The Influence of Baffle Gap to The Effectiveness of Shell and Tube Heat Exchanger with Helical Baffle

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Abstract. One of heat exchangers now commonly used in industries is shell and tube heat exchanger. The design of heat exchanger process is a major thing and is important in obtaining the effectiveness of the heat exchanger work, including the design of its baffle gap. The purpose of this study is to determine the effect of baffle gap against the effectiveness of the shell and tube heat exchanger with helical baffle type. The object of this experimental study is a shell and tube type heat exchanger with variation in the baffle spacing, which are 4 cm, 8 cm and 12 cm. The type of baffle used is helical baffle. This study obtained the data by measuring the temperature of fluid entering and exiting, using thermocouple installed in various points of inlet and outlet fluid channels, and then analyzed descriptively. The results shows that 4 cm baffle gap leads to largest effectiveness which is 39.86% with a heat transfer rate of 4867.4 Watts. The 8 cm baffle gap has the effectiveness value 35.23% with the heat transfer rate of 3,709.12 Watts and then baffle gap of 12 cm leads to the lowest effectiveness, 29.59% with a heat transfer rate only 3301.21 Watts.

Keywords: Shell and tube heat exchanger, baffle distance, helical baffle, effectiveness.

1. Introduction

The heat transfer process requires several requirements, including certain temperature requirement, supporting the system to able run properly the heat transfer process requires several requirements, including certain temperature requirement, supporting the system to be able run properly as planned. Therefore, to regulate the heat transfer occurs, it needs a tool named heat exchanger.

Heat exchanger is a production supporting device which functions to transfer heat energy from flowing liquid to other flowing liquid. The type and size of the heat exchanger varies depending on needs [1,2]. The design quality of a heat exchanger is absolutely important to be able to deliver high heat transfer effectiveness with smaller dimensions. With its good performance, it is expected to bring maximum results and good support to fabrication operation. Theoretically, short gap between baffles will increase the heat transfer between the two fluids, so in other words the effectiveness increases, but it also increase the heat resistance of the flow which goes through the baffles gap so that the pressure drop becomes large. Meanwhile if the baffles gap is installed too far, the pressure drop will be small, but the heat transfer will not be good and it brings vibration. It shows that the baffles gap cannot be too close nor too far. Therefore, an analysis and research is needed to determine the effect of baffles gap against the effectiveness of shell and tube heat exchangers. The flow pattern in the shell side of the heat exchanger with continuous helical baffles are forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a in a significant increase in heat transfer.
coefficient per unit pressure drop in the heat exchanger [3]. Simulation performance of shell and tube heat exchanger with helical baffle using ANSYS 16.0 program, the result of simulation analysis shows that the use of helical baffle can improve the effectivity of heat exchanger because when the fluid flows in spiral path, centrifugal force causes secondary flow which can increase heat transfer, this causes the effectiveness value of helical baffle become high that is equal to 34, 89% [4]. The thermal analysis of helical baffle heat exchanger using this method give us clear idea that the ratio of heat transfer coefficient per unit pressure drop is maximum in helical baffle heat exchanger as compared to segmental baffle heat exchanger [5]. A research is done to find out the effect of battle use toward the tiveness and pressure drop in heat exchanger. The result is that the effectiveness increases when the baffles are installed. Effectiveness increases as the spacing between the baffles is smaller until certain spacing, and then it decreases [6]. The angle of baffle is varying from 0 to 30 degrees. The results are drawn the thermal and hydraulic analysis of a (Continuous Helical baffled Heat Exchanger) with segmental baffle. It gives us a clear idea that the Overall h coefficient is maximum in helixchanger as compared to segmental baffle. The pressure drop decreases with the increase in helix angle [7]. Analysis is used to find out how this heat exchanger works at its optimal state. The result of this research is the effectiveness value of shell and tube heat exchanger using double segmental baffle is 29,51%. while the variation of battle helical is 34,89% [8]. The segmental baffle forces the liquid in a Zigzag flow and improving heat transfer and a high pressure drop and increase the fouling resistance and Helical Baffle have a Effective Performance of increasing heat transfer performance. The desirable features of heat exchanger obtain a maximum heat transfer Coefficient and a lower pressure drop. From the Numerical Experimentation result the performance of heat exchanger is increased in Helical Baffle instead of Segmental Baffle [9]. Meanwhile, the baffle spacing variations experimental results depicted baffle spacing 5 cm produced maximum total heat transfer coefficient of 651 W/m2.K at mass rate 0.166 kg/s while baffle spacing 5 cm was solely performed better than the baffle spacing 10 cm at mass rate 0.133 kg/s. [10].

1.1. Components of shell and tube heat exchanger
There are important components in a shell and tube heat exchanger as follows:

![Figure 1. Components of heat exchanger](image-url)

- Pass partition, is a component which serves as barrier between the incoming and outcoming fluid from the tube.
Stationary Head Channel, is one of end section parts of heat exchanger which has a channel for the incoming fluid which flows through the tube. This component made of standard cast iron.

Stationary Tube sheet, serves as a place to assemble all the ends of the tube becomes one, called a tube bundle. Heat exchangers with straight tubes generally use two tube sheets. Meanwhile the U tube using a tube sheet that serves to unite the tubes into a bundle tube.

Shell, is a cylindrical component containing tube bundle which serves as a container of fluid flow and is usually protected with high quality paint to inhibit corrosion.

Tie rods and spacers, are components have the form of iron bars which are placed parallel to the tube and placed on the outside of the baffles which serves as a buffer so that the distance between the baffles is fixed with one another.

Baffles, a component used to deflect or divide the flow of fluid in a heat exchanger. To determine the baffles, technical and operational considerations are needed.

Shell cover and channel cover, as a cover that can be opened during cleaning or maintenance.

1.2. Baffle in shell and tube
Baffle is a circular plate that is partially cut (depending on the value of the baffle cut) that is installed along the flow in the shell to maximize heat transfer that occurs between fluids, hold the tube-bundle and to prevent or resist vibration in the tubes. In this research, a double segmental baffle type baffle is adopted.

Baffles in shell and tube heat exchangers have several functions:
- Directing the flowing fluid become cross flow that flows outside the tube.
- With the help of cross flow, it will make the contact area between the fluid inside the shell with the tube wall getting bigger and it leads to longer time in contact.
- As a tube holder to prevent vibration.

2. Methodology
Based on the problem and objectives of this study the authors used a type of experimental research which aims to determinate the increase the rate of heat transfer of convection and effectiveness that is influenced by the distance and type of baffle.

2.1. Independent variable
The independent variable of this research is the variation of the baffle gap: 4 cm, 8 cm and 12 cm.

2.2. Dependent variable
In this study the dependent variable is the effectiveness of shell and tube heat exchanger with helical baffle.

2.3. Control variables
The control variables in this study are:
- Temperature of incoming hot and cold fluid (Thin) of 80°C and (Tc_in) of 30°C.
- The debit of hot fluid flow is determined in amount of 2 lpm and debit of the cold fluid flow rate is determined in amount of 6 lpm.

2.4. The instrument and tools used in study
To determine the influence of baffle gap against the effectiveness of shell and tube heat exchanger, the setting of experiment tools has been designed as the following figure:
Figure 2. Components of heat exchanger

1. Baffle  
2. Pressure gauge  
3. Instrumen box  
4. Flow meter  
5. Channel tube of cold fluid  
6. Shell  
7. Pum of cold fluid  
8. Tube  
9. Container in coming cold fluid  
10. Container in coming fluid  
11. Tube  
12. Channel tube of cold fluid  
13. Pum of hot fluid  
14. Container in coming hot fluid  
15. Heater

Shell and tube heat exchanger, this prototype has been designed with the following specification:
Shell specification adopted in experiment tools explained as follows.

| Table 1. Shell spesifications |
|--------------------------------|
| Number of Shell | : 1 | Shell |
| Number of shell pass | : 1 | Shell |
| (do,s) outer shell diameter | : 0.17 | Meter |
| (di,s) inner shell diameter | : 0.164 | Meter |
| (Ls) Shell length | : 0.955 | Meter |
| Shell thickness | : 0.803 | Meter |
| (k) Thermal conductivity | : 15.1 | W/m°C |
| Shell material | : Stainless steel 304 (SS 304) |

Tube specification adopted in experiment tools explained as follows:

| Table 2. Tube spesifications |
|--------------------------------|
| (Nt) Number of tube | : 12 | Tube |
| (n) Number of tube pass | : 1 | Tube |
(do,t) outer tube diameter : 0.0127 Meter
(di,t) inner tube diameter : 0.0097 Meter
(Lt) Tube length : 0.966 Meter
(Pt) Pitch tube : 0.045 Meter
(C) Tube Clearence : 0.029 Meter
Tube thickness : 0.0015 Meter
Tube arrangement : 60° Triangular
(k)Thermal conductivity : 385 W/m°C
Material : Cuprum (Cu)

Baffle specifiction adopted in experiment tools explained as follows:

Table 3. Baffle specifcations

| Diameter of baffle inside | : 0.163 Meter |
|---------------------------|---------------|
| Baffle thickness          | : 0.003 Meter |

3. Results and Discussions

Research results obtained the effect of baffle gap variation against heat transfer rate.

![Figure 3](image.png)

**Figure 3.** Graph describes the effect of baffle gap variation against heat transfer rate

From the graph above, it can be seen that the heat transfer occurs at a baffle gap of 4 cm is 4,867.4 Watts. While at baffle gap of 8 cm, its heat transfer is 3,709.12 Watts. Then at baffle gap of 12 cm, the heat transfer value is 3301.21 Watts.

Research results obtained the effect of various baffle gap against effectivity of shell and tube heat exchanger.
In Figure 4 it can be seen that the graph of the effect of variations in baffle distance from the baffle gap of 4 cm, 8 cm, to 12 cm on the effectiveness of the heat exchanger. The graph shows the highest heat exchanger effectiveness occurs at 4 cm of baffle gap and the lowest heat exchanger effectiveness occurs at baffle gap of 16 cm. At baffle gap of 4 cm the heat exchanger effectiveness is 39.86%, at 8 cm the effectiveness is 35.23% and at 12 cm the effectiveness is 29.59%. From the graph data it can be concluded that the relationship between baffle gap and heat exchanger effectiveness is the closer baffle distance will increase the effectiveness of the heat exchanger. This is because the small baffle gap will increase the point of contact between the cold fluid on the shell side and the hot fluid on the tube side. With the number of contact points, the cold fluid has longer time in contact with the tube walls so that the heat transfer from the hot fluid to the cold fluid becomes greater (the heat energy derived from the hot fluid in the tube can be absorbed more by the cold fluid in the shell).

4. Conclusions
The experiment result of using helical baffle toward shell and tube heat exchanger its data processing result any conclusions obtained can be explained as follows.

- There is an influence of baffles gap against the effectiveness of shell and tube heat exchangers, with using the helical baffle, which the closer gap will bring more effectiveness to the heat exchanger because the close baffles gap will bring more points of contact between the cold fluid on the shell side and the hot fluid on the tube side so that the heat transfer process become more maximal.

- The most optimal heat transfer rate and its effectiveness of shell and tube type heat exchanger with helical baffle from three gap variations of 4 cm, 8 cm, and 12 cm, is 4 cm with a value of 4,867.4 Watts and 39.864%, because this gap has the most optimal heat transfer process between cold fluid and hot fluid.

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