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Thermal Conductivity Analysis of Coconut Fiber As an Insulating Material in Heat Exchangers

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ABSTRACT: *Coconut fiber is an abundant natural material and has thermal properties that allow its use in thermal insulation applications. This study aims to analyze the thermal conductivity of coconut fiber and evaluate its effectiveness as an insulating material in heat exchangers. Through experiments and testing, this study is expected to contribute to the development of natural resource-based insulation materials that are more environmentally friendly and economical. The research method involves testing the thermal conductivity of coconut fiber with variations in the thickness of the insulator used, namely 0.005 m, 0.01 m and 0.015 m. Coconut fiber is wrapped around a copper pipe with a diameter of 1.22 cm and a length of 28 cm. The inlet water temperature is 82ºC ± 1ºC, the outlet water temperature is 80.7ºC ± 1ºC, the pipe surface temperature is 77ºC ± 1.5ºC and the coconut fiber surface temperature is 36.8ºC. The results of the study showed that the smallest heat transfer rate occurred in coconut fiber with a thickness of 0.015 m, which was 80.52 watts, while the largest heat transfer rate occurred in coconut fiber with a thickness of 0.005 m, which was 134.21 watts. This happens because the thicker the insulator, the smaller the heat transfer rate that occurs. The thermal conductivity that occurs for variations in coconut fiber thickness is at a thickness of 0.005 m of 1,279 W/m.ºC, at a thickness of 0.01 m of 1,355 W/m.ºC and at a thickness of 0.015 cm of 1,393 W/m.ºC. Data analysis shows that coconut fiber has low thermal conductivity, so it can reduce heat transfer effectively. Factors such as fiber density and water content have a significant effect on insulation performance. From the results of the study, coconut fiber has been proven to be an alternative thermal insulator material that is environmentally friendly, cheap, and easy to obtain. The application of this material to heat exchangers has the potential to increase energy efficiency while reducing environmental impacts compared to synthetic insulators.*

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I. INTRODUCTION

Thermal efficiency in heat exchange systems is highly dependent on the insulating ability of the materials used. Heat exchangers play an important role in various industrial applications, such as power generation, cooling systems, and manufacturing. One of the main factors affecting the efficiency of heat exchangers is unwanted heat loss, which can be reduced by using the right insulating material.

Currently, many widely used thermal insulating materials are derived from synthetic materials such as fiberglass and polyurethane. However, these materials have several disadvantages, such as high production costs and significant environmental impacts due to the difficulty of the degradation process. Therefore, alternative insulators are needed that are more environmentally friendly, cheap, and easily recycled.

Coconut fiber is one of the natural materials that has great potential as a thermal insulator. Coconut fiber has a porous structure that can inhibit heat transfer, thus potentially reducing energy loss in heat exchange systems. In addition, coconut fiber is available in abundance, especially in tropical countries such as Indonesia, so its use can be a sustainable solution.

Energy conservation is one of the important issues 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 a wall covering material for heat exchangers, ovens, kilns, pipe installations in AC, 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 heat insulating materials depends on the thermal properties and thickness of the media used. A material is said to be an insulator if it meets several requirements, including having low thermal conductivity, being able to prevent heat leakage, having durability and light weight, the materials used are easy to obtain, and having 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 is developed not only to avoid heat leakage, but is used to control temperature. The function of thermal insulation 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 thermal conductivity of the material [2].

This heat transfer mechanism is called heat transfer by conduction and convection. Conduction heat transfer is the process of transfer through a stationary medium such as: copper, water or air. Conduction heat transfer if there is a temperature gradient in an object, then according to experience there will be a transfer of energy from the high temperature part to the low temperature part. We say that energy is transferred by conduction or delivery and that the rate of heat transfer is proportional to the normal temperature gradient [3]. By convection, heat transfer is heat transfer through a fluid, either moving naturally or forcibly.

Research on the effect of density and thickness on the properties of rice husk particle board heat insulators. The utilization of rice husks which are mostly agricultural waste, so researchers utilize 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 the thermal conductivity study on rice husk particle boards 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.ºC), at a thickness of 2 cm, a density of 12-2 the thermal conductivity value was large (0.238 W/m.ºC) so that particle boards with a thickness of 1 cm and a density of 6-1 are good for use as heat insulators [4].

Research on kapok fiber used as a raw material for making heat insulators. Kapok fiber is used as a reinforcement and polypropylene nets are used as a matrix. The manufacture of composites from these two materials is carried out using the hot press method. Composites are made with 3 different kapok and polypropylene compositions, namely 25:75, 20:80 and 15:85. Based on the results of the hot and cold temperature resistance test, it is known that the composite with a composition of 25:75 has 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 hot and cold room temperatures [5].

Evaluation of 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 analysis of the lost heat can be concluded that the use of insulators in the heat exchange system is very necessary to reduce the amount of heat lost and can save energy use. The amount of heat savings obtained is 394.34 BTU/hr.ft with an insulation thickness of 3.24 inches [6]. The addition of insulator thickness is 3 mm, 6 mm, up to 9 mm. The research results show that an insulator with a thickness of 9 mm can reduce heat best, so the thermal resistance value is higher and conversely the heat rate value coming out of the furnace surface is smaller [7].

II. RESEARCH METHODS

The method used is a pure experiment by conducting research in the laboratory to determine the processes as a whole and the factors that affect the heat transfer process.

The tools and materials used in this study include:

a. Research tools

1. Pan

   This pan will be used as a container to heat water.

2. Electric water heater

   An electric water heater is a tool used to heat water where electricity is the source of energy or heat. The power of the water heater to be used in this study is 1000 Watts.

3. Thermocouple

   A thermocouple is a type of temperature sensor used to detect or measure temperature through two different types of conductor metals that are combined at the ends to create a "thermo-electric" effect.

4. PID

   The PID control system is a controller to determine 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), each with 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 regulate the output temperature to be measured.

6. Digital thermometer

   On this tool, the temperature can be read or to find out the output results of the measured temperature.

7. Pump

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

b. Research materials

Water, connecting hose, copper pipe, PVC pipe, pipe joints, brass taps, insulation, buckets, containers, clamps, coconut fiber, bolts, nuts and washers, electrical cable terminals, cables, boards, wires, glass wool, aluminum foil. insulating material is made from coconut fiber that is dried for ± 1 week. Furthermore, the coconut fiber is twisted and wrapped around the copper pipe and pressed so that it is tight and solid, with variations in thickness of 0.005 m, 0.01 cm, 0.015 cm. The input water is heated to a temperature of 82°C ± 1°C. The mass flow rate of water entering the copper pipe is 0.016 kg/s for all variations.

Scheme of research tools

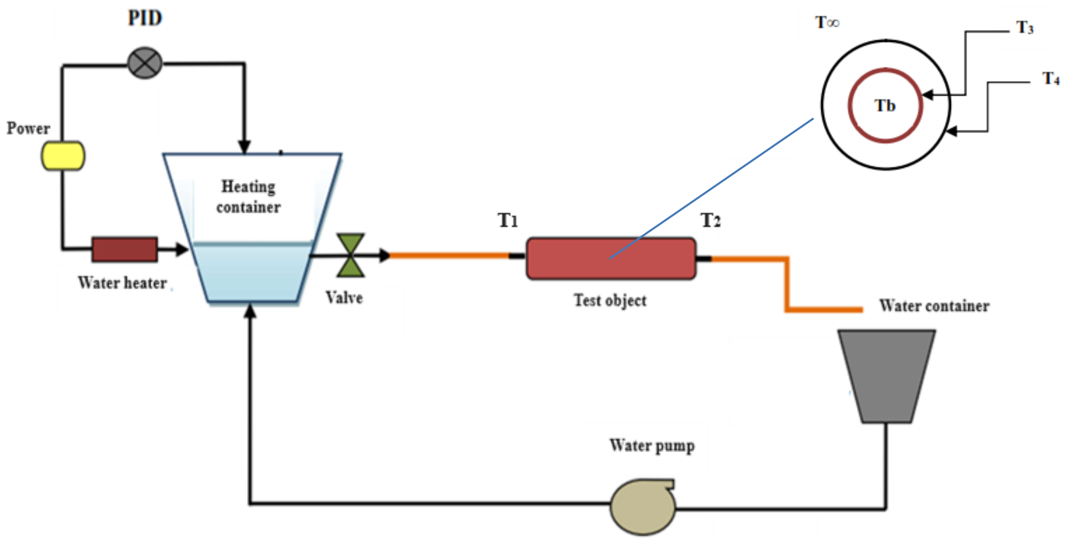

Figure 1. Test tool installation

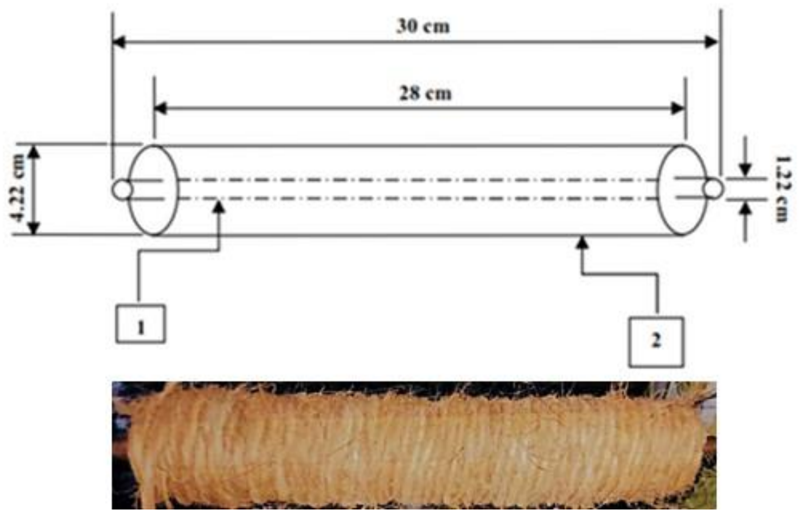

Figure 2. Test object, 1. copper pipe, 2. coconut fiber insulator

III. RESULTS AND DISCUSSION

The results showed that for coconut fibers with a thickness of 0.005 m obtained the value of the heat transfer rate of 134.21 watts, the thickness of 0.01 M heat transfer rate of 93.95 watts. While coconut fibers with a thickness of 0.015 m heat transfer rate of 80.52 watts (Table 2). The smallest heat transfer rate is shown in coconut fibers with a thickness of 0.015 m which is 80.52 watts and the largest is shown in coconut fibers with a thickness of 0.005 m which is 134.21 watts (Figure 3). This is because with the thicker the insulator or the thicker the arrangement of the coconut fibers, the surface temperature of the outer part of the insulator is smaller, this brings the consequences at the smaller the rate of heat transfer that occurs (Figure 3). The addition of thick coconut fibers can reduce the rate of heat transfer.

Table 1. The size of the dimensions of the pipe and coconut fibers

Thick coconut fibers (m)	The outer diameter of the pipe (di) (m)	Diameter of coconut fibers (do) (m)	Pipe length (L_1) (m)	Length of coconut fibers (L_2) (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 results data

Thick coconut fibers (m)	T1 (℃)	T2 (℃)	Tb (ºC)	T3 (ºC)	T4 (ºC)	ΔT (ºC)	$\dot{q}$ (Watt)	k (W/m.ºC)
0.005	81.8	79.8	80.8	76.2	39.7	36.5	134.21	1.279
0,010	82.1	80.7	81.4	77.1	37.5	39.6	93.95	1.355
0,015	83.0	81.8	82.4	78.8	33.2	45.6	80.52	1.393

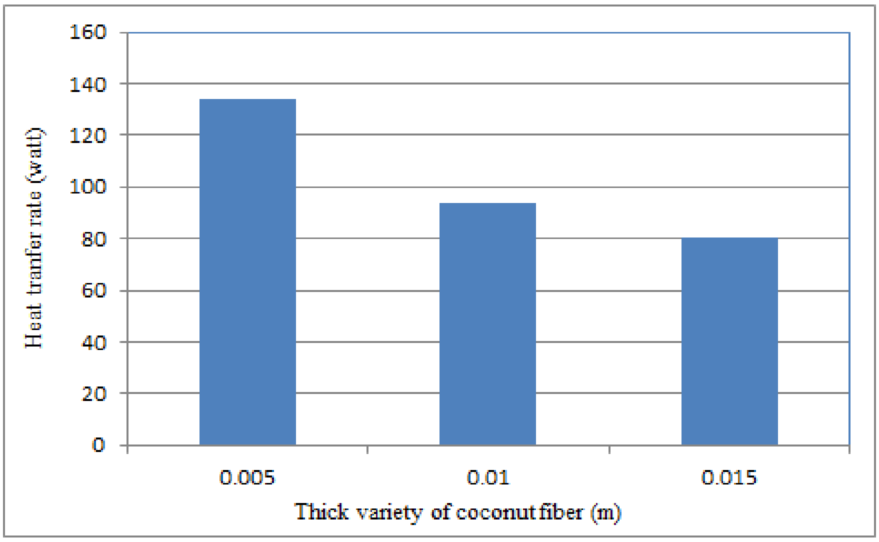

Figure 3. The graph of the relationship between the rate of heat transfer and the thickness of coconut fibers

Figure 4 shows that for coconut fibers with a thickness of 0.005 m obtained thermal conductivity value of 1,279 W/M ℃, coconut fibers with a thickness of 0.01 cm obtained the thermal conductivity value of 1,355 W/M ℃, and coconut fibers with a thickness of 0.015 cm obtained a thermal conductivity value of 1,393 W/M ℃. The thermal conductivity value of a material is constant not affected by the thickness of a material. In this study obtained the value of the thermal conductivity of the coconut fibers changed along with changes in the thickness of the coconut fibers, this is due to the density of the insulator consisting of the arrangement of coconut fibers uneven so that it affects the surface temperature of the outside of the insulator.

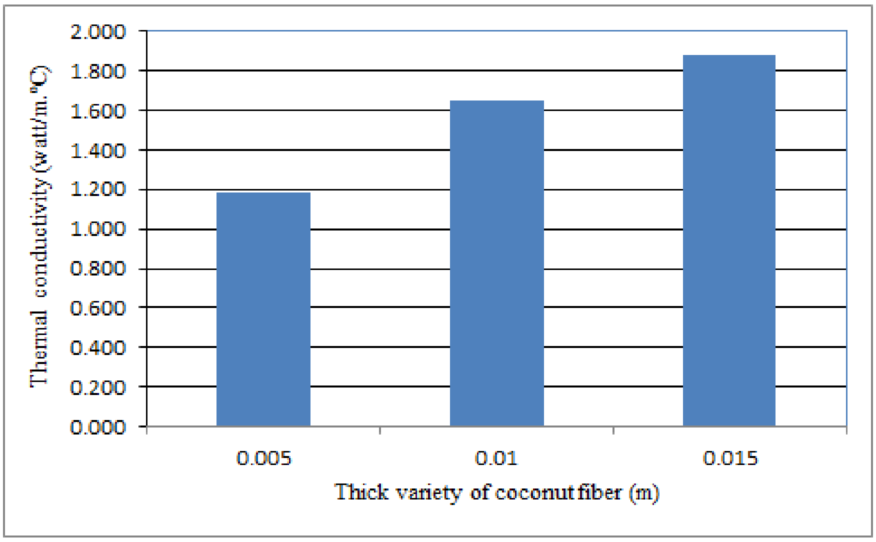

Figure 4. The graph of the relationship between thermal conductivity and the thickness of coconut fibers

IV. CONCLUSION

Based on the results of research conducted, conclusions can be drawn as follows: With a thickness of coconut fibers that the smallest heat transfer rate occurs in coconut fibers with a thickness of 0.015 m which is 80.52 watts. The greatest heat transfer rate occurs in coconut fibers with a thickness of 0.005 m which is 134.21 watts. This happens because the thicker the insulator, the smaller the heat transfer rate. Thermal conductivity of 1,279 W/M OC occurs at the thickness of coconut fibers, namely at 0.005 m thickness, at 0.01 M thick value of thermal conductivity of 1,355 W/M.oC and at a thickness of 0.015 M thermal conductivity value of 1,393 W/M.C. The thermal conductivity value that occurs for variations in thickness of coconut fibers is different due to uniform density. Adding thickness of coconut fibers can reduce the rate of heat transfer.

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