ANALYSIS OF THERMAL CONDUCTIVITY OF EPOXY COMPOSITES WITH FILLERS PINEAPPLE FIBER AND NA2SIO3 AS CAR LIGHT SOCKET MATERIAL

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ABSTRACT

Lighting system problem in the form of melting car light socket is a problem that often occurs in used cars. The causes of the socket melting are due to improper installation and the material from which it is made that melts easily. This research aims to find a new material for car light sockets using the hot wire method testing standard. The research method used was observing various literature and carrying out experiments. Researchers made 3 specimen samples from a mixture of pineapple leaf fiber, resin epoxy-hardener, and Na_2SiO_3 which were tested twice. Based on the experiment, the results of thermal conductivity values can be influenced by the voids contained in the specimen. The conclusion of this research that the best specimen used as material for making car light sockets is specimen 1, with an average thermal conductivity value of 0.2233 W/mK and a composition ratio of 15: 7.5: 1: 3.75.

Keywords: composite, pineapple fiber, thermal conductivity, socket, catalyst

INTRODUCTION

Nowadays, the number of motorized vehicles, both two-wheeled and four-wheeled, is increasing. This increase in vehicle volume is caused by vehicle model updates, which are carried out on a large scale to keep up with customer demand, especially automotive enthusiasts. The data on the number of motorized vehicles, primarily passenger cars, from 2018 to 2021, respectively, is 14,838,106, 15,592,419, 15,797,746, and 16,903,094 [1]. However, this update results in a faster service life of vehicles, primarily cars.

A problem that often occurs in cars that have passed their useful life, whether they are old or used, is lighting system problems. One of the components of the lighting system in a car is the socket or lamp holder, which is part of the headlights [2]. Used cars whose main lights still use filament bulbs must have light sockets. The problem that often occurs with this type of lamp is the melting of the light socket, which can cause damage to the car lights [3].

A light socket is a lamp holder that distributes the light using an electrical network wire to connect it to the car's lighting [4]. In general, the light socket melts because the socket is not installed correctly or tight. This can cause heat and melt the light socket [5]. Besides that, car light sockets are also made of plastic and rubber, which function as a seal, so they are vulnerable to melting if exposed to heat [6]. One type of plastic that can be applied in the field of electronics, especially in the field of lighting, is acrylonitrile butadiene styrene or ABS [7]. The melting temperature of ABS plastic is 88-77°C and has a thermal conductivity of 0.23 W/mK [8]. Meanwhile, the temperature of halogen-type car lights reaches 250°C, which functions as the main light [9]. Therefore, new materials are needed to replace the materials used to make light sockets in cars and reduce these problems.

In this case, the constituent materials that will be used are pineapple leaf fiber and epoxy resin, as well as the addition of Na_2SiO_3. The choice of pineapple leaves as the constituent material was due to their abundant natural availability and non-thermal properties. Besides that, epoxy resin and Na_2SiO_3 have high heat resistance and can be used as insulators. The insulating properties of a material can be known by carrying out a thermal conductivity test [10]. The thermal conductivity of an object is the ability of an object to transfer heat from that object [11].

The distribution of pineapple leaves is based on fruit production data in 2021, with the highest being occupied by Lampung province at 705,883 tons and South Sumatra province at 476,074 [1]. The abundance of the largest pineapple producers means that the pineapple leaves produced are very abundant, but the use of pineapple leaves has yet to be optimal, so there may be waste if they are not processed. Pineapple leaf fiber's low thermal conductivity also makes this fiber a good thermal insulator [12]. So, the alternative is to create a pineapple fiber composite because the mechanical characteristics of pineapple fiber are strong, like aluminum [13]. Therefore, pineapple leaf fiber can be used as a filler for composite components in this research.

Providing epoxy resin is helpful as a binder for pineapple leaf fibers to maximize the resulting material. Besides that, epoxy resin also has high heat resistance properties. Epoxy resin is a material that has a solid or liquid form at room temperature and has a melting point above 200℃ [14]. Sodium silica or Na_2SiO_3 is one of the ingredients used in cement and textile mixtures, which can protect from heat [15]. This solution does not produce an odor or emit smoke or soot during fire resistance testing compared to the $MgCl_2$ solution [13]. Thus, the choice of epoxy resin is very suitable for this research.

Researchers reviewed several other studies on pineapple fiber and epoxy resin composites, including by [16-18]. [16] analyzed the effect of the resin-epoxy matrix on the physical properties and impact strength of pineapple fiber, [17] analyzed the effect of alkalization on the mechanical properties in the form of tensile and impact strength in pineapple fiber and epoxy composites, and [18] analyzed the effect of microwave oven heating power, on the mechanical strength of pineapple leaf fiber composites with epoxy matrix. That research only examined the mechanical strength of composites, especially tensile strength and impact strength. Therefore, the researchers will focus on the insulating strength of the pineapple fiber and epoxy resin composite using a thermal conductivity test.

This research aims to find new materials that makeup car light socket using the hot wire method testing standard.

RESEARCH METHODS

The Research on the manufacturing and testing processes was carried out in the Gajah Tunggal Polytechnic workshop with predetermined standards.

Research Materials

1. Pineapple Fiber
   The pineapple fiber used in this research is made from pineapple leaves. The pineapple leaves were obtained from pineapple plantations in Subang, West Java. The pineapple fiber specifications are shown in Table 1.

Table 1. Pineapple fiber specifications

Variable	Value
Type of pineapple	*Smooth cayene*
Colour	white
Water content	3-5%
Selulosa	69,5-71,5%
Length	2 cm

2. Epoxy resin
   The specifications of the epoxy resin can be seen in Table 2.

Table 2. Epoxy resin specifications

Variable	Value
Type of resin	Crystal clear-high gloss
Colour	Clear white
Resin weight	150 grams
Hardener weight	75 grams
Mix ratio	2: 1

3. Na_2SiO_3 or sodium silica
   Specifications for Na_2SiO_3 or sodium silica solutions can be seen in Table 3.

Table 3. Specifications of Na_2SiO_3

Material	Pecentage
SiO2	31,78%
Na_2O	14,5%
Solid total	46,28%
Density	1,55 gr/ml
Beaume	58

Research Tools

Composite mold as shown in Figure 1, Thermal conductivity tester or QTM-500 Conductometer (Quick Thermal Conductivity Meter) located at the Pusat Riset Teknologi Roket, Bogor Regency, West Java as shown in figure 2, SF-400 digital electronic balance, and monocular digital magnifier microscope.

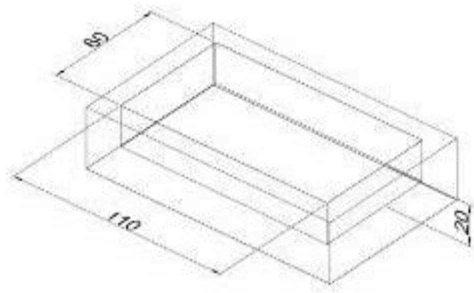

Figure 1. Test specimen mold

The dimensions of the composite mold are 110 x 60 x 20 mm (length x width x height). The mold is made of wood glued together to form the desired dimensions.

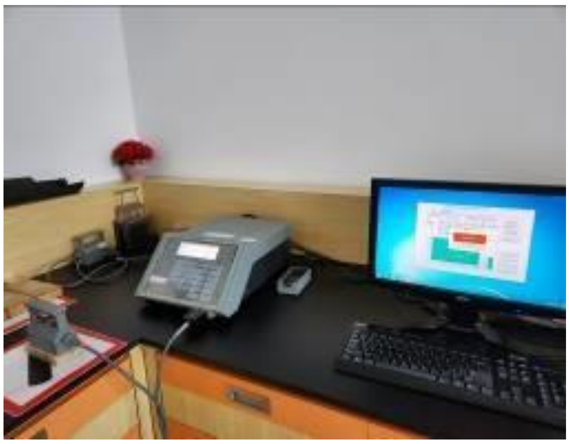

Figure 2. QTM-500 Conductometer

The specifications for the thermal conductivity tester or Conductometer QTM-500 can be seen in Table 4.

Table 4. QTM-500 Conductometer Specifications

Variable	Value
Room temp.	22-24°C
Humidity	60-70%
Method	Hot wire method
Quadratic Flow (I^2)	1,0 A^2
Test type	Polymers/Composites/ Insulators

Work Procedures

Making the composite begins by selecting old pineapple leaves and then separating the fibers. The pineapple fiber is dried in the sun until dry or for two days. Next, the dried pineapple fiber is mixed with epoxy resin and hardener using the hand lay-up or manual method. The ratio between epoxy resin and hardener is 2:1. After that, add pineapple leaf fibers that have been cut to a size of 2 cm and Na_2SiO_3 solution in the specified ratio. The results of the length of the cut pineapple fiber can be seen in Figure 3.

Figure 3. Results of cutting pineapple fiber

Prepare a mold with 110 x 60 x 20 mm dimensions according to the hot wire method. Before use, coat the mold with mirror glaze so it doesn't stick when removing the composite. Put the epoxy resin into the beaker, adding fiber and Na2SiO3 solution. Stir the mixture for 5 minutes until evenly mixed. At this stage, the mixing process is carried out manually or using the hand lay-up method. Then, pour into the mold and let sit for one day at room temperature. After hardening, the composite is removed from the mold, and the surface is smoothed.

In this study, researchers made three specimens with varying mass fractions of pineapple fiber. These specimens were tested twice, so there were six specimens in total. The composition of the test specimens can be seen in Table 5.

Table 5. Composition of test specimens

Specimen	Epoxy resin (g)	Hardener (g)	Pineapple fiber (g)	Sodium silicate (g)
1	150	75	10	37,5
2	150	75	12	37,5
3	150	75	14	37,5

The complete work procedure of this research can be illustrated with the flow diagram shown in Figure 4.

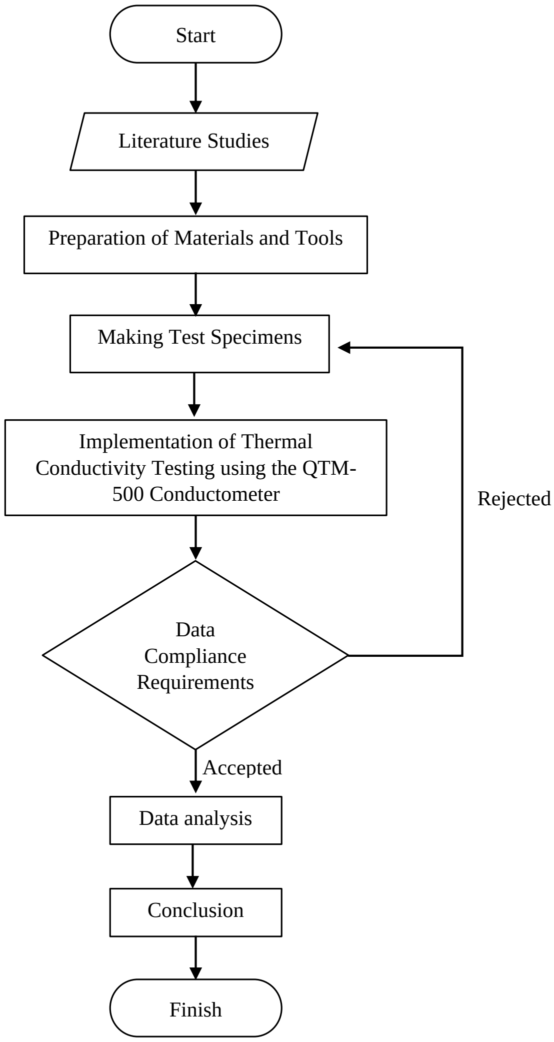

Figure 4. Research flow diagram

RESULTS AND DISCUSSION

Research result

Thermal conductivity testing aims to determine the conductivity properties of the test specimen. Researchers have made 3 test specimen samples according to the specified composition. Based on the test specimens that have been made, the heavier the mass fraction of pineapple fiber when mixing epoxy resin, hardener, and sodium silicate, the heavier the mass of the resulting specimen. The masses of the test specimens produced were 271 g, 273 g, and 276 g, respectively.

The results of the thermal conductivity test on three specimens with varying mass fractions carried out two times can be seen in Table 6 and Figure 5.

Table 6. Thermal conductivity test results

Specimen	Thermal conductivity (W/mK)		Average (W/mK)
	Test Object 1	Test Object 2	
1	0,2231	0,2235	0,2233
2	0,2061	0,2247	0,2154
3	0,2249	0,2272	0,2261

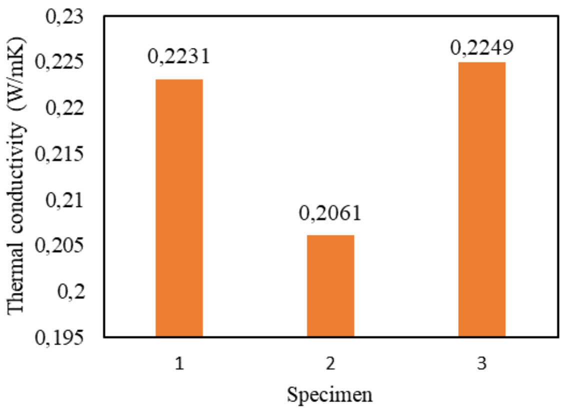

Figure 5. Graph of average thermal conductivity values

Based on Table 6 and Figure 5, the average thermal conductivity of the pineapple fiber composite in specimen 1 with a fiber mass of 10 grams is 0.2233 W/mK, the average pineapple fiber composite with a fiber mass of 12 grams is 0.2154 W/mK, and the average pineapple fiber composite with a fiber mass of 14 grams is 0.2261 W/mK.

Discussion

In specimen 2, there was a significant change in thermal conductivity values compared to the other specimens. Many factors can influence changes in thermal conductivity values. One of these factors is material porosity or space [19]. The more space or porosity in the material, the smaller its conductivity. This is because the air in the space is a poor conductor of heat, and the decrease in the heat flow rate is proportional to the number of space or void [20]. The hand lay-up method for making specimens and the coarse structure of pineapple fibers create a lot of porosity in the specimens.

To determine the amount of porosity, researchers observed the microstructure of the specimens. These observations were carried out using a digital microscope with 100x magnification to analyze the decrease in the thermal conductivity value of the composite specimens. Researchers took pictures in the same position to make observation easier.

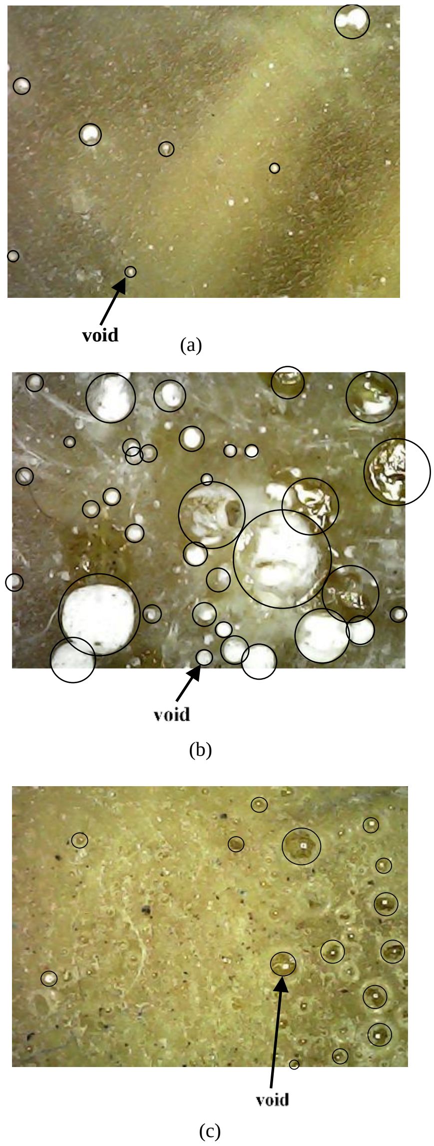

Figure 6. Results of photo micro of composite specimens:
(a) specimen 1, (b) specimen 2, and (c) specimen 3

In Figure 6, there are a large number of spaces or voids in specimen 2 (Figure 6b) compared to specimen 1 (Figure 6a) and specimen 3 (Figure 6c). This is what resulted in the thermal conductivity value in specimen 2 having a significant decrease.

However, in this study, all specimens qualified to be used as material for making car light sockets because the average thermal conductivity value of all specimens was lower than that of the previous socket material, about 0.23 W/mK. The best specimen composition is specimen 1, with an average thermal conductivity value of 0.2233 W/mK. This is because specimen 1 has little porosity or voids and a small conductivity value. So, the composition ratio that is best used in making car light sockets, systematically, based on the mass amount of resin, hardener, pineapple fiber, and sodium silicate, is 15: 7.5: 1: 3.75.

Thus, pineapple fiber has a high potential to be used as a reinforcing material in making car light sockets. Besides that, pineapple fiber can also be a natural filler for previous lamp socket materials because pineapple fiber has characteristics that can adapt to other materials, like plastic. With the lower thermal conductivity (heat-conducting properties) of pineapple fiber compared to the thermal conductivity of previous lamp socket-making materials, pineapple fiber has higher and better insulating power (heat-inhibiting properties). The insulating ability of pineapple fiber makes it have longer heat resistance than the previous material for making lamp sockets, which was called ABS plastic.

CONCLUSION

Based on data from thermal conductivity tests and observations of the microstructure of composite specimens, it can be concluded that the best specimen used as material for making car light sockets is specimen 1, with an average thermal conductivity value of 0.2233 W/mK and a ratio of the composition of the specimens of 15:7.5:1:3.75. In this research, pineapple fiber has a lower thermal conductivity value (heat-conducting properties) than previous materials for making lamp sockets, so pineapple fiber has better insulation and heat resistance. The researcher provides recommendations for future researchers by carrying out tensile or bending tests on pineapple fiber and epoxy resin composite materials, where the test results can be used as a reference in making automotive parts. By processing pineapple leaf fiber as a composite, it is hoped that pineapple leaf fiber waste can be useful and support automotive progress in Indonesia.

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