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An Experimental Approach for Enhancement of Heat Transfer Using TTHE: U Valve

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ABSTRACT

The conventional double pipe heat exchanger has less heat transfer rate, so to overcome this problem, this paper focuses on establishing the Triple Tube Heat Exchanger (TTHE) is modified constructive version of double concentric tube heat exchanger by adding an intermediate tube for hot fluid. In this paper the experimental data obtained during the test in a double and triple concentric tube heat exchangers are very much impressive. However, U valve also fitted and were analyzed and the experiment results conforms the effectiveness of the triple tube heat exchanger.

Introduction

Recently, heat exchangers are widely used in industries, thermal power plants and different engineering applications. There is a rapid growth can be observed in the field of heat exchangers. Researchers are trying to increase the heat transfer rate of heat exchangers in an effective way. A heat exchanger may be defined as the equipment which transfers the energy from a hot fluid to cold fluid with maximum rate and minimum investments. It can also be said that 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

An impressive list of information is available in relevant references for double pipe heat exchanger. Many researchers have performed the design and analysis of double pipe heat exchanger [1-4]. Researchers have done theoretical as well as experimental analysis of triple concentric pipe heat exchanger. The set of equations for design and performance analysis have been developed. But the information available for TTHE is still less compared to double pipe heat exchanger. From the available literatures, the major contributions of researchers are as follows: C. A. Zuritz [5] developed a set of analytical equations for fluid temperatures at any axial location along the heat exchanger for parallel and counter flow configurations and conducted simulation of triple concentric pipe heat exchanger. The equations account for heat losses to the surroundings and are useful for design purposes Simulations show that the creation of an annular region within the inner pipe increases the overall heat transfer efficiency and reduces the heat exchanger length requirement by almost 25%. D. P. Sekulic et al. [6]offered in detail a review on thermal design theory of three fluid heat exchanger, where they have allowed for third fluid temperature to vary according to main thermal communication while neglecting interaction with ambient. He used effectiveness- NTU (number of heat transfer units) approach and corresponding rating and sizing problems for the determination of the effectiveness or NTU for a three-fluid heat exchanger. Ahmet Unal [7] in his first part developed a mathematical model, consisting the derivation and possible solutions of the governing equations for both counter-flow and parallel-flow arrangements. The equations derived in this study can be used for both design calculations and performance calculations, besides they can be used for the determination of bulk temperature variation along the exchanger. Ahmet Unal [8] in his second part conducted several case studies for counter-flow arrangement in his second part based on the solution obtained in the first part. It has been demonstrated that demonstrates that: 1) the relative sizes of the tubes (the tube radii) play a very important role on the exchanger performance and/or on the exchanger length. 2) Optimizing triple tube heat exchanger effectiveness provides a considerable amount of increase in the exchanger performance. Ahmet Unal [9] derived the effectiveness-NTU relations for triple concentric tube heat exchanger including both counter-flow and parallel flow arrangements. Some representative data are represented in graphical form. This graphs can be used for determining effectiveness of triple concentric pipe heat exchanger by using input parameters i.e. heat capacity ratio and number of transfer units. O. García-Valladares [10] developed a numerical model for analyzing the behavior of triple concentric tube heat exchangers by means of a transient one-dimensional analysis of the fluid flow governing equations and the heat conduction in solids. He concluded that, the model developed can be an excellent tool to optimize the efficiency of triple concentric-tube heat exchangers, and consequently the energy consumption. Ediz Batmaz [11] developed a more generic way of calculating overall heat transfer coefficient in a triple tube heat exchanger for both counter-flow and parallel-flow arrangements using the energy balance equations on a control volume. Further, he derived the equations for determining the axial temperature distribution of the fluids.

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He concluded that 1) overall heat transfer coefficients and the temperature profiles are useful for designing a heat exchanger to meet the process requirements. 2) Overall heat transfer coefficients values may also be useful for determining the convective heat transfer coefficient values (h). **S Radulescu [12]** established an algorithm for the calculation of partial coefficient of heat transfer for a fluid which flows through an inner annular space of a triple concentric-tube heat exchanger in transition regime based on experimental results. He developed a new correlation for design purposes on heat transfer devices, such as triple concentric pipe heat exchanger. The correlation obtained is:

NuH =2.718 ReH0.597 PrH1/3 (dh2/L1)2/3

It molds the heat exchange for Reynolds values that go from 2264 to 7893 and for the velocities values between 0.11 and 0.36 m/s. The practical applicability of the obtained correlation in the study applies for Prandtl values between 3.30 and 3.70. G.A. Quadir et al. [13] analysed performance of heat exchanger for two flow arrangements, called N–H–C and C–H–N, and for insulated as well as non-insulated conditions of the heat exchanger. The three fluids being considered are hot water, cold water and the normal tap water. Under N–H–C arrangement, normal water flows in the innermost pipe, hot water flows in the inner annulus, and the cold water flows in the outer annulus. All fluids flow parallel to each other. Cold and normal water are interchanged in the C–H–N arrangement keeping hot water flow unchanged. He concluded that the heat transfer between the three fluids considered is more effective in N–H–C arrangement of the heat exchanger as compared to that in C–H–N arrangement.

Here N-H-C: - Normal-Hot-Cold

C-H-N: - Cold-Hot-Normal

This study was devoted to the analysis of the heat transfer phenomenon in a triple tube heat exchanger (TTHE). During the literature review on the subject, it was seen that no procedure is available for accurate calculation of overall heat transfer coefficients in a TTHE. Therefore, initial studies focused on developing a procedure for accurate computation of the overall heat transfer coefficients and temperature profiles of the fluids in a TTHE. An effective overall heat transfer coefficient concept was also established. However, another type heat exchanger are shell and tube type but they are mostly use in laboratories [14]

Methodology

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 [14]. Heat exchanger have been classified in several ways, according to transfer process (direct contact, indirect contact), according to geometry of constructions (plate, tube, extended surfaces), according to heat transfer mechanisms (single phase, two phases), according to flow arrangements (parallel, counter, cross flow) [15-19]. The type of heat exchanger to be used is determined by the process and product specifications. Nevertheless, concentric tube heat exchanger play a major role in accomplishing the heat exchanger needs of food industry. The most common heat exchanger is double pipe heat exchanger [12]. A typical double pipes heat exchanger consists of one pipe places concentrically inside another of a large diameter pipe with appropriate fitting to direct the flow from one section to the next [13]. Introducing an intermediate pipe to a double concentric pipe heat exchanger provides triple pipe heat exchanger and the latter performs better compared to the prior one. Triple concentric pipes heat exchanger consists of three pipes of different diameters and three fluids exchange heats between them. Thus in this case, there are three sections: central pipe, inner annular space and outer annular space. In triple pipe heat exchangers, a thermal fluid is passed through an inner annular space and heat transfer mediums are passed through the central pipe and outer annular space. Diagram and line diagram of triple tube pipes were shown in fig. 1 & 2.

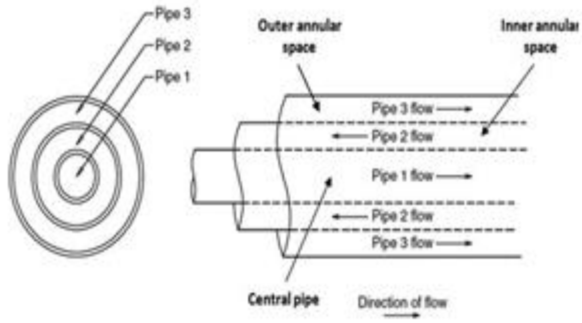

Fig 1. Triple concentric pipes.

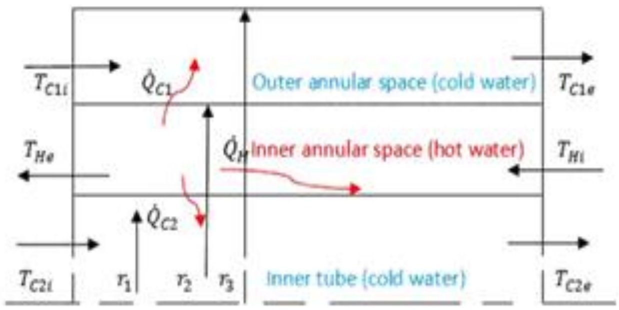

Fig 2. Line diagram of triple tube.

Triple concentric-pipes heat exchangers are used for food processing, pasteurization of viscous food products (milk, cream, pulpy orange juice, apple mash), sterilization, cooling, energy conversion, Refrigeration.

The most common problems in heat exchanger design are rating and sizing. The rating problem is concerned with the determination of the heat transfer rate and the fluid outlet temperatures for prescribed fluid flow rates, inlet temperature, and allowable pressure drop of an existing heat exchanger. On the other hand, the sizing problem is concerned with determination of dimension of heat exchanger, that is, selecting an appropriate heat exchanger type and determining the size to meet the specified hot and cold fluid inlet and outlet temperatures, flow rates, and pressure drop requirements [14-19]. In this study, the sizing procedure of triple concentric pipe heat exchanger is presented, in which, length of the heat exchanger is calculated for the available dimensions of three pipes to meet the required temperature drop of hot water. Triple concentric-pipes heat exchangers are used for food processing, pasteurization of viscous food products (milk, cream, pulpy orange juice, apple mash), sterilization, cooling, energy conversion, Refrigeration.

4.1.1 Outer tube-

Dimension-

Outer diameter of the tube=0.0338m

Inner diameter of the tube=0.0318m

Thickness of the tube=0.001m

Length of the tube=1.1176m

4.1.2 Intermediate tube-

Inter mediate tube is made up of copper material, which is used for the flow of hot water. The photographic image of the experimental setup shown in Fig. 3

Dimension-

Outer diameter of the intermediate tube=0.0179mnner diameter of the inter mediate tube=0.0159m

Thickness of the inter mediate tube=0.001m

Length of the inter mediate tube=1.3208m

4.1.3 Central tube-

Central tube is made up of copper materials, which is used for the flow of cold water.

Dimension-

Outer diameter of the centre tube=0.0115m

Inner diameter of the central tube=0.0095m

Thickness of the central tube=0.001m

Length of the central tube=1.524m

Fig.3 photographic image of the experimental setup

Results &Discussion

The overall heat transfer coefficients of triple concentric pipe heat exchanger were found out using input parameters i.e. geometrical characteristics of three pipes, mass flow rates and thermo physical properties of three fluids. There are two overall heat transfer coefficients in triple pipe heat exchanger: one based on outside area of central pipe (U_{02}) and second based on inside area of intermediate pipe (U_{i1}).

The overall heat transfer coefficients based on outside area of central pipe and based on inside area of intermediate pipe were found to be different for different mass flow rate. The results were shown in table 1, 2 and 3 respectively. Theoretically the energy balance equation i.e. total heat transferred by hot fluid should be equal to the sum of heat received by both the cold fluids, but in practical case for different mass flow rate there is some difference in the energy transferred. The parallel flow counter flow and combination of both were shown in fig. 4, 5 & 6 respectively. The flow regimes in triple pipe heat exchanger were observed to be: Transition in the central pipe and inner annular space and laminar in outer annular space.

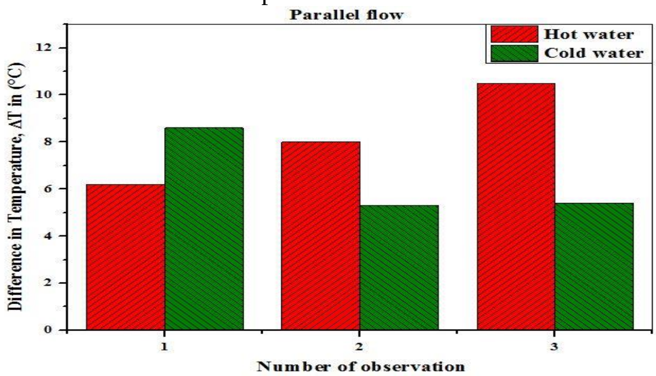

Figure 4. Parallel flow heat exchanger

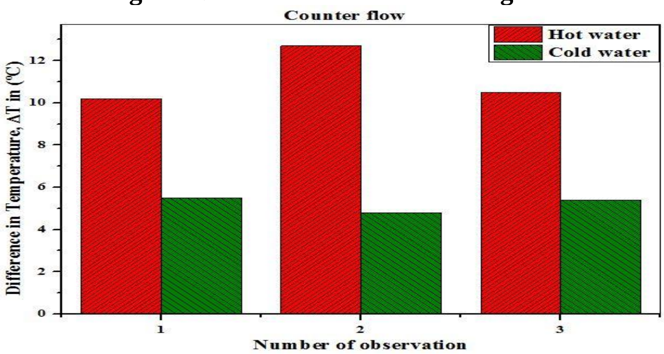

Figure 5. Counter flow heat exchanger

Table 1. Parallel flow heat exchanger

No. of observation	Hot water			Cold water					
				Outer tube			Central tube		
	Temperature (^{0}C)		Time for 1ltr. Of water	Temperature (^{0}C)		Time for 1ltr. Of water	Temperature (^{0}C)		Time for 1ltr. Of water
	Inlet	Outlet	X sec	Inlet	Outlet	X sec	Inlet	Outlet	X sec
1	56.1	42.8	53.00	33.1	40.3	107.0	33.1	39.8	45.60
2	55.3	43.8	53.00	32.9	38.3	107.0	32.9	41.3	46.80
3	57.3	40.9	66.20	30.2	37.5	77.61	30.2	37.2	40.96
4	59.2	39.5	66.20	30.2	35.3	77.61	30.2	37.3	54.65

Table 2. Observation for counter flow triple tube heat exchanger

Types of flow	No. of observation	Hot water			Cold water		
		Temperature(^{0}C)		Time for 1ltr. Of water	Temperature(^{0}C)		Time for 1ltr. Of water
		Inlet (T_{hi})	Outlet (T_{ho})	X_h in sec	Inlet (T_{ci})	Outlet (T_{co})	X_c in sec
Counter flow	1	58.1	47.6	65.1	32.3	37.8	39.7
	2	58.5	45.8	81.5	31.5	36.3	42.3
	3	57.0	46.5	85.5	31.8	37.2	52.7
Parallel flow	1	55.8	49.6	42.4	31.6	40.2	60.9
	2	52.6	44.6	50.6	31.5	36.8	39.4
	3	56.0	45.5	74.1	31.6	37.0	41.8

Table 3. Observation for double tube heat exchange

Expt. No.	Mass flow rate (kg/sec)			Heat transfer coefficient (Watt/m2K)			QH (J)	QC1+QC2 (J)	H- (QC1+QC2)(J)
	Inner	Middle	Outer	αC1	αH	αC2			
1	0.00935	0.018	0.029	2169.1	546.8	193.9	102.47	1012.87	7.6
2	0.00935	0.018	0.021	2226.9	547.1	1904.2	1182.36	1164.68	17.68
3	0.0129	0.015	0.024	2605.9	477.7	2079.5	1196.92	1180.11	16.81
4	0.0129	0.015	0.018	2583.2	478.3	1507.3	1209.54	1193.87	15.67

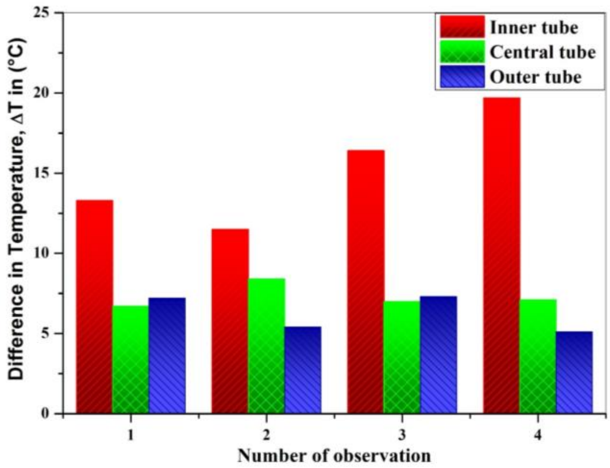

Figure 6. Tipple tube heat exchanger.

In this paper, the triple tube heat exchanger was analysed for temperature variation, heat transfer rate, pressure drop and mass flow rate. Number of experiments were performed to determine the heat transfer rate of the heat exchanger having a counter flow arrangement with normal water flow through the inner pipe whereas the hot water flows through inner annulus and inner pipe.

Conclusion

Experiments were conducted in a corrugated surface TTHE and the data gathered was used to compute the overall heat transfer coefficients, and the effectiveness values for each run.

- It was found that the effectiveness of the co-current runs in a TTHE was not always greater than the effectiveness of the theoretical co-current runs in a DTHE.
- The changes in calculated U values were also analysed for changes in flow rates of fluids and product inlet temperatures and the heat transfer rate is very efficient.
- The results were in good agreement with the literature with respect to the factors affecting the U values; supporting the reliability of the developed method.
- From the above study it may conclude that the TTHE with U valve showed an effective result in all expects. So it may be recommended for the commercial application.

References

References

[1] F.P. Incropera, D.P. Dewitt, Fundamentals of Heat and Mass Transfer, third Edn., Wiley, New York, 1990.

[2] R.K. Shah and D.P. Sekulic, Fundamental of heat exchanger design, Wiley, New York, 2003.

[3] S Kakac and H Liu, Heat exchanger selection, Rating and Thermal design, second Edn., CRC Press,2002.

[4] S. Jarallah, Master of science thesis, "Experimental and numerical investigation of the performance of three concentric pipe heat exchanger", University Malaysia

[5] Carlos A Zuritz, "On the design of triple concentric-tube heat exchangers", Journal of Food Process Engineering, 1990, 12,pp, 113-130.

[6] D.P.Sekulic, R.K.Shah, "Thermal design theory of three fluid heat exchangers", Advances in Heat Transfer, 1995, 26,pp, 219-328.

[7] Ahmet Unal, "Theoretical analysis of triple concentric-tube heat exchanger Part-1 Mathematical modeling", International Communication Heat Mass Transfer, 1998, 25,pp, 949-958.

[8] Ahmet Unal, "Theoretical analysis of triple concentric-tube heat exchanger Part-2 Case studies", International Communication Heat Mass Transfer, 2001, 28, pp, 243- 256.

[9] Ahmet Unal, "Effectiveness-NTU relation for triple concentric-tube heat exchangers", International Communication Heat Mass Transfer, 2003, 30, pp, 261-272.

[10] O.Garcia-valladares, "Numerical simulation of triple concentric pipe heat exchangers", International Journal of Thermal sciences, 2004, 43, pp, 979-991.

[11] Ediz Batmaz, K.P.Sandeep, "Calculation of overall heat transfer coefficients in a triple tube heat exchangers", Heat Mass Transfer, 2005, 41, pp, 271-279.

[12] Sinziana Radulescu, Irena Loredana Negoita, Ion Onutu, "Heat transfer coefficient solver for a triple concentric-tube heat exchanger in transition regime", REV. CHIM, 2012, 63.

[13] G.A.Quadir, Saqab.S.Jarallah, N.J.Salman Ahmed, Irfan Anjum Badruddin, "Experimental investigation of the performance of a triple concentric pipe heat exchanger", International Journal of Heat and Mass Transfer, 2013, 62, pp, 562–566.

[14] B. C. Chukwudi and M. B. Ogunedo, Design and Construction of a Shell and Tube Heat Exchanger. Elixir Mech. Engg. 118, 2018 pp, 50687-5069,

[15] Sahoo P.K., Datta A. K., "Computer aided design and performance evaluation of an indirect type helical tube ultra-high temperature milk sterilizer", Journal of food engineering, 26, 1995, p. 379.

[16] J. Peter clark, Matster of science Thesis, Practical design construction and facilities, First Edn., Food science and technology international series, 2009.

[17] V. Giovannoni, R. N. Sharma, R. R. Raine, Numerical prediction of thermal performances in a concentric triple tube heat exchanger, International Journal of Thermal Sciences 120, 2017, pp 860-868.

[18] Abdalla Gomaa1, M. A. Halim2, and Ashraf Mimi Elsaid, Experimental and numerical Investigations of a Triple Concentric-Tube Heat Exchanger, (15) 01434-39.

[19] M. S. Baba,, A.V. S. R. Raju, M. B. Rao, Heat transfer enhancement and pressure drop of Fe3O4 –water nanofluid in a double tube counter flow heat exchanger with internal longitudinal fins, Case Studies in Thermal Engineering 12, 2018, pp, 600–607.