{actual} = m_h c_{ph} (T_{hi} - T_{ho}) = m_c c_{pc} (T_{co} - T_{ci})$

Table4 :Effectiveness of Heat exchanger:

S.NO	Type of Heat Exchanger	T_{ci}(K)	T_{CO}(K)	T_{hi}(K)	T_{ho}(K)	Effectiveness (ϵ)
1	tube in tube	298	317	370	343	0.509
2	shell in tube	298	323	370	337	0.7021

6. CONCLUSION

The heat transfer and flow distribution are discussed in detail and proposed model is compared with tube in tube heat exchanger and shell in tube heat exchanger.

The assumption worked well in this geometry and meshing expect the outlet and inlet region where rapid mixing and change in flow direction takes place. Thus improvement is expected in the model should have complete contact with the surface of the shell, it will help in more turbulence across shell side and the heat transfer rate will increase.

If different flow rate is taken, it might be help to get better heat transfer and to get better temperature difference between inlet and outlet. Moreover, the model has provided the reliable results by considering the standard k-e and standard wall function model, but this model over predicts the turbulence in regions with large normal strain.

Furthermore, the enhance wall function are not use in this project, but they can be very useful. The heat transfer rate is more in shell and tube heat exchanger because most of the fluid passes have the more contact surface area.

Thus the design can be modified for better heat transfer in two ways either the decreasing the shell. The temperature distribution for different in lets of hot and cold water were found that the shell and tube heat exchanger have the more heat transfer rate even tough these both heat exchangers have the same mass flow rate and same volume of heat interaction. The effective ness also calculated

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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