INVESTIGATION OF CONVECTIVE HEAT TRANSFER IN A HEAT EXCHANGER

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Investigation of Convective Heat Transfer in a Heat Exchanger” is the result of my own work except as cited in the references

Signature : .....

Name : Muhammad Azrul Amri Bin Shahril

Date : 3 July 2019

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	: .....
Supervisor‘s Name	: Shamsul Bahari Bin Azraai
Date	: 3 July 2019

DEDICATION

Special to

Father and mother, family, lectures and friends

ABSTRACT

The main purposes of this study is to simulate the heat transfer rate of convection for the two types of tube bank arrangements, which is the inline and staggered arrangement by using the ANSYS Fluent software. The results from the simulation that are used the cross-flow heat exchanger for both arrangements has been discussed in this report, which is by presenting the temperature, velocity and pressure profiles. From the simulation results, the comparison of performance heat transfer rate for both arrangements also determined in this study by using the air temperature difference to indicate the heat transfer for each the arrangements. The performances of both arrangements show that the staggered tube bank arrangement has a higher heat transfer rate compared to the inline tube bank arrangement. The result from simulation also has been validated by comparing with the experimental result and from the comparison, the results from both approaches are in good arrangements.

ABSTRAK

Tujuan utama kajian ini adalah untuk mesimulasikan kadar pemindahan haba konveksi bagi dua jenis susuan tiub bank, iaitu susunan sebaris dan berperingkat dangan mengunakan perisian ANSYS Fluent. Hasil daripada simulasi yang mengunakan penukar haba aliran siling untuk kedua-dua susunan tiub bank telah dibincangkan dalam laporan ini dengan menyampaikan profil suhu, hadlaju dan juga tekanan. Dari hasil simulasi, perbandingan prestasi kadar pemindahan haba untuk kedua-dua susunan juga ditentukan dalam kajian ini dengan mengunakan perbezaan pada suhu udara untuk menunjukkan kadar pemindahan haba bagi setiap susunan. Prestasi kedua-dua susunan menunjukkan bahawa susunan tiub bank berperingkat mempunyai kadar pemindahan haba yang lebih tinggi berbanding susunan tiub bank sebaris. Hasil daripada simulasi juga telah disahkan dengan membandingkan hasil daripada eksperimen dan dari perbandingan tersebut, hasil dari kedua-dua pendekatan adalah dalam susunan yang baik.

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LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamic
DM	Design Modeller
SIMPLE	Semi-Implicit Method for Pressure Linked Equations

LIST OF SYMBOL

A	Area
d	Diameter
D	Outer diameter
S_T	Transverse pitch
S_L	Longitudinal pitch
S_D	Diagonal pitch
W	Watt
β	Angle

CHAPTER 1

INTRODUCTION

1.1 Background

Heat exchanger is a device or component that are used to change temperature between two fluid that have different temperature, which is it involve the heat transfer between fluid flow with the solid wall in order to make the fluid that flow to change the temperature as that are required. This application are widely used in engineering industry such as application in energy production, chemical processing, space heating and air-conditioning, food industry, waste heat recovery and many others in order to decreases the cost of fluid used. There are many types of heat exchanger that are used in industry like counter-flow, parallel-flow and cross-flow with mixed or unmixed as show in **Figure 1.1,** where the most common type of heat exchanger in industrial application due to large number of tube that packed in a shell with their axes parallel to that of the shell.

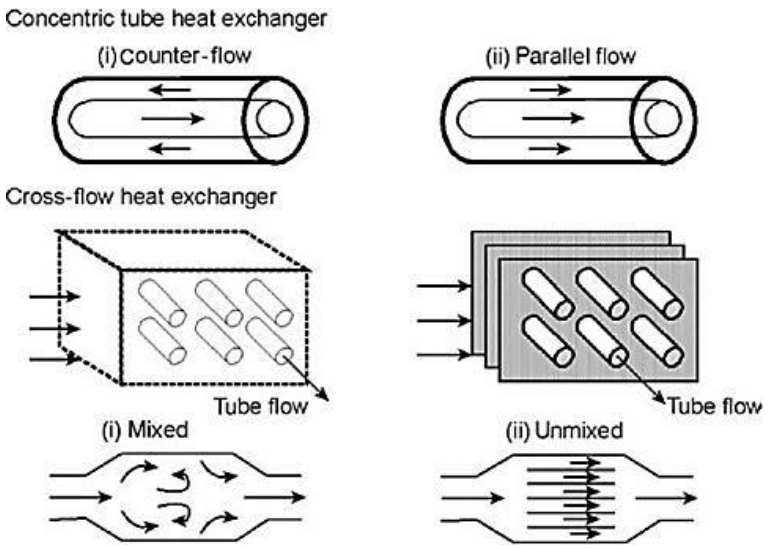

Figure 1.1 : Type of fluid flow (Incropera et al. 2007).

Mirzakhanlari et al. (2015) reported that there are classes of natural convention heat transfer over varied body separated into the internal and external flows, the internal flow is restricted by surface or crater meanwhile external flows around the body are evaluated in unrestricted area. In the heat exchanger, there have only the internal convection between the tube and two type of fluid which are in different temperature. Furthermore, Khan et al. (2006) reported that tube bank for heat exchanger in industry are commonly in an inline or staggered arrangement and there are categorised by the dimensionless transverse, longitudinal and diagonal pitches. To get the maximum of heat transfer rate on tube arrangement, the categorised must meet the perfect design and there need to study and proof by research.

The type of heat exchanger are not main concern for rate heat transfer in this study because the different of that type are only on direction of fluid flow, the main factor is the process of convection heat transfer between the tube and fluid flow. That why the design of tube arrangement in the heat exchanger also are one of the factor to achieve the maximum rate of heat transfer in that process.

1.2 Problem Statement

Mavridou et al. (2015) stated that the one of the main issues of heat exchange is that encounter throughout their operation is the deposit formation on the heat transfer area, that will increase the thermal resistance of the tube walls and decrease device potency. To archive the maximum rate of heat transfer on the process in heat exchanger, there many factors can help the process of heat transfer on fluid successful and one of the factors is the arrangement of tube bank in heat exchanger with categorised by the dimensionless transverse, longitudinal and diagonal pitches. Meanwhile, Saraireh et al. (2017) founded the type of tube bank which is a compact or widely tube bank also factor where given an

effect for result rate of heat transfer in the exchanger during their operation. Furthermore, Qiu et al. (2004) stated the tube spacing also give the very significant effect on the boiling heat transfer in compact tube bank whether of inline or straggled tube bank arrangement. To increase rate heat transfer, two type design of tube bank arrangement are study which is inline tube and staggered tube bank.

From the previous study of Saraireh et al. (2017) and Qiu et al. (2004), the arrangement of tube at tube bank are given significant effect on rate of heat transfer where it the most important criteria of heat exchanger during their operation. When the heat exchangers are producing the poor rate of heat transfer, it will give effect to the other system that required the fluid became the lowest temperature such as at power plant where the heat exchanger are used to cooling down the oil lubricant for bearing inside the turbine. If the oil lubricant are not in lowest temperature, it can make the bearing became hotter and expanded due to temperature lubricant and operation which can be damage the bearing and also the rotor shaft.

1.3 Objective

In this study, there are focuses on the convective rate of heat transfer in heat exchanger between two types of tube bank arrangement that have in an industry today. The objectives of this study are:-

- To study and simulate the heat transfer in an array of inline tube and staggered tube.
- To study and compare the performance of inline tube and staggered tube.
- To study and validate the result with experiment.

1.4 Scope

For this study, the objectives is focus to simulate and comparing the heat transfer rate between two type arrangement, which is inline and staggered arrangements by referring the temperature difference of air that flow through the heat exchanger. Furthermore, the type of heat exchanger that is considered in this study is only the cross-flow heat exchanger. Moreover, to achieve the objective of this study, there have the scope of work to be done so that at in the end of this study get the proper result of rate of heat transfer by referring the temperature different of air flow of each tube bank arrangement. Firstly, there need to construct the tube bank arrangement, which is the inline and staggered tube arrangement type by set the value of longitudinal and transverse pitch using SOLIDWORK. Secondly, to simulate the heat transfer rate in an array of inline tube and staggered tube arrangements is using Computational fluid dynamic (CFD), which the software is the ANSYS Fluent. Lastly, to analyses and validate the result from simulation, which is CFD by comparing with experimental result.

CHAPTER 2

LITERATURE REVIEW

2.1 Tube Bank

Tube bank is the array of tube that are commonly design in the heat exchanger and it usually found in circular tube but it also can be other geometry like the rectangular tube. The tube banks are also attached on the plain plate surface or finned plate.

2.1.1 Tube Bank Arrangement

This study is to investigate the type of the arrangement for tube bank, which is commonly used in cross-flow of heat exchanger, so the understanding of tube arrangement are needed before do the comparison of the heat transfer rate by referring the temperature different between the tube bank arrangement. Tube is a hollow circular component of metal where are used in heat exchanger to transmit or holding a substance such as fluid or gas from inlet section to outlet section. Furthermore, in the industrial application there have a tube material that can transmit the fluid with a highest temperature like in the boiler, which is at the inside of boiler there have many tubes to produce the superheated steam to supply at turbine in order to generate the electricity. Other than that, the tube also can be found as circular component where acting as fin where to increase the heat transfer rate for cooling. By attaching the surface extended surface called as a fin, it will increase the surface area, which is used to transmit the heat to surrounding by convection process (Incropera et al. 2007).

When the array of tube are arranged in a set of tube, it is called as tube bank or tube bundle and usually it was found in the heat exchanger such as condenser, boiler, and radiator, where the applications have widely in industry such as power plant, chemical industry, food industry, air conditioning and many other. Furthermore, Qiu et al. (2004) also stated there have the tube bank have been widely used for desalination and solar power absorption chillier which flooded type or full liquid type evaporator where the fluid boils on outside of tube bank. Furthermore, there have two types of arrangement that have widely used in industry application which inline arrangement and staggered arrangement with plain surface plate of tube bank (Saraireh et al. 2017, Wang et al. 2016). In particular, the arrays of tube bank arrangement are typically used to enhance the maximum of heat transfer rate compare to the single passes tube (Bender et al. 2018, Uguru-Okorie et al. 2018).

Moreover, the inline and staggered tube bank arrangement are usually in the type of cross flow where the two type of fluid at a perpendicular angle to each other flow direction. According to the configurations of flow in model heat exchanger, the flow can be categorised into their type and there have two types of flow in cross flow heat exchanger, which is mixed and unmixed flow. If the fluid flow on surface tube and it is can move freely in a transverse direction, then this arrangement called as mixed meanwhile if both of the fluid flow passes through their own tunnel and only strictly move in a transverse direction, the arrangement called as unmixed (Rathore et al. 2011).

Furthermore, in the both of tube bank arrangement there has two type fluids with different state, which is one fluid moves over the tubes, while a second fluid different temperature passes through the tube. The fluid that are move over the tube surface will exchange the heat between with the fluid the passes through the tube in order to increase or decrease the temperature fluid that passes through the tube (Mangrulkar et al. 2017). On

the other hand, there was had the studies to purpose the new design of tube bank arrangement which trapezoidal tube bank, which is the new design are for enhance the heat transfer rate in heat exchangers (Bender et al. 2018).

2.1.2 Tube Bank Characteristics

For the both tube bank arrangement, which is the inline tube bank and staggered tube bank, there have a configuration that can affect the value of heat transfer rate on the heat exchanger. According Incropera et al. (2007), the configuration parameter that consider is diameter (d), transverse pitch (S_T), longitudinal pitch (S_L), diagonal pitch (S_D), and Reynolds number. The outer Diameter (D) of the tube is a characteristic length, where are used to identified the Reynolds numbers.

Figure 2.1 shows that the parameter in the inline and staggered tube bank arrangement. Firstly, the S_T is the transverse distance between two tube on tube bank from the air flow direction, meanwhile S_L is the longitudinal distance between two tube on tube bank from air flow direction which both configuration important in tube bank design. On the other name, Gowda et al. (1998) are called as pitch to diameter for both pitch and for this two configuration, there have in both arrangement, inline tube bank arrangement and staggered tube bank arrangement. However, in staggered arrangement of tube bank there has additional configuration that need to consider, which is the S_D and it is the diagonal distance between two tube canter in the tube bank.

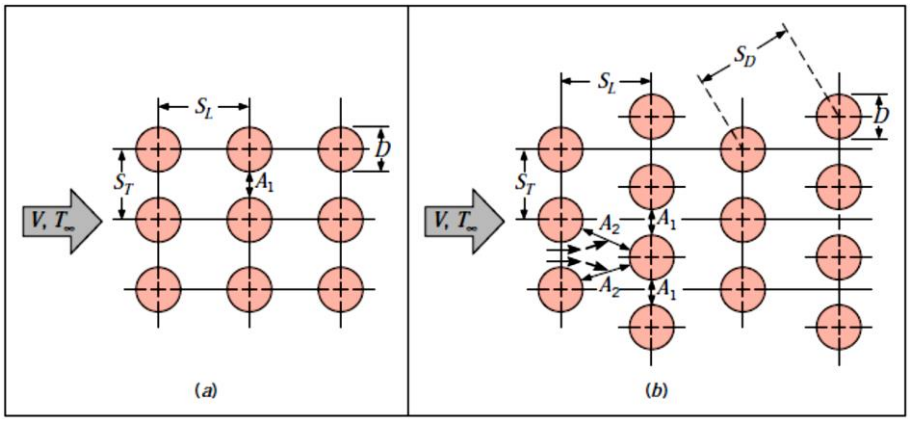

Figure 2.1 : Tube bank arrangements. (a) Inline. (b) Staggered (Incropera et al. 2007).

2.2 Convection Heat Transfer

Convection is one of modes in heat transfer process. This process are involve energy transfer between a solid surface and the fluid that flow outside of solid surface.

2.2.1 Tube Bank Arrangement

The capability of heat exchanger during operation to change the different temperature of fluid or gas was measured by the values of heat transfer rate that it will capable to archive during the process. To get the better heat transfer rate for the heat exchanger, the arrangements of tube are also one of factor to enhance the maximum heat transfer rate, so that in this study the comparison between inline and staggered tube bank arrangement were investigate. The designs of the tube bank are important to make the heat exchanger more favourable with its dimension and value heat transfer. Saraireh et al. (2017) found that the inline tube arrangement provided higher heat transfer rate compared to the staggered tube arrangement where 10.14 kW and 9.39 kW, respectively through the comparison of Computational Fluid Dynamic simulation by using FLUENT software. The configuration for the tube that are used in the study is diameter tube equal to 10 mm, transverse pitch S_T = 30 mm and longitudinal pitch S_L = 35 mm. In the terms for spacing between tube on the tube bank, **Table 2.1** shows the result that the compact of tube bank