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Analysis of Heat Transfer of Fiber Mesocarp of Palm Oil (*Elaeis Guineensis Jacq*) as Roof Building

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ABSTRACT

Palm oil fibers are waste products from Palm Oil Mill which is in the form of debris, solid, length of 3-4 cm, contained in coconut fruit (mesocarp) meat. Fiber roof building is the result of utilization of palm fiber waste as a roof of a building that is used to reduce heat from sunlight or from heat sources, so it is not directly exposed to humans and the surrounding environment. Fiber roof building is made by arranging the fiber in the mold and arranged in accordance with the dimensions to be made. To bind between fibers, used resin that has been mixed with the catalyst material, so easy to dry quickly. The ratio between resin and fiber is 1: ¼. The result of conduction heat conduction test that has been done on the fiber test object can reduce the highest heat of 125 °C and the lowest is 109 °C from the given heat source of 200 °C. This shows that palm fiber can be used as a heat reducer for buildings.

INTRODUCTION

Palm Oil Factory (PKS) is a factory that process Fresh Fruit Bunches (TBS) of palm oil into Crude Palm Oil (CPO) and Palm Kernel (PK). PKS in addition to producing FFB and CPO in its processing, also produces sideline products in the form of Solid Waste of Palm Oil Factory (LP2KS) and Liquid Waste of Palm Oil Mill (LCPKS), [1-2].

The development of oil palm plantation areas followed by rapidly growing factories will affect the surrounding environment, especially the environment of waste recipients. To reduce the negative impact of palm oil processing plants referring to the law no. 4 of 1982 and government regulations, the control of palm oil mill waste should be done well. The control of palm oil mill effluent can be done by utilization, reduction of waste volume and quality control of waste [3]. Solid waste generated by palm oil processing plants is empty bunches, fibers and shell [4]. Utilization of palm oil waste, especially fiber can be used for daily needs in the community and industry. Palm fiber can be used as cattle feed [5].

Mesocarp fiber (fiber contained in the flesh of the fruit) oil palm is a natural material in the form of long fibers between 3-4 cm. Utilization of palm oil mesocarp fibers can be useful for triplex boards, plywood, flat tables, fiber plates, and so on. With the current development occurring, palm oil mesocarp fibers can be used for roofing the house as a heat insulator material that protects from the hot sun. Coconut fibers can be used as helmets [6]. According to [7] utilization of rice husk waste can be made boards that are used to withstand heat. Utilization of hyacinth fiber for textile materials can be processed using low temperature [8].

The heat transfer by conduction is a heat transfer process in which heat flows from a high temperature region to a low temperature region in a medium (solid, liquid or gaseous) or between different mediums directly tangent resulting in energy exchange and momentum [9]. According to [10] mentioned the comfort in the room associated with thermal conductivity

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(the ability of heat creates in objects). The constituent constant (k) is the physical property of a material or material called thermal conductivity. In general, thermal conductivity is highly dependent on temperature. Palm fiber can absorb about 55.5% of the heat it receives [11].

This research focuses specifically on the object of study: Heat Transfer Fiber Roof Building Oil Palm (Elaeis Guineensis Jacq) plate-shaped with dimensions of 6 mm thick, 100 cm long and 50 cm wide.

Thermal Conductivity of Composites

Composites are mixtures of materials that have mechanical bonds, but the boundaries between each of the constituent components can be clearly visually separated. Composites are alloys of various materials whose composition, microstructure or mechanical stress conditions are selected in such a way as to give desirable properties, which are generally better than the nature of the pure component. The process of composite formation can be done in various ways, for example by modifying the surface of the material, mixing, forming a solid solution, forming layers or intertwining one another [8].

Pure materials, such as pure ceramics, usually still have disadvantages on certain practical properties, such as pure concrete even though the compressive strength is high but the tensile strength is low. To overcome such strengths, ceramics are mixed with other materials to form composites with properties as desired. For example, the addition of iron rods in concrete to reinforced concrete produces a doubled increase in tensile strength, bending and sliding [8].

The composite properties, whether mechanical, electrical, magnetic, optical or thermal depend on the properties of each of its constituent components, the microstructure, the number of each component and the manner in which it is prepared. Ceramics are also influenced by the number of pores (total porosity), pore location and pore continuity. When viewed from the definition of composite, then porous ceramics can be considered as a composite between pure ceramics and air [8].

The preparation or distribution of phase phases in the composite ideally can be distinguished by three types of arrangements:
1. Preparation of parallel slabs.
2. The preparation is mixed with the main phase or the continuous major phase, while the additional phase or discontinuous phase is dispersed.
3. The preparation is mixed with the main phase of discontinu or continuous minor phase.

In addition, there are also other arrangements that are somewhat complicated when reviewed theoretically, for example by making the form of matrix and fiber, making the form of braided and so forth.

The shape of the layer is a very ideal form, and the discussion of the composite properties is theoretically, generally starting from this parallel layer form. To calculate the composite thermal conductivity, several theoretical models can be used. For example a homogeneous two-phase mixed thermal conductivity (such as a continuous or continuous minor phase) can be calculated using potential theory. The result has been stated by Maxwell and Eucken as equation (1):

$$K_M = K_C \left[\frac{1 + 2 f_d (1 - K_c/K_d)/(2K_d + 1)}{1 - f_d (1 - K_c/K_d)/(K_c/K_d + 1)} \right] \quad (1)$$

With:
K_M: Thermal conductivity mix (composite)
K_c: Thermal conductivity of continuous phase
K_d: Thermal conductivity dispersed
f_d: The phase fraction of the phase is dispersed

EXPERIMENTAL METHOD

Research methods are performed as in Fig. 1.

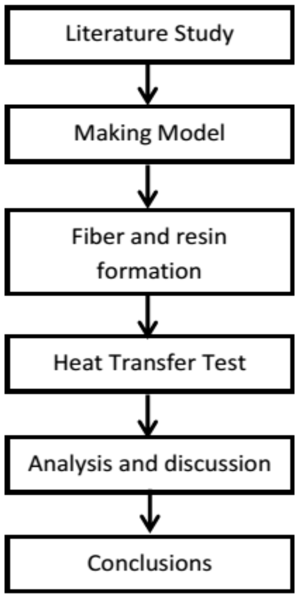

Fig. 1. Flow chart this research

The study phase of this research is carried out as follows:
1. Preparing print media (plywood).
2. Gives a molding pad with a board.
3. Pouring and flattening the fiber in the mold throughout the mold surface.
4. Prepare the binder (resin) with composite.
5. Pour the resin into the mold evenly to all sides of the mold for the fiber and resin to blend perfectly.
6. Dry the semi-finished plate for a few minutes until it solidifies perfectly.
7. Conducting heat transfer test on plate.

RESULTS AND DISCUSSION

Making Fiber Roof Building

Palm oil fibers are palm oil mill waste (PMKS) resulted from the pressing of pulp meat (mesocarp) which has fiber texture, with a length of 3-4 cm, small diameter. This fiber in PMKS is a boiler fuel unit that is used as operational in all PMKS that need it. Fiber is quite abundant of PMKS very much in use in everyday life, so it can be applied to the environment.

Making fiber as one of application form is roof of building. Roof wakes that still use clay materials, asbestos, polyethylene, and others are available in the market and used by the general public. Fiber can be formed according to the size and shape desired. The easiest fiber-roof making is in the form of a flat plate, which needs to be prepared for its formation. The steps to make fiber roof are as follows:
1. Prepare the mold material that will be used to print the fiber roof.
2. Arrange the palm fiber in accordance with the mold and arranged in such a way as to fill the mold.
3. Input the binder (resin) as needed into the mold and fill all the parts of the fiber.
4. Dry on free air or hot sun, so it becomes dry and hard.
5. Separate the mold with the fiber that has been formed, and clean.

The fiber roof that has been printed with the size of 100 cm x 50 cm x 6 mm can be seen in Fig. 2.

Fig. 2. Fiber Roof Building with dimensions of 100 cm x 50 cm x 6 mm

Heat Transfer and Mass for Fiber Roof Building

Tests conducted to determine the resistance to heat, then testing heat transfer for fiber work piece. The work piece is formed rectangle with size 21 cm x 12 cm x 6 mm, where the experiment of heating with heat on the work piece is from temperature 30 - 200 °C. The work piece done experiments can be seen in Fig. 3.

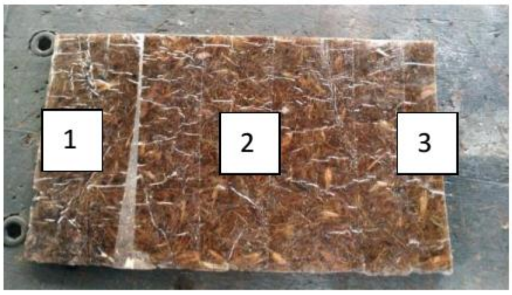

Fig. 3. Work piece and Temperature Measurement Position

The test data of heat transfer can be seen in Table 3-9.

Table 3. Testing Heat Transfer Object I

No	Heat Sources (ºC)	Time (minute)	Point 1 (ºC)	Point 2 (ºC)	Point 3 (ºC)
1	40	2.70	34	37	35
2	58	1.11	34	40	34
3	69	1.45	34	41	35
4	70	2.18	35	42	35
5	80	3.47	36	43	36
6	94	5.27	39	45	39
7	105	6.05	40	48	40
8	120	7.14	41	50	41
9	135	8.31	43	52	44
10	140	9.53	45	61	45
11	165	11.13	48	68	50
12	180	12.29	49	71	51

Table 3 shows that the test is carried out using a heat source of 40 °C with point 1 having a temperature of 34 °C (ambient temperature), while at position 2, the temperature rises (different) from the first point, i.e. 37 °C. This indicates that at point 2 the heat propagation is received by the fiber work piece. At point 3, the temperature is almost similar to the first point, which is 35 °C.

So it is known that the position at the edge (point 1 and point 2) is the same, whereas at point 2 (in the middle of the heat source) has a greater propagation and significant. This test continues to increase its heating source, reaching a temperature of 180 °C. At a temperature source of 180 °C., the specimens having heat at point 1, point 2, and point 3, are: 49 °C, 71 °C, 51 °C. At point 2 it has a considerable displacement compared to points 1 and 3. The fiber material can reduce source heat from 180 °C to 71 °C, which is 109 °C.

Table 4. Testing Heat Transfer Object II

No	Heat Sources (ºC)	Time (minute)	Point 1 (ºC)	Point 2 (ºC)	Point 3 (ºC)
1	50	0.10	32	33	31
2	74	0.37	32	33	32
3	80	1.23	33	35	33
4	95	2.42	35	37	34
5	110	2.40	36	39	34
6	115	3.11	37	41	35
7	120	3.35	38	44	35
8	131	4.07	38	45	36
9	139	5.00	40	49	39
10	146	6.22	44	55	41
11	150	7.42	47	60	44
12	165	8.05	49	64	45
13	178	8.38	51	66	47
14	185	8.55	53	68	47
15	195	9.17	54	70	48
16	200	9.43	56	73	50

In the test of object II in Table 4, the work piece is heated from a 50 °C heat source, at which point 1, 2, 3 heats the work piece, at 32 °C, 33 °C, and 31 °C. In this condition the work piece I s still normal (not hampered by the heat source), so the work piece is still able to reduce the heat source. By adding a heat source to the work piece (fiber), not too significant the heat propagation received by the fiber object, so that the work piece is able to withstand heat. At a given heat source reaching 200 °C, the fiber work piece does not experience significant thermal propagation, which at 1, 2, and 3 points, is: 56 °C, 73 °C, and 50 °C, so that the work piece the fiber can withstand heat transfer from 200 °C to 73 °C at 127 °C. This indicates that the fiber work piece is subjected to heat transfer testing, can absorb very large heat.

Table 5. Testing Heat Transfer Object III

No	Heat Sources (ºC)	Time (minute)	Point 1 (ºC)	Point 2 (ºC)	Point 3 (ºC)
1	34	0.17	32	31	39
2	44	0.52	32	31	37
3	50	1.18	32	32	37
4	60	2.18	33	33	35
5	70	2.42	34	34	35
6	80	3.00	35	35	35
7	90	4.20	37	38	35
8	100	4.55	38	40	36
9	110	5.57	40	43	37
10	120	8.10	45	50	40
11	130	10.10	50	58	44
12	140	11.13	53	65	48
13	150	12.09	57	69	49
14	160	12.28	58	70	50
15	170	13.05	59	71	51
16	180	13.54	63	74	52
17	190	14.58	66	76	54
18	200	18.11	69	91	57

In Table 5, the test is carried out by providing a heat source of 34 °C, and it will raise the temperature by 10 °C each level until it reaches 200 °C. At room temperature given the heating to the specimen, the other side remains the same as the given source temperature. At a given temperature of 80 °C, the specimen can still withstand the transfer of heat received, so that the specimen is the same as the ambient temperature. Giving of 90 °C, increased heat transfer, but not significant. At the source temperature given to the specimen at 200 °C, at the test specimens at point 1, 2, 3 experienced heat transfer, but not significantly: 69 °C, 91 °C, and 57 °C. The specimens undergo large displacements only in the middle, but can absorb heat from 200 °C to 91 °C at 109 °C. This indicates that the test material can withstand significant heat transfer.

Table 6. Testing Heat Transfer Object IV

No	Heat Sources (ºC)	Time (minute)	Point 1 (ºC)	Point 2 (ºC)	Point 3 (ºC)
1	34	0.16	32	31	32
2	40	0.45	32	31	33
3	50	1,22	32	31	34
4	60	1.45	33	32	33
5	70	2.22	34	33	34

6	80	3.00	34	34	34
7	90	3.43	35	35	35
8	100	5.15	37	38	36
9	110	5.52	38	40	38
10	120	6.54	40	44	39
11	130	7.37	43	47	40
12	140	10.00	48	53	43
13	150	10.15	49	55	44
14	160	10.42	50	56	45
15	170	11.37	52	62	48
16	180	12.25	56	69	50
17	190	13.22	58	68	52
18	200	14.09	59	75	54

In Table 6 of the object test in heat transfer, it is carried out from 34 °C to 200 °C, by adding 10 °C heat source at each level. In this test, the specimen is still capable of reducing heat transfer to a 90 °C heat source, wherein the specimen ranges from 31-34 °C. By adding the heat source to the specimen, the heat transfer was not significant, at a source reaching 200 °C, at point 1, 2, 3 the specimens had heat transfer of 59 °C, 75 °C, and 54 °C. This indicates that the specimen has a sufficiently good heat sink, which can dampen the heat by 125 °C from 200 °C heat source to 75 °C. This provides evidence that a fiber-type test object can be used to absorb high heat, so it can be used for heat absorbers for waking, building or roofing.

The table calculation results of work piece displacement can be seen in the Table 7-10.

Table 7. Result of Heat Transfer Object I

No	Heat Sources (°C)	Time (minute)	Section exposed to heat (°C)	Heat Transfer (W)
1	40	2.70	37	0.743
2	58	1.11	40	4.460
3	69	1.45	41	6.938
4	70	2.18	42	6.938
5	80	3.47	43	9.168
6	94	5.27	45	12.142
7	105	6.05	48	14.124
8	120	7.14	50	17.346
9	135	8.31	52	20.567
10	140	9.53	61	19.576
11	165	11.13	68	24.036
12	180	12.29	71	27.010

Table 8. Result of Heat Transfer Object II

No	Heat Sources (°C)	Time (minute)	Section exposed to heat (°C)	Heat Transfer (W)
1	50	0.10	33	4.213
2	74	0.37	33	10.159
3	80	1.23	35	11.151
4	95	2.42	37	14.372
5	110	2.40	39	17.594
6	115	3.11	41	18.337
7	120	3.35	44	18.833
8	131	4.07	45	21.311
9	139	5.00	49	22.302
10	146	6.22	55	22.549
11	150	7.42	60	22.302
12	165	8.05	64	25.028
13	178	8.38	66	27.754
14	185	8.55	68	28.993
15	195	9.17	70	30.975
16	200	9.43	73	31.471

Table 9. Result of Heat Transfer Object III

No	Heat Sources (°C)	Time (minute)	Section exposed to heat (°C)	Heat Transfer (W)
1	34	0.17	31	0.756
2	44	0.52	31	3.275
3	50	1.18	32	4.535
4	60	2.18	33	6.802
5	70	2.42	34	9.069
6	80	3.00	35	11.337
7	90	4.20	38	13.100
8	100	4.55	40	15.116
9	110	5.57	43	16.879
10	120	8.10	50	17.635
11	130	10.10	58	18.139
12	140	11.13	65	18.895
13	150	12.09	69	20.406
14	160	12.28	70	22.674
15	170	13.05	71	24.941
16	180	13.54	74	26.705
17	190	14.58	76	28.720
18	200	18.11	91	27.460

Table 10. Result of Heat Transfer Object IV

No	Heat Sources (°C)	Time (minute)	Section exposed to heat (°C)	Heat Transfer (W)
1	34	0.16	31	0.762
2	40	0.45	31	2.286
3	50	1.22	31	4.826
4	60	1.45	32	7.112
5	70	2.22	33	9.398
6	80	3.00	34	11.684
7	90	3.43	35	13.969
8	100	5.15	38	15.748
9	110	5.52	40	17.779
10	120	6.54	44	19.304
11	130	7.37	47	21.082
12	140	10.00	53	22.098
13	150	10.15	55	24.129
14	160	10.42	56	26.415
15	170	11.37	62	27.431
16	180	12.25	69	28.193
17	190	13.22	68	30.987
18	200	14.09	75	31.749

The results of heat transfer calculation experienced by the work piece 1 in Table 7 are: 27 Watt, for work piece 2, 3, and 4 the result is 31.47 Watt, 27.46 Watt and 31.74 Watt. The heat transfer of the work piece is very small, in which the specimen can absorb considerable heat, as an insulator, and has a very small thermal conductivity (heat transfer rate) of 0.059 W/m°C. The test specimens of the fiber are not like ferrous materials which are conductive materials, good heat conducers, and have good thermal conductivity, which is 73 W/m°C [4].

Table 11, the test specimens 1,2,3, and 4 have different dimensions, so the area, the volume is different too. The use of this dimension in the calculation of heat transfer is required to measure the rate of heat transfer occurring. As the width of the cross-sectional area is larger, the amount of heat transfer required. In Table 11, shows the specimens have different masses, so that in the density (between the parts of the work piece) will be different. In the work piece 1 has a density of objects (density between objects) of 920.37 kg/m^3, while in objects 2, 3 and 4 have a density (workload density) of 879.29 kg/m^3, 851.02 kg/m^3, and 887.14 kg/m^3. This exposure is influenced by the mass possessed by every object is directly proportional to the volume it has. The greater the mass possessed by the work piece with a fixed volume dimension, it will give the density (density between parts of the body) the larger and the more flat.

Table 11. Dimensions of Test and Density Material

Material	Mass (kg)	Thickness (m)	Length (m)	Width (m)	Cross Sectional Area (m²)	Volume (m³)	Density (kg/m³)
1	0.13916	0.006	0.21	0.12	0.0252	0.000151	920.37037
2	0.13295	0.006	0.21	0.12	0.0252	0.000151	879.298942
3	0.13082	0.006	0.21	0.122	0.02562	0.000154	851.027843
4	0.13749	0.006	0.21	0.123	0.02583	0.000155	887.146729

CONCLUSION

From experiment and testing of heat transfer of workpiece (fiber) can be given some conclusion as:

Forming a flat plate-shaped Fiber Roof can be used resin and palm fiber binder at a ratio of 1: ¼, by printing on the provided mold (100 cm x 50 cm x 6mm). The heat transfer process that occurs is conduction, where the heat source from 34-200 °C, can reduce heat to the fiber test object of 125 °C.

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