

Design, Development and Comparison of Double Pipe Heat Exchanger with Conventional and Annular Baffles

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Abstract

The experimental comparison of different types of heat transfer augmentation techniques in heat exchangers by extended surfaces, obstruction devices and swirl flow device. Concentric tube type heat exchanger is one of simplest type of heat exchanger. Efficiency and heat transfer rate of double pipe tube heat exchanger without conventional and annular baffles is not much. On the basis of literature study different design parameters like velocity, dimensionless numbers, fin co-efficient, overall heat transfer co-efficient, and length were identified. Literature describes the different methods which may help to improve the heat transfer rate. This paper shows the experimental setup and apparatus needed to carry out the double pipe heat exchanger experiment. The apparatus includes double pipe heat exchangers with infrared temperature gun, flow control valve, rotameter, water pump and storage tank. Heat exchangers are modified in space of annular and conventional baffles. Results shows that performance parameters of conventional baffle is higher than the annular baffle of double pipe heat exchanger. Heat transfer rate and efficiency increase with increase of mass flow rate.

Keywords- Double-pipe heat exchanger, conventional baffles, annular baffles, heat and mass transfer, heat transfer rate and efficiency.

I. INTRODUCTION

Heat exchanger are devices that exchange heat between two fluids of different temperatures that are separated by a solid wall. The temperature gradient or the differences in temperature facilitate this transfer of heat. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment.

Double pipe heat exchangers are the simplest exchanger used in industries. On one hand, these heat exchanger are cheap for both design and maintenance, making them a good choice for small industries. But on the other hand, low efficiency of them beside high space occupied for such heat exchanger in large scales, has led modern industries to use more efficient heat exchanger like shell and tube or other one.

II. LITERATURE SURVEY

M. Kannan et al. [1] have discussed and outlined an experimental setup for the evaluation of different heat exchanger enhancement techniques. Different mass flow rate readings were recorded. It was observed that the heat transfer loss and gain by hot and cold fluid. Finally, from the experimental and analytical results it is concluded that the annular method reached higher heat transfer than other methods. Veeresh fuskele et al. [2] described Experimental investigations of heat transfer and friction factor characteristics of double pipe heat exchanger fitted with twisted wire mesh for twist ratios 7.0 and 5.0 carried out for turbulent flow. Heat transfer coefficient and friction factor increases with the decrease in twist ratio compared with plain tube. C.K. Pardhi et al. [3] have found after investigating different heat transfer augmentation techniques that As compared to conventional heat exchanger the

augmented has shown a significant improvement in heat transfer coefficient by 61 % for twisted tape I and 78% for twisted tape II. Twisted tape of lower twist ratio ($p/d = 3.5$) gives higher heat transfer coefficient (by 1.39 times) than higher twist ratio of $p/d = 7$. Shevale Omkar M et al. [4] shown that the Nusselt number obtained from the experimental results are higher than that of theoretical values obtained from Dittus-Boelter equation. The helical fins over the inner tube results into the increase in the heat transfer area and reduction in the hydraulic diameter of the flow channel. In addition to this the rotation of inner tube enhances the turbulence and mixing of fluid molecules which is necessary to enhance the heat transfer rate in the convection mode of heat transfer. Antony luki.A et al. [5] described that augmented surfaces to increasing the heat transfer coefficient with a consequent increase in the friction factor. Here investigation dimpled tube is used. From theoretical calculation the overall heat transfer coefficient is increased and also effectiveness of the dimpled tube with concentric tube heat exchanger is increased 8% compare to plain tube concentric tube heat exchanger. From theoretical results shows that dimpled tube heat exchanger gives better performance. So we suggest the dimpled tube is used in concentric tube heat exchanger in various applications will give high heat transfer. Artit Ridluan et al. [6] presented experimental study to improve the double pipe heat exchanger by installing the louvered strips. The results can be concluded as follows. 1. Louvered strips enhanced heat transfer performance. The 17, 26, and 31 degrees of incidence of the strips augmented average heat transfer by approximately 133, 186, and 246 %, respectively for Reynolds number range of 6000 to 65000. 2. Louvered strips increased friction factors of the heat exchange device. The friction factors were increased approximately 119, 145, and 167 % by installing the inclined strips of 17, 26, and 31 degrees, respectively. Shiva kumar et al. [7] shown numerical simulation of finned double pipe heat exchanger

is done with hot fluid flowing in the inner tube and cold fluid in the annulus. After validating the results for a bare heat exchanger with the experimental results Simulation was done using rectangular, triangular and concave parabolic finned configurations on the outer body of inner tube. Results indicated finned configurations show an overall improvement in the thermal characteristics compared with unfinned one. P. Anipey et al. [8] have described Experimental results and they are validated by generating the 3D models of the heat exchangers using CATIA and the analysis part is done using ALGOR software. Analysis results have validated the experimental results and the results show that the heat transfer rate for different variations in decreasing order is annular disc, twisted tape, fins and basic heat exchanger. N. Sahiti et al. [9] have shown that considerable enhancements were demonstrated by using small cylindrical pins on surfaces of heat exchangers. A partly quantitative theoretical treatment of the proposed method is presented. It uses simple relationships for the conductive and convective heat transfer to derive an equation that shows which parameters permit the achievement of heat transfer enhancements. Experiments are reported that demonstrate the effectiveness of the results of the proposed approach. It is shown that the suggested method of heat transfer enhancements is much more effective than existing methods, since it results in an increase in heat transfer area (like fins) and also an increase in the heat transfer coefficient. Ojha Pramod Kailash et al. [10] described that the fins were taken in the form of semi-circular type arranged in alternating way with spacing of 50mm. The fins were only provided on the inner tube for creating turbulence of cold water. The number of fin were 18 and its height and thickness 10 and 1.6mm respectively. Experiment were performed for heat exchanger with fins and without fins. The experiment were performed for different flow rates of hot and cold fluid Different parameters like Overall heat transfer, Nusselt number, Convective heat transfer coefficient, Pressure drop, friction factor were obtained and compared for simple inner tube and finned tube.

Following are the objectives of this work

- To find out which one is most suitable Conventional baffle or annular baffle.
- Increased heat transfer rate with the use of conventional and annular baffles.
- Increased efficiency.
- Reduced Fouling Factor.
- Ease of operation.
- U-tube structure handle differential thermal expansions.

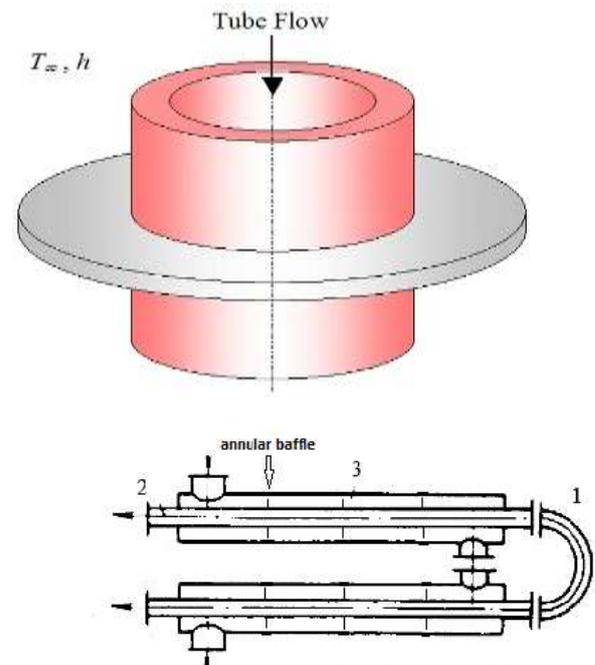
III. METHODOLOGY OF WORK

- Literature study of double pipe tube heat-exchanger.
- Theoretical analysis of double pipe heat-exchanger with conventional and annular baffles.
- Design and development of double pipe heat exchanger with conventional and annular baffles.

- Experimental analysis of double pipe heat-exchanger with conventional and annular baffles.
- Comparison of performance parameters between conventional and annular baffles heat exchanger.

A. DOUBLE PIPE HEAT EXCHANGER WITH ANNULAR BAFFLE(FIN) ON INNER PIPE:

Generally, the fins are used on the surfaces where the heat transfer coefficient is very low. For example, in a car radiator the outer surface of the tubes is finned because the heat transfer coefficient for air at the outer surfaces is much smaller than that of water flow inside tubes. When the fin is on the external side of inner pipe it is called as annular baffle rather than annular fin. An Annular baffle (fin) circumferentially attached to a cylinder or in this case inner pipe and its cross section varies from center line of cylinder. In contrast, pin fin or spine is an extended surface of circular cross section whose diameter is much smaller than its length. The pin fins may be of uniform or non-uniform cross section.



Structure of double-pipe heat exchanger

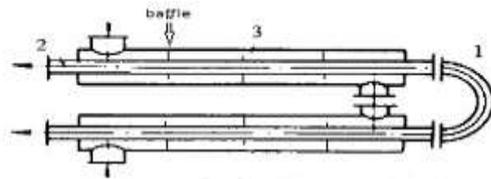
1-elbow pipe; 2-internal pipe; 3-external pipe

“Figure 1. Double pipe heat exchanger with annular baffles (fin)”

B. DOUBLE PIPE HEAT EXCHANGER WITH CONVENTIONAL BAFFLE:

Baffles are flow-directing or obstructing vanes or panels used in some industrial process vessels (tanks), such as shell and tube heat exchangers, chemical reactors, and static mixers. Baffles are an integral part of the shell and tube heat exchanger design. A baffle is designed to support tube

bundles and direct the flow of fluids for maximum efficiency. Baffles are frequently used in pressure vessel either vertical or horizontal to divide the interior volume into different compartments. These compartments may be used to segregate liquids or provide over flow weirs for the separation of liquid. We are going to use baffles in double pipe heat exchanger and then by doing experiment on it, we will observe the improvement in the efficiency and heat transfer rate.



Structure of double-pipe heat exchanger
 1-elbow pipe; 2-internal pipe; 3-external pipe

“Figure 2. Double pipe heat exchanger with conventional baffles (fin)”

C. DESIGN DATA REDUCTION:

The data reduction of the measured results is summarized in following procedures

$$Q = m_c \times C_{p_c} \times (t_{\text{cold out}} - t_{\text{cold in}})$$

Where,

m_c : Mass flow rate of Cold Stream

C_{p_c} : Specific Heat of Cold Stream

$T_{\text{cold in}}$, $t_{\text{cold out}}$: Inlet and outlet temperature of cold stream.

For Counter-current flow,

$$LMTD = (\Delta T_1 - \Delta T_2) / \ln (\Delta T_1 / \Delta T_2)$$

Inner Tube: $D_e = D_i$

$$A_f = \pi D_i^2 / 4$$

Annular Space: $D_e = D_1 - D_o$

$$A_f = \pi (D_1^2 - D_o^2) / 4$$

For Inner Tube and outer tube,

$$V = W / (\rho \times A_f)$$

$$Re = D_e \times V \times \rho / \mu$$

$$Pr = C_p \times \mu / k$$

$Re > 2300$,

$$Nu = (f/8) \cdot (Re - 1000) \cdot Pr \cdot (1 + D_e/L)^{2/3} / [1 + 12.7 \cdot (f/8) \cdot 0.5 \cdot (Pr^{2/3} - 1)] \cdot (\mu / \mu_w)^{0.14}$$

$$f = (0.782 \cdot \ln(Re) - 1.51) - 2$$

$$f = (0.782 \cdot \ln(Re) - 1.51) - 2$$

$Re < 2300$,

$$Nu = 1.86 \cdot (Re \cdot Pr \cdot D_e/L)^{1/3} \cdot (\mu / \mu_w)^{0.14}$$

$$T_w = (h_i \cdot t_{\text{avg}} + h_o \cdot T_{\text{avg}} \cdot D_o / D_i) / (h_i + h_o \cdot D_o / D_i)$$

where,

h_i : Film coefficient Inner pipe

h_o : Film coefficient for Annulus

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t_{avg} : Mean temperature for Inner pipe fluid stream

T_{avg} : Mean temperature for Annulus fluid stream

$$1/U = D_o/h_i D_i + D_o \cdot \ln(D_o / D_i) / 2k_t + 1/h_o + R_i \cdot D_o / D_i + R_o$$

Where,

R_i : Fouling factor Inner pipe

R_o : Fouling factor for Annulus

k_t : Thermal conductivity of tube material

$$1/U = 0.0021103$$

$$U = 473.865$$

$$\text{Area} = Q / (U \times LMTD)$$

$$\text{Area} = 0.131165 \text{ m}^2$$

$$L = \text{Area} / \pi \times D_o$$

$$L = 0.82 \text{ m}$$

Baffle spacing

Space between two baffles-15 cm

Length of pipe- 1 m

No. of baffles – (L/ space between two baffles)-1

Cold Stream

Fluids:

Cold water in outer pipe and hot water in inner pipe.

“Table 1. Calculation of design data”

DATA	INNER PIPE	OUTER PIPE
Inlet temperature	80 °C	22 °C
Outlet temperature	70 °C	27 °C
Flow rate	0.05 kg/s	0.15kg/s
Density	997.7 kg/m ³	972 kg/m ³
Viscosity	0.982×10 ⁻³ Ns/m ³	0.347 × 10 ⁻³ Ns/m ³
Specific heat	4.181 × 10 ³ J/kg.K	4.198×10 ³ J/kg.K
Thermal conductivity at mean temperature	54 × 10 ³ W/mK	52.5×10 ³ W/mK
Nominal diameter	6.35 cm(2 ¹ / ₂ inch)	3.175 cm(1 ¹ / ₄ inch)
Thickness	0.5156 cm(0.203 inch)	0.3556 cm(0.140 inch)
Velocity	0.082395 m/s	0.08849 m/s
Reynold number	6507.72	2076.79
Prandtl number	0.00002774	0.000076032
Nusselt number	0.0060177	0.286316
Film coefficient	11205.5 W/m ² K	669.311 W/m ² K

D. EXPERIMENTAL SETUP

Instrument used in the experiments are Storage tank: Storage tank is used for storing the hot and cold fluid. Pump: It is use for supply water from storage tank to the heat exchanger. Rotameter: It is measuring device which measure the flow rate of water. Infrared temperature gun: It is use for measure temperature of any fluid at any place.

Pipe: It is used for flowing fluid. Flow control valve: It is use for control the fluid flow which is achieved from the pump and supply to the heat exchanger.



“Figure 3. Experimental set up for double pipe heat exchanger”

A. Fabricated models



“Figure 4. Inner pipe with conventional baffles”



“Figure 5. Inner pipe with annular baffles”



“Figure 6. Double pipe heat exchanger with conventional and annular baffles”

E. EXPERIMENTAL RESULT

Conventional Baffle
 Hot water (Inner Pipe)
 Cold water (Outer Pipe)

“Table 2. Calculation for conventional baffle”

Sr No	Flow rate m_h (LPH)	Inlet temp. ($^{\circ}\text{C}$) (T_{hi})	Outlet temp. ($^{\circ}\text{C}$) (T_{ho})	Flow rate m_c (LPC)	Inlet temp. ($^{\circ}\text{C}$) (T_{ci})	Outlet temp. ($^{\circ}\text{C}$) (T_{co})
1.	180	71.2	51.6	540	23.9	30.1
2.	220	70	60.1	500	24.2	29.1
3.	300	70.4	59.4	460	24.6	28.8

Annular Baffle
 Hot water (Inner Pipe)
 Cold water (Outer Pipe)

“Table 3. Calculation for Annular baffle”

Sr No	Flow rate m_h (LPH)	Inlet temp. ($^{\circ}\text{C}$) (T_{hi})	Outlet temp. ($^{\circ}\text{C}$) (T_{ho})	Flow rate m_c (LPC)	Inlet temp. ($^{\circ}\text{C}$) (T_{ci})	Outlet temp. ($^{\circ}\text{C}$) (T_{co})
1.	180	70.1	55.4	540	23	28.3
2.	220	71.6	61.4	500	23	27.8
3.	300	71.9	62.3	460	23.1	26

- Comparison of data:

Sr No.	Conventional baffle	Annular baffle
	Effectiveness	Effectiveness
1.	0.2236	0.2042
2.	0.23	0.2105
3.	0.4129	0.3132
No.	Conventional baffle	Annular baffle
	Overall heat transfer co efficient(W/m ² C)	Overall heat transfer co efficient(W/m ² C)
1.	180.504	173.73
2.	275.15	227.88
3.	330.75	230.04
No.	Conventional baffle	Annular baffle
	Efficiency (%)	Efficiency (%)
1.	16.15	12.80
2.	16.59	15.42
3.	27.45	21.23

F. CONCLUSION.

This paper shows the experimental study to design, development and comparison of counter flow double pipe heat exchangers by using conventional and annular baffles. Various heat transfer enhancement methods and techniques, such as twisted tapes, snails, swirl flow devices and dimples, etc., have been described in the literature.

A design data reduction of the proposed method is presented. Testing were carried out on counter flow arrangement at different flow rates on fabricated models of conventional and annular baffles. Experimental results demonstrate the comparison of proposed methods which shows the value of efficiency, overall heat transfer coefficient and effectiveness. It is shown that the suggested method of heat transfer enhancements is much more effective than existing methods. From the calculation we conclude that conventional baffle has better efficiency and effectiveness than annular baffles.

ACKNOWLEDGEMENT

The author would like to acknowledge group of project students of mechanical engineering department Babaria institute of technology, Vadodara for this research work.

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