PERFORMANCE ANALYSIS OF PARALLEL FLOW HEAT EXCHANGER

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Abstract*-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 & work interactions. Typical applications involve heating or cooling of a fluid stream of concern & 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, distill, concentrate, crystallize, or control a process fluid. Heat exchangers are used in wide range for different types of industrial and domestic applications. In this project we use indirect type of heat exchanger i.e. Parallel flow heat exchanger, By using this apparatus the readings can be taken & then the analysis of heat exchanger can be done experimentally in that calculations of heat transfer rate, LMTD (log mean temperature difference), heat transfer coefficient, overall heat transfer coefficient, heat exchanger effectiveness, etc. for the above calculations the different properties of heat exchanger such as mass flow rate of hot & cold fluid, temperature of hot & cold fluid by using a thermometer, Measuring flask, etc. can be taken. The objective of this project is to determine the performance of parallel flow heat exchanger practically & by using the CFD software.

***Keywords:* Heat exchanger, Thermometer, CFD**

I. Introduction

To achieve a particular engineering objective, it is very important to apply certain principles so that the product development is done economically. This economic is important for the design and selection of good heat transfer equipment. The heat exchangers are manufactured in different types, however the simplest form of the heat exchanger consist of two concentric pipes of different diameters known as double pipe heat exchanger. In this type of heat exchanger, one fluid flows through the small pipe and another fluid flows through the space between both the pipes. The flows of these two different fluids, one is at higher temperature called hot fluid and another is at lower temperature called cold fluid, can be in same or in opposite directions. If the flows are in same direction then the heat exchanger is called as PARALLEL FLOW HEAT EXCHANGER.

The application of the principles of heat transfer to the design of equipment to accomplish a certain engineering objective is of extreme importance, for in applying the principles to design, the individual is working towards theimportant goal of product development for economic gain. Eventually, economics plays a key role in the design and selection of heat-exchange equipment, and the engineer should bear this in mind when embarking on any new heat-transfer design problem. The weight and size of heat exchangers used in space or aeronautical applications are very important parameters, and in these cases cost considerations are frequently subordinated insofar as material and heat exchanger construction costs are concerned, however, the weight and size are important cost factors in the overall application in these fields and thus may still be considered as economic variables.

II. Types of Heat Exchanger

Heat exchangers are devices in which heat is transferred from one fluid to another. The necessity for doing this arises in a multitude of industrial applications. Common example of best exchangers is the radiator of car, the condenser at the back of a domestic refrigerator and the steam boiler of a thermal power plant. Heat exchangers are classified in three categories:

(1) Transfer type
(2) Storage type
(3) Direct contact type

A transfer type heat exchanger is one in which both fluid pass simultaneously through the device and heat is transferred through separating walls. In practice most of the heat exchangers used are transfer type. The transfer type exchangers are further classified according to flow arrangements as

1. Parallel Flow in which fluids flow in the same direction.
2. Counter Flow in which they flow in opposed direction.
3. Cross Flow in which they flow at right angles to each other.[3]

1.1.1 Parallel Flow Heat Exchanger:

In a parallel flow heat exchanger, as the name suggest, the two fluid streams (hot and cold) travel in the same direction. The two streams enter at one end and leaves at the other end. The flow arrangement and variation of temperatures of the fluid streams in case of parallel flow heat exchangers, are shown in fig. It is evident from the fig that the temperature difference between the hot and cold fluids goes on decreasing from inlet to outlet. Since this type of heat exchanger needs a large area of heat transfer, therefore, it is rarely used in practice.[1]

Examples: Oil coolers, oil heaters, water heaters etc.

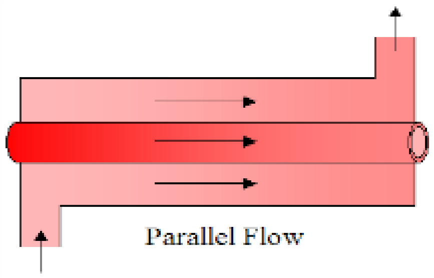


Fig1: Schematic diagram of Parallel flow heat exchanger

1.1.2 Counter Flow Heat Exchangers:

In a counter flow heat exchanger, the two fluids flow in opposite directions. The hot and cold fluids enter at the opposite ends. The flow arrangement and temperature distribution for such a heat exchanger are shown schematically in fig. The temperature difference between the two fluids remains more or less nearly constant. This type of heat exchanger, due to counter flow, gives maximum rate of heat transfer for a given surface area. Hence such heat exchangers are most favored for heating and cooling of fluids.

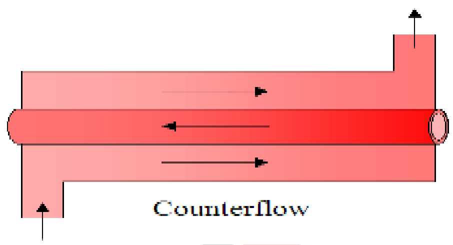


Fig2: Schematic diagram of Counter flow heat exchanger

1.1.3 Cross Flow Heat Exchanger:

In cross-flow heat exchangers, the two fluids (hot and cold) cross one another in space, usually at right angles. Fig. shows a schematic diagram of common arrangements of cross flow heat exchangers.Fig 3 shows hot fluid flows in the separate tubes and there is no mixing of the fluid streams. The cold fluid is perfectly mixed as it flows through the exchanger. The temperature of this mixed fluid will be uniform across any section and will vary only in the direction of flow.

Examples: The cooling unit of refrigeration system etc.

In this case each fluids follows a prescribed path and is unmixed as it flows through heat exchanger. Hence the temperature of the fluid leaving the heater section is not uniform.

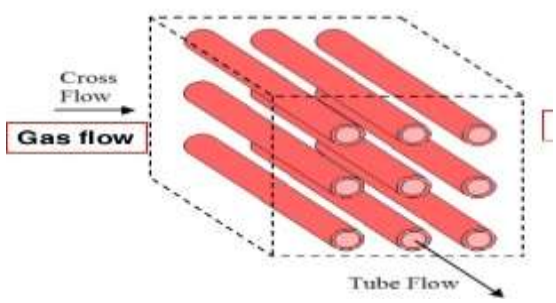


Fig3: Schematic diagram of Cross flow heat exchanger

III. OBJECTIVE:

In this project the performance analysis of a parallel flow heat exchanger performed by the experimental set up of parallel flow heat exchanger. By taking Experimental readings at different of mass flow rate of cold fluid and hot fluid, which is a water i.e. coolant with the help of thermometer and measuring flask. After that calculations of heat exchanger such as heat transfer rate, heat transfer coefficient, overall heat transfer coefficient, effectiveness, LMTD (Log mean temperature difference), etc. also in this project we are used the log mean temperature difference because here we know the all inlet and outlet temperature, for the prediction of the heat exchanger performance.

After the calculations of above values we can find out the performance of parallel flow heat exchanger by practically and then we make model of parallel flow heatexchanger in CFD software and check the performance of Parallel flow heat exchanger with the help of software.

IV. METHODOLOGY

This part consists of the Performance analysis of with two different techniques:

1) Experimental analysis.

2)CFD Analysis.

1. EXPERIMENTAL ANALYSIS:

An experimental model has been created of same dimension as of CFD model, four thermometers are installed at inlet of hot fluid and cold fluid also outlet of hot and cold fluid, after installation measures temperatures T_{hi}, T_{ho}, $T_{ci,}T_{co}$ and measuring flask is used to measure mass flow rate.

1.1 Procedure for Experiment

Step1: First start heater for heating water(hot water).
Step 2: Start flow of hot water from inner pipe.
Step 3: Start flow of cold water by outer pipe.
Step 4: Arrange the thermometer at inlet of hot and cold pipe.
Step 5: Arrange the thermometer at outlet of hot and cold pipe.
Step 6: Measure the mass flow rate of cold and hot water.
Step 7: Wait upto 10 minutes & then taking the readings of temperature of cold water and hot water.
Step 8: Repeat same process every 10 minutes.

Above procedure follow every time when we change mass flow rate of hot and cold fluid.
Observation Table for Parallel Flow Heat Exchanger:

1.2 Observations for Calculations:

Sr. No.	Mass flow rate		Thi	Tho	Tci	Tco
	Mhi	Mco				
1	0.03571kg/sec	0.0333kg/sec	60	56	29	34
2	0.025kg/sec	0.033kg/sec	60	54	29	33
3	0.0181kg/sec	0.0294kg/sec	80	72	26	36
4	0.0166kg/sec	0.025kg/sec	85	75	26	38

1.3 CALCULATIONS FOR ANALYSIS:

For designing or predicting the performance of a heat exchanger it is necessary that the total heat transfer may be related with its governing parameters: 1) Heat transfer coefficient. 2) LMTD 3) Heat transfer rate of particular fluid. 4) Overall heat transfer coefficient. 5) A total surface area of the heat transfer and 6) Total heat transfer rate.

For Second Readings:

Heat given up by the hot fluid:

$Q_h = M_h * C_{ph} * (T_{hi} - T_{ho})$ ($C_{ph} = 4.187$)

Q_h = 0.5980kJ/sec

Heat pick up by the cold fluid:

$Q_c = M_c * C_{pc} * (T_{co}-T_{ci})$ (C_{pc}= 4.187)

Qc= 0.6971kJ/sec

Log Mean Temperature Difference (LMTD)

$$\theta_m = \frac{\theta 1-\theta 2}{\ln(\theta 1/\theta 2)} = \frac{(Thi-Tci)-(Tho-Tco)}{\ln(Thi-Tci)/(Tho-Tco)}$$

$\theta_{m = 26.24}$ ^{0}c

Overall heat transfer coefficients (U):
For velocity
M= ρAV
A= 0.06479m^2

V= 5.44 * 10^{-4} m/s

$$Re = \frac{V*do}{v}$$

Re = 11.11
NusseltNo:
For inside tube hi:

$$Nu = 3.66 + \frac{0.0668*\left(\frac{d}{l}\right)*Re\ Pr}{1+0.04\left(\left(\frac{d}{l}\right)*Re*Pr\right)2/3}$$

Nu= 3.6822

$$Nu = \frac{hi*do}{k}$$

hi = 186.45 w/m^{2o}c

For outside tube:
M= ρAV --------------(I)
A= 0.1752 m^2
Putting the values in equation (1)
We get
V=1.91*10^{-4} m/s

$$Re = \frac{V*Do}{v}$$

Re= 10.738

Nusselt No.

$$Nu = 3.66 + \frac{0.0668*\left(\frac{Do}{l}\right)*Re\ Pr}{1+0.04\left(\left(\frac{Do}{l}\right)*Re*Pr\right)2/3}$$

Nu= 3.7167
Now,

$$Nu = \frac{ho*Do}{k}$$

h_o= 69.49737 w/m^{2o}c

Overall heat transfer coefficient

$$\frac{1}{U} = \frac{1}{hi} + \frac{1}{ho}$$

U= 50.626 w/m^{20}c

Total heat transfer in heat exchanger:
$Q=UA\theta_m$ $A=0.0647m^2$

Q = 85.950kJ/s

Effectiveness of the heat exchanger:
Compaire:
$M_h*C_{ph} = M_c* C_{pc}$

0.1495 > 0.1394
$C_{max}>C_{min}$

$$\varepsilon = \frac{Qactual}{Qmax}$$

$$= \frac{mc*cp*(Tco-Tci)}{Cmin*(Thi-Tci)}$$

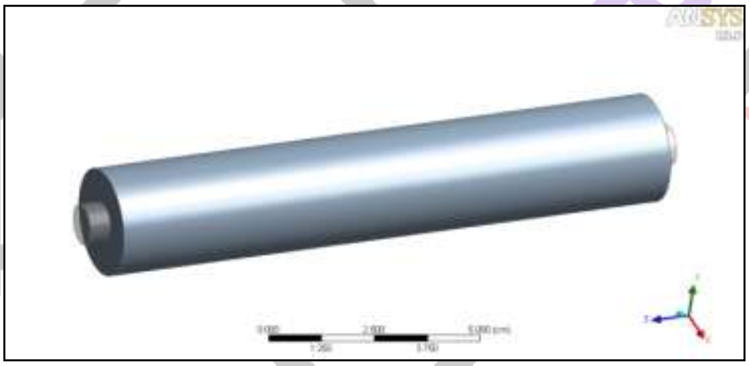
ε = 0.1612

2. CFD Analysis of Parallel Flow Heat Exchanger

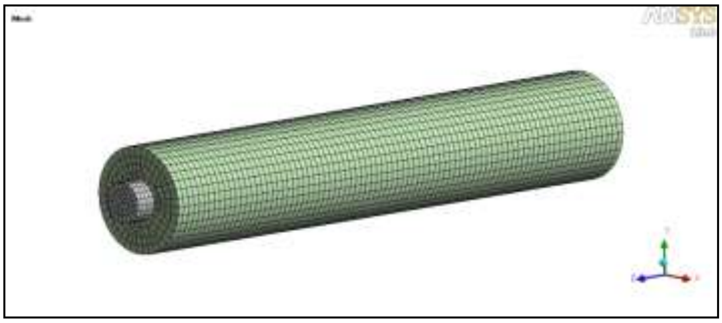
For the analysis of parallel flow heat exchanger following steps has been performed:

1] 3DModelling
2] Meshing
3]Application of boundary conditions
4] Plotting Results

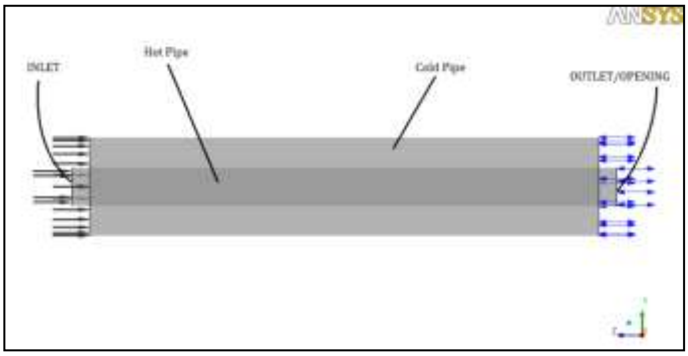
1) MODELLING



2) MESHING



3) BOUNDARY CONDITION



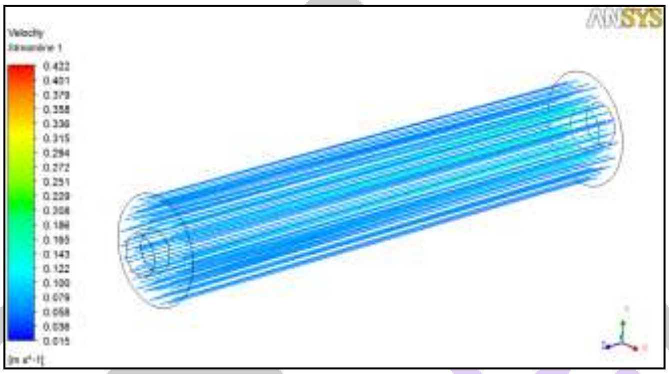


Fig:Velocity of cold pipe

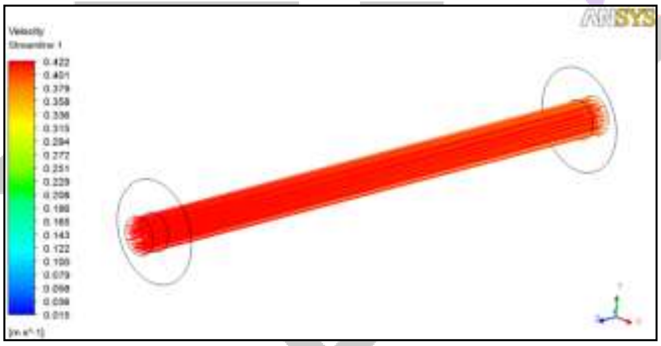


Fig:Velocity of hot pipe

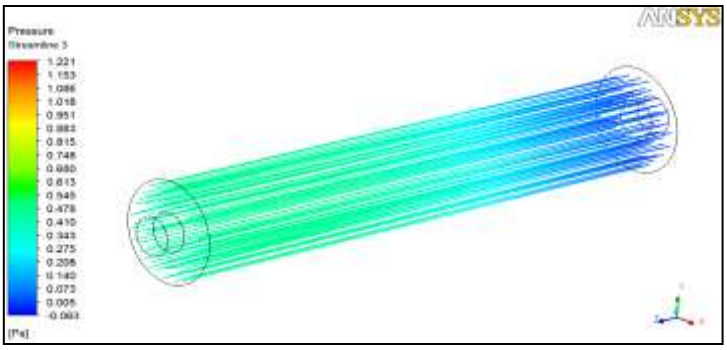


Fig:Pressure diagram of cold pipe

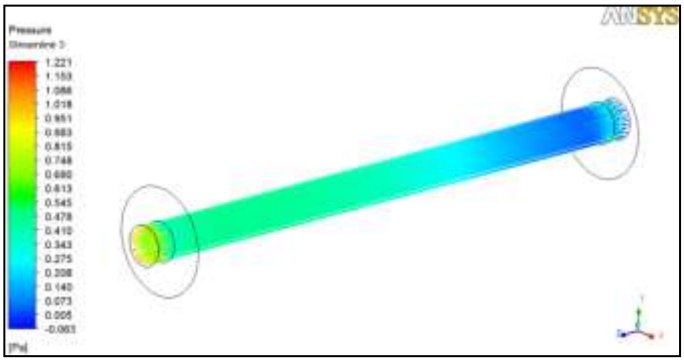


Fig:Pressure diagram of hot pipe

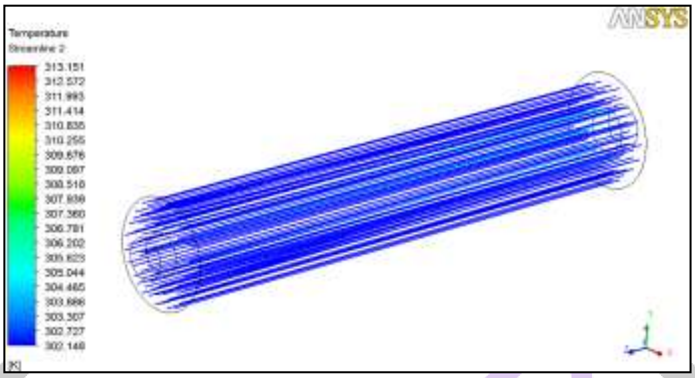


Fig:Temperature of cold fluid

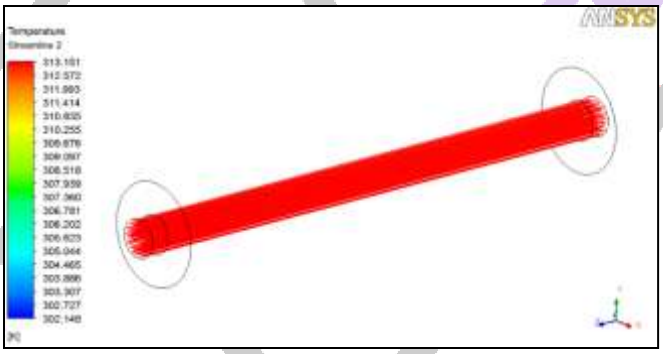


Fig:Temperature of hot fluid

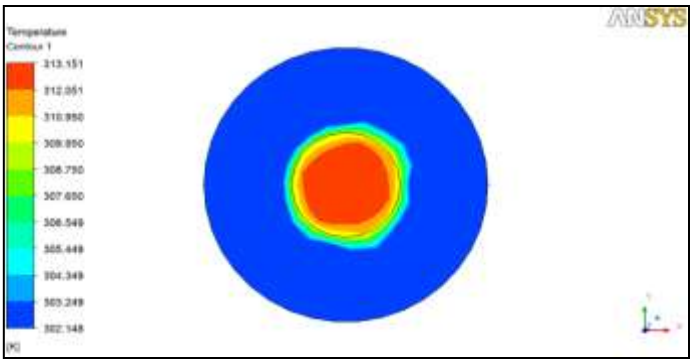
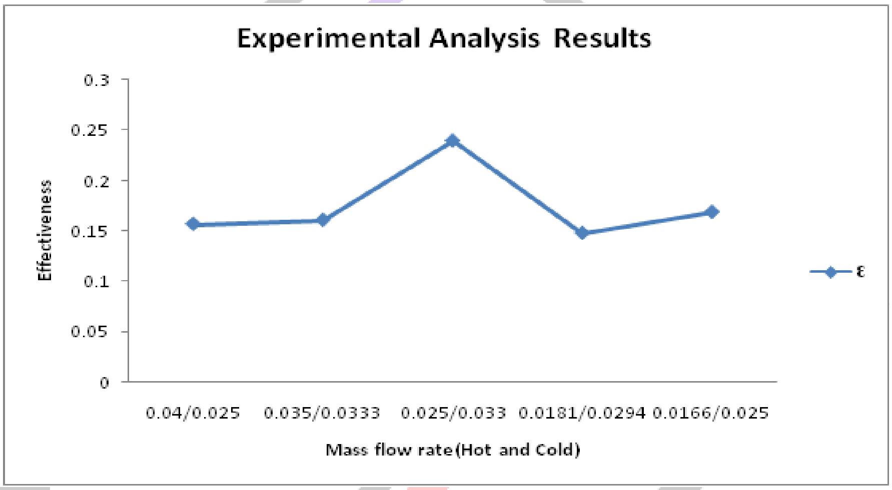
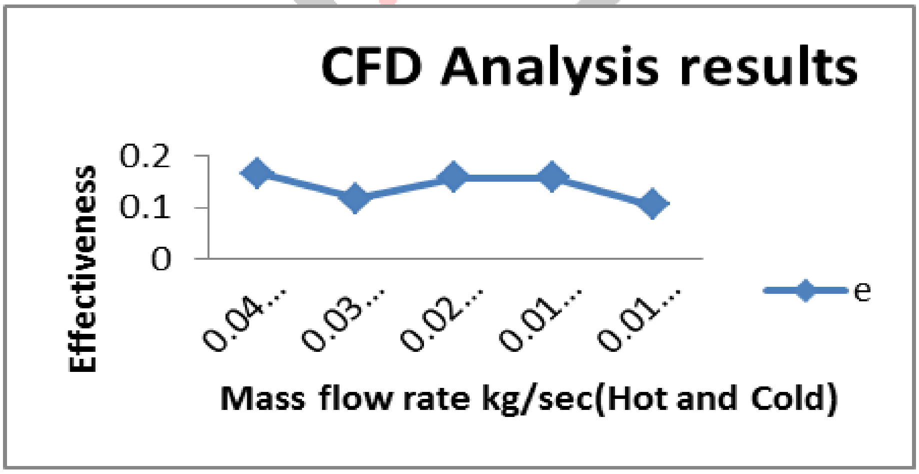


Fig: Temperature distribution diagram

V. Comparison between Experimental Analysis And CFD Analysis

EXPERIMENTAL ANALYSIS	CFD ANALYSIS
Heat given up by the hot water(Q_h)=0.50244kJ/s	Heat given up by the hot water(Q_h)=**0.441kJ/s**
Heat pick up by the cold water(Q_c)=0.314kJ/s	Heat pick up by the cold water(Q_c)=**0.331kJ/s**
LMTD(θ_m)=15.81°C	LMTD(θ_m)=**14.73°C**
Heat transfer coefficient for Hot pipe(hi)=240.47w/m²°C	Heat transfer coefficient for Hot pipe(hi)=**240.59w/m²°C**
Heat transfer coefficient for Hot pipe(ho) 90.56=w/m²°C	Heat transfer coefficient for Hot pipe(ho) =**91.45w/m²°C**
Overall heat transfer coefficient (U)=65.78w/m²°C	Overall heat transfer coefficient (U)=**66.26w/m²°C**
Total heat transfer rate (Q)=0.090 kJ/s	Total heat transfer rate (Q)=**0.0845 kJ/s**
Effectiveness of heat exchanger(ε)=0.157	Effectiveness of heat exchanger(ε)=**0.1667**





CONCLUSION

1. LMTD method used to calculate the different parameters such as Heat transfer rate, Effectiveness, etc.
2. CFD tool can be used for performance analysis of heat exchanger.
3. Calculate the parameters by using software values.
4. Comparison between CFD analysis and Experimental analysis.

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