Numerical Modeling of Shell Side Water Flow on Single Segmented Baffles

Tsegay Gebru, Dr. Nigusie Mulugeta

***Abstract*— shell and tube heat exchangers are the common type of heat exchangers used in different industries. From its advantageous visualizing of water flow in shell side and single segmented baffles is one way to improve the performance of shell and tube heat exchanger.**

Some outers write the effect of water flow on different baffle spacing, and different baffle segment. But they did not model the velocity vector, velocity contour, streamline velocity, and plots of velocity magnitude. Modeling of water flow in shell side and single segmented baffles using computational fluid dynamics tool (ANSYS15) is the best one to optimize the device.

This paper shows numerical modeling of shell side water flow on different percentage cut of baffles, when baffle cut varies by 15%, 20%, 25%, 30%, 35%, 40%, and 45%. Velocity vector, velocity contour, streamline velocity, and plots of velocity magnitude results are obtained using TICT shell and tube heat exchanger model and ANSYS15 (fluent) software.

***Index Terms*— shell and tube heat exchanger, single segmented baffles, water flow analysis, computational fluid dynamics.**

I. Introduction

Heat exchangers are devices used to transfer heat between two processing streams. One of the most common and applicable heat exchanger is shell and tube heat exchanger. It is widely used in power plant, refrigeration, air-conditioning systems, chemical, nuclear, and petrochemical, and cryogenic industries. From its advantageous many engineers recover its rate and size by using theoretical methods continuously.

Though the theoretical method is one way to improve or analysis of systems, numerical method is too important for modeling and analysis of the fluid flow.

Literature

In1998 *Rajiv Mukherjee*, studied on performance of baffle cut of shell and tube heat exchangers. As Rajiv Mukherjee study, Baffle cut can vary between 15% and 45% of the shell inside diameter. Both very small and very large baffle cuts are detrimental to efficient heat transfer on the shell side due to large deviation from an ideal situation. It is strongly recommended that only baffle cuts between 20% and 35% be employed. Reducing baffle cut below 20% to increase the shell side heat-transfer coefficient or increasing the baffle cut beyond 35% to decrease the shell side pressure drop usually lead to poor designs. Other aspects of tube bundle geometry should be changed instead to achieve those goals. For example, double segmental baffles or a divided-flow shell, or even a cross-flow shell, may be used to reduce the shell side pressure drop. In 2012 *Jurandir Primo,* The optimum thermal design of a shell and tube heat exchanger involves the consideration of many interacting design parameters such as: Process fluid assignments to shell side or tube side Setting shell side and tube side pressure drop design limits. Setting shell side and tube side velocity limits.

In 2012 *Sandeep K. Patel*, studied in baffle function and its cut area. Baffles serve two important functions. They support the tubes during assembly and operation and help prevent vibration from flow induced eddies and direct the shell side fluid back and forth across the tube bundle to provide effective velocity and Heat Transfer rates.

The diameter of the baffle must be slightly less than the shell inside diameter to allow assembly, but must be close enough to avoid the substantial performance penalty caused by fluid bypass around the baffles.

Baffles can be made from a variety of materials compatible with the shell side fluid. They can be punched or machined. Some baffles are made by a punch which provides a lip around the tube hole to provide more surfaces against the tube and eliminate tube wall cutting from the baffle edge. The tube holes must be precise enough to allow easy assembly and field tube replacement, yet minimize the chance of fluid flowing between the tube wall and baffle hole resulting in reduced thermal performance and increased potential for tube wall cutting from vibration.

Baffles do not extend edge to edge, but have a cut that allows shell side fluid to flow to the next baffled chamber. For most liquid applications, the cuts areas represent 20-25% of the shell diameter. For gases, where a lower pressure drop is desirable, baffle cuts of 40-45% is common.

Baffles must overlap at least one tube row in order to provide adequate tube support. They are spaced throughout the tube bundle somewhat evenly to provide even fluid velocity and pressure drop at each baffled tube section.

Single-segmented baffles force the fluid or gas across the entire tube count, where is changes direction as dictated by the baffle cut and spacing. This can result in excessive pressure loss in high velocity gases.

In 2014 *Vindhya Vasiny Prasad Dubey*[1], *Raj Rajat Verma*[2], *Piyush Shanker Verma*[3], *A.K. Srivastava*[4] ware wrote in their article as Baffles serve two functions; most importantly they support the tubes in the proper position during assembly and operation and prevent vibration of the tubes caused by flow induced eddies, and secondly, they guide the shell side flow back and forth across the tube field, increasing the velocity and heat transfer coefficient.

In 2015 *Su Pon Chit, Nyein Aye San, Myat Myat Soe* supposed that Baffle cut is the height of the segment that is cut in each baffle to permit the shell-side fluid to flow across the baffle. This is expressed as a percentage of the shell inside

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diameter. Although this too is an important parameter for shell and tube heat exchanger designs. Its effect is less profound than that of baffle spacing.

Baffle cut can vary between 15% and 45% of the shell inside diameter. Both very small and very large baffle cuts are detrimental to efficient heat transfer on the shell side due to large deviation from an ideal situation.
From the outers context their analysis was justified by ideal and theoretical method. Since water flow velocity has great impact on design of shell and tube heat exchanger. But both outers did not model the velocity stream line, velocity contour, or velocity vector of the flowing water on the effect of single segmented baffles.

In analysis of heat exchangers especially in shell and tube heat exchanger investigation, investigating of water parameters numerically or modeling of water parameters using computational fluid dynamics tools helps outers to find the accurate value, to simulate, visualize processes simply. And also results can validate by visualizing the velocity stream lines, velocity vector and plot of velocity magnitude.

This paper models shell side water flow, the **velocity vector, velocity contour, velocity stream line, Isosurface velocity, and plots or velocity magnitude** of water when it flows over the four seriously arranged single segmented baffles. This numerical modeling is repeated for seven times as the percentage of baffle cut vary. The effect of percentage cut of 15%, 20%, 25%, 30%, 35%, 40%, and 45% are processed by using computational fluid dynamics tool (ANSYS 15 using fluent solver).

Method

In this work the TICT shell and tube heat exchanger model is used to analyze the effects of percentage cut of baffles. As the TICT model specified the external shell diameter is 160mm, the internal shell diameter is 148mm, and total length of shell is 500mm. To find the final results the theoretical and numerical methods are the two important methods of this work. Using the theoretical method baffle space, baffle thickness, number of baffles, baffle clearance, and baffle cut are determined. Using the numerical method or by ANSYS15 (FLUENT) geometry creation, grid generation (meshing), and post processing results like velocity vector, velocity contour, velocity stream line, isosurface velocity, and plot of velocity magnitude are determined.

Result and discussion

From the numerical method when water flows over the single segmented baffles, velocity magnitude of water varies as the percentage of baffle segment varies. Simply from the velocity contour, velocity stream line, velocity vector, and velocity magnitude plots as the percentage of baffle cut increase the flowing water velocity decrease. The maximum velocity of water for small baffle cut (15%) and large baffle cut (45%) is $1.6x10^{-7}$m/s and $6.2x10^{-8}$m/s respectively.
Table 1 shows the velocity magnitude of water flowing in shell side and single segmented baffles. As you note from table 1 the velocity magnitude varies when baffle cut varies by 15%, 20%, 25%, 30%, 35%, 40%, and 45%. Lines, line10, line11, line12, and line13 represents velocity distribution on single segment baffles such as, baffle1, baffle2, baffle3, and baffle4 respectively. Baffle count starts from inlet side or left side of the figures. Generally the maximum velocity of water is in between segmented baffle face and inner wall of the shell.

Table1: Velocity magnitudes of flowing water at various single segmented baffles.

line	Velocity at various segments 10^{-7}m/s						
	15%	20%	25%	30%	35%	40%	45%
10	1.6	1.3	1	0.86	0.7	0.64	0.62
11	1.6	1.3	1	0.86	0.7	0.64	0.62
12	1.56	1.27	0.98	0.85	0.7	0.64	0.62
13	1.5	1.2	0.9	0.8	0.68	0.62	0.6

Figure1 shows the velocity vector of flowing water in shell side and 15% single segmented baffles. As the legend indicates the maximum velocity vector is $2x10^{-0.07}$m/s and minimum velocity vector is 0m/s which is at the wall surface. The maximum velocity vector is at the area between shell inner wall surface and segmented baffle face.
Figure2 shows velocity contour of flowing water in shell side and 15% single segmented baffles. By observing the water contour velocity from the figure respective colored values can read from the legend. Figure3 shows velocity streamline of flowing water in shell aide and 15% single segmented baffles. Figure4 shows isosurface velocity of flowing water in shell side and 15% single segmented baffles. Figure5 shows isosurface velocity of flowing water in shell side and 45% single segmented baffles. Both figure4 and figgure5 shows isosurface velocity of the flowing water in shell side and single segmented baffle but since percentage cut is different the isosurface velocity value of figure4 and figure5 is different.

Figure6 shows the velocity profile of flowing water in shell side and single segment baffles. This plot shows the velocity of water at center of shell and total length of shell (from inlet to outlet). This plot indicates that at 100mm, 200mm, 300mm, and 400mm the velocity magnitude is 0m/s which is at the wall of the baffle. The flow point at the wall surface of the baffles is called the stagnation point.
Starting from figure7 up to figure13 all figured shows the velocity magnitude of flowing water on single segmented baffles. As percentage of baffle cut and baffle height varies, velocity magnitude of flowing water on surface of baffles also vary. Hence the velocity magnitudes of flowing water have reverse relation with percentage of baffle cut.

Conclusion

Shell and tube heat exchanger is the most applicable type of heat exchanger. Its best design makes it to be more preferable by users. Analysis of water flow using computational fluid dynamics tool (ANSYSY-FLUENT) helps to show results at each point of the shell and single segmented baffles. Investigating of baffle segment on the effect of flowing water is one way to design effective and efficient shell and tube heat exchanger.
From this investigation (from the velocity vector, velocity

contour, streamline velocity and velocity plots) when the percentage of baffle cut increase the velocity of water flowing inside the shell side decrease.

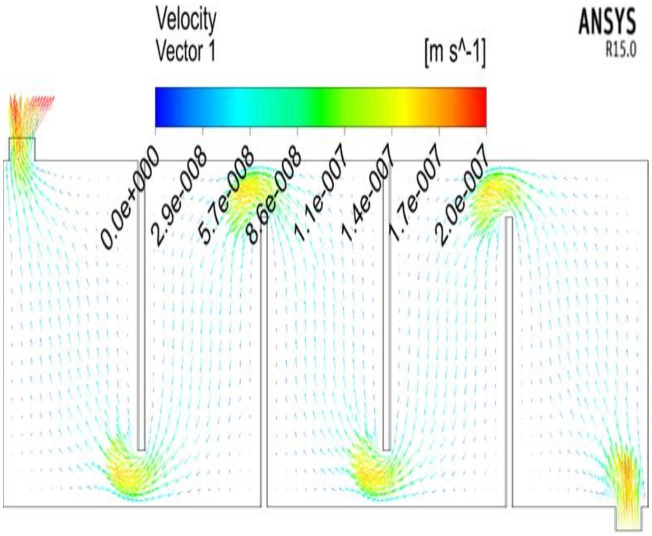

Fig.1 Velocity vector in shell side and single segmented baffles

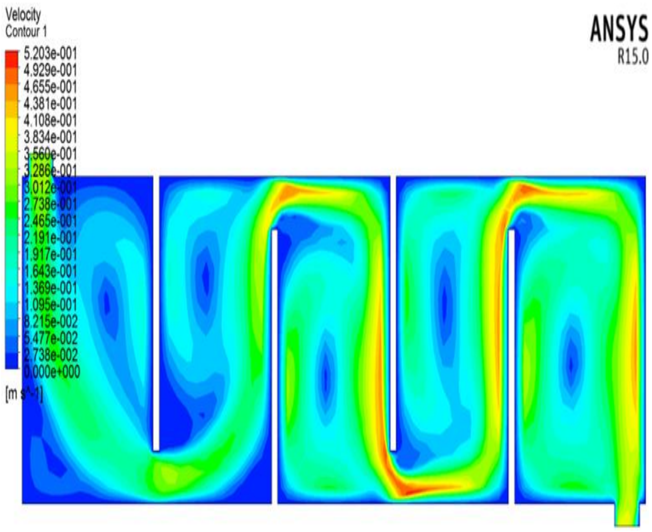

Fig.2 Velocity contour in shell side and single segmented baffles

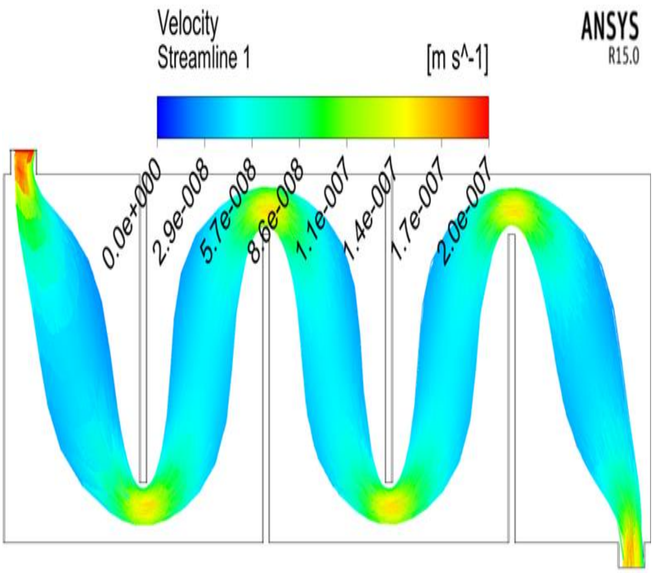

Fig.3 Velocity stream line in shell side and single segmented baffles

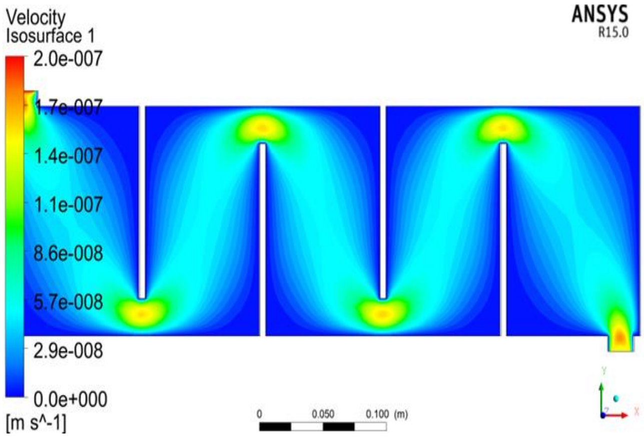

Fig.4 Isosurface velocity in shell side and 15% single segmented baffles

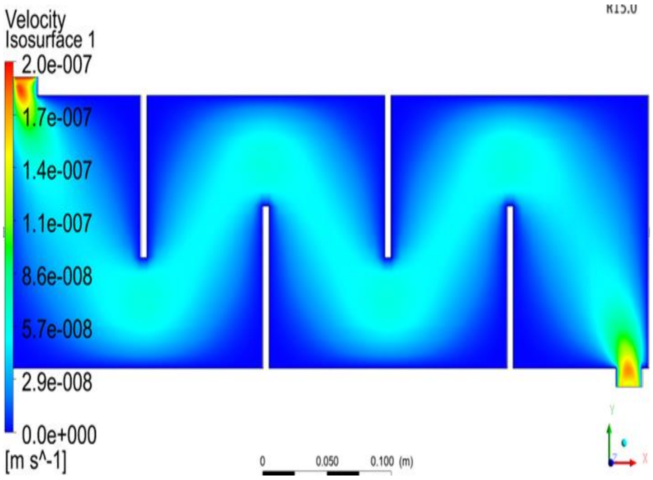

Fig.5 Isosurface velocity in shell side and 45% single segmented baffles

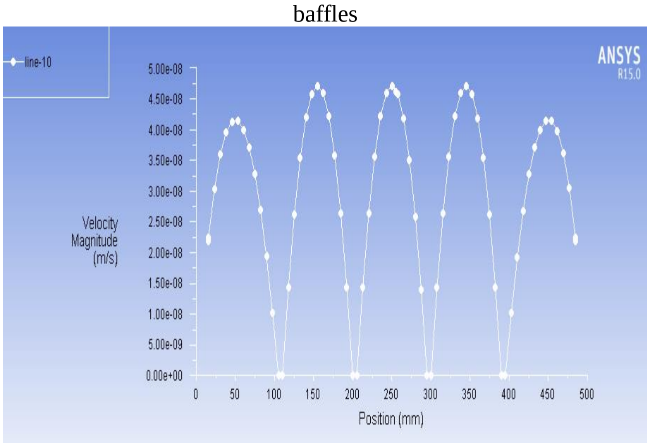

Fig.6 Variation of water velocity with respect to length of shell

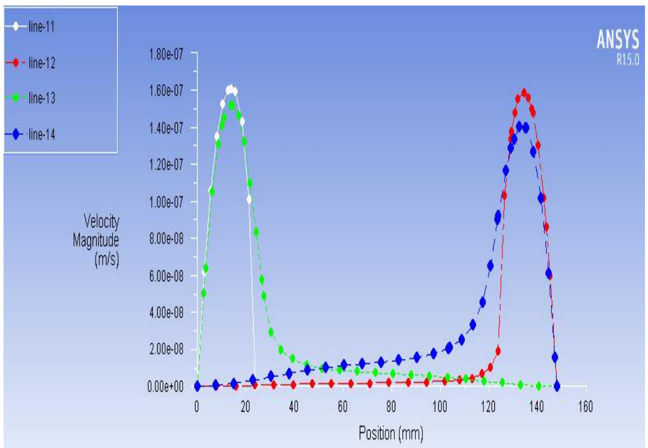

Fig.7 Variation of velocity magnitude on 15% segmented baffles

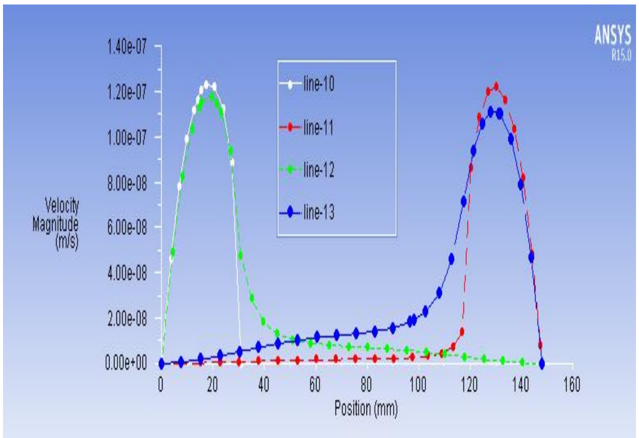

Fig.8 Variation of velocity magnitude on 20% segmented baffles

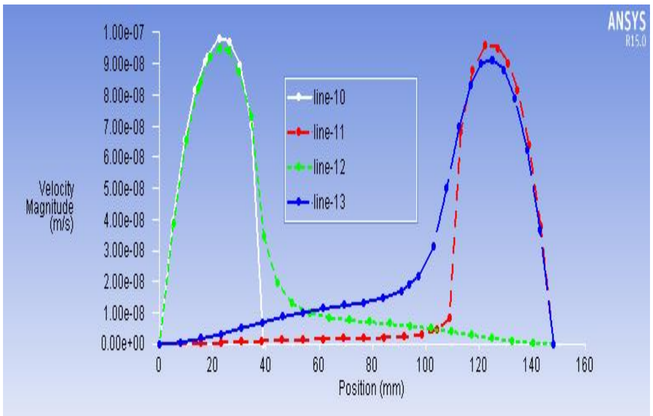

Fig.9 Variation of velocity magnitude on 25% segmented baffles

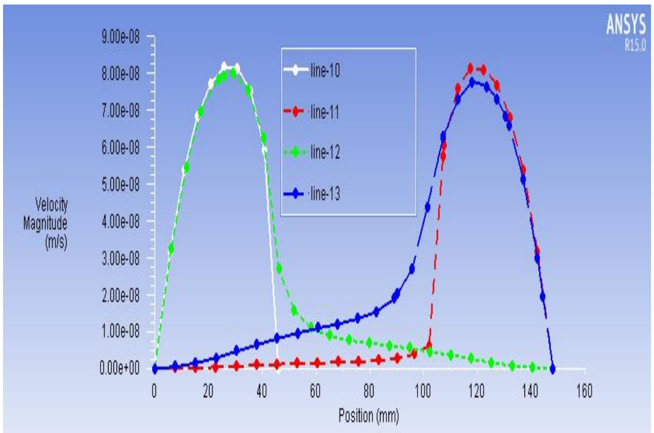

Fig.10 Variation of velocity magnitude on 30% segmented baffles

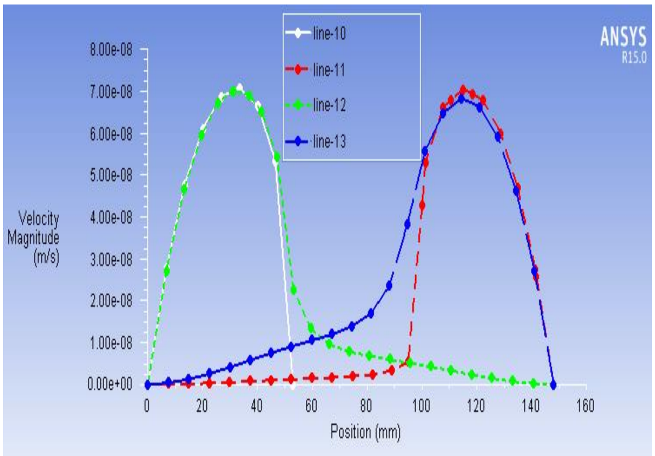

Fig.11 Variation of Velocity magnitude on 35% segmented baffles

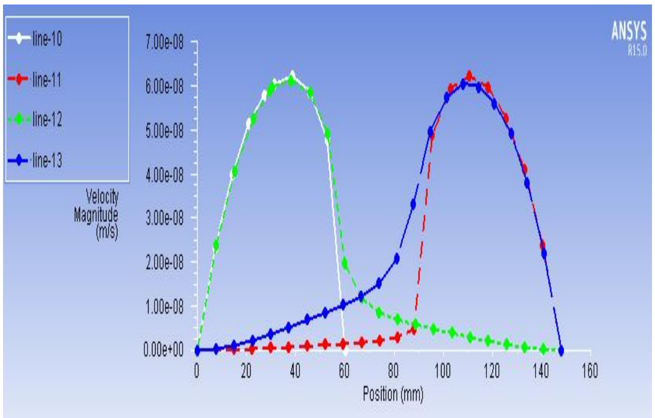

Fig.12 Variation of Velocity magnitude on 40% segmented baffles

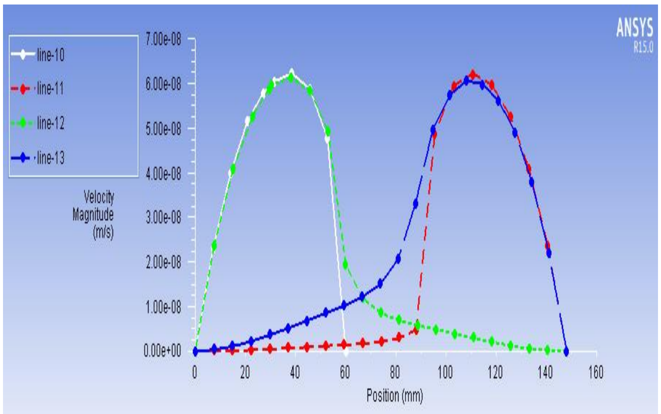

Fig.13 Variation of velocity magnitude on 45% segmented baffles

REFERENCE

[1] **A.GopiChand A. V. N. L. Sharma, G. Vijay Kumar, A.Srividya** thermal analysis of shell and tube heat exchangerusing mathlab and flofd software [Journal]. - Andhra Pradesh : [s.n.], Nov,2013. - 3 : Vol. 1.

[2] **Ferziger Joel H.** computational method for fluid dynamics [Book]. - USA : [s.n.], 2002.

[3] **Mukherjee Rajiv** effective design of shell and tube heat exchangers [Book]. - Feb,1998.

[4] **Noel D.princelin** design of gas pipes and analysis of flow induced vibration [Journal]. - Coimbatore : [s.n.], March 2014. - 1 : Vol. 1.

[5] **O. Saheed Ismail George T. Adewoye** Analyses and Modeling of Laminar Flow in Pipes Using Numerical Approach [Journal]. - Ibadan : [s.n.], Sptember, 2012.

[6] **Pulliam Harvard Lomax and Thomas H.** Fundamentals of Computational Fluid dynamics [Book]. - Toronto : [s.n.], August 26, 1999.

[7] **S.Rajasekaran Dr.T.Kannadasan** Optimization of Shell and Tube Heat Exchangers Using modified algorithm [Journal]. - Coimbatore : [s.n.], December, 2010. - Vol. 3. - 4.

[8] **Sandeep K. Patel Professor Alkesh M. Mavani** shell and tube heat exchanger thermal design with optimization of mass flowrate and baffle spacing [Journal]. - Gandhinagar : [s.n.], oct 2012. - 1 : Vol. 2.

[9] **Su Pon Chit Nyein Aye San, Myat Myat Soe** Flow Analysis in Shell Side on the Effect of Baffle Spacing [Journal]. - August 27, 2015.

[10] **V.Hari Haran g.Ravindra Reddy and b.Sreehari** Thermal Analysis of Shell and Tube Heat Ex-Changer Using C and [Journal]. - Siddharth : [s.n.], july, 2013. - 7 : Vol. 4.

[11] **Vindhya Vasiny Prasad Dubey Raj Rajat Verma, Piyush Shanker Verma, A.K. Srivastava** over view of shell and tube type heat exchanger [Journal]. - June 2014. - 6 : Vol. 2.