Convective heat transfer study on the spiral finned tube heat exchanger under various fin pitch arrangements

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Abstract. Tube-type compact heat exchangers are one of the most commonly used heat exchangers in the industry. Compact heat exchangers are known for their large surface area to volume ratios allowing more optimal heat transfer rate. This study examines both the coefficient and the rate of convective heat transfer on the outer surface of a tube-type compact heat exchanger. The heat exchanger was configured in the sharp turns and spiral fin which is varied in pitch. The Fin pitches were 1 cm, 2 cm, 3 cm, 5 cm, and 7 cm. The length of the heat exchanger pass was 30 cm with a turn length was 8.2 cm and the total length of the heat exchanger was 6 m. Heat exchangers were made using galvanized pipes with an inside diameter (Di) 20 mm and an outside diameter (Do) of 22 mm, fins are made using aluminium with a thickness of 0.3 mm. Water was maintained at a constant temperature of 80 °C and circulated into the heat exchanger with a flow rate of 0.4 L/s. The air was blown using a fan with varying speeds of 2.4 m/s, 2.8 m/s and 3.4 m/s (the ambient air temperature was 28 °C). The results showed that the highest convection heat transfer coefficient and heat transfer rate occurred in the heat exchanger with a fin pitch of 2 cm, because the turbulence was more optimal and fewer airflow losses. In the heat exchanger with a fin pitch of 3 cm, 5 cm and 7 cm has a large gap between the fins so that turbulence is not optimal while in the heat exchanger with a fin pitch of 1 cm the gap between the fins is too small so that it inhibits the rate of airflow.

Keywords: Compact heat exchanger, Fin pitch, Convection heat transfer

1. Introduction

The process of thermal energy exchange between two or more fluids at different temperatures takes place in many engineering applications. The device used to exchange thermal energy is known as a heat exchanger. Specific applications of heat exchangers can be found in air conditioning system, power generation, and many industrial processes.

The classification of the heat exchanger depends on the aspect reviewed, one of which is based on the surface area of the heat transfer. The compact heat exchanger is a type of heat exchanger that is commonly applied in many industrial processes. This is due to the compact heat exchanger has a large heat transfer area to volume ratio. So that with a small size, the compact heat exchanger can produce a large convection heat transfer coefficient \( h_c \).

One of the factors that influence the performance of the heat exchanger is the convection heat transfer coefficient. The convection heat transfer coefficient is influenced by fluid flow turbulence [1]. To

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increase the turbulence of fluid flow can be done in various ways, including using a sharp turn heat exchanger, increasing the speed of fluid flow, increasing the mass flow rate of the fluid, and adding internal and external fins [2-4]. The addition of fins to the outer surface of the heat exchanger can increase the turbulence of fluid flow that passes through the heat exchanger [5].

Characteristics of forced convection heat transfers in a tube-type heat exchanger with sharp turn have been conducted by Hafiz et al and Pratama et al [6,7]. Carija et al [8] have carried out the heat transfer analysis of fin-and-tube heat exchanger with flat and louvre fin geometries. The effect of performance parameters on the turbulent flow regime on plate-fin and tube heat exchanger has been studied by Bhuiyan et al [9]. To enhance the performance of tube heat exchanger with several fin geometries (plain, herringbone wavy, smooth wavy, louvre, slit, composite, annular, and corrugated fins) have investigated by some researches [10-15].

A review of the literature [1-15] shows that there is no study on the Spiral finned tube heat exchanger that specifically addresses the convective heat transfer of the heat exchanger under various fin’s pitch arrangements. This study aims to investigate the convection heat transfer on the outer surface of the tube-type heat exchanger with a sharp turn. The spiral fin added to the outer surface of a heat exchanger with fin pitch variation. This study involved the finless heat exchanger, heat exchanger with fin pitch 1 cm, 2 cm, 3 cm, 5 cm, and 7 cm.

2. Experimental setup
The schematic of the test rig can be seen in Figure 1. The main components of the system are heat exchangers, heaters, fans, and measuring devices. The working fluids used in this study are water and air.

![Figure 1. Test rig](image)

This study involving finned-tube heat exchangers (spiral fin) with sharp turns. The heat exchanger was made using galvanized pipes with an inside diameter of 20 mm and an outside diameter of 22 mm, the total length of the heat exchanger was 6 meters. Aluminium spiral fins were mounted on the outer surface of the heat exchanger. The heat exchanger configuration that studies are finless heat exchanger, heat exchanger with fin pitch of 1 cm, 2 cm, 3 cm, 5 cm, and 7 cm (see Figure 2).
Figure 2. Heat exchanger configuration (a) fin pitch of 1 cm, (b) fin pitch of 2 cm, (c) fin pitch of 3 cm, (d) fin pitch of 5 cm, (e) fin pitch of 7 cm, (f) finless heat exchanger

An integrated water heater-pump was used to heat up the water to a temperature of 80 °C, then circulated into a heat exchanger with a flow rate of 0.4 L/s. Water entering the heat exchanger maintains at a constant temperature throughout the study. Thermocouples were used to measure the temperature of the water placed in the inlet and outlet of the heat exchanger. Air with a constant speed and temperature is circulated by the fan through the outer surface of the heat exchanger. Each heat exchanger configuration was studied using three variations of air velocity namely 2.4 m/s, 2.8 m/s and 3.4 m/s. The temperature of the air was measured using a thermocouple that placed in front of and behind the heat exchanger with a distance of 10 cm. The study was conducted for 40 minutes for each heat exchanger configuration, experimental data was collected every 5 minutes.

3. Result and discussion
3.1. Result
The results of the study that have been carried out are shown in Figure 3.
Figure 3 shows the temperature difference (ΔT) of water at an air velocity of 2.4 m/s, 2.8 m/s, and 3.4 m/s. A decrease in the temperature of the water exiting the heat exchanger is directly proportional to the air velocity. The greater the air velocity the greater the temperature decrease. This is due to the turbulence of airflow through the heat exchanger increases so that the rate of heat absorption also increases.

3.2. Analysis
Convection heat transfer rate analysis was performed based on experimental data of water temperature difference. The results of the convection heat transfer rate analysis are shown in Figure 4.
Figure 4. Convection heat transfer rates at three different air velocity

Figure 4 shows the average convection heat transfer rate for each heat exchanger configuration with different airspeeds. The addition of spiral fins to the outer surface of the heat exchanger can significantly increase the rate of convection heat transfer. Different fin pitch configurations affect the rate of convection heat transfer. The heat exchanger with a fin pitch of 2 cm produces the most optimal convection heat transfer rate compared to other heat exchanger configurations.

At an air velocity of 2.4 m/s the average convection heat transfer rate for heat exchangers with fin pitch of 2 cm is 6811.7 W. The average convection heat transfer rate for heat exchangers with fin pitch of 2 cm increased by 3.9% at an airspeed of 2.8 m/s. The increase in the average convection heat transfer rate at an air velocity of 3.4 m/s for heat exchangers with a fin pitch of 2 cm is 5.2%.

3.3. Discussion
Convection heat transfer coefficient was analyzed based on the convection heat transfer rate. The average convection heat transfer coefficient for each heat exchanger configuration is shown in Figure 5.

Figure 5. Average convection heat transfer coefficient
Figure 5 shows the average convection heat transfer coefficient for each heat exchanger configuration at an air velocity of 2.4 m/s, 2.8 m/s and 3.4 m/s. The convection heat coefficient is influenced by several factors including the difference in temperature (ΔT), heat transfer rate (Q) and surface area (A).

The heat exchanger with fin pitch of 2 cm produces the highest convection heat transfer coefficient compared to a heat exchanger with fin pitch of 1 cm, 3 cm, 5 cm, and 7 cm. The airflow turbulence in the heat exchanger with fin pitch of 2 cm is more optimal, due to their gap of the fin is not inhibit the airflow. In the heat exchanger with a fin pitch of 1 cm, the fin gap is too small causes the rate of airflow is inhibited. While the heat exchanger with fin pitch of 3 cm, 5 cm, and 7 cm have a large fin gap so the airflow turbulence is not optimal.

4. Conclusion
For this study, it can be concluded that the fin pitch affects the rate of convection heat transfer and the coefficient of convection heat transfer that occurs in finned-tube heat exchangers. The greatest convection heat transfer rate and the convection heat transfer coefficient were produced by a heat exchanger with a fin pitch of 2 cm. Due to the airflow turbulence that passes through the fins on the heat exchanger with a fin pitch of 2 cm is more optimal compared to the heat exchanger with fin pitch of 1 cm, 2 cm, 3 cm, 5 cm, and 7 cm.

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