Performance of Shell and Tube Heat Exchanger using Flow Divider Dimpled Type Baffles

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Abstract— In present work experimentation of shell and tube heat exchanger containing flow divider dimpled and without dimpled type baffles, at different mass flow rate (i.e. 4 (0.07kg/s), 6 (0.1kg/s), 8 (0.13kg/s), and 10 lpm (0.17kg/s)) has been conducted to determine pressure drop and heat transfer coefficient for shell side fluid. The more work had already been done on the heat exchanger performance. The heat exchanger performance enhanced by introducing new innovative baffles i.e. flow divider dimpled type baffles. In addition, the comparative study of shell and tube heat exchanger with flow divider dimpled and without dimpled type baffles were studied. Water is used for both shell and tubes as a working fluid. Based on the experimental result it has been establishing that the percentage increase in pressure drop and heat transfer coefficient for shell side is better in a heat exchanger with flow divider dimpled type baffles than without dimpled type baffles. The percentage increase in heat transfer coefficient and pressure drop for 4, 6, 8 and 10 lpm flow rates of shell side fluid was found to be 18%, 22%, 25%, and 33% and pressure drop 30%, 20%, 17% and 30% more in a heat exchanger with flow divider dimpled type baffles.

Keywords: Shell and Tube Heat Exchanger, Pressure Drop, Heat Transfer Coefficient, Flow Divider without dimpled type baffles, Flow Divider Dimpled type Baffles

I. INTRODUCTION

Heat exchangers are devices used to transfer heat among two or more fluids at a dissimilar temperature [1]. They are commonly used in thermal power plant, refrigeration, food industry, air conditioning, petrochemical industries, and automotive applications [2]. Kumar and Jhinge carried out experimentation of shell and tube heat exchanger containing segmental baffles at the various position with varying different Reynolds number [3]. Son and Shin studied heat exchanger by spiral baffle plates. Fluids flowing rotationally contact with tubes inside the shell [4]. Edward and Volker studied the effect of pressure drop for shell side of heat exchanger using segmental baffles [5]. Gu et al. investigated experimentally of heat exchanger using trapezoidal baffle [6]. Akpabio et al. studied the baffle spacing effect at a fixed baffle cut for the overall heat transfer coefficient in heat exchanger[7].

II. BAFFLES

The baffles are the significant parts in a shell and tube heat exchangers. Baffles are used to hold and avoid vibration of the tubes. The heat transfer coefficient for shell side fluid enhanced by the introduction of the new baffle is "flow divider dimpled type baffles". The flow divider dimpled baffles serve primarily two functions first one is flow divides into two partitions and second is to create instability in laminar flow for the shell side.

In this first, the design of flow divider baffles is done and then fabricated for conducting tests. There is a total of six plates of baffles connected perpendicularly to each other. The 8mm diameters dimple created on each plate of baffles by using the punching operation.

Figure 2.1 shows the fabricated flow divider without dimpled type baffles.

Fig. 2.1: Flow Divider without dimpled type baffles

Figure 2.2 shows the fabricated flow divider with dimpled type baffles.

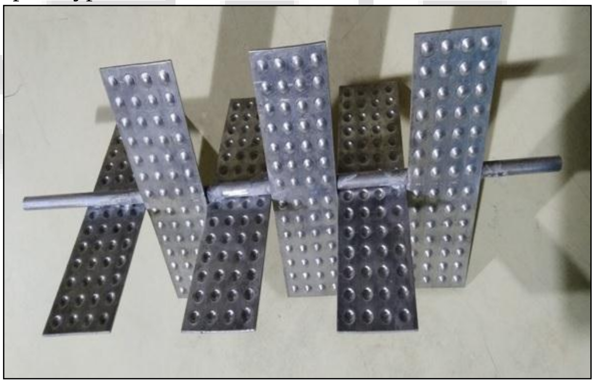

Fig. 2.2: Flow divider dimpled type baffles

III. COMPONENTS USED FOR SETUP

Table 3.1 shows the components used in the experimental setup of shell and tube heat exchanger and their specification are tabulated in the table:

Sr.No	Component Name	Specification
1	Diameter of inner shell	203.2mm
2	Diameter of outer tube	16mm
3	Diameter of inner tube	14mm
4	Thickness of tube	1mm
5	Length of tube	500mm
6	Number of tubes	8
7	Number of baffles	6
8	Electric heater	230V AC 50HZ 3000W
Measuring Devices		
9	Rotameter	2

10	Digital thermometer	1
11	U-Tube manometer	1

Table 3:1 Component and their specification

IV. EXPERIMENTAL SETUP

The experimental setup used for testing is shown in figure 4.1. It consists of following important parts, shell, tubes, tube sheets, front and rear heads, heater, pipes and valve arrangement and measuring instruments. The experimental setup BEM type heat exchanger with one tube and one shell pass consist of shell in which stainless steel tube is placed through which hot water is passed. To ensure maximum heat transfer the cold water is flowing over the tubes inside the shell. The shell is properly insulated to avoiding the surrounding heat losses.

Fig. 4 1: Experimental setup

V. DATA REDUCTION

Table 5.1 shows equations for calculating the performance parameter.

Sr.No	Parameter	Equation
1	Heat removed by hot water	$Q_{hot} = m_h \times C_{ph} \times \Delta T$
2	Heat absorbed by cold water	$Q_{cold} = m_c \times C_{pc} \times \Delta T$
3	Average heat transfer rate	$Q_{avg} = \frac{Q_h + Q_c}{2}$
4	Log mean temperature difference	$LMTD = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln \frac{(T_{hi} - T_{co})}{(T_{ho} - T_{ci})}}$
5	Outer surface area	$A_o = \pi \times d_o \times L \times no.of\ tubes$
6	Reynolds number	$Re = \frac{4 \times m}{\pi \times d \times \mu}$
7	Parental number	$Pr = \frac{\mu \times C_p}{k_{cond}}$
8	Nusselt number for tube side	$Nu = 0.023 \times (Re)^{0.8} \times (Pr)^n$ $Heating\,(n) = 0.4$ $Cooling\,(n) = 0.3$
9	Overall heat transfer coefficient	$U_o = \frac{Q_{avg}}{A_o \times LMTD}$
10	Heat transfer coefficient for shell side	$\frac{1}{h_2} = \frac{1}{U_o} - \frac{1}{h_1}$

Table 5:1 Data reduction

VI. RESULT AND DISCUSSION

In current work, experimentation of counter flow shell and tube heat exchanger containing flow divider dimpled and without dimpled type baffles had been conducted. Hot water from geysers was passed through the tubes and for shell side, cold water is circulated throughout. Experimentation was conducted for constant flow rate of hot water at 4 lpm (0.07kg/s) and varying cold water flow rate in shell side from 4, 6 (0.01kg/s), 8 (0.13kg/s) and 10 lpm (0.17kg/s). The inlet and outlet temperature of the hot and cold fluids are recorded at a different mass flow rate for the shell side and constant flow rate for the tube side. The parameters are used to determining the variation of pressure drop and heat transfer coefficient for the shell side of the heat exchanger with flow divider dimpled and without dimpled types baffles.

Table 6.1 shows the inlet and outlet temperature of shell and tube side fluid for heat exchanger with flow divider dimpled type baffles. Also shows the effects of pressure drop and heat transfer coefficient for 4, 6, 8, and 10 lpm flow rate of shell side.

Mass Flow Rate	4 lpm	6 lpm	8 lpm	10 lpm	Unit
T_{ci}	297	297	297	297	K
T_{co}	303.5	302.4	301.8	301.4	K
T_{hi}	321	321	321	321	K
T_{ho}	315.8	314.8	314.6	314.4	K
h_2	619.2	780.7	881.9	1049.2	W/m^2K
Δp	173.3	319.9	933.2	1733.19	Pa

Table 6.1: Heat exchanger with flow divider dimpled baffles

Table 6.2 shows the temperature values at inlet and outlet of shell side and tube side fluid for heat exchanger with flow divider without dimpled type baffles. Also shows the effects of heat transfer coefficient and pressure drop for 4, 6, 8, and 10 lpm mass flow rate of shell side fluid.

The heat transfer and fluid flow characteristics of shell and tube heat exchanger for flow divider dimpled and without dimpled baffles are shown by plotting graphs.

Mass Flow Rate	4 lpm	6 lpm	8 lpm	10 lpm	Unit

T_{ci}	297	297	297	297	K
T_{co}	302.8	302	301.4	300.8	K
T_{hi}	321	321	321	321	K
T_{ho}	316.7	315.7	315.6	315.4	K
h_2	524.3	638.9	705.7	786.8	W/m^2K
Δp	133.3	266.6	799.9	1333.2	Pa

Table 6.2: Heat exchanger with flow divider without dimpled type baffles

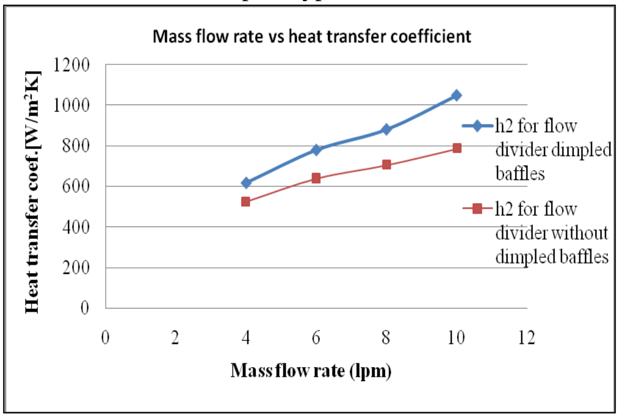

Fig. 6.1: Heat transfer coefficient vs. mass flow rate

Figure 6.2 shows the relations of pressure drop versus mass flow rate for heat exchanger with flow divider. dimpled and without dimpled type baffles. From the Figure 6.2, it is cleared that the pressure drop found more in a heat exchanger with dimpled type baffles than without dimpled type baffles and pressure drop goes on rising with the rise in mass flow rate.

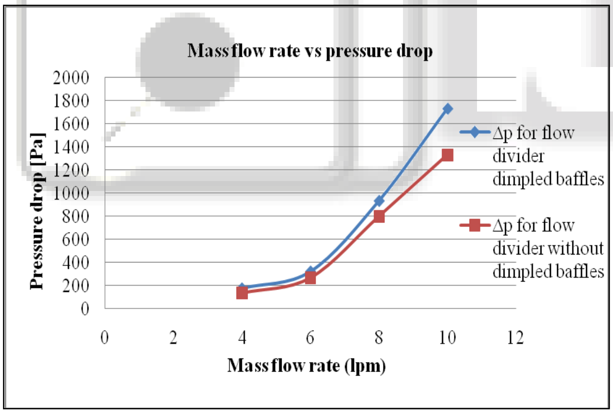

Fig. 6.2: Pressure drop vs. mass flow rate

VII. Conclusion

In this work experimentation on counter flow shell and tube heat exchanger containing flow divider dimpled and flow divider without dimpled type baffles at different mass flow rate has been conducted to determine the pressure drop and heat transfer coefficient for shell side.

From the experimentation, the result has been found that the pressure drop and heat transfer coefficient of shell side is more in a heat exchanger with flow divider dimpled types baffles. And it goes on increasing with the increase in the mass flow rate of the shell side. Heat exchanger with flow divider dimpled type baffles, percentage of increase in heat transfer coefficient for 4, 6, 8, and 10 lpm mass flow rates is 18%, 22%, 25%, and 33%. And the percentage of increase in pressure drop for 4, 6, 8 and 10 lpm mass flow rate is 30%, 20%, 17 and 30% respectively.

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