Study of Segmental Baffles using in Shell and Tube Heat Exchanger

Shankar Prasad Suman[1], N. V. Saxena[2]
[1]Research Scholar, [2]Assistant Professor,
[1, 2]Department of ME, MIT, Bhopal, India

Abstract - In this work, the Numerical investigation has been done for single pass shell and tube heat exchanger with segmental baffles. Heat transfer and flow pattern are numerically studied by varying numberof baffles. Standard model is used for solving the above problem. Numerical simulation has been done for three different cases of baffle spacing with square bundle of tubes. Numerical solutions are obtained by solving 3D continuity, momentum, energy and turbulence equations using commercial solver CFD. To analyze the phenomenon, number of baffles is taken as varying parameter; other parameters like velocity, temperature, pressure andbaffle cut are kept constant. Results obtained from numerical solution are analyzed extensively to get the effect of number of baffles on heat transfer rate and pressure drop on shellside
Keywords — shell and tube heat exchanger, segmental baffle, Pressure, temp. velocity.

***How to cite this article**: Shankar Prasad Suman, N. V. Saxena, "Study of Segmental Baffles using in Shell and Tube Heat Exchanger" Published in International Journal of Scientific Modern Research and Technology (IJSMRT), ISSN: 2582-8150, Volume-14, Issue-2, Number-2, February 2024, pp.6-11, URL: https://www.ijsmrt.com/wp-content/uploads/2024/04/ IJSMRT-24140202.pdf*

IJSMRT-24140202

I. INTRODUCTION

Heat Exchanger is a device in which the exchange of energy takes place between two fluids at different temperature. A heat exchanger utilizes the fact that, where ever there is a temperature difference, flow of energy occurs. So, that Heat will Flow from higher Temperature heat reservoir to the Lower Temperature heat Reservoir. The flowing fluids provide the necessary temperature difference and thus force the energy to flow between them. The energy flowing in a heat exchanger may be either sensible energy or latent heat of flowing fluids. The fluid which gives its energy is known as hot fluid. The fluid which receives energy is known as cold fluid. It is but obvious that, Temperature of hot fluid will decrease while the temperature of cold fluid will increase in heat exchanger. The purpose of heat exchanger is either to heat or cool the desired fluid.

In a special case, when one of fluid undergoes change in its phase, its temperature remains unchanged. These types of heat exchanger are known as condensers or evaporators. Heat exchangers with the convective heat transfer of fluid inside the tubes are frequently used in many engineering applications. The techniques of heat transfer enhancement to accommodate high heat flux i.e., to reduce size and cost of heat exchangers have received serious attention passed years. Enhancement of heat transfer Rate in all types of thermo-technical apparatus is of great significance for industry. Beside the savings of primary energy, it also leads to a reduction in size and weight. Up to the present, several heat transfer enhancement techniques have been developed. Twisted-tape is one of the most important members of enhancement techniques, which employed extensively in heat exchangers.

II. TYPES OF HEAT EXCHANGER

On the basis of nature of heat exchange procedure:

Direct contact heat exchanger: In this HE, fluids are mixed with each other and heat transfer will take place.

Indirect contact heat exchanger: In this HE, fluids are separated by a thin wall and heat transfer takes place by convection and conduction.

Indirect contact HE has two types:

a. Regenerator type: In this HE, hot and cold fluid pass alternately through a space which contains solid matrix. When hot fluid pass through matrix then it heats the matrix and after that cold fluid pass through it then hot matrix transfer heat to the cold fluid.

b. Recuperator type: It is most useful HE in which two or more fluid pass simultane- ously but they are not allowed to be mixed. in this type of HE, heat transfer takes place in both side of dividing wall(pipes or tubes).

On the basis of relative direction of fluid motion:

i. Parallel flow heat exchanger: In this HE, both fluid flowing in the same direction.

ii. Counter flow heat exchanger: In this HE, both fluid flowing the opposite direction.

iii. Cross flow heat exchanger: In this HE, one fluid flows at some angle to the other fluid.

III. LITERATURE SURVEY

Yonghua You et al 2023, in the field of performance improvement of shell and tube heat exchanger. They used trefoil hole baffles to make the heat exchanger cross flow type. By introducing baffles, heat transfer area increased so heat trans- fer also increases. The effect of baffle distance is also investigated by them. They validated their numerical solution with experimental data. They used 12.8 mm internal diameter stainless steel tubes, low carbon steel baffles aligned in staggered manner. They found thatpressure loss in shell side increases with increase in shell side Reynolds number. They alsofound that heat transfer per unit area initially decreases with increase in shell side Reynolds number but after some value it starts increasing with increase in Reynolds number. Convec- tive heat transfer coefficient increases with increase in shell side Reynolds number. With decrease in number of baffles, heat transfer coefficient and heat flux decreases. They got to know that when number of baffles is decreased from 6 to 3 then pressure loss is decreased by 35%. They found that overall thermo hydraulic performance is decreasing with increase in number of baffles.

Yan Zhou et al 2022- the flow characteristics in shell andtube heat exchanger with trefoil hole baffle. A numerical investigation on shell side flow and heat transfer based on RNG k-ε model has been done. They used 12.2 mm internal diameter tubes which are arranged in rotational regular triangle pattern. They validated their results with experimental data. They found that fluid flow on shell side of shell and tube heat exchanger is periodic due to the structural characteristics. The fluid gets accelerated and jetand swirl flow generated near the baffles because of decrement in area of the flow. Gradualdecrement of velocity in radial direction takes place which leads to decrement in average heat transfer coefficient. They found that pressure drop and coefficient of heat transfer vary periodically along the longitudinal direction. Secondary flow is developed both sides of thebaffles which decreases the thickness of boundary layer and increase the heat transfer.

Ali et.al 2021 This paper defines the thermal analysis of reclined parallel to surface of the ground and upright at right angle to surface of the ground, slinky horizontal ground heat exchangers with ground about the sprawled horizontal ground heat exchangers due to extraction of heat, as well as the influence of deviation in temperature of ground on reclined horizontal ground heat exchangers performance. The thermal performance improvements by intermittent operations of ground heat exchangers are also discussed. Moreover, the allocations of temperature of the unobstructed ground and temperature of the environs are also taking into account. The evaluated unobstructed temperature of ground data delivers a useful needle of the installation of ground heat exchangers at an appropriate deepness for heating as well as cooling purposes changed water rates of mass flow in the reheating manner of constant and discontinuous actions. A copper tube like an outer area secured with low density polyethylene has been designated as the tube material of the heat exchanger identified as ground. The practical thermal enactments of slinky horizontal ground heat exchangers standing and reclined orientation being taken into account in altered modes of heating. The practical outcomes define the differences of the enactments of standing and reclined orientation, impacts on temperature of ground on reclined horizontal ground heat exchangers are also discussed.

Reza Tasouji Azar et. al. [2019] "Modeling for shell-side heat transfer coefficient and pressure drop of helical baffle heat exchangers" The existing warmth exchange and weight drop rectification components of the modified Bell Delaware approach used for warmth exchangers with segmental astounds have been suitably adjusted in this investigation, taking into account the helical bewilder shape. The creators have created a computational code to figure out the shell-side warmth exchange coefficient and weight drop using the current technique. Using the model similar to the approach for segmental confuses presented, adjustment variables for the helical astound geometry of warmth exchangers are proposed in this study. Furthermore, in order to assess the validity, the outcomes of code for a contextual investigation are compared to the findings obtained via Express programming and exploratory recipes demonstrated by Zhang. The findings of the investigation show that the recommended technique is accurate and can undoubtedly be used by architects.

Anas El Maakoul et. al. [2018] "Numerical comparison of shell-side performance for shell and tube heat exchangers with trefoil-hole, helical and segmental baffles" At low shell side stream rates, three-dimensional computational liquid elements (CFD) simulations were performed using the business programming ANSYS FLUENT to investigate and consider the shell-side stream circulation, warm exchange coefficient, and weight drop between the recently created trefoil-gap, helical perplexes, and regular segmental confuses. The entire warmth exchangers are displayed in this numerical correlation, which includes the shell, tubes, confuses, and spouts. The numerical model predicts the thermo-pressure driven execution with a significantly decent exactness, by contrasting and testing information for single segmental puzzles. The thermo-water powered displays of shell-and-tube warm exchangers with diverse confound composes: segmental, helical, and trefoil-gap bewilders are registered and considered using a numerical model. In comparison to segmental and trefoil-opening confuses, speed circulation in helical bewilders is more uniform and homogeneous, according to a stream examination on the shell side. As a result, there are fewer no-man's-lands and liquid distribution regions inside the shell.

Avinash D Jadhav et al 2015 numerically investigated the dependency of heat transfer coefficient and pressure drop on baffle spacing and baffle cut. They compared their results with the Bell-Delaware method results. They performed simulation for two values of bafflecut and different varying flow rate.

Chetan Namdeo Patil et al 2014 numerically investigated the effect of baffle cut on heat transfer coefficient and pressure drop with constant baffle spacing. They found that for 30%baffle cut pressure drop is less and heat transfer co-efficient almost same for 30% and 25%baffle cut.

Edward S. Gaddis et al 2008 proposed a procedure to find the pressure drop equation consists of correlation factor which is influenced by leakage and bypass stream. They have validated their equation by comparing their results with experimental data.

Prasanna J et al 2001 analyzed the hydrodynamic and heat transfer effect on shell and tube heat exchanger with different baffle cut and spacing. They found that for 25% baffle cut, results are slightly better. As baffle spacing decreases, the heat transfer is improved.

IV. OBJECTIVES

The main objectives of this works are:

- Design and simulation of shell and tube heat exchanger with segmental baffle.
- To study the baffle for turbulence factor, the

increase in number of baffles for covering the working fluid.

- Study the effect of baffle spacing on heat transfer and pres-sure drop and heat transfer rate.

V. METHODOLOGY OF CFD PROGRAMS

All established CFD software contain three elements

(i) a pre-processor, (ii) the main solver,and (iii) a post-processor

The preprocessor

Pre-processing is the first step of CFD analysis in which the user

a. characterizes the displaying targets,

b. Distinguishes the computational area, and

c. Outlines and makes the framework

d. Definition of material properties

e. Define boundary conditions

f. Solution initialization.

g. Setting of relaxation factor

h. Setting of convergence criteria

i. Run calculation

j. Saving results

The main solver

The main solver does follow functions: Selection of physical model.

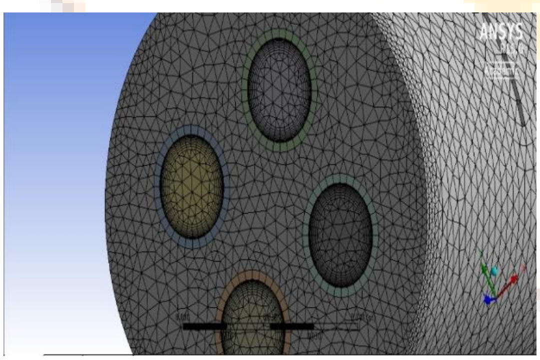

Figure 1: Overall geometry of shell and tube heat exchanger with 8 baffles

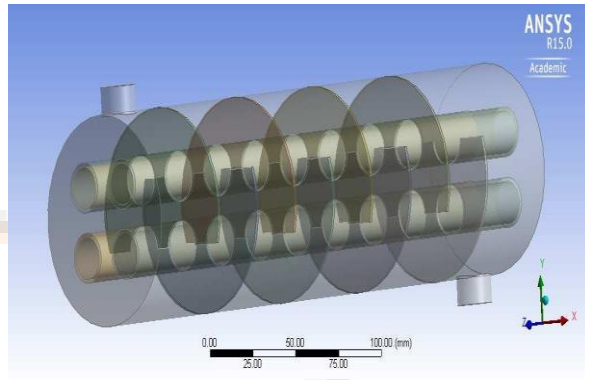

Figure 2: Front view of geometry with 4 baffles

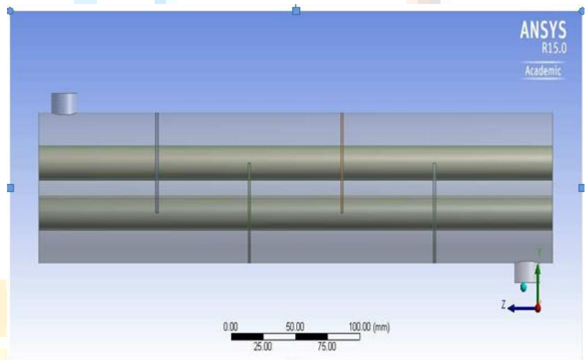

Figure 3: Magnified view of meshing

VI. RESULTS

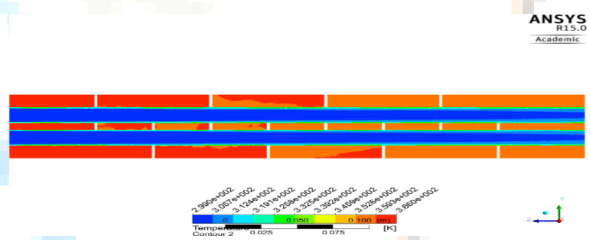

Figure 4: Temperature contour

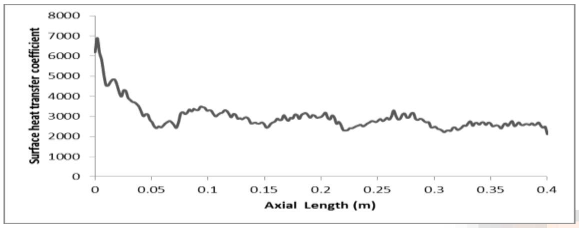

Figure 5: surface heat transfer coefficient vs length

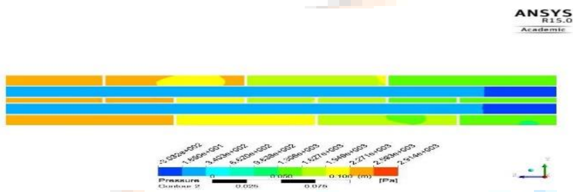

Figure 6: streamlines

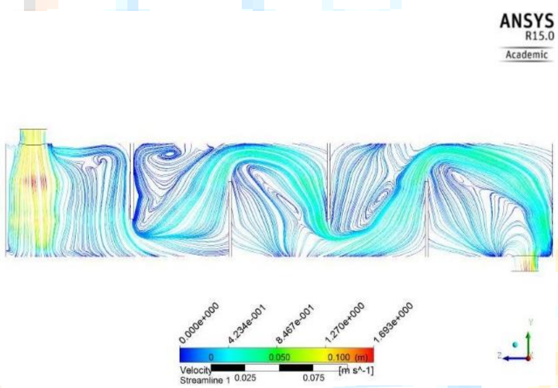

Figure 7: pressure contour

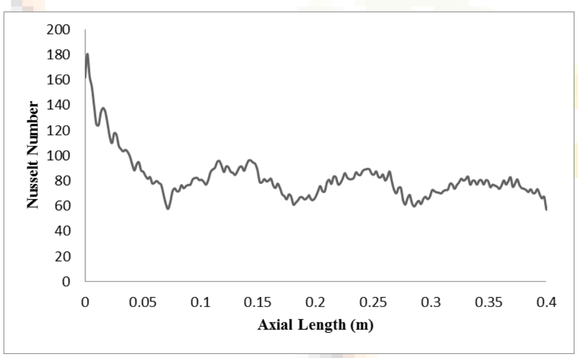

Figure 8: Nusselt number vs length

Table 1: Heat transfer rate, Shell side pressure drop in various cases

Number of baffles	Heat transfer rate (W)	Shell side pressure drop (Pa)
4	8043.8305154292	2116.44502
6	9884.910562944	2695.90933
8	11053.37143	3160.72314

VII. CONCLUSION

As the number of baffles increasing for same length of shell, then spacing between the baffles are decreasing. Since the spacing between the baffle is less so the area of recirculation is less and high turbulence is developed. In high turbulence region, heat transfer rate is also high. Another point of interest is that due to increase in number of baffles, fluid has tocover more distance in the shell so the effective heat transfer area increases which is results in high heat transfer rate. Heat transfer is 37.414 % more in case of 8 baffles as compared to 4 baffles.

REFERENCES

[1] G.V. Srinivasa Rao et al "Performance Analysis of Heat Transfer Parameters in Shell and Tube Heat Exchanger with Circumferential Turbulator" ICTAMDMES'20 IOP Conf. Series: Materials Science and Engineering 923 (2023) 012062 IOP Publishing doi:10.1088/1757-899X/923/1/012062

[2] Yonghua et al "Experimental analysis on performance assessment of a hybrid double cross flow tube arrangement in a shell and tube heat exchanger" Journal of Mechanical Science and Technology Article Published: 08 January 2022 36, pages499–511 (2022)

[3] F. Afshari, H. G. Zavargh and G. D. Nicola, Numerical analysis of ball-type turbulators in tube heat exchangers with computational fluid dynamic

simulations, International Journal of Environmental Science and Technology, 16 (2019), 3771–3780.

[4] Y. You, Y. Chen, M. Xie, X. Luo, L. Jiao, and S. Huang, "Numerical simulation and performance improvement for a small size shell-and-tube heat exchanger with trefoil- hole baffles", Applied Thermal Engineering, vol. 89, pp. 220–228, 2015.

[5] G.-Y. Zhou, J. Xiao, L. Zhu, J. Wang, and S.-T. Tu, "A numerical study on the shell-side turbulent heat transfer enhancement of shell-and-tube heat exchanger with trefoil- hole baffles", In The 7th International Conference on Applied Energy, Energy Proce-dia, pp. 3174–3179, 2015.

[6] J. Yang and W. Liu, "Numerical investigation on a novel shell-and-tube heat exchangerwith plate baffles and experimental validation", Energy Conversion and Management,vol. 101, pp. 689–696, 2015.

[7] J. Wen, H. Yang, S. Wang, Y. Xue, and X. Tong, "Experimental investigation on performance comparison for shell-and-tube heat exchangers with different baffles", International Journal of Heat and Mass Transfer, vol. 84, pp. 990–997, 2015.

[8] E. Ozden and I. Tari, "Shell side CFD analysis of a small shell-and-tube heat ex- changer", Energy Conversion and Management, vol. 51, pp. 1004–1014, 2010.

[9] Davood Panahi ,et al. Heat transfer enhancement of shell-and-coiled tube heat exchanger utilizing helical wire tabulator, App. thermal engineering, 1-24 (2019).

[10] A. D. Jadhav and T. A. Koli, "CFD Analysis of Shell and Tube Heat Exchanger to Study the Effect of Baffle Cut on the Pressure Drop", International Journal of Re- search in Aeronautical and Mechanical Engineering, vol. 2, pp. 1–7, July 2014.

[11] C. N. Patil and N. S. Bhalkikar, "CFD Analysis of Shell and Tube Heat Exchanger toStudy the Effect of Baffle Cut on the Pressure Drop and Heat Transfer Coefficient", International Journal for Scientific Research and Development, vol. 2, pp. 649–654, 2014.

[12] S. P. Chit, N. A. San, and M. M. Soe, "Flow Analysis in Shell Side on the Effect of Baffle Spacing of Shell and Tube Heat Exchanger", International Journal of Science, Technology and Society, vol. 3(5), pp. 254–259, 2015.

[13] B. Peng, Q. W. Wang, C. Zhang, G. N. Xie, L. Q. Luo, Q. Y. Chen, and M. Zeng, "An experimantal study of Sheel-and-Tube Heat Exchnagers with continuous helicalbaffles", Journal of Heat Transfer, vol. 129, pp. 1425–1431, 2007.

[14] H. D. Li and V. Kottke, "Visualization and determination of local heat transfer coeffi-cients in shell-and-tube heat exchangers for in-line tube arrangement by mass transfermeasurements", Heat and Mass Transfer, vol. 33, pp. 371–376, 1998.

[15] K. Kiran, A. M. M. Manoj, and C. J. Umesh, "Investigation of baffle spacing effect onshell side heat transfer characteristics in shell and tube heat exchanger using compu- tational fluid dynamics", Thermal Engineering, vol. 73, pp. 26022–26026, 2014.

[16] J. Prasanna, H. R. Purushothama, and D. K. Murugeshan, "A numerical analysis of hydrodynamic and heat transfer effects of shell and tube heat exchanger for differentbaffle space and cut", Mechanica Confab, vol. 2, June-July 2013.