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

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Abstract - *In present work experimentation of shell and tube heat exchanger containing flow divider perforation, eight partition baffle & without baffles, at different mass flow rate {i.e. 4LPM (0.7kg/s), 6 LPM (0.1kg/s), 8 LPM (1.3kg/s), and 10 LPM (0.17kg/s)} has been conducted to determine pressure drop, overall heat transfer coefficient, heat transfer rate. The more work had already done on the heat exchanger performance. The heat exchanger performance enhanced by introducing new innovative baffles i.e. flow divider perforated baffles. A comparison study of shell and tube heat exchangers either with or without perforated baffles was conducted. Water is used for both shell and tubes has working fluid. Based on the results it has been establishing that percentage of increases in ΔP, OHTC, HTR and ε for shell side is better in flow divider perforation baffles than the without perforation baffles. The percentage increase in OHTC, HTR, ΔP and ε for 4, 6, 8, 10 lpm flow rates of shell side fluid was found that OHTC is 12.78%, 13.06%, 23.27%, 35.55%; HTR is 7.23%, 9.2%, 11.46%, 30.02%; ΔP is 30%, 14.78%, 16.66% and 23.08% and ε is 31.66%, 26.32%, 27.84%, 30.29% more in a heat exchanger with flow divider perforated baffles.*

Key Words: Shell and tube heat exchanger, Heat transfer coefficient, Heat transfer rate, Pressure drop, Flow divider without perforated baffles, Flow divider with perforated baffles

1.INTRODUCTION

A heat exchangers are devices that transfers heat from one medium to another for transport and process energy. They are most frequently encountered in petrochemical industry, chemical plants, petroleum facilities, natural gas, air - conditioners, refrigeration, and automotive applications. The most popular type of heat exchanger is SHTE. It is critical to understand that a heat exchanger is a pressure or containment vessel and a device for transferring heat from one place to another. Kumar and Jhinge [1] tested a SHTE with segmental baffle at various places and with varying Reynolds numbers. Bichkar et.al. [2] have numerical simulation carried out a various type baffles. They show the effect of pressure drop in the SHTE. They prove that thermal efficiency improved by the use of helical baffles. Ali et. al. [3] have investigated the effect of tube length and shell diameter on the ΔP and HTC for the shell side with triangular and square pitch. While HTC increases when reducing cutting space and baffle spacing. Joemer, Thomas, Rakesh.D, and Nidheesh.P [4] used CFD software to adjust the baffle cut and angle of SHTE. Son and Shin [5] researched heat exchangers that used spiral baffle plates. The fluid rationally contacts the inside of shell. Petrik and Gabor [6] statistically studied shell-and-tube exchangers with horizontal baffles and compared the findings to the commercial program SC – Tetra V11. Edward and Volker [7] used a segmental baffle to explore the effect of drop in pressure mostly on shell side of a heat exchanger. Gu et al. [8] investigated the experimental performances of a trapezoidal baffled heat exchanger. Akpabio et al. [9] investigated the impact of baffles spacing on the total heat transfer coefficient inside a HEX with a fixed baffle cut. Gurbir et.al. [10] This article examines the SHTE, in which heated water flows to one tube and cold water flowing beyond this tube. The numerical simulation approach, which is a computer-based study, is used to model the heat exchanger, involving fluid flow and heat transfer. Irshad et. Al [11] This study compares various SHTEs featuring segmental baffles. The aim of this project is to develop a heat exchanger with segmental baffles and to explore the flow and temperatures within the shell and tubes through using ANSYS software tool for various baffle assemblies and orientations. For each baffle assembly and orientation, OHTC is determined. Menni et.al.[12] the same approach is used in this computational study to improve the thermal behavior of Shell and tube heat exchangers by adding W-shaped Baffle-type Vortices Generators. To simulate and evaluate the investigated physical model, the numerical simulation represented by computational FVM (Finite Volume Method) is used. Bicer et.al. [13] After determining the variety of design parameters for this type of baffle, the Taguchi technique has been used to find potential design configurations for optimal performance. Feng et. al. [14] This research looks at a SHTE for the organic fluid vaporization. These results show that by selecting an appropriate working fluid, heated water mass flow rate, and total tube number, the overall impact of the shell-and-tube heat exchanger may be improved even further. Ali et. al. [15] In this work, the fluid flow and heat transport of waters within the segmental baffle shell & tube heat exchanger (SB-STHE) are improved by combining a baffle and a longitudinally ribbed tube configuration. Marzouk et. al. [16] there has been a lot of attention recently in employing bubbles injecting with insets within the tubes to increase thermal performance in shell and tube heat exchanger STHEs. Under this study, air was pumped into tube sides containing wiring nails-circular rod insertion (WNCR) in a straightforward way, with the water tube side flow rate

TSFR varying from 14 LPM through 18 LPM and also the water shell side flow rate remaining constant at a suitable range of 18 LPM. Mohammad et. al. [17] In this investigation, a shell - and - tube exchanger with a 25% baffle reduction was used. The impact of tube location on heat transfer was investigated. It was revealed that tubes around the shell include a greater influence on heat transmission than tubes in the shell's Centre.

1.1 BAFFLES

The baffles are the significant parts in a SHTE. Baffles is used to hold and avoid vibrations of tubes. The HTC for shell side fluid enhanced by introduction of new baffle is “flow divider eight partition perforated baffle”. This flow divider eight partition perforated baffles serve two functions; first one flow divides into two partitions and second is to create turbulent flow in the shell side.

In this first, the design of flow divider baffles are done and then it fabricated for the conducting tests. There are total eight plates of baffles connected in perpendicularly to each other. The 3 mm diameters hole created on each plate of baffles by using the punch and drilling operation.

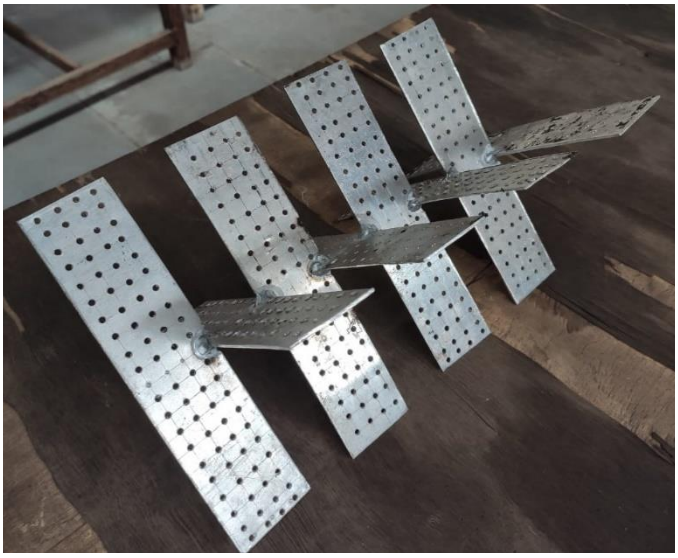

Fig.-1: Flow divider perforated type baffles

1.2 PROPOSED WORK

This study presents experiments with a single pass and counter flow SHTE featuring flow divider eight partition baffles at different position in the shell for calculate various parameters (HTR, OHTC, ε).

Water is used as the working fluid in both shell and tube. Because it is much more effective than parallel flow, then the flow arrangement is of the counter type.

In present work, an attempt has been increasing the HTR, ε and OHTC by using the flow divider eight partition baffles.

1.3 COMPONENTS USED FOR SETUP

Table 1 shows the elements utilized in the SHTE for experimental setup, as well as its specifications:

Table – 1: Specification of experimental setup

Sr. No.	Component Name	Specification
1	Inner shell diameter	203.2 mm
2	Outer tube diameter	16mm
3	Inner tube diameter	14mm
4	Tube thickness	1mm
5	Length of the tube	500mm
6	Count of tubes	8
7	Count of baffles	6
8	Electric Gyser	230 V AC 50HZ 3000W
Measuring Instruments		
9	Rotameter	2
10	Thermometer Digital	1
11	Manometer with a U-Tube	1

2. EXPERIMENTAL SETUP

This experimental setup is available in Walchand College of Engineering Sangli. The experimental setup is used for the perform the work is as shown in the figure. It consists of the following important parts; shell, tube, front and rear heads, heater, pipes and valve arrangement and measuring instruments. This Setup is BEM type heat exchanger with one shell and single tube pass consists of shell in which stainless steel is placed in which hot water is passed. The maximum gap between each shell and tube side fluid is not adequate, as well as less gap between them is also not good. So to check that the highest heat transfer the cold water is flowing over the tubes inside the shell. The shell is properly insulated to avoid the heat loss.

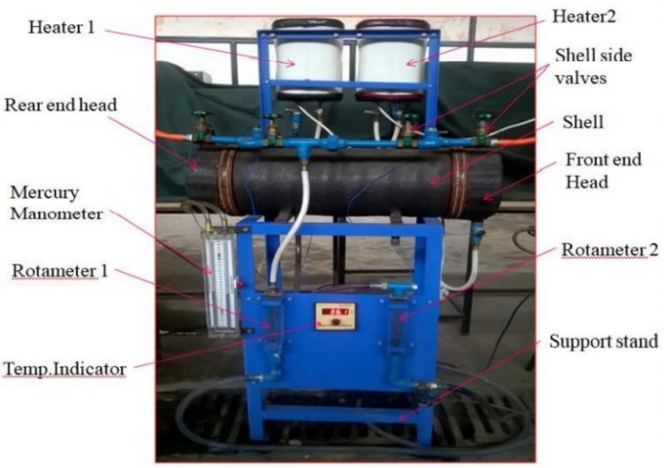

Fig-2: Experimental Setup

2.1 FORMULAE

Table 2 shows the equations for calculating the performance parameter.

Table -2: Calculating performance parameters

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	Overall heat transfer coefficient	$U_o = \frac{Q_{avg}}{A_o \times LMTD}$
7	Maximum possible heat transfer	$Q_{max} = m_{min} \times c_{min} \times (T_{hi} - T_{ci})$
8	Effectiveness	$\varepsilon = \frac{Q_{actual}}{Q_{max}}$

3. CFD SIMULATION

Ansys-Workbench is used to simulate the heat exchanger, which is important for researchers these days. The following procedure is followed in all techniques.

3.1 Geometry: Geometry is done in ansys design modeler. This geometry is parallel flow as well as counter flow in heat exchanger. The geometry has one shell, eight tube bundle and one flow divider 8 partition baffles.

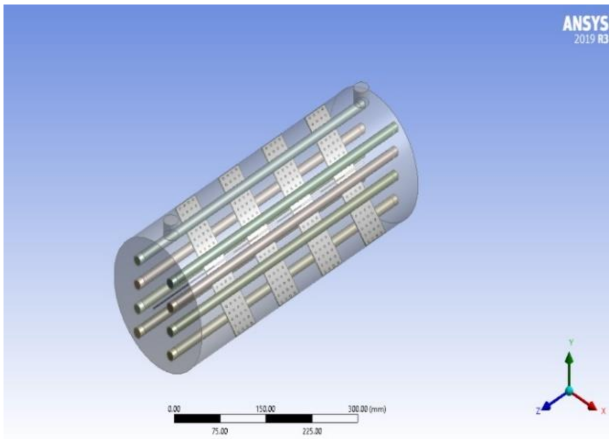

Fig-3: Geometry of STHE

3.2 Meshing: After the geometry relatively fine mesh is generated. However, the heat exchanger is a shell - and - tube design, which means that hot water flows through a tube within the shell and cold water flows through a tube outside the shell. It is composed of tetrahedral as well as hexahedral cells with triangular and quadrilateral faces at their boundaries. Later, a fine mesh is created using edge sizing. In mesh generation 430975 nodes and 1848773 elements are generated. Figure shows the wireframe mesh.

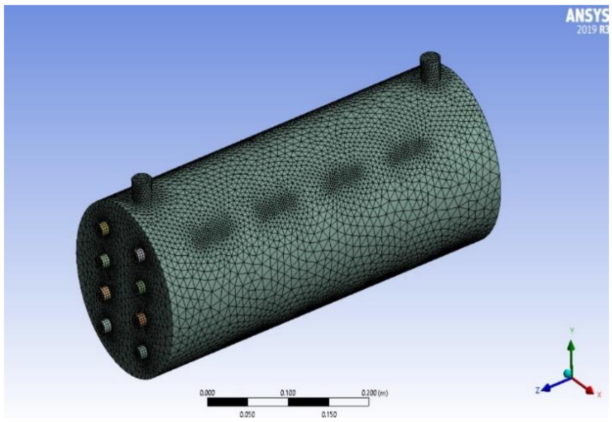

Fig-4: Mesh of the STHE

3.3 Boundary conditions: Each zone has its own set of boundary criteria. Since the SHTE has two inlets and two outlets. These inlets was defined by mass flow inlets as well as outlets were defined has pressure based outlet. This is the important step for defining a model that is include defining material properties, cell zone and boundary conditions for model. A misleading boundary condition will result in deviating results.

The model was treated as pressure based and Time is – Steady.

In models the Energy equation on and Viscous – Standard k-ε, Standard wall fin.

3.4 Boundary Conditions

Table -3: Boundary conditions for CFD simulation

Zone	Type	Value
Inlet of tube	Inlet mass flow kg/s	ṁ= 0.07 kg/s, Temp = 318.3K
Outlet of tube	Pressure-outlet	Gauge pressure= 0
Inlet of shell	Inlet mass flow kg/s	ṁ= 0.07 kg/s, Temp = 301.5K
Outlet of shell	Pressure-outlet	Gauge pressure= 0
Outer tube wall	wall	coupled
Thickness of Wall	wall	coupled
Wall shell	wall	Heat flux = 0

4. RESULT AND DISCUSSION

In the current study, counter flow SHTEs with flow divider perforation and without perforation type baffles were tested. Hot water was passed via the tubes from geysers, while cold water circulated throughout shell side. Mass flow rate of the inlet hot fluid is maintained constant, i.e. 4 LPM (0.0667Kg/s), while the mass flow rate of inlet cold fluid varies between 4 LPM, 6LPM, 8 LPM, and 10 LPM, i.e. (0.0667 kg/s, 0.1 kg/s, 1.333 kg/s, 1.667 kg/s). The parameters are used to determine the fluctuation of HTR, OHTC, and effectiveness (ε) for the shell side of the heat exchanger with flow divider perforation types baffles.

Table 4 displays the experimental findings of inlet and outlet temperature of the shell and tube side fluids for a heat exchanger with flow divider perforated baffles. Also depicted are the effects of ΔP, effectiveness (ε), HTR, and OHTC at flow rates of 4, 6, 8, and 10 lpm on the shell side.

Table -4: Heat exchanger with flow divider perforated baffles by experimentation

Mass Flow Rate	4 lpm	6 lpm	8 lpm	10 lpm	Unit
Tci	301.9	301.9	302.4	301.3	K
Tco	306.5	305.2	304.9	303.8	K
Thi	320.5	320.5	320.7	321.1	K
Tho	316.1	315.9	315.3	314.5	K
Uo	459.1	463.9	516.2	603.2	W/m2K
Q	1.256	1.333	1.451	1.794	KW
ε	0.2473	0.2660	0.2730	0.3156	
Δp	174	319.9	933.2	1733.19	Pa

Table 5 displays the CFD results of inlet and outlet temperatures of shell and tube side fluids for a heat exchanger with and without flow divider perforation baffles. Also depicted is the effect of effectiveness (ε), HTR, and OHTC for flow rates of 4, 6, 8, and 10 lpm on shell side.

Table -5: Heat exchanger with flow divider with perforated baffles by CFD

Mass Flow Rate	4 lpm	6 lpm	8 lpm	10 lpm	Unit
Tci	300.3	301.3	300.8	301	K
Tco	305.2	304.7	304	303.9	K
Thi	320.9	320	321.3	321.1	K
Tho	317.61	316.63	317.38	316.88	K
Uo	351.3	390.1	428.9	489	W/m 2K

Q	1.142	1.182	1.439	1.601	KW
ε	0.2379	0.2726	0.3120	0.3606	

The HTR, OHTC, effectiveness (ε) vs mass flow characteristics of SHTE for flow divider perforated and without perforated baffles shown by plotting graphs. (shown the data CFD and Experimentally).

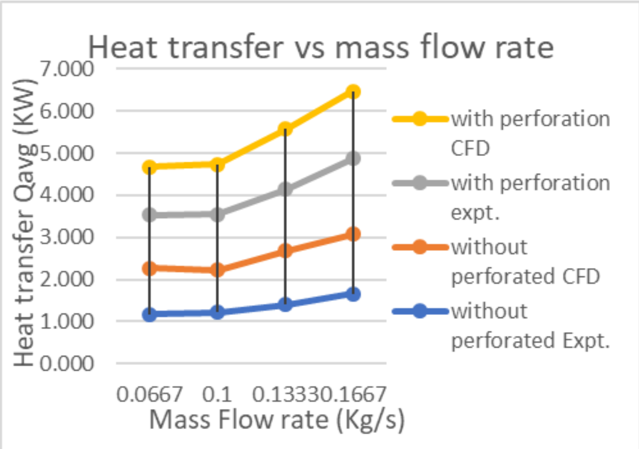

Chart-1: Heat transfer vs mass flow rate

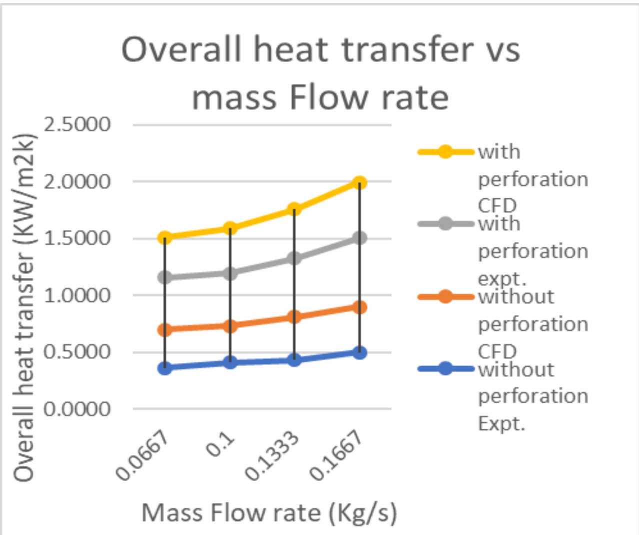

Chart-2: Overall Heat transfer vs mass flow rate

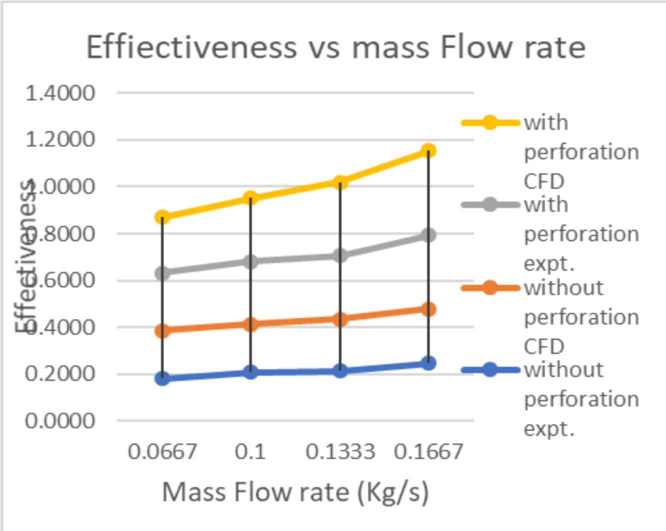

Chart-3: Effectiveness vs mass flow rate

Figure 5 & figure 6 shows the temperature contour of perforated baffles for both shell and tube side.

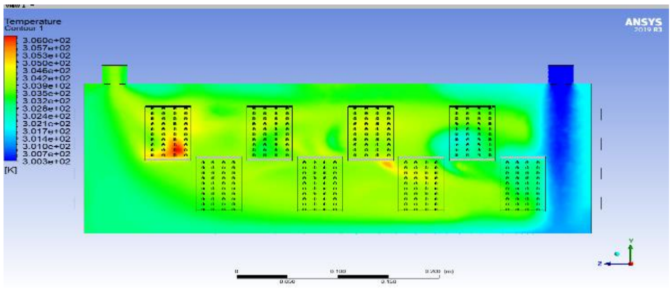

Fig.-5: shell side temperature contour

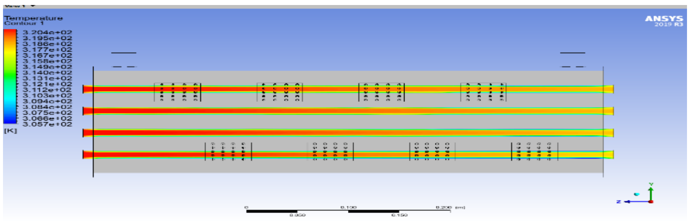

Fig.-6: tube side temperature contour

5. CONCLUSIONS

From the experimentation, the result has been found that effectiveness, pressure drop, overall heat transfer coefficient and heat transfer rate is greater in perforation type baffles than without perforation baffles. And is gone increasing the increase in mass flow rate of shell side fluid.

The percentage increase in heat transfer coefficient, heat transfer rate and pressure drop for 4, 6, 8, 10 lpm flow rates of shell side fluid was found that heat transfer coefficient is 12.78%, 13.06%, 23.27%, 35.55%; heat transfer rate is 7.23%, 9.2%, 11.46%, 30.02%; pressure drop is 30%, 14.78%, 16.66% and 23.08% and effectiveness is 31.66%, 26.32%, 27.84%, 30.29% more in a heat exchanger with flow divider perforated baffles.

Numerical results such as average heat transfer rate, overall heat transfer coefficient, pressure drop and effectiveness are more accurate than the experimental results due to losses in the system.

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