Design , Analysis and Fabrication of a Three Fluid Counter Flow Heat Exchanger

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Abstract- *The main motto of this project is to understand the thermal performance of a three fluid counter flow heat exchanger .The hot stream is assumed to flow in the middle of two different cold streams and exchange heat with them. The performance of this heat exchanger will be better than the traditional two fluid heat exchangers. Heat exchangers for both con current and counter current flow has been studied for selected operating conditions. The detailed behavior of three fluid counter flow heat exchangers has been investigated and we have found that by using three fluids there is an increase in the heat transfer area and thus the effectiveness of the heat exchanger increases. We will discuss about the technical analysis of the heat exchangers along with the method for predicting heat exchanger performance and operational parameters. We will consider that the heat transfer will primarily be taken by conduction and convection only. We will describe the commonly used heat exchangers and their important characteristics.* (i)

***Key Words*: LMTD(log mean temperature difference); Effectiveness; HE(Heat Exchanger); NTU(Number of transfer units; MHT(maximum heat transfer).**

1.INTRODUCTION

In any process industry, we need to transfer heat for different operations (like cooling, heating, vaporising, or condensing) to or from various fluid streams in various equipment like condensers, water heaters, re-boilers, air heating or cooling devices etc., where heat exchanges between the two fluids. In a chemical process industry, the heat exchanger is frequently used for such applications. A heat exchanger is a device where two fluids streams come into thermal contact in order to transfer the heat from hot fluid to cold fluid stream. In this chapter, we will discuss about the technical analysis of the heat exchangers along with the method for predicting heat exchanger performance and operational parameters. The detailed behavior of three fluid counter flow heat exchangers has been investigated and we have found that by using three fluids there is an increase in the heat transfer area and thus the effectiveness of the heat exchanger increases

1.1 Observations and Calculations

Solutions	Specific heat(KJ/kgK)	Viscosity(cP)
Coolant	3.78	1.5 (at 25 C)
Cold Water	4.18	0.89(at 25 C)
Hot Water	4.18	0.466(at 60 C)

Table 3.4 Fluids used

Mass Flow Rate

Mass flow rate	(Kg/sec)
Hot Water	0.30
Cold Water	0.22
Coolant	0.36

Effectiveness was calculated by using the formula :

$$\epsilon = \{(Th)i-(Th)e\}/\{(Th)i-(Tc)i\}$$

It has been found that the effectiveness of the three fluid heat exchanger could not be calculated directly by using the direct formula as of two fluid heat exchanger , therefore we have tried to find the results by using the average or mean method.

1.2 Designing of the apparatus

We have used Solid Works to design the basic frame of the heat exchanger model and it is shown below in the following model :

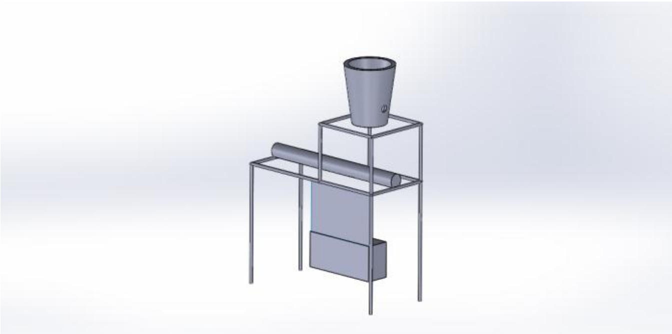

Fig-1.2.1Model design

2. APPLICATIONS

Cryogenics, in heating and air conditioning systems, in food industries, in chemical industries, in dairy industries, in petroleum industries, in nuclear power plant, in surface condenser in power plants.

3. LITERATURE REVIEW

Triple concentric tube heat exchanger has major advantage of increase in heat transfer area and compactness (lesser length) over double tube heat exchanger. Which subsequently increases the heat transfer rate and efficiency of heat exchanger. These improvement is very welcoming as far as the energy conservation is concern. Various studies and research work has already been done on the performance of double concentric tube heat exchanger but very less work has been done in the triple concentric tube heat exchanger despite of having advantages over double tube heat exchanger.

Some of them are as follows:

Carlos a. Zuritz studied a set of analytical equations for fluid temperatures at any axial location along the length of heat exchanger. He has derived three first order differential equations through Laplace transformation for three fluid flows in triple concentric tube heat exchanger. At the end, he came to a conclusion that the creation of an annular region within the inner pipe in double tube heat exchanger increases the overall heat transfer efficiency and reduces the heat exchanger length requirement by almost 25%. [1] Ahmet Ünal firstly done the derivation and possible solutions of the governing differential equations for both counter-flow and parallel-flow arrangements in triple concentric tube heat exchanger. Equation was derived for well insulated triple pipe heat exchanger under fully developed flow condition and using some properly defined parameter such as heat capacity flow rates, NTU and some other non-directional parameters. [2] The set of first order differential equations solved through Laplace transformation for distinct real roots only. Resultant equations express bulk temperature variation of three fluids with exchanger length. Then he found that the relative size of the tubes influences the performance of triple concentric tube heat exchanger. Results on experimental work present in the graphical form the effect of tube radius ratio on performance and length of heat exchanger. [3] The other results are given in effectiveness versus NTU graph for individual tubes. He concluded based on results that the effectiveness for counter flow arrangement is better than parallel flow arrangements. [4] O.García-Valladares takes the governing equations (continuity, momentum and energy) and solved it iteratively in a segregated manner. Then the flow variables (enthalpies, temperatures, pressures, mass fractions, velocities, heat fluxes, etc.) are evaluated at each point of the grid on heat exchanger surface. He has used implicit central difference scheme for solid. He added that it can be used as tool for optimizing energy efficiency. At the end, he found 12% more efficiency for counter flow arrangement. [5] Ediz Batmaz and K.P.Sandeep has derived new LMTD formula from energy balance equation. They have determined the temperature profiles in axial direction and effective overall heat transfer coefficient for triple tube heat exchanger and double tube heat exchanger for the comparison purposes. [6] They found that in a co current manner, the temperature of the cooling medium with lower heat capacity exceeded the temperature of the product before the fluids exit the triple tube heat exchanger. The other major findings were the overall heat transfer coefficient is higher in counter flow than in parallel flow and effectiveness in triple tube heat exchanger is lower for co-current flow than in double tube heat exchanger because of crossover occurring in triple tube heat exchanger. [7] Min Zhao and Yanzhong Li has developed mean temperature difference model for parallel flow arrangement in heat exchanger having three fluids. This design model significantly improves the iteration performance of the design procedure and fast convergence which is within 10 steps. They have found the relation between NTU, reduction ratio and inlet/outlet temperature from heat transfer and energy conversion equation. [8]. G.A. Quadir et. al. carried out experimental study for N-H-C and C-H-N arrangements insulated and non insulated conditions in triple tube heat exchanger experimentally. They came to know that heat transfer is more effective in N-H-C and heat transfer from hot to outer annulus fluid is more in N-H-C where it is same for both in C-H-N. After experimentation they have numerically carried out the performance of triple concentric tube heat exchanger using Finite Element Method for above flow arrangements. They represented numerical results in graphical form of temperatures along with the length of heat exchanger for all flow arrangements which are mentioned above. They concluded that both the experimental and numerical results are close enough. [9] Cristian Patrascioiu and Sinziana Radulescu developed a numerical model using equations of heat transfer and fluid dynamics for laminar flow in triple concentric tube heat exchanger for prediction of outlet temperature. [10]. They have used mineral oil as hot fluid in inner annulus and water as coolant in inner tube and outer annulus. Average deviation ranging in the domain 3.5 to 4.8 % for temperature prediction. [11] Abdalla Gomaa et. al. developed numerical CFD model using a finite volume discretization method for triple tube heat exchanger. Correlations of Nusselt number, friction factor and heat exchanger effectiveness with the dimensionless design parameters are also presented in their work. The experiments were done for a range of Reynolds number 1720 < Re < 6260 and they found that higher the Re number higher the heat transfer rate. [12]

4. EXPERIMENTAL SETUP AND PARTS USED

1-Voltmeter-0-300V
2-Toggle switches-10A
3-Temperature Display-220V
4-K-type Thermocouple sensors
5-Buckets and Pipes
6-Rotary Switch
7-Pipe Clamps

Fig 4.1-Experimental setup

5. CONCLUSION

The performance of this heat exchanger will be better than the traditional two fluid heat exchangers
Effectiveness of two fluids counter flow heat exchanger = 0.567
Effectiveness of three fluids counter flow heat exchanger = 0.8539
THUS, The Effectiveness of three fluids counter flow heat exchanger is **increased.**

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