Heat transfer analysis in fluidized bed dryer with heat exchanger pipe for corn material

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Abstract. This research aims to know the heat transfer process on the fluidized bed dryer for corn material. In this study conducted observations on the temperature and heat produced during the drying process, with three different pipe heat exchanger: spiral, parallel, and combination; The air of the air was 2 m/s, 4 m/s, and 6 m/s and the mass of corn material was 1.5 kg with an initial moisture content of 24%. Test results showed that the highest-produced temperature in the combination heat exchanger pipe with a drying room temperature averaged 54°C. The value of the highest convection coefficient of heat transfer in the combination heat exchanger pipe flow treatment with the air velocity of 6 m/s by 29.4 W/m²K. The heat energy that enters at the treatment of combination heat exchanger pipe with the air speed of 6 m/s by 1774 Watts. Heat energy is lost through the highest wall drying chamber at the combination heat exchanger pipe flow treatment with the air velocity of 6 m/s by 409 Watts. The heat energy used is 335 Watts to dry the highest material in the combination heat exchanger pipe flow treatment with the air speed of 6 m/s.

1. Introduction

Fluidization is closely related to many industrial chemical processes, non-catalytic chemical processes such as thermal cracking and coal gasification, and physical processes such as drying and absorption. In addition, continuous fluidization is widely used in processing plants to move solids from one place to another and is used in the drying process of agricultural products in the form of grains. In the power generation industry, fluidization is used for the drying process of coal.

Fluidization is also used to dry agricultural products such as corn. The working principle of fluidization in drying is blowing hot air by a blower fan through a channel above the dryer that penetrates the expanse of material so that the material can move and has fluid-like properties. In the use of this dryer, it is necessary to pay attention to the temperature setting, the speed of the drying air flow, and the thickness of the pile of material being dried so that the expected dry results can be achieved [1].

In the previous study, Syahrul et al [2] have investigated the effect of the air temperature entering the fluidized grain drying chamber. Following by A. Halim [3] has conducted research on fluidized bed dryers by examining modifications of fluidized bed dryers by adding a heating system using biomass fuel. In the fluidized bed dryer this has been modified and added a heating system with a spiral pipe type using biomass with candlenut shell fuel. As it is known that by using biomass, the heat produced will be difficult to control, so the researchers modified the biomass furnace by heating the water to a temperature of 100°C, then the water flowed through a spiral type pipe that is installed in the heat conductor pipe to the drying chamber. In drying with this fluidized system where air has an important role. By adding a heating system as a tool to heat water using biomass, it is expected to stabilize the temperature during the drying process. After modification and performance test, the resulting temperature during drying is around 53°C. With the addition of a spiral pipe to the plenum pipe, the temperature increase in the drying chamber has
not been maximized; therefore further research is carried out by adding a parallel heat exchanger pipe in the drying chamber.

In this study, the researchers wanted to analyze the heat transfer in a fluidized bed dryer with the addition of a heat exchanger pipe in the drying chamber which is in direct contact with the material to be dried. With the addition of a heat exchanger pipe in the drying chamber, it is hoped that more time efficiency during the drying process occurs. The process that occurs in the heat exchanger pipe in the drying room is the same as the process in the spiral pipe in the plenum where the hot water source is in the heated boiler. The addition of parallel heat exchanger pipes in the drying chamber in order to increase the hot air entering the drying chamber. Based on the description above, research was conducted on "Analysis of Heat Transfer in Fluidized Bed Dryers". The purpose of this study was to determine the process of heat transfer in the fluidized bed dryer.

2. Materials and Methods
The tools used in this research are fluidized beds dryer, biomass furnace, 24 volt DC pump, anemometer, grain moisture meter 6MK-303RS, 4 in blower, analytical balance, wet bulb and dry bulb thermometer, stopwatch, ruler, and gas stove. While the research materials used in this study were shelled corn kernels with an initial moisture content of 24%. The methods used in this research are experimental and theoretical methods. This test was carried out using a fluidized bed dryer on corn with a mass of 1.5 kg and air flow velocities of 2, 4, and 6 m/s. This study used 3 treatments, namely spiral heat exchanger pipe flow, parallel heat exchanger pipe, and a combination of both heat exchanger pipes.

The incoming heat is the heat received into the drying chamber which can be calculated by the following equation [4]:

\[ q_k = h A (T_s - T_\infty) \]  

where:
- \( q_k \) = Convective heat transfer rate (Watt)
- \( h \) = Convection heat transfer coefficient (W/m²°C)
- \( A \) = Heat transfer surface area (m²)
- \( T_s \) = Surface temperature (°C)
- \( T_\infty \) = Fluid temperature (°C)

The heat loss that occurs through the walls of the drying chamber can be calculated by the following equation [5]:

\[ Q_{Wall} = h A \frac{T}{\Delta X} \]  

where:
- \( Q_{Wall} \) = Heat lost through the walls of the drying chamber (Watt)
- \( h \) = Coefficient of convection (W/m²°C)
- \( A \) = The outer surface area of the drying chamber wall (m²)
- \( T \) = Temperature Difference (°C)
- \( \Delta X \) = Drying chamber wall thickness (m)

The heat used to dry the material can be calculated by the following equation [6]:

\[ Q = m C_p T \]  

where:
- \( m \) = Intake air flow rate (kg/s)
- \( C_p \) = Specific heat of air (J/kg°C)
$T = \text{Temperature difference (°C)}$

Figure 1. Fluidized bed dryer.

The experimental apparatus can be seen in Figure 1.

- T1 = Blower Temperature
- T2 = Heater Temperature
- T3 = Plenum Pipe Temperature
- T4 = Inlet Water Temperature in Spiral Pipe
- T5 = Outlet Water Temperature in Spiral Pipe
- T6 = Inlet Water Temperature in Parallel Pipe
- T7 = Outlet Water Temperature in Parallel Pipe
- T8 = Inlet Temperature
- T9 = Bottom Dryer Room Temperature
- T10 = Middle Drying Room Temperature
- T11 = Top Dryer Room Temperature
- T12 = Outlet Temperature

3. Results and Discussion

The following results have been calculated from the experimental data. As a heat transfer analysis, the data error might range from 10 to 15 percent. Figure 2 shows the highest amount of heat entering the drying chamber in the combined pipe flow treatment, air velocity 6 m/s of 1774 Watt, air velocity of 4 m/s of 1243 Watt, and air velocity of 2 m/s of 753 Watt. This is because in the combined pipe treatment there are two heat sources, namely the spiral and parallel heat exchanger pipes. Comparing the research results between each flow in the spiral and parallel heat exchanger pipes, the highest amount of heat entering the drying chamber is in the parallel heat exchanger pipe flow with an air velocity of 6 m/s of 301 Watt, an air velocity of 4 m/s of 221.8 Watt, and a speed of 2 m/s of 119.7 Watt, and the lowest amount of heat entering the drying chamber on a spiral heat exchanger pipe flow with an air velocity of 6 m/s of 275.5 Watt, an air velocity of 4 m/s of 195 Watt, and the air speed of 2 m/s is 115.5 Watt. This is because the parallel pipe flow that is located in the drying chamber is in direct contact with the material so that the resulting temperature is greater. The greater the temperature produced, the greater the incoming heat.
Figure 2. Heat Inlet to Drying Room.

Figure 3. Heat Loss from Drying Room.

As seen in Figure 3. The heat energy lost through the walls of the drying chamber in the combined heat exchanger pipe flow treatment with an air velocity of 6 m/s of 409 Watt, an air velocity of 4 m/s of 244 Watt, and air velocity of 2 m/s of 162 Watts.
Figure 4. Heat Use to Dry Material.

Viewed from Figure 4, it shows the calculation results of the highest heat values occur in the treatment of combined heat exchanger pipe flow with an air velocity of 6 m/s of 335 Watt, an air velocity of 4 m/s of 202 Watt and an air velocity of 2 m/s of 117 Watt. This is due to the heat used to dry the material. There are two sources of spiral and parallel heat exchanger pipe flow. Comparing the results of research on the treatment of each flow in spiral and parallel heat exchanger pipes, the heat value used to dry the material is the highest in the treatment of parallel heat exchanger pipe flow with an air velocity of 6 m/s of 240 Watt, an air velocity of 4 m/s of 176.5 Watt, and air velocity of 2 m/s of 96 Watt, and the amount of heat used to dry the lowest material in a spiral heat exchanger pipe flow with an air velocity of 6 m/s of 226 Watt, speed 4 m/s air is 157.5 Watt, and 2 m/s air speed is 87.6 Watt. This is because the parallel heat exchanger pipe is in the drying chamber which is in direct contact with the material so that it produces a higher temperature than the treatment in the spiral heat exchanger pipe flow. The higher the temperature in the drying chamber, the higher the heat used to dry the material. More study to analyze and optimize the energy consumption in fluidized bed drying can be found in Babaki et al. [7].

4. Conclusion
The highest amount of heat energy entering the drying chamber in the combined heat exchanger pipe flow is 1774 Watt, 1243 Watt, and 753 Watts with an air velocity of 6, 4 and 2 m/s respectively. The energy used to dry the material is highest in the combined heat exchanger pipe flow treatment with an air velocity of 6 m/s of 335 Watt, an air velocity of 4 m/s of 202 Watt and 117 Watts for air velocity of 2 m/s.

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