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ANALYSIS OF THE THERMAL CONDUCTIVITY OF CORN HAIR (ZEA MAYS) AS AN ALTERNATIVE INSULATOR MATERIAL IN HEAT EXCHANGERS

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KeyWords
heat transfer rate, thermal conductivity, insulator, corn hair

ABSTRACT

Corn hair biomass (zea mays) is an agricultural commodity that is available in large quantities and is underutilized. In this research, corn hair biomass was used as an insulating material to reduce heat loss in heat exchangers in the form of heating pipes. Tests were carried out using corn hair as an insulating material. Variations in the thickness of the insulators used are 0.005 m, 0.01 m and 0.015 m. Corn hair (zea mays) is wrapped around a copper pipe that has a diameter of 1.22 cm and a length of 28 cm. The inlet water temperature is 71.5^0C ± 1^0C, the outlet water temperature is 70.5^0C ± 1^0C, the pipe surface temperature is 65.5^0C ± 1.5^0C and the corn hair (zea mays) surface temperature is 37^0C ± 1.5^0C. The results of the research show that the smallest heat transfer rate occurs in corn hair with a thickness of 0.015 m, namely 87.2 watts, while the highest heat transfer rate occurs in corn hair with a thickness of 0.005 m, namely 93.95 watts. This happens because the thicker the insulator, the smaller the rate of heat transfer that occurs. The thermal conductivity that occurs for variations in the thickness of corn hair (zea mays) is at a thickness of 0.005 m it is 1.181 W/m.^{0}C, at a thickness of 0.01 m it is 1.654 W/m.^{0}C and at a thickness of 0.015 m it is 1.881 W/m.^{0}C. The thermal conductivity values that occur for variations in corn hair thickness are different, this is more due to the non-uniform density of the corn hair arrangement.

Introduction

Energy conservation is an important issue in the modern era. There are several forms of energy conservation, one of which is through heat insulators. Heat insulators have wide applications, including as wall lining materials for heat exchangers, ovens, kilns, pipe installations in air conditioners, hot water pipe installations in bathrooms, and other hot water pipe installations. Heat insulators are materials or combinations of materials that can inhibit the flow of heat energy. The energy lost for a heat insulator material depends on the thermal properties and thickness of the medium used. A material is said to be an insulator if it meets several requirements, including having low thermal conductivity, being able to prevent heat leaks, having durability and light weight, the material used is easy to obtain, and has a fairly economical price [1].

Thermal insulation is used to reduce excessive energy losses due to heat transfer from the system to the environment or vice versa. Thermal insulation evolved not only to avoid heat leaks, but is used to control temperature. The thermal insulation function is very important in the use of heat energy which must be as efficient as possible. Therefore, thermal insulation materials are needed that have low material thermal conductivity [2].

This type of heat transfer mechanism is called heat transfer by conduction and convection. Conduction heat transfer is the process of moving through a stationary medium such as: copper, water or air. Conduction heat transfer: If an object has a temperature gradient, then according to experience there will be a transfer of energy from the high temperature area to the low temperature area. We say that energy is transferred by conduction and that the rate of heat transfer is proportional to the normal temperature gradient [3]. In terms of convection, heat transfer is the transfer of heat by means of fluids either moving naturally or by force.

Research on the effect of density and thickness on the heat insulator properties of rice husk particle board. The use of rice husks is mostly agricultural waste, so researchers use it more in the engineering field, where the rice husks are made into rice husk particle boards with 3 thickness variations and 4 compaction variations. The results of thermal conductivity research on rice husk particle board with several thickness variations were obtained at a thickness of 1 cm and a density of 6-1 & 5-1, the thermal conductivity value was small (0.0798 W/m.^{0}C), at a thickness of 2 cm, a density of 12-2 The thermal conductivity value is large (0.238 W/m.^{0}C) so that particle board with a thickness of 1 cm and a density of 6-1 is good for use as a heat insulator material [4].

Research on kapok fiber which is used as raw material for making heat insulators. Kapok fiber is used as reinforcement and polypropylene mesh is used as matrix. Making composites from these two materials is carried out using the hot press method. The composite is made with 3 different compositions of kapok and polypropylene, namely 25:75, 20:80 and 15:85. Based on the results of hot and cold temperature resistance testing, it is known that composites with a composition of 25:75 have the best ability to maintain room temperature. The percentage of kapok fiber in the composite is directly proportional to the thickness of the composite and the ability of the composite to maintain temperatures in hot and cold rooms [5].

Evaluate the heat loss results when the heat exchanger uses an insulator and without an insulator. The analysis results obtained show a very significant difference where the amount of heat lost when the heat exchanger does not use an insulator is very large, namely 655.7 BTU/hr.ft, while the amount of heat lost when using an insulator is only 261.36 BTU/hr.ft. The results of the heat loss analysis can be concluded that the use of insulators in heat exchange systems is very necessary to reduce the amount of heat lost and can save energy use. The amount of heat savings obtained was 394.34 BTU/hr.ft with an insulation thickness of 3.24 inches [6]. Addition of insulator thickness from 3 mm, 6 mm, to 9 mm. The research results show that an insulator with a thickness of 9 mm can reduce heat the best, so the thermal resistance value is higher and conversely the value of the heat rate coming out of the furnace surface is getting smaller [7].

Research Methods

The method used is pure experimentation by conducting research in the laboratory to understand the processes as a whole and the factors that influence the heat transfer process.

The tools and materials used in this research include:

a. Research tools

1. Pan

   This pan will be used as a container for heating water.

2. Electric water heater

   An electric water heater is a device used to heat water where electricity is a source of energy or heat. The water heater power that will be used in this research is 1000 Watts.

3. Thermocouple

   A thermocouple is a type of temperature sensor that is used to detect or measure temperature through two different types of metal conductors which are combined at the ends, causing a "thermo-electric" effect.

4. PID

   The PID control system is a controller for determining the precision of an instrumentation system with the characteristics of feedback on the system. The PID control system consists of three control methods, namely P (proportional), D (derivative) and I (integral) control, each of which has advantages and disadvantages. The implementation of each method can work alone or in combination. In research, PID works to regulate the temperature to be constant.

5. Selector

   The selector is a tool for connecting a thermocouple so that it can set or adjust the output temperature to be measured.

6. Digital thermometer

   With this tool the temperature can be read or to find out the output of the measured temperature.

7. Pump

   A water pump is an element that functions to absorb and push water contained in a cooling or heating system into a container so that the water can circulate.

b. Research materials

Water, connecting hoses, copper pipes, pvc pipes, pipe connections, brass faucets, insulation, buckets, storage containers, clamps, corn hair (zea mays), bolts, nuts and washers, electrical cable terminals, cables, boards, wire, glass wool, aluminum foil. The insulator material is made from corn hair which is dried for ± 1 week. Next, the corn hair is twisted and wrapped around a copper pipe and pressed so that it is tight and dense, with thickness variations of 0.005 m, 0.01 m, 0.015 m. The input water is heated until the temperature reaches 72^{o}C ± 1.5^{o}C. The mass flow rate of water entering the copper pipe is 0.016 kg/s for all variations.

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Research tool scheme

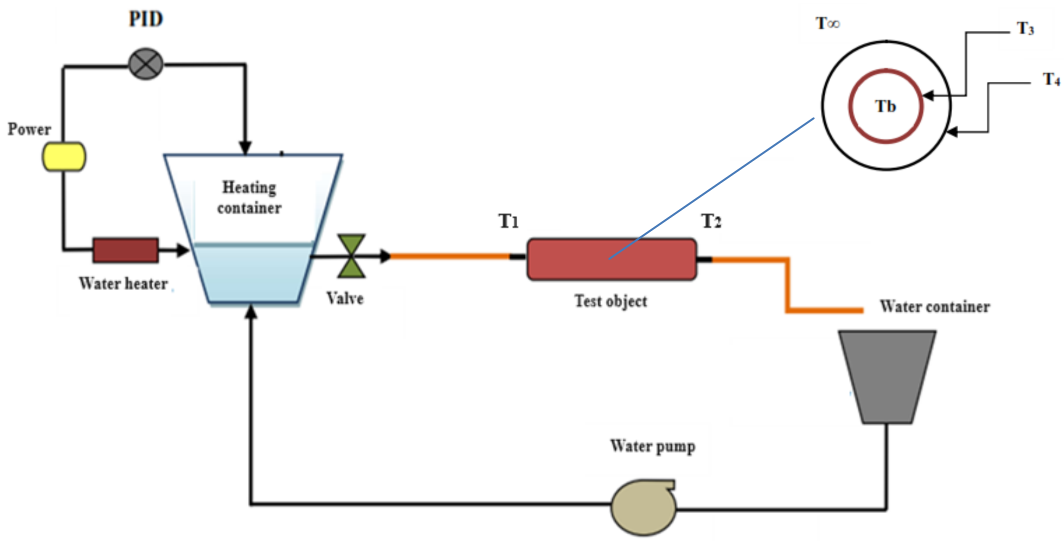

Figure 1. Test tool installation

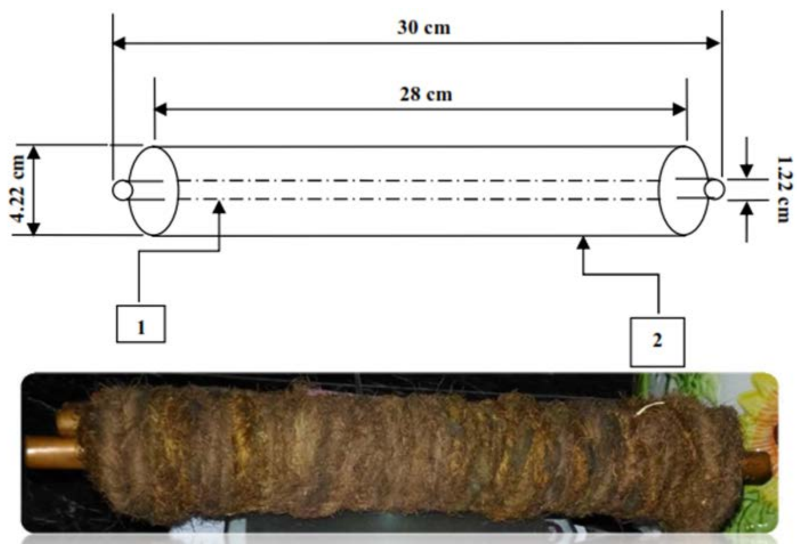

Figure 2. Test object, 1. copper pipe, 2. orn hair insulator

Results and Discussion

Table 1. Dimensions of pipes and corn hair (zea mays)

Thick corn hair (m)	Pipe outer diameter (m)	Corn hair diameter (m)	Long pipe (m)	Corn hair length (m)
0,005	0,0122	0,0222	0,30	0,28
0,010	0,0122	0,0322	0,30	0,28
0,015	0,0122	0,0422	0.,30	0,28

Table 2. Research data

Thick corn hair (m)	T1 (°C)	T2 (°C)	Tb (°C)	T3 (°C)	T4 (°C)	ΔT (°C)	$\dot{q}$ (Watt)	k (W/m °C)
0.005	71,3	69,9	70.,6	68,4	41,3	27,1	93,95	1,181

0,010	71,7	70,3	71,0	68,1	36,7	31,4	93,93	1,654
0,015	72,3	71,0	71,7	66,5	33,8	32,7	87,20	1,881

The research results show that for corn hair (zea mays) with a thickness of 0.005 m, the heat transfer rate value is 93.95 watts, with a thickness of 0.01 m the heat transfer rate is 93.93 watts. Meanwhile, corn hair with a thickness of 0.015 m has a heat transfer rate of 87.2 watts (table 2). The smallest heat transfer rate was shown in corn hair with a thickness of 0.015 m, namely 87.2 watts and the largest was shown in corn hair with a thickness of 0.005 m, namely 93.95 watts (figure 3). This is because the thicker the insulator or the thicker the layer of corn hair (zea mays), the smaller the outer surface temperature of the insulator, this has the consequence that the rate of heat transfer that occurs is also smaller (figure 3). The addition of thick corn hair (zea mays) can reduce the rate of heat transfer.

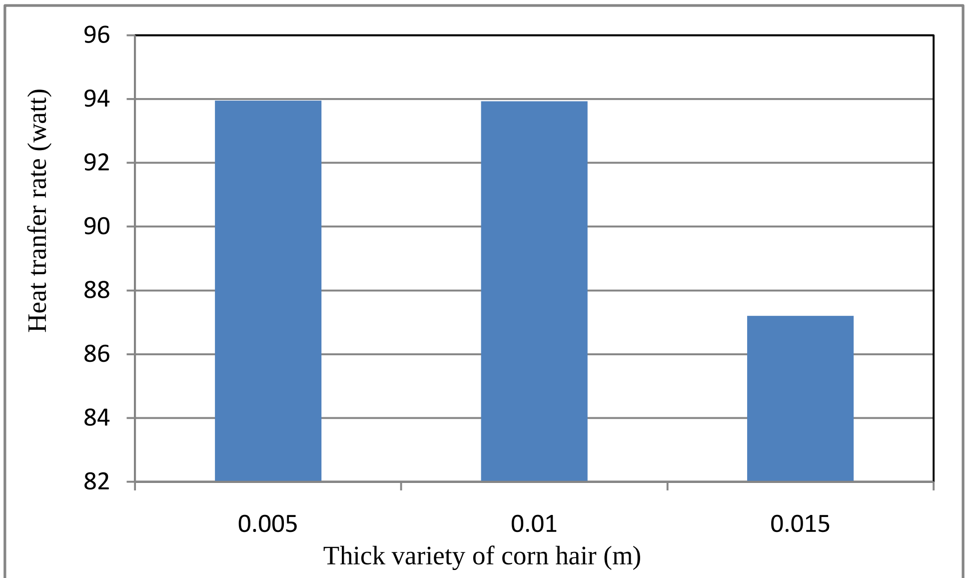

Figure 3. Graph of the relationship between heat transfer rate and variations in corn hair thickness

Figure 4 shows that for corn hair with a thickness of 0.005 m the thermal conductivity value is 1.181 W/m℃, for corn hair with a thickness of 0.01 cm the thermal conductivity value is 1.654 W/m℃, and for corn hair with a thickness of 0.015 cm the thermal conductivity value is obtained. of 1,881 W/m℃. The thermal conductivity value of a material is constant and is not affected by the thickness of a material. In this study, it was found that the thermal conductivity value of corn hair changes along with changes in the thickness of the corn hair, this is because the density of the insulator consisting of an arrangement of corn hair is not evenly distributed, thus affecting the temperature of the outer surface of the insulator.

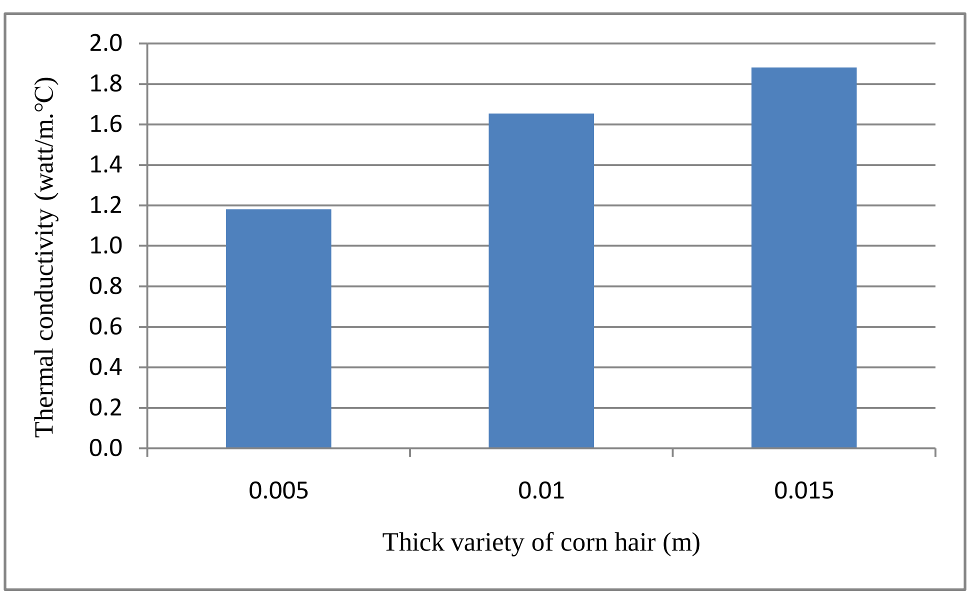

Figure 4. Graph of the relationship between thermal conductivity and variations in corn hair thickness

Conclusion

The smallest heat transfer rate occurs in corn hair with a thickness of 0.015 m, namely 87.2 watts, the greatest heat transfer rate occurs in corn hair with a thickness of 0.005 m, namely 93.95 watts. A thermal conductivity of 1,181 W/m oC occurs in the thickness of corn silk, namely at a thickness of 0.005 m, at a thickness of 0.01 m the thermal conductivity value is 1,654 W/m oC and at a thickness of 0.015 m the thermal conductivity value is 1,881 W/m oC. The addition of thick corn silk (zea mays) can reduce the rate of heat transfer.

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