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Bending Strength and Thermal Conductivity are Two Aspects that are Affected by the Engineering Management of Using Composite Materials in Intake Manifolds

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Abstract: Currently, a significant number of automobile manufacturers, particularly automobile manufacturers, have fabricated intake manifolds out of ebonite. Where it has been possible to get a smooth interior surface. The purpose of this study is to investigate the impact that the incorporation of alumina has on the conductivity and bending strength of composites made from coconut fiber. Fiber Preparation, Fiber Soaking, Mold Making, Composite Making, Specimen Making, Composite Volume Fraction, Thermal Conductivity Testing, Bending Testing, Flexural Stress, and Elastic Modulus were the methodological approaches that were used in the study process. Because of the fact that alumina is capable of conducting heat, the thermal conductivity value increases in proportion to the amount of alumina that is added to the mixture, as shown by the findings of thermal testing. The composition that has the highest thermal conductivity value is 0,146333 W/m°C. It is composed of 30%, 67%, and 3%, and in addition to that, it has excellent insulating qualities in comparison to the other two compositions. According to the findings of the bending tests, the additional coconut belt fibers will result in an increase in the bending strength and modulus of elasticity. Additionally, the incorporation of alumina will result in a decrease in the bending strength. This is due to the fact that alumina has brittle qualities, meaning that it is readily broken.

Keywords: Composite material, coconut fiber, bending strength, and thermal conductivity

1. Introduction

In today's world, several automobile manufacturers, particularly those that specialize in automobile manufacturing, have fabricated intake manifolds out of ebonite, achieving a smooth inner surface. On the other hand, motorcycles from the past up to the present day continue to employ intake manifolds that are manufactured from materials that are not renewable natural resources, namely aluminum, and have not yet attained a smooth inner surface.

The intake manifold is a component of the vehicle that is responsible for distributing the air and fuel combination that is processed by the carburetor to the cylinders. Aluminum alloy, which is used to construct the intake manifold, is superior to other metals in terms of its ability to perform heat transmission. The intake manifold is positioned in such a way that it is as near as possible to the source of heat, which enables the combination of air and gasoline to evaporate as soon as possible. Additionally, the intake manifold may be situated in close proximity to the exhaust manifold on some engines [1].

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The fiber found in coconut belt also serves as an alternative natural fiber material that may be used in the production of composites. The use of coconut fiber is beginning to attract attention because, in addition to being simple to acquire and inexpensive, it has the potential to lessen the amount of pollution that is released into the environment (biodegradability). As a result, the utilization of coconut belt as a fiber in composites will be able to find solutions to environmental issues that may be caused by the large number of coconut belts that are not being utilized. Because this composite is safe for the environment and does not pose a threat to human health, its use is still being researched and refined in order to create composites that are more perfect and beneficial [2].

The function of reinforcement is to provide the composite with a strengthening effect. As a result of the reinforcement's larger elastic modulus in comparison to that of the matrix, the reinforcement is less ductile but more rigid and stronger. There are both positive and negative aspects associated with alumina, including its resistance to friction and its benefit in terms of strength. Excellent heat conductivity, excellent electrical conductivity, resilience to shear stress, and resistance to high temperatures are some of the benefits.

In light of the information presented above, it is essential to carry out research by constructing an intake manifold out of natural fiber composite materials. The purpose of this study is to investigate the impact that the incorporation of alumina has on the conductivity of composites made from coconut fibers, as well as the impact that alumina has on the bending strength of composites made from coconut fibers.

The investigation that was carried out was an experimental investigation, namely via the manipulation of the study object, which was the intake manifold. This study was carried out with the purpose of determining the impact that installation of an intake manifold made of a composite base material (pineapple fiber) would have on the torque and power output of a Honda Supra X 125 motorcycle manufactured in 2007 [3].

During the course of this investigation, a regular intake manifold and an intake manifold that has been expanded and smoothed on the inner surface were used as the materials that were selected for comparison. The engine speed was varied and measured at intervals of 500 revolutions per minute during the course of the tests, which ranged from 1500 to 2500 revolutions per minute. This study's findings indicate that by enlarging and smoothing the inner surface of the intake manifold, it is possible to increase the maximum torque by 31.6%, the maximum effective power by 27.9%, and the fuel consumption by 18.8%, and the specific effective fuel consumption by 36.9% [4]. In addition, the maximum torque can be increased by approximately 31.6%.

For the purpose of this study, a comparison is made between epoxy resin and polyurethane resin. The findings of this study indicate that the use of epoxy resin in pineapple fiber composites has superior mechanical capabilities in comparison to polyurethane. Furthermore, the degumming procedure in pineapple fiber has been shown to enhance the mechanical link between the fiber and the resin [5].

As a result of this study, an aluminium matrix composite material that is reinforced with alumina (Al2O3) and silicon carbide (SiC) is produced. This material has the most advantageous mechanical characteristics. There are variants in the alumina volume fraction of 10% without the inclusion of SiC, as well as with the addition of 5% and 10% SiC. The composite is constructed from an Al-3Si-9Zn-6Mg matrix that is reinforced with alumina particles (Al2O3) and silicon carbide (SiC for reinforcement. Squeeze casting is the procedure that is used during the casting process [6].

During the course of this investigation, insulators were also produced from three other materials: wood, rubber, and Styrofoam. These materials are capable of producing excellent heat insulators in thermo electrics [7].

Specifically, the purpose of this study is to investigate how the density of epoxy-alumina composites is affected when alumina powder is added to epoxy. Epoxy serves as the matrix, and alumina serves as the reinforcement among the ingredients that are used [8].

The objective of this experiment is to ascertain the thermal conductivity values of a number of different materials and to identify the elements that have an impact on the thermal conductivity values of a number of different materials. The fundamental idea behind this experiment is derived from Fourier's law and the concept of heat transport along the axial direction of a one-dimensional space. When heat energy is applied to one side of the aluminum material, the heat will be transported to the opposite side of the material. This heat will be conveyed to one side of the material that is not metallic, and then it will be given to the other side [9]

Engineering materials are materials that have unique properties or characteristics that can be utilized by engineering experts to facilitate the implementation of their engineering tasks and engineering. In general, materials consist of metal (ferrous) materials and non-metal (non-ferrous) materials. In general, non-ferrous materials can be classified as follows:

a. Plastic.

b. Ceramic.

c. Composite.

The discovery of several fibers can encourage the emergence of various kinds of composite materials, composites can be obtained from a combination of metal with ceramic, metal with plastic, ceramic with plastic, and others [10].

1.1. Composite Definition

A composite is a structural material consisting of a combination of two or more elements that are combined at the macroscopic level and are insoluble in each other. One element is called a reinforce and the other element that functions as a binder is called the matrix. Reinforcing elements can be in the form of fibers, particles or flakes. Examples of materials that include composites are concrete reinforced with steel, and epoxy reinforced with graphite fiber, etc. (7).

In composite materials the properties of the supporting elements are still clearly visible, whereas in alloys the supporting elements are no longer visible. One of the advantages of composite materials when compared to other materials is the combination of superior elements from each of the constituent elements. It is hoped that the properties of the material resulting from this combination can complement the weaknesses of each of the constituent materials. Renewable properties include:

1. *Strength.*
2. *Stiffness.*
3. *Corrosion Resistance.*
4. *Wear resistance.*
5. *Weight.*

6. *Fatigue life.*

7. Increases heat conductivity.

8. Long lasting.

Naturally, the above abilities do not all exist at the same time. Currently, the development of composite technology is starting to develop rapidly. Composites are currently used in various components, including automotive, airplanes, spacecraft, ships, building materials, and sports equipment [11].

1.2. Composite Classification

Composites are classified according to their reinforcing materials, namely in the form of particles, flakes and fibers. Meanwhile, according to the binder/matrix, it is polymer, metal, ceramic and carbon [12].

In general, composites are classified into three types [13], namely:

1. Fiber composites (Fibrous Composites).

Fiber composites are composites consisting of fiber in a matrix. Naturally, long fibers have more strength than fibers in bulk form. Bulk is a type of composite which consists of only one laminate or one layer which uses reinforcement in the form of fiber.

2. Particulate Composite.

Particle composites are composites that use particles or powder as reinforcement and are evenly distributed in the matrix.

3. Layered composites (Laminates Composites).

Particle composites are composites that use particles or powder as reinforcement and are evenly distributed in the matrix.

1.3. Coconut Fiber

Coconut coir is a material containing ligneous cellulose which can be used as an alternative to coco fiber. So far, there has been a lot of research and experiments carried out by experts to increase the economic value of coconut coir to get a product that has high quality but with ingredients that are easily available [14].

Coconut is a plantation crop that comes from the Palmae family. The coconut plant (cocos nucifera L) is a multipurpose plant or a plant that has high economic value. All parts of the coconut tree can be used for human benefit, so this tree is often called the tree of life because almost all parts of the tree, roots, stems, leaves and fruit can be used for everyday human life. The elements in coconut, namely coconut fiber, are taken after removing the coconut meat and are used in industry to make yarn and coir-based products such as carpets and mats [15]

1.4. Fiber

Fibers consist of thousands of filaments, each filament has a diameter of between 5 and 15 micrometers, making it possible to produce them using textile machines. Fiber composites consist of a matrix reinforced by long fibers (continuous fiber) or short fibers (discontinuous fiber) [16].

Glass fiber is the most widely used fiber for polymer matrix composites (PMC) because it has many advantages, including high strength, low cost, high chemical resistance, and good insulating properties. However, fiber glass also has several disadvantages, including low elastic modulus, poor adhesion to polymers, high specific gravity, sensitivity to scratches (reduces tensile strength), and low fatigue strength [16].

1.5. Alumina

Alumina is a chemical compound of aluminum and oxygen, with the chemical formula Al_2O_3 or what is usually called alumina. Aluminum oxide/alumina occurs naturally as ruby, sapphire, corundum and emery and is used in glass making and heating furnaces. Alumina has good heat and electrical insulator (barrier) properties, good thermal conductivity, high hardness, high strength and stiffness. Generally Al_2O_3 is found in a crystalline form called corundum or α-aluminum oxide. Al_2O_3 is used as an abrasive material and as a component in cutting tools, because of its hardness (17).

1.6. Polymers as Matrices

Matrix is a substance/material that is used as a binder for fillers but does not undergo a chemical reaction with fillers. In general, the matrix functions as a composite protector from damage, both mechanical and chemical damage, to transfer loads from the outside to the filler material, to bind the filler material [18].

1.7. Epoxy Resin

Epoxy resin is included in the thermosetting group, so when printing you need to pay attention to the following things: It has a small shrinkage when cured. Can be measured at room temperature for an optimal time. Has a low viscosity adapted to the support material. Has good adhesion to the support material. The characteristics of epoxy chain production are process ability and degree of banding. Making a very good epoxy network by adding a catalyst that will react well with the network structure, the mechanical ability of the epoxy depends on the type of catalyst used. Epoxy resin contains epoxy or ox Irene structures. This resin is in the form of a thick or almost solid liquid, which is used as a material when it is about to be hardened. When epoxy resin is reacted with hardener it will form a crosslink polymer. Hardeners for curing systems at room temperature with epoxy resin are generally polyamide compounds consisting of two or more amine groups. The curing time of the epoxy system depends on the reactivity of the hydrogen atoms in the amine compound [19].

1.8. Catalyst

A catalyst is a substance that accelerates the rate of a chemical reaction at a certain temperature, without changing or being used up by the reaction itself. A catalyst plays a role in a reaction but is not a reactant or product. Catalysts can be divided into two main groups, namely homogeneous catalysts and heterogeneous catalysts. A heterogeneous catalyst is a catalyst that is in a different phase from the reactants in the reaction it catalyzes, while a homogeneous catalyst is in the same phase [20].

1.9. Intake Manifold

The intake manifold is a vehicle component whose function is to distribute the air and fuel mixture processed by the carburetor to the cylinders. The intake manifold is made from aluminum alloy, which can transfer heat more effectively than other metals. The intake manifold is placed as close as possible to the heat source which allows the air and gasoline mixture to evaporate quickly. On some engines, the intake manifold is located close to the exhaust manifold. [21]

1.10. Volume Fraction

Volume fraction is a comparison rule for mixing the fiber volume and matrix volume of the composite forming material to the total volume of the composite. To calculate the volume fraction, the parameters that must be known are the specific gravity of the resin, the specific gravity of the fiber, the weight of the composite and the weight of the fiber. The equation used to find the volume fraction is as follows: [22]

$$\text{Vf} = \frac{mf/\rho f}{Vc} \times 100\%$$

Where:

Vf = Fiber Volume Fraction (cm^3)

Mf = Fiber Mass (gr)

Pf = Fiber Density (gr/cm^3)

Vc = Composite Volume(cm^3)

1.11. Mechanical Properties

Mechanical properties of composites are properties related to the material after forces are applied to the material. The mechanical properties of materials include stress, strain and elastic modulus. Measuring mechanical properties includes measuring the tensile strength, flexural strength, impact strength, compressive strength, thermal strength and density strength of the composite. Tensile testing is carried out by applying a maximum pull until the composite material breaks, flexural testing is carried out by applying a maximum load so that the composite material breaks, impact testing is carried out by applying a shock load, compression testing is carried out by applying an axial load to the maximum limit. (23).

1.12. Bending Strength

To determine the bending strength of a material, you can do a bending test on the composite material. Bending strength or bending strength is the largest bending stress that can be received due to external loading without experiencing large deformation or failure. The amount of bending strength depends on the type of material and loading. As a result of the bending test, the top part of the specimen experiences pressure, while the bottom part experiences tensile stress. In composite materials the compressive strength is higher than the tensile strength. Because it is unable to withstand the tensile stress received, the specimen will break, resulting in failure in the composite test. The bending strength on the top side is the same value as the bending strength on the bottom side. The test was carried out by three point bending [24].

Composite materials have better compressive properties than tensile properties. In the bending test treatment, the top of the specimen experiences a pressing process and the bottom of the specimen experiences a tensile process so that as a result the specimen experiences a fracture at the bottom because it is unable to withstand the tensile stress. Bending test specimens were made according to ASTM D-618 standard [25].

For bending strength calculations, the following equation can be used:

$$\sigma b = \frac{3\ FL}{2.b.d^2}$$

Where:

σb = Bending stress (MPa)

F = Load (N)

L = Specimen length (mm)

b = Specimen width (mm)

d = Specimen thickness (mm)

1.13. Thermal Conductivity

Thermal conductivity is a measure of the ability of a material or materials to conduct energy. Thermal energy is transmitted in solids through the vibration of the free electron lattice. In a good conductor, where there are free electrons moving within the lattice structure of the material, the electrons, besides being able to lift electrical charges, can also carry thermal energy from high temperature areas to low temperature areas [26].

The equation used to determine the thermal conductivity value of the specimen is:

$$\text{K} = \frac{q.L}{A.\Delta T}$$

Where:

Q = Heat transfer rate (w)

K = Thermal Conductivity (w/m°C)

A = Cross-sectional area (m^2)

ΔT = Temperature Difference (°C)

L = Specimen Thickness (m)

2. Research Methodology

The research will be carried out from April to November 2023. This research was carried out at the Materials and Mechanical Technology Laboratory and at the Integrated Laboratory UPT, Halu Oleo University.

2.1. Specimen Making

After the composite material has been made, the next step is the cutting process to a length of 80 mm, width of 20 mm, thickness of 1.2 mm according to the bending testing standard, namely ASTM D-618.

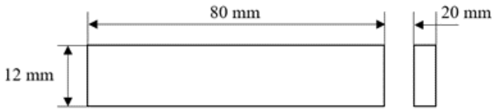

Fig. 6. Bending Test Specimen Shape

2.2. Composite Volume Fraction

The composite is made using a mold with a ratio of fiber to matrix, namely 30%:70%. [27]

2.3. Calculating Mold Volume

To calculate the mold volume, the following equation is used:

Is known:

P = 20 cm

L = 20 cm

T = 5 cm

Solution:

V_{cet} = P × L × T
= 20 cm × 20 cm × 5 cm
= 200 cm^3

Where:

V_{cet} : Mold volume (cm^3)
V_{komp} : Composite volume (cm^3)

a. Calculating Fiber Volume
To determine the amount of fiber volume, the following equation can be used:

V_s = 30% × V_{komp}

b. Calculating the volume of the matrix

To calculate the matrix volume, the following equation is used:

V_m = 68% × V_{komp}

c. Calculate the catalyst volume

The catalyst volume can be calculated using the following equation:

V_k = 2% × V_{komp}

d. Calculate the volume of alumina
To calculate the volume of alumina, the following equation is used:

V_m = 3% × V_{komp}

3. Data analysis

The data that will be obtained from the experimental results is entered into a table, and displayed in graphic form and then compared between a Honda Tiger motorbike using a standard intake manifold and a coconut fiber composite intake manifold.

Table 1. Bending Test Product Composition

	Mixing Process			
Composition	Alumina (Al_2O_3)	Epoxy Resin	Coconut Fiber	Number of Products
1	3%	67%	30%	3
2	6%	74%	20%	3
3	9%	81%	10%	3

Table 2. Thermal Test Product Composition

	Proses Pencampuran			
Composition	Alumina	Epoxy Resin	Coconut Fiber	Number of Products
1	3%	67%	30%	3
2	6%	74%	20%	3
3	9%	81%	10%	3

4. Results And Discussion

Table 4. Test Results for Bending Stress and Modulus of Elasticity**.**

No	Variasi Fraksi Volume	F	L	b	d	σb	Eb
		(N)	(mm)	(mm)	(mm)	(MPa)	(Gpa)
1	10%	552	76	20,5	12,5	19,646	0,962657
2		559	76	20,5	12,5	19,895	0,962664
3		400	76	22	12,1	14,157	0,962667
	rata-rata					17,89933	0,962663
4	20%	761	76	20,2	12,3	28,388	0,962651
5		783	76	21	13,6	22,98	0,96271
6		655	76	22	12	23,57	0,962662
	rata-rata					24,97933	0,962674
7	30%	1015	76	20,6	13,4	31,282	0,962666
8		1230	76	21,1	14,1	33,426	0,962678
9		1045	76	21,6	14,1	27,741	0,962686
	rata-rata					30,81633	0,962677

Bending strength is the greatest bending stress that can be received due to external loading without experiencing large deformation or failure. The table above shows the results of calculating the average bending stress and elastic modulus of specimens with a volume fraction of 10%, 20% and 30% coconut fiber combined with alumina powder.

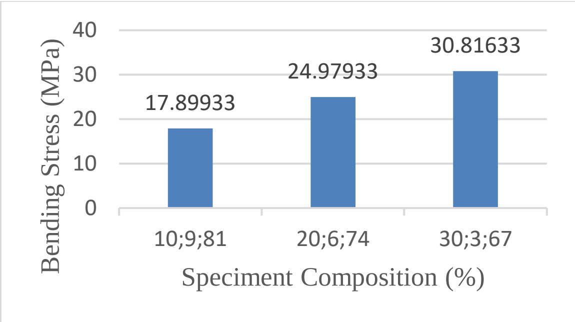

Fig. 7. Composite Bending Stress Graph at various volume fractions (Coconut Fiber, Alumina, Resin)

From the calculated data and values shown in Table 4, the researcher took the largest average load on each test sample, with the composition of specimen variation 1 having a ratio of 10% fiber; 9% alumina; 81% resin, specimen 2, 20% fiber; 6% alumina; 74% resin, and specimen 3, with a variation of 30% fiber; 3% alumina; 67% resin.

Pig. 7. Above shows the relationship between bending stress in several volume fractions. From this graph, bending stress relative to volume fraction tends to increase. The greatest bending strength value is found in composite specimens with a volume fraction of 30% fiber; 67% resin; 3% alumina has a bending stress value of 30.81633 MPa, while the lowest bending stress is found in the volume fraction of 10% fiber; 81% resin; 9% alumina with a bending stress value of 17.89933 MPa. This is caused by the combined elements, where the smaller the number of fibers and the greater the amount of alumina, the smaller the bending stress value. This is caused by the lack of mechanical bonding between the fiber-matrix and also the low bending strength value. This is also influenced by the amount of alumina. The more alumina it can cause the specimen to become brittle.

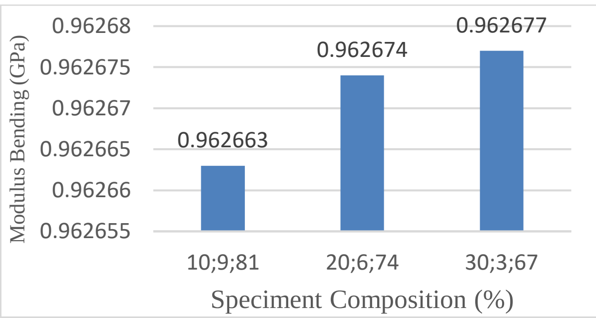

Fig. 8. Graph of composite elastic modulus at various volume fractions (Coconut Fiber, Alumina, and Resin)

The results of the elastic modulus of pigure 8, can be seen that the volume fraction is 30% fiber; 3% alumina; 67% resin has the highest value of the two specimens, namely 0.962677 GPa and the lowest value is shown in the specimen with a volume fraction of 10% fiber; 81% resin; 9% alumina, with an average value of 0.962663 GPa.

From the data results fig., the average of the three specimens has a low elastic modulus value of only 0.962 GPA. This is due to the addition of alumina which makes these three specimens have low elasticity values.

4.1. Thermal Test Results Data

The experimental procedure for testing composite specimens reinforced with coconut fiber was carried out using a Temperature Recorder located at the UPT Integrated Laboratory, Halu Oleo University.

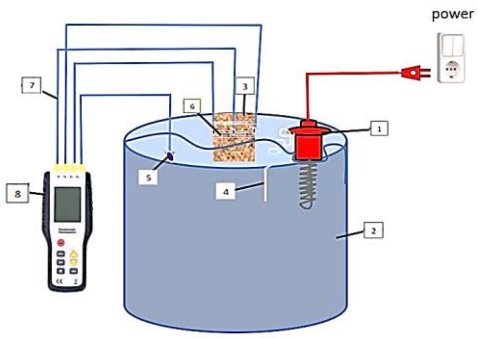

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Fig. 9. Thermal Conductivity Test Data Collection Scheme

Information:

1. Heater and Thermostat
2. Oil container
3. Test specimen
4. Thermostat temperature control
5. Temperature reading sensor
6. Thermocouple cable binding thread
7. Thermocouple cable
8. Digital thermocouple

Table 5. Thermal Test Data Specifications for Composite Specimens Reinforced with Coconut Fiber.

NO	COMPOSITION		T (out) (°C)			T (in) (°C)		
			15 Minute	30 minute	45 minute	15 minute	30 minute	45 minute
1	Speciment 10 %	Spesimen 1	67,9	69,2	68	104,2	109,7	106,5
2		Spesimen 2	69,3	64,4	67,5	102,9	105,1	103,6
3		Spesimen 3	74,8	72,4	76,7	109,1	106,4	103,4
Rata-rata			70,66667	68,66667	70,73333	105,4	107,0667	104,5
4	Speciment 20 %	Spesimen 1	53,6	57,2	58,2	103,3	103,8	106,7
5		Spesimen 2	54	60,6	60,7	103.5	104,5	109,6
6		Spesimen 3	57,2	59	61,7	105,6	106,7	105,4
Rata-rata			54,93333	58,93333	60,2	104,45	105	107,2333
7	Speciment 30%	Spesimen 1	55	57	56,3	106,5	106,9	104,3
8		Spesimen 2	58,2	66,7	64,2	104,7	109,8	105,2
9		Spesimen 3	62,1	66,3	67,2	102,8	105,9	107,4
Rata-rata			58,43333	63,33333	62,56667	104,6667	107,5333	105,6333

Table 6. Results of Thermal Test Data Analysis

No	variations in volume fraction		q	L	A	ΔT	K	Rata-rata
			(w)	(cm)	(cm)	(°C)	(w/m°C)	
1	10%	specimen 1	350	0,5	25	34,733	0,202	0,197
2		specimen 2	350	0,5	25	38,4	0,182	
3		specimen 3	350	0,5	25	33,767	0,207	
4	20%	specimen 1	350	0,5	25	46,233	0,151	0,15733
5		specimen 2	350	0,5	25	44,2	0,158	
6		specimen 3	350	0,5	25	43,067	0,163	
7	30%	specimen 1	350	0,5	25	49,517	0,141	0,14733
8		specimen 2	350	0,5	25	46,067	0,152	
9		specimen 3	350	0,5	25	47,033	0,149	

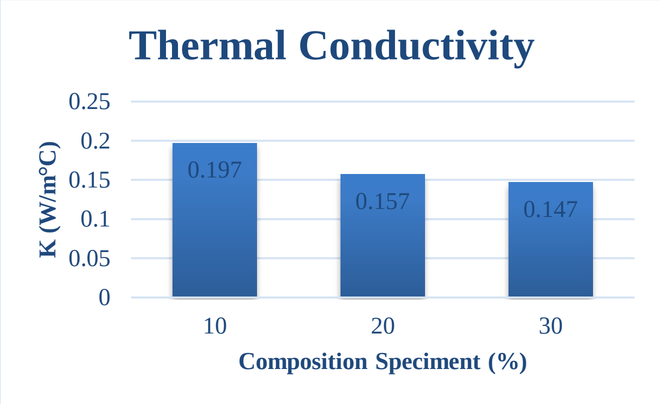

Fig. 10. Variation of Volume Fraction Composition on Thermal Conductivity (k) (Coconut Fiber, Alumina, and Resin)

Based on Figure 10 above, it is clear that the largest thermal conductivity value is in the volume fraction composition of 10% fiber: 9% alumina: 81% resin, namely k = 0.198 W/m°C. The lowest thermal conductivity value is in the composition of 30% fiber: 3% alumina: 67% resin, namely k = 0.146 W/m°C. Meanwhile, the thermal conductivity value for the composition volume fraction 20% fiber: 6% alumina: 74% resin is between the other two compositions, namely k = 0.158 W/m°C.

The difference in thermal conductivity values is caused by differences in the elemental composition of each composite, the higher the composition of the coconut fiber, the lower the thermal conductivity value. This is because the greater the percentage of palm fiber, the more porosity will arise. And basically polyester resin contains peroxide elements, namely an aqueous solution of hydrogen peroxide (HOOH or H2O2) which has a high conductor ability so that in composites with more matrix elements the thermal conductivity value will be higher. And this is also added by the addition of alumina which is increasingly the more alumina, the higher the thermal conductivity.

5. Conclusion

Based on the analysis of the results of research regarding variations in the ratio of fiber volume fraction and the addition of alumina, the following conclusions can be drawn:

1. Based on the results of thermal testing, the more alumina added, the higher the thermal conductivity value, because the nature of alumina can conduct heat. The composition that has the best thermal conductivity value is 0.146333 W/m°C with a composition of 30%: 67%: 3%, besides this composition has good insulating capabilities compared to the other two compositions.

2. Based on the results of bending tests, the more coconut fiber fiber, the greater the bending strength and modulus of elasticity of the specimen, and also with the addition of alumina, the more alumina added, the lower the bending strength, this is because alumina has brittle properties or breaks easily.

6. Suggestion

In future research, it is hoped that further research will be carried out on the use of composites in motorcycle manifolds.

Author contributions

Name1 Yuspian Gunawan: Conceptualization, Methodology, Software, Field study **Name2 Aminur:** Data curation, Writing-Original draft preparation, Software, Validation. Field study **Name3 & 4 Akbar Prasetiawan & Suharjito:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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