A BASIC REVIEW ON TRIPLE CONCENTRIC TUBE HEAT EXCHANGER

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ABSTRACT

Triple concentric tube heat exchanger is modified design of double tube heat exchanger. Objective is to study the triple concentric tube heat exchanger and analyze the same for the better understanding of this heat exchanger. Overview and basic concepts of triple concentric tube heat exchanger is presented which helps to contemplate over the evaluation of different aspects of triple concentric tube heat exchanger.

Keywords : Double Tube, Heat Exchanger, Triple Tube

I. INTRODUCTION

Double tube heat exchanger is a system which exchanges heat between two fluids (hot fluid and cold fluid). It is a basic type of heat exchanger which is easy to use and has wide span of application. Mainly it is used in dairy, food, pharmaceutical, chemical and beverage industries for pasteurization, evaporation, refrigeration, sterilization, chilling, freezing, boiling, drying etc. For certain high range of temperature differences within in the heat exchanger, it requires more heat exchange area. The higher heat exchange area can only be achieved by increasing the length of double concentric tube heat exchanger. But for some applications it is not feasible to increase heat exchanger's length. In that case, triple tube heat exchanger comes in as a solution because it has larger heat transfer area for same length of double tube heat exchanger.

Triple tube heat exchanger has three tubes connected concentrically as two tubes in double tube heat exchanger. Triple tube heat exchanger consists mainly three compartments which are inner tube, inner annulus and outer annulus. It is required to flow the objective fluid whose temperature differences is of main concern for application fulfilment in the inner annulus for taking maximum benefit of the heat exchanger. The other two compartments which are inner tube and outer annulus have to be filled with appropriate temperature fluid as per the application requirement. The inner annulus has two heat exchange surfaces (inner tube outer surface and outer tube inner surface) which increases the heat exchange area of heat exchanger marginally compared to double tube heat exchanger (has only one heat exchange surface) subsequently increases the rate of heat exchange. It also in terms increases the efficiency of heat exchanger. Therefore, it also decreases the length of heat exchanger for the same temperature difference compared to double tube heat exchanger.

Double concentric tube heat exchanger can be divided in two parts as far as the fluid flow arrangements are concern which are parallel flow arrangement and counter flow arrangement. Now triple concentric tube heat exchanger has three flowing fluids so it can be divided for four different flow arrangements which are explained

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in below figures. It can also be divided as other two different flow arrangements which are N-H-C and C-H-N. By combining these flow arrangements, we can get eight different flow arrangements for triple concentric tube heat exchanger which are explained in diagrammatically.

TABLE 1 Flow Arrangement Configuration

Flow	Outer Annulus	Inner Annulus	Inner Tube
N-H-C	Normal temperature fluid	Hot fluid	Cold fluid
C-H-N	Cold fluid	Hot fluid	Normal temperature fluid

Outer Annulus	→
Inner Annulus	→
Inner Tube	→

Fig. 1 : Co Current Flow Arrangement

Outer Annulus	→
Inner Annulus	←
Inner Tube	→

Fig. 2 : Counter Current Flow Arrangement

Outer Annulus	→
Inner Annulus	→
Inner Tube	←

Fig. 3 : Co-Counter Current Flow Arrangement

Outer Annulus	←
Inner Annulus	→
Inner Tube	→

Fig. 4 : Counter-Co Current Flow Arrangement

II. 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. So, this overview will present the basic understanding and fundamentals of triple concentric tube heat exchanger. It will give the brief findings of researchers who have done work on this heat exchanger over the past few years. It consists design, mathematical models, experimental works, experimental analysis for different parameters, simulation etc.

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 nondirectional 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 co efficient 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 in 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. Four flow patterns are conducted of counter current, co-current, counter current with co-current and co-current with counter current flow. 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]

Sanjay K Singh et. al. has done thermo hydraulic behavior of triple concentric tube heat exchanger with two thermal communications and experimental investigation carried out for Reynolds number ranging 2800 to 1100 for different inlet temperature. They found that higher the Reynolds number higher the heat transfer rate for this limit. The relation between f and Re has been found as f = 0:46Re-0.28.[13]

Nora Boultif and Cherif Bougriou has done Numerical analysis by finite difference method for triple tube heat exchanger. The results of analysis are presented as variation of temperatures of the three fluids with time along the length of the heat exchanger. They found that the three fluids have a time lag for parallel flow, which is not in the case for the counter flow, because the only fluid that have a time lag is the hot fluid and heat exchanges are lower in unsteady state than the steady state case.[14]

III. CONCLUSION

Triple concentric tube heat exchanger performs better in counter flow arrangement then in parallel flow arrangements. C-H-N arrangement ha higher heat exchange rate then N-H-C arrangement. For higher mass flow rate, heat transfer rate is higher. Overall steady state counter flow arrangement for C-H-N arrangement with insulation with higher RE number is the best possible flow configuration for the triple concentric tube heat exchanger.

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