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Investigation on Shell and Tube Heat Exchanger by Using CFD - A Literature Review

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Abstract: *In this study, the Shell and tube heat exchanger (STHE) was studied with variations in baffle types. Various baffle types and angles allow a wide range of possibilities. Baffles can be configured in a variety of ways to achieve better results at various phases of their use. Many additional improvements can be made to STHXs to improve performance. In order to optimize the design of STHE, material selection is critical. The distribution of temperature was produced using the Computational Fluid Dynamic (CFD) approach in the ANSYS FLUENT program due to the use of various materials. This publication compiles a list of successful changes that have left enough traces for future research.*

Keywords: Shell and tube heat exchanger, Baffle angle, Material, computational fluid dynamic (CFD), ANSYS FLUENT.

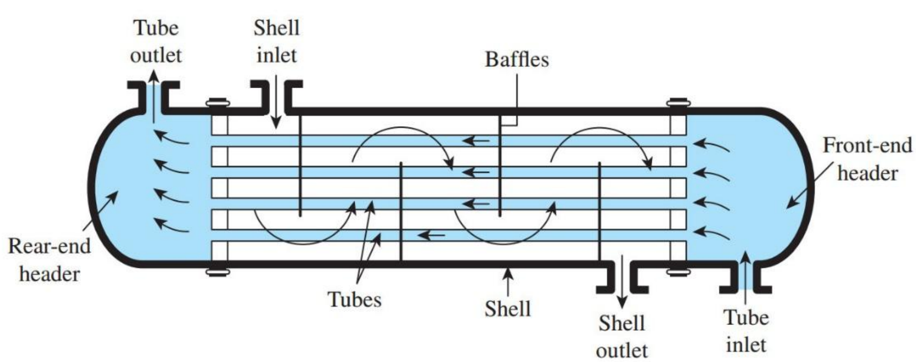
I. Introduction

Heat exchangers are devices used for transferring thermal energy between a solid object and a fluid, or between two or more fluids. The fluids could be separated by a solid wall to keep them from mixing, or they could be in direct touch. They're employed in a variety of applications, including space heating, refrigeration, air conditioning, power plants, petrochemical, chemical, and pharmaceutical industries, natural gas processing, and wastewater treatment.

The baffle range and baffle gap are critical parameters in the STHE design. Large vortices of poorly dispersed flow, dead zones, and higher pressure losses than planned occur when baffle spaces are left larger or smaller than the optimum design. (Biçer et al., 2020)

Baffles are used to support heat transfer tubes and manage shell-side flow distribution on the shell side of heat exchangers, which has a considerable impact on heat transfer enhancement and thermal-hydraulic performance. (Wang et al., 2018) According to research, because of its solid structure and ease of maintenance, 35–40% of the heat exchangers used in industries are ST. The use of baffles can improve the effectiveness of ST. (Kunwer et al., 2020)

To arrive at an optimal heat exchanger design, several quantitative design features such as thermodynamic and geometric characteristics are used. The duty and corrosive qualities of the process fluids will influence the material of construction of the specific. (Vetrivel et al., 2015)



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The shell side design is extremely challenging due to the various leakage channels and bypass streams that exist within the various flow zones; the leakages and streams vary depending on the shell design and size. Computational Fluid Dynamics (CFD) is a well-established technology in the industry, capable of visualizing flow and temperature fields on the shell side, as well as simplifying the assessment of flaws and directing the designer on the appropriate path.(Vetrivel et al., 2015)

The selection of material and the number of baffles have a significant impact on the change of coefficient and the rate of heat transfer from STHE. The change in material and the number of baffles affect the temperature at the outside of the shell. The change in material and the number of baffles inside the shell affect the value of the pressure drop. (Permatasari & Yusuf, 2018)

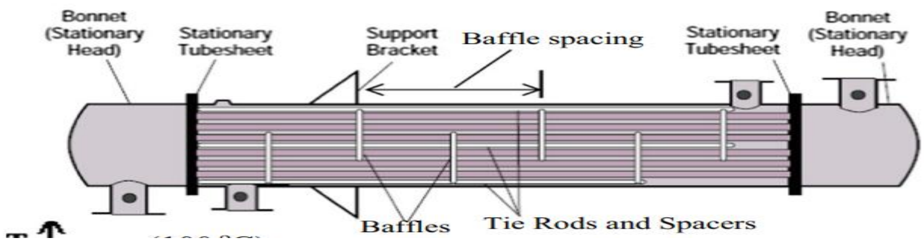

Figure 1: The arrangement of the heat exchanger with its T-x diagram. (Abeykoon, 2020)

The working fluids enter at the opposite ends (i.e., a counter-flow) of the heat exchanger, and baffles are added to produce turbulence and cross-flow velocity components to raise the convection coefficient of the shell side fluid. In this heat exchanger design, the combined effects of cross and counter flow configurations occur.

The baffles also prevent bending of the tube bundle and the effects of vibration induced by the fluid stream on the shell side. The tubes are secured by the tube sheets, which are welded to the shell body. (Abeykoon, 2020)

II. Literature Work

The most popular configuration for the optimal heat recovery rate and low cost is the segmental baffle. The segmental baffle (STs) is compared to continuous helical baffles with a helix angle of 25° (STc) in experimental research. STs are more effective at all mass flow rates that are changed.

Helical baffles were given a fixed helix angle of 25°, which resulted in a higher heat transfer coefficient (HTC) at a smaller pressure drop. (Kunwer et al., 2020)

When the baffle cut ratio is reduced, the heat transfer coefficient in the shell increases, but the pressure drop increases as well. The number of tubes in a heat exchanger affects tube flow velocity in order to maintain the required mass flow rate, with the fewer the number of tubes, the higher the pressure drop for a particular task. (Abeykoon, 2020)

Stainless steel has a lower heat transfer coefficient than aluminum. Materials selection and compatibility between building materials and working fluids are critical considerations, especially when it comes to corrosion and/or operation at high temperatures.

- Aluminum is frequently chosen as the heat transfer surface due to its low cost, lightweight, high conductivity, and good joining qualities.(Vetrivel et al., 2015)

Single segmental baffles demonstrate the establishment of dead zones when heat transport is impeded.

- When compared to single segmental baffles, double segmental baffles reduce vibrational damage.
- Because dead zones are eliminated when helical baffles are used, the pressure drop is reduced. Heat transfer is improved when there are fewer dead zones.
- A reduced pressure drop means less pumping power is used, which improves overall system efficiency.(Bichkar et al., 2018)

Due to the directional movement of the fluid along the axis of the tubes, the pressure drop diminishes. The results of this study reveal that a disc baffle shell and tube heat exchanger (DB-STHE) and a combined segmental-disk baffle shell and tube heat exchanger (CSDB-STHE) lower the pressure drop on the shell side much more than a common segmental baffle shell and tube heat exchanger (SB-STHE).

- Heat transfer is also improved with new tubes, thanks to the ribbed tube's greater area for heat exchange.(Abbasian Arani & Moradi, 2019)

When compared to a standard heat exchanger, our constructed heat exchanger has more efficient cooling. The parameters in temperature, velocity, and pressure fluctuations are examined using flow simulation software. (Mahendran, 2020)

- As the diameter of the shell grows, so does the heat transfer coefficient and pressure drop.
- To improve the heat transfer coefficient, the pull through the head with a triangular pitch may be the best option.
- Increases in baffle spacing and cutting space, on the other hand, reduced the heat transmission coefficient.
- Because fouling on the shell side can influence heat transfer much more than fouling on the tube side, it is critical to eliminate fouling on the shell side.
- Both the overall heat transfer coefficient and the pressure drop are directly affected by parameter selection. (Abd et al., 2018)

Because the factors shell inside diameter, tube outside diameter, baffle cut, baffle spacing, and baffle orientation angle has such a significant impact on the variation of heat transfer rate and pressure drop, they cannot be ignored in the optimization study.

- Taguchi's experimental design for the combination of design parameters minimizes the number of trials necessary for optimization, resulting in fewer 3D model configurations and numerical simulation data.(Thondiyil & Kizhakke Kodakkattu, 2019)

The helical baffle's helix angle and axial overlapped ratio are critical factors in the thermo-hydraulic performance of the shell side. Helix angle increases and axial overlapped ratio decreases both results in quicker shell-side axial velocity; also, the larger the helix angle or axial overlapped ratio, the weaker the axial back-mixing flow. Heat flux density on tube bundle surfaces behaves differently depending on helix angles and axial overlapped ratios.(Cao et al., 2021)

- As the wavy beginning length and hot water flow rate increase, the thermal performance factor drops. The thermal performance factor improves as the cold water flow rate increases.
- The thermal performance factor is greater than unity in all circumstances. This is significant from the standpoint of energy conservation.
- It can be claimed that corrugating tubes and employing them in tube bundles increases prices, but from an economic standpoint, it is fully cost-effective. (Milani Shirvan et al., 2018)
- The sextant helical (SH) scheme has better thermo-hydraulic performance than the continuous helical (CH) and quadrant helical (QH) schemes when analyzing heat transfer, resistance, and comprehensive characteristics in the shell side; additionally, the SH and QH schemes generate the least entropy at low Reynolds numbers.

Furthermore, a higher axial overlapped ratio results in a higher heat transfer coefficient and pressure drop, but a smaller ratio and higher thermodynamic irreversible loss. (Cao et al., 2020)

- Rectangular section baffles are more efficient in terms of heat transmission and flow structure change than triangular section baffles for the same tubular heat exchanger. The inserts, in general, facilitate convective flow and increase the fluid-wall contact area, boosting heat exchange between the base heat transfer fluid and the (heated) duct wall. (Salhi et al., 2021)

The heat transmission is somewhat boosted by about 7% when the splitter thickness is increased to approximately 20% of the pipe diameter, but the pressure loss is drastically increased by about 20%.

- When the length of the splitter is raised to an L/D ratio of 1.5, the heat transfer is doubled, and the pressure drop is increased by around 20%. (Elmekawy et al., 2021)
- Numerical studies show that by inserting fins on each tube, the melting time of Gallium is reduced from 301 to 290 seconds, resulting in improved heat transfer from tubes to Phase Change Materials (PCM). - The time it takes for the PCM to reach the temperature of the water flowing in the tubes (800C) is also reduced from 460 to 425 seconds. (Rana et al., 2021)

The flow in the shell-side is not partially blocked by the three-zonal baffle. As a result, no stagnant zones exist behind the baffles. This cuts down on fouling and assures long-term operation.

- In comparison to conventional baffles, three-zonal baffles produce very modest pressure drops on the shell side. When compared to a standard segmentally baffled arrangement, the pressure loss in the shell-side has been reduced by 49% with the usage of three-zonal baffles. As a result, by employing a pump with lower input power, running expenses can be reduced.

- When compared to conventional baffles, the installation of a three-zonal baffle has resulted in significant increases in temperature differential in the heat exchanger. Depending on the heat exchanger's operating parameters, a maximum gain of 6.75 percent was obtained. (Biçer et al., 2020)

III. Outcomes of the Literature Survey

According to the above literature survey, most research works were done on the different kinds of baffles, Only a few focus on the kind of material they are going to use for greater effectiveness of shell and tube heat exchanger. So, one of the gaps is finding out effective material which is suitable for baffles for better performance at a different mass flow rate. As well as if the number of baffle changes the effectiveness of Shell and tube heat exchanger also changes.

IV. Conclusion

Based on the findings, it is obvious that the shell and tube heat exchanger is the most versatile type of heat transfer device, and as a result, it is the most widely employed in a wide range of applications. By varying the key characteristics were baffles, baffle spacing, baffle angles, tube diameter, working fluid, and so on. The results were promising, and shell and tube heat exchanger efficiency increased significantly. The type of material used and the number of baffles used have a great impact on the change in coefficient and heat transfer rate from STHE. The temperature outside the shell is affected by changes in material and the number of baffles. The value of pressure drop is affected by changes in material and the number of baffles inside the shell.

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