Dinamika Teknik Mesin 15(2) (2025) 133-142

Dinamika Teknik Mesin
Jurnal Keilmuan dan Terapan Teknik Mesin
http://dinamika.unram.ac.id/index.php/DTM/index

The effect of variations in vulcan concentration in agel-cotton rope as a reinforcement for ripoxy composites on thermal conductivity properties

I.K. Suarsana*[1], I.G.N.N. Santhiarsa[1], I.G.N.P. Tenaya[1], A.R.F. Tarigan[1], A.A.A. Triadi[2]
[1]Mechanical Engineering Department, Engineering Faculty, Udayana University, Jl. Raya Kampus Unud Jimbaran, Badung Regency, Bali 80361, Indonesia. HP. 081338606307
[2]Mechanical Engineering Department, Engineering Faculty, Mataram University, Jl. Majapahit no. 62, Mataram, NTB,83125, Indonesia
*E-mail: suarsana@unud.ac.id

ARTICLE INFO

Article History:
Received 06 April 2025
Accepted 22 September 2025
Available online 01 October 2025

Keywords:
Composite
NaOH
Polyester
Fiber
Thermogravimetric analysis (TGA)

ABSTRACT

Ripoxy composites reinforced with natural agel-cotton rope reinforcement have attracted attention in engineering material applications due to their mechanical properties and environmentally friendly waste. Vulcan chemicals, which are fillers or additives in the composite manufacturing industry, are believed to be able to improve the thermal properties of the composite. This study aims to examine the effect of vulcan chemical treatment on thermal conductivity in ripoxy composites reinforced with cotton rope. This test was carried out by soaking agel-cotton rope textiles in Vulcan solution for 1 hour with variations in solution concentration: 0%, 25%, and 50%. The printing of test specimens was carried out using a Vacuum Infusion printing tool, so that the printed specimen results were not contaminated by outside air. Thermal conductivity tests were carried out using the ASTM - D5470 standard. The test results that have been obtained, the 25% concentration variation has the smallest thermal conductivity value, with a value of 0.064 W / m°C at a temperature of 100° C and 0.171 W / m°C at a temperature of 200°C. Meanwhile, with a concentration variation of 50% the value increases because the greater the concentration of Vulcan given, the density of the composite material will increase, and higher concentrations can reduce the number of pores or voids in the composite which can usually inhibit heat flow.

Dinamika Teknik Mesin, Vol. 15, No. 2, Oktober 2025, ***p. ISSN: 2088-088X, e. ISSN:*** **2502-1729**

1. INTRODUCTION

Research on the development of composite materials has become a major concern in recent decades (Julian, 2022). One type of composite that attracts attention is textile fiber composites, because the combination of mechanical and thermal properties is very good in the polymer matrix (Nisa et al., 2022). Composites have the advantage of high strength and stiffness, so they are widely used in various industries, including construction,

https://doi.org/10.29303/dtm.v15i2.1097

automotive, and aerospace (Diana et al., 2020). In various industrial sectors, the use of composites is increasing, especially in the automotive industry because of their superior properties, such as ease of formation, strength, stiffness, light weight, and resistance to corrosion. The advantages offered by natural fiber composites, such as bamboo fiber, water hyacinth, hemp, and agel-cotton rope, are that they have very good physical and mechanical properties, so they are widely used in the automotive industry. Natural fibers offer mechanical properties comparable to synthetic fibers, with the added advantage of reduced weight, fuel efficiency, especially in vehicles (Koronis et al., 2013).

Research on textile fiber composites has been widely conducted, but there are still several challenges that need to be resolved. One of the main challenges is increasing the adhesion between the fiber and the polymer matrix, which directly affects the mechanical and thermal properties of the composite (Abidnejad et al., 2025). The thermal properties of the composite related to thermal conductivity are one of the important aspects that affect various material use applications. Thermal conductivity is the ability of a material to conduct heat in a material. Its application can be found in various fields, such as the electronics industry, where materials with high thermal conductivity such as metals are used as coolants to transfer heat from electronic components. In addition, in the construction industry, materials with low thermal conductivity are used as insulators to reduce heat transfer from inside to outside the building and vice versa. Previous studies have shown that the type of textile fiber, fiber orientation, and composite manufacturing process affect the mechanical and thermal properties of textile fiber composites(Azizi, 2021). Natural plant-based fibers are highly flammable. Polymer composites are reinforced with fibers, so they need to be protected from fire if used in applications such as the automotive, civil, or aircraft industries. The use of fire-retardant fluids for composites can inhibit or even suppress the combustion process, for example during heating, decomposition, ignition, and fire spread. The increased fire resistance of composites can be done by adding fire-reducing additives such as halogen-based compounds, nitrogen, and phosphorus (Bachtiar et al., 2019).

Previous studies have been conducted by Bachtiar in 2019, which showed that the type of addition of fire retardant fluids such as ammonium polyphosphate and aluminum hydroxide affects the thermal properties of textile fiber composites (Bachtiar et al., 2019). Composites from coffee grounds showed improved characteristics such as mechanical, thermal, and fire resistance properties (Nguyen & Nguyen, 2021). Agrigan in previous studies said that single-layer composite materials can be selected in industrial insulation applications because materials with low thermal conductivity coefficients are the best choice for thermal insulation purposes (Agirgan et al., 2022). Thermal characterization is shown by the thermal conductivity properties of biocomposite materials, especially hemp fiber as its constituent element (Dahal et al., 2022). The development of a sustainable fire retardant fluid system, based on renewable raw materials, is a feasible and promising approach to producing biocomposites with better fire resistance, lower environmental impact, and better health and safety performance (Madyaratri et al., 2022). enerally, composites consist of two main materials including matrix and reinforcement (Farahmand, 2025). The matrix functions as an adhesive and protector, and the reinforcement functions as the main load support for the composite (Saleh & Dawoud, 2018).

Increasing the adhesion between the fiber and the polymer matrix, which has an impact on the mechanical and thermal properties of the composite is a major challenge. It is also important to learn more about how different types of textile fibers affect the properties of the composite (Mahmuda et al., 2013). Previous researchers have shown that the type of textile fiber, fiber orientation, and composite manufacturing process affect the mechanical and thermal properties of textile fiber composites (Azizi, 2021). The subject of the research conducted focused on the use of vulcan liquid concentration added to the ripoxy polymer composite. In this study, the researchers produced a composite material discovery with the addition of vulcan concentration, the results of which were better than the halogen-based concentration in the ripoxy textile composite reinforced with cotton agel rope. The effect on the thermal conductivity value was better than without the Vulcan concentration. The purpose of this study was to determine the effect of adding vulcan concentration to the ripoxy textile composite reinforced with agel-cotton rope on thermal conductivity.

2. RESEARCH METHODS

2.1 Cotton rope reinforced composite

Composites are materials formed from two or more materials with different characteristics that are combined to create a material with better mechanical properties than the original materials. In general, composites consist of two main components, namely the matrix and the reinforcement. The matrix functions as an adhesive or protector, and the reinforcement/filler functions as the main load-bearing material in the composite. The matrix is a material that acts as a binder in the composite, which functions to maintain structural integrity and ensure that the reinforcing material remains one. The main role of the matrix is to maintain the position of the reinforcing material and help withstand the load given to the composite. As a binder, the matrix generally consists of metals, ceramics, and polymers (Alovsat, 2024). Polymers are one of the most commonly used matrices in composite materials (Sharma et al., 2020).

Agel rope is a rope that comes from the process of twisting fibers obtained from the processing of agel or lontar leaves. This plant is often found in the areas of Bali, East Java, Madura, and Nusa Tenggara. Agel fiber is obtained by drying young leaves of the lontar tree. The fibers from the dried leaves are then shaved and twisted with a special machine. Agel rope made from natural fibers has lower breaking strength and elongation when compared to ropes made from synthetic fibers. In addition, agel rope is also easily damaged due to the rotting process by bacteria. This results in a relatively low technical life of this rope.

Cotton is a natural fiber that is widely used as a material for textiles because of its strong and durable nature. The process of making cotton begins with sorting the cotton that has been picked. Then the cotton is processed into cotton fibers so that they can connect and lengthen. After that, the cotton fibers are processed using yarning techniques to produce yarn, which can then be dyed to get the desired color.

Resin is a polymer compound that has high viscosity, is easy to harden, is flammable, and is insoluble in water. Resin is made from exudate (sap) released by many types of plants, especially by conifers. This sap usually solidifies, slowly or immediately, and forms a hard and, more or less, transparent mass. Resin has been widely used as a varnish, adhesive, food coating (to make it shiny), an ingredient in incense and perfume, and a source of raw materials for processed organic materials.

Vulcan AF-21 liquid is water-based and functions as a flame retardant. This liquid is colorless, odorless, and does not change the appearance or texture of the material it protects. For flammable interior materials, such as fabrics, wood, carpets, and sofas, Vulcan AF-21 liquid is selected as suitable. Once applied, the protected material becomes fireproof and non-flammable. The fire resistance test using vulcan AF-21 is in accordance with the BS 476 part 5 standards of 1979 and ASTM D-3806 of 1979. Vulcan AF-21 has a base material of ammonium phosphate $(NH_4)_3PO_4$ and ammonium sulfate $(NH_4)_2SO_4$. The materials used in the study can be seen in Figure 1.

(a) (b) (c)

Figure 1. (a) Woven or woven fibers (b) Vulcan liquid (c) Ripoxy resin

2.2 Vacuum infusion

Vacuum infusion is a composite manufacturing method that utilizes low-pressure air to prevent the formation of voids due to trapped air during the lamination process. This method has several advantages, including being able to produce complex composites with good thickness and mechanical properties by producing little resin waste compared to traditional methods. The molding tool in this study is Vacuum Infusion as shown in Figure 2.

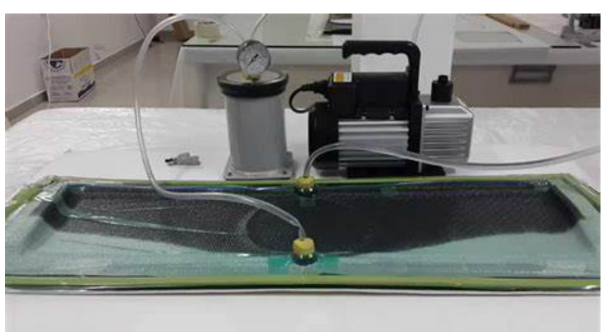

Figure 2. Vacuum infusion

2.3 Thermal Conductivity

Thermal conductivity is a measure of the ability of a material to conduct heat from one place to another. Several factors that affect thermal conductivity include temperature, density and porosity, and water vapor content. The effect of temperature on thermal conductivity is small, but in general it can be said that thermal conductivity will increase if the temperature (Saputra et al., 2022). To find out the thermal conductivity value, you can look at the existing table or conduct a test. The thermal conductivity value can be used to determine the type of material, whether it is an insulator or a conductor. Materials that have low thermal conductivity can be said to be good heat inhibitors (insulators), while materials that have high thermal conductivity can be said to be good heat conductors (conductors) (Pratama et al., 2016).

The application of thermal conductivity can be found in various daily lives, for example in the electronics industry. High thermal conductivity such as metal is often used as a coolant to transfer heat from hot electronic components to the surrounding air. Thermal conductivity is also important in building design, using low-conductivity thermal insulator materials to prevent heat flow from inside the house to the outside and vice versa. Thermal conductivity testing is carried out by analyzing the temperature difference measured at points T1 to T10 using the OSK 4565 machine obtained from the mechanical engineering laboratory in Brawijaya University. Points T1 to T10 refer to the location of the temperature sensor installed on the device, which automatically records the temperature at various positions in the system to calculate the temperature gradient required in the calculation of thermal conductivity.

The temperature difference on the specimen (T1-T4 (A), T7-T10 (B)) and the temperature difference on the standard cyclinder (T5-T6) are known to be indicated by the test equipment, then continue to calculate ΔTb, ΔTa, average temperature difference (ΔTr), λA, λB, and its conductivity (λ) according to the thermal machine (OSK 4565) of the Brawijaya mechanical engineering laboratory. The thermal conductivity value can be calculated using the following equation:

$$\Delta Tb = T4 - T5 \quad (1)$$

Where: ΔTb = Temperature difference between the upper specimen and the standard cylinder,
T4 = 4th temperature, T5 = 5th temperature

$$\Delta Ta = T6 - T7 \quad (2)$$

Where: ΔTa = Difference in temperature between the lower specimen and the standard cylinder,
T6 = 6th temperature, T7 = 7th temperature

$$\Delta Tr = \frac{(T1 - T2) + (T2 - T3) + (T3 - T4) + (T7 - T8) + (T8 - T9) + (T9 - T10)}{6} \quad (3)$$

Where: ΔTr = Average temperature difference of specimens A and B from T1 to T10

$$\lambda a = \frac{\Delta Tr}{\Delta Ta} \times \frac{La}{Lr} \times \lambda R \quad (4)$$

Where: λa - Conductivity of the specimen (A). La = thickness of the specimen (A), Lr = average thickness of the specimen (A)

$$\lambda b = \frac{\Delta Tr}{\Delta Tb} \times \frac{Lb}{Lr} \times \lambda R \quad (5)$$

Where: λb = Conductivity of the specimen (B), Lb = thickness of the specimen (B), Lr = average thickness of the specimen (B)

$$\lambda = \frac{Lb - La}{\frac{Lb}{\lambda b} - \frac{La}{\lambda a}} \quad (6)$$

Where: λ = Conductivity), La = thickness of the sample/specimen being tested, Lb = thickness of the test copper, Lr = average thickness of the specimen

2.4 Research test parameters and tools

The research parameters were conducted with independent variables and dependent variables, where the independent variable was the concentration of vulcan chemical solution: 0%, 25% and 50%, control variable: soaking for 1 hour. The dependent variable was the thermal conductivity of the cotton agel rope reinforced repoxy resin composite. The tools used for data collection in the study are shown in Figure 3 as follows:

Figure 3. Thermal conductivity tester (OSK 4565)

2.5 Test implementation procedures

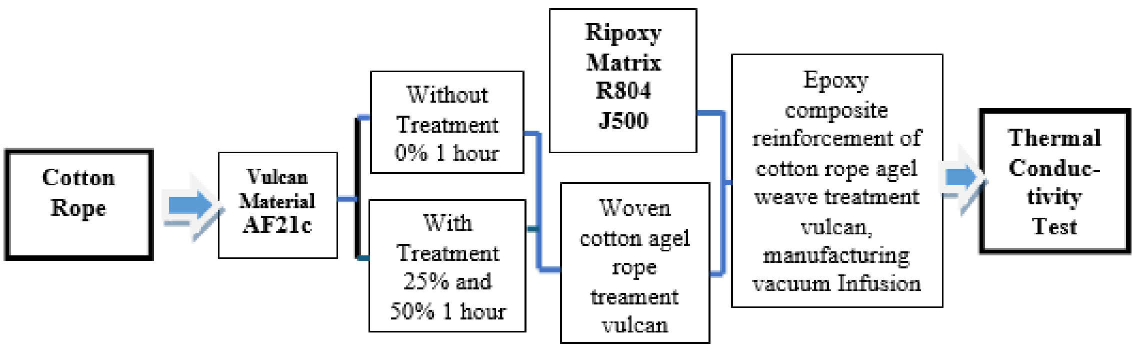

Figure 4. Illustration of research procedures

The thermal conductivity test method is to measure the temperature difference of a material due to the addition of heat energy at one end of the material. This planning is based on the concept of conduction, which based on the second law of thermodynamics, thermal conductivity can be measured if heat transfer occurs from high to low temperatures. Thermal conductivity test procedure with Thermal Conductivity test equipment (OSK 4565). Specimens according to the thermal conductivity test with standards (ASTM D5470) according to the test equipment.

3. RESULT AND DISCUSSION

In this section, the results obtained from the thermal conductivity testing using the OSK 4565 device. The data collected are analyzed to determine the thermal conductivity values of the tested materials, followed by interpretation and discussion of the findings. The presentation begins with the raw test results, which are then followed by the calculation outcomes.

3.1 Thermal conductivity test result data

Based on the tests carried out, the data and results of the thermal conductivity tests for all specimens were obtained in the following table.

Table 1. Thermal conductivity test at 100°C on ripoxy composite material

Vulcan Treatment	Temperature (T°C)									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
	100	99	98	98	34	34	25	25	25	25
0%	100	99	99	98	34	34	26	26	25	25
	100	99	99	98	36	34	27	27	27	26
	100	100	99	99	35	34	26	26	26	26
25%	100	100	99	99	36	35	27	27	27	27
	100	100	99	99	36	36	27	27	27	27
	100	100	99	98	35	34	27	27	27	26
50%	100	99	99	98	34	34	26	26	26	26
	100	100	99	98	35	35	27	27	27	27

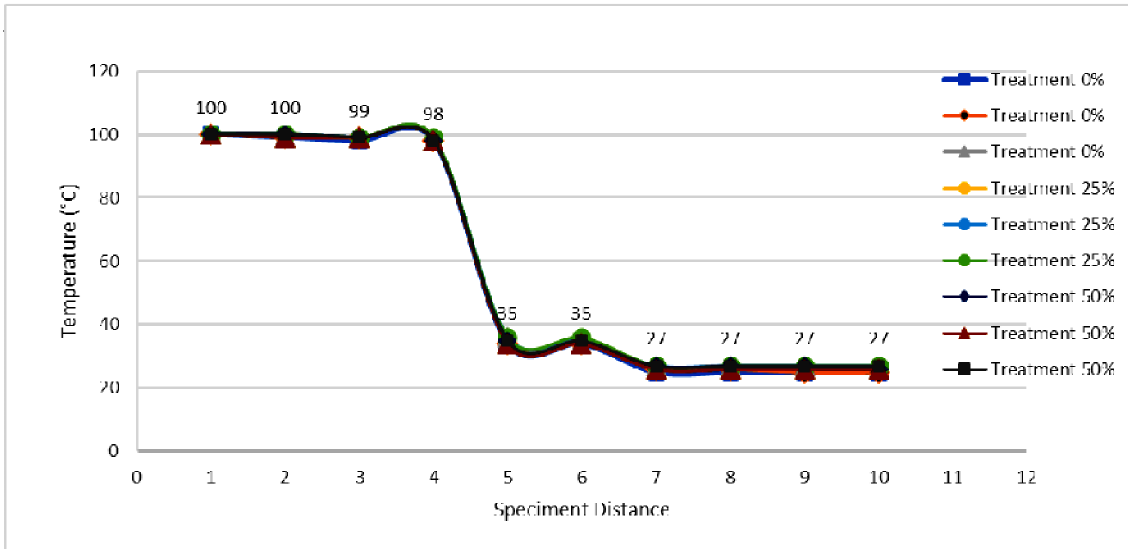

Figure 5. Thermal conductivity graph 100°C

Figure 5 shows the relationship between distance and temperature with a graph pattern. Thermal conductivity can be analyzed in the initial zone (T1 - T4), where the temperature is relatively high and stable at around 100°C. This indicates that heat conduction is still taking place efficiently, in materials with high thermal conductivity. At temperatures (T4 - T5), there is a very sharp decrease from 100°C around 30-40°C, this indicates that there is a change in material or contact with another medium that has a much lower thermal conductivity in the specimen and can also indicate that the material has high thermal resistance or there is a dominant heat transfer by convection and radiation. The temperature begins to stabilize (T6 - T10), tends to be constant in the range of 20-30°C, indicating that heat has been dissipated and reached a state of thermal equilibrium with the environment. A drastic decrease in temperature indicates the presence of materials with low thermal conductivity or high thermal resistance. Based on the test results at a temperature of 100°C, there is no significant difference in thermal conductivity, as shown in Figure 5. The graph shows that samples with Vulcan concentrations of 0%, 25%, and 50% have relatively similar thermal conductivity values. This indicates that the addition of Vulcan as filler in the process of making repoxy composites does not have a significant effect on its thermal conductivity properties (Amran et al., 2022). Thus, this material still shows characteristics as a low heat conductor or has properties as an insulating material.

Table 2. Thermal conductivity test at 200°C on ripoxy composite material

Vulcan treatment	Temperature (T°C)									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
	200	195	190	98	40	40	27	27	27	27
0%	200	195	193	98	42	41	27	27	27	26
	200	196	194	98	44	44	27	27	27	26
	200	196	193	99	45	45	27	27	27	27
25%	200	196	195	99	45	45	28	28	27	27
	200	198	198	99	47	47	29	28	28	27
	200	198	198	98	45	45	28	28	27	27
50%	200	198	198	98	47	47	28	28	28	27
	200	198	198	98	47	45	28	28	28	27

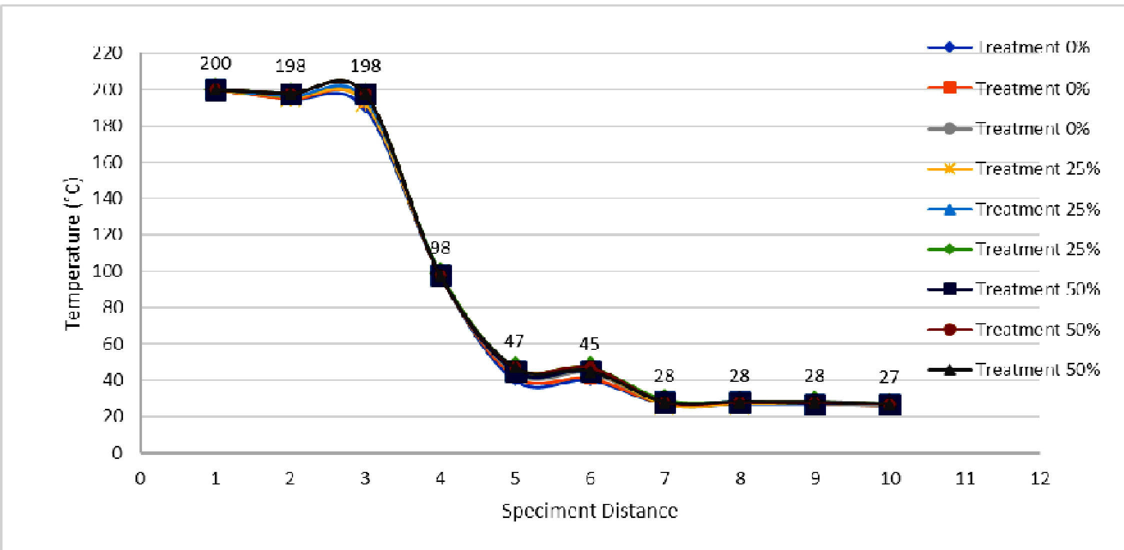

Figure 6. Thermal conductivity graph 200°C

Figure 6 shows the temperature distribution versus distance, which illustrates the phenomenon of heat transfer through conduction in a material. In the early part of the graph (T1–T3), the temperature is relatively high and stable at around 200°C, indicating that the material in this area has high thermal conductivity, so that heat can be transferred efficiently. The sharp temperature drop between the distance T3–T5 indicates a change in material or interface with lower thermal conductivity, causing significant thermal resistance and limited heat transfer. After the distance T5, the temperature reaches equilibrium at around 20–40°C, indicating that most of the heat energy has been dissipated to the environment. Overall, this graph reflects the characteristics of heat transfer in heterogeneous materials and the effect of changes in thermal conductivity on temperature gradients. Based on the test result graph at a temperature of 200°C, there is no significant difference in the ability to conduct heat. As shown in Figure 5, the graph shows that samples with Vulcan concentrations of 0%, 25%, and 50%, as well as the same agel rope composition, have curves that almost overlap. This shows that the addition of Vulcan (AF21c) in the manufacture of repoxy composites does not have a significant effect on the ability to conduct heat. Thus, this material still has properties as a low thermal conductor. This shows that the combination of vulcan as filler does not result in the expected increase in thermal conductivity (Caradonna et al., 2019)

3.2 Thermal Conductivity calculation results

The temperature difference on the specimen (T1-T4 (A), T7-T10 (B) and the temperature difference on the standard cylinder (T5-T6) have been obtained. The next step is to calculate ΔTb, ΔTa, the average temperature difference (ΔTr), λA, λB, and its conductivity (λ), obtained from the machine data: La = 2; Lb = 4;

Lr = 30 and λR = 320 then the thermal conductivity can be calculated according to equation (6). The calculation results can be seen in Table 3 for a temperature of 100°C and Table 4 for a temperature of 200°C on the ripoxy composite.

Table 3. Conductivity calculation results data at a temperature of 100°C on the ripoxy composite.

Treatment	Specimen	ΔTb	ΔTa	ΔTr	λA	λB	λ
0%	1	64	9	0.333	0.790	0.222	0.129
	2	64	8	0.500	1.333	0.333	0.190
	3	62	7	0.500	1.524	0.344	0.194
			Average				**0.171**
25%	1	64	8	0.167	0.444	0.111	0.063
	2	63	8	0.167	0.444	0.113	0.065
	3	63	9	0.167	0.395	0.113	0.066
			Average				**0.064**
50%	1	63	7	0.500	1.524	0.339	0.190
	2	64	8	0.333	0.889	0.222	0.127
	3	63	8	0.333	0.889	0.226	0.129
			Average				**0.148**

Table 4. Conductivity calculation results data at a temperature of 200°C on the ripoxy composite.

Treatment	Specimen	ΔTb	ΔTa	ΔTr	λA	λB	λ
0%	1	150	13	1.667	2.735	0.474	0.260
	2	150	14	1.500	2.286	0.427	0.235
	3	149	17	1.333	1.673	0.382	0.215
			Average				**0.236**
25%	1	148	18	1.167	1.383	0.336	0.191
	2	149	17	1.167	1.464	0.334	0.189
	3	150	18	0.833	0.988	0.237	0.135
			Average				**0.171**
50%	1	149	17	1.167	1.464	0.334	0.189
	2	147	19	1.167	1.310	0.339	0.194
	3	146	17	1.333	1.673	0.390	0.220
			Average				**0.201**

Table 5. Average thermal conductivity of rope-egel reinforced ripoxy composites with vulcan treatment

Temperature	Vulcan Treatment	Thermal conductivity (W/m°C)
100 °C	0%	0.171
	25%	0.04
	50%	0.148
200 °C	0%	0.236
	25%	0.171
	50%	0.201

https://doi.org/10.29303/dtm.v15i2.1097

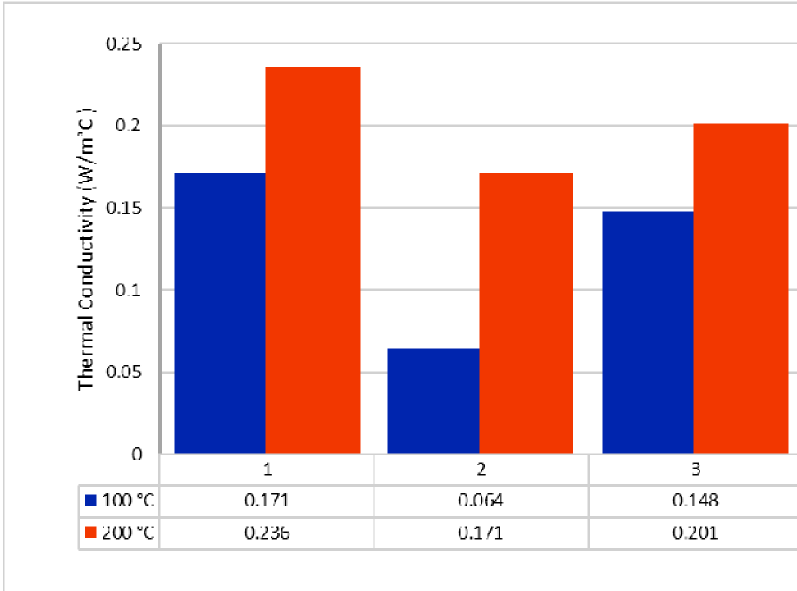

Figure 7. Graph of the average values of thermal conductivity test results at temperatures of 100°C and 200°C.

Based on Table 5 and Figure 7, the average value and thermal conductivity graph of ripoxy composite reinforced with rope-gel with vulcan treatment are shown. The test results show a graph of ripoxy matrix specimen reinforced with cotton rope-gel without concentration (0%) vulcan at a temperature of 100°C of (0.148 W/m°C) and at a temperature of 200°C of (0.236 W/m°C). The thermal conductivity value of the specimen with a concentration of 25% vulcan at a temperature of 100°C is (0.064 W/m°C) and at a temperature of 200°C is (0.171 W/m°C). The average value of thermal conductivity in specimens with a concentration of 50% vulcan at a temperature of 100°C is (0.171 W/m°C) and at a temperature of 200°C is (0.201 W/m°C). So it can be seen at a concentration of 25% Vulcan both at temperatures of 100°C and 200°C the specimen has a low average thermal conductivity value. This is because the Vulcan liquid can inhibit the thermal conductivity of the specimen, but other factors that affect the thermal conductivity value are the composition of the test specimen itself, namely porosity and density where at a concentration of 25% there is still empty space that can inhibit heat flow while at 50% the material has become too dense or saturated so that it does not have much empty space to inhibit heat flow (Song et al., 2023).

4. CONCLUSION

The addition of vulcan concentration to the ripoxy matrix composite reinforced with cotton agel rope has an effect on the thermal conductivity value compared to without Vulcan concentration. The test results show that the specimen with the smallest or lowest conductivity value is the specimen with a concentration variation of 25%, at a temperature of 100°C has an average value of 0.064W/m°C and at a temperature of 200°C has an average value of 0.171W/m°C. Variations in Vulcan concentration can affect the thermal properties of the material. Higher concentrations can form more cross-links and make the material too dense and saturated, making the material less good at inhibiting heat flow.

ACKNOWLEDGEMENTS

The author on this occasion would like to thank all parties who have helped in the form of materials and thoughts so that this research and paper can be completed. Secondly, the author would like to thank all Lecturers of the Department of Mechanical Engineering, Faculty of Engineering, Udayana University who have provided a lot of input and views in completing this research.

REFERENCES

Abidnejad, R., Baniasadi, H., Fazeli, M., Lipponen, S., Kontturi, E., Rojas, O. J., & Mattos, B. D., High-fiber content composites produced from mixed textile waste: balancing cotton and polyester fibers for improved composite performance, International Journal of Biological Macromolecules, 292, 2025.

Agirgan, M., Ahmet Ozgur, A., Taskin, V., Investigation of thermal conductivity and sound absorption properties of rice straw fiber/polylactic acid biocomposite material, Journal of Natural Fibers, 19(16), 15071–15084, 2022.

Alovsat, T. Y., Classification and properties of composites based on matrix material, World Journal of Advanced Research and Reviews, 24(02), 2278–2282, 2024.

Amran, Subaer, Husain., Produksi dan karakterisasi komposit ringan geopoplimer- serat gelas, Jurnal Sains dan Pendidikan Fisika (JSPF), 18(1), 101–110, 2022.

Azizi, R., Karakterisasi pengaruh orientasi serat terhadap sifat mekanis dan fisis komposit serat tandan kosong kelapa sawit, Jurnal Teknologi Rekayasa Teknik Mesin, 2(1), 28–35, 2021.

Bachtiar, E. V., Kurkowiak, K., Yan, L., Kasal, B., Kolb, T., Thermal stability, fire performance, and mechanical properties of natural fibre fabric-reinforced polymer composites with different fire retardants. Polymers, 11(4), 2019.

Caradonna, A., Badini, C., Padovano, E., Pietroluongo, M., Electrical and thermal conductivity of epoxy-carbon filler composites processed by calendaring, Materials, 12(1522), 1–17, 2019.

Dahal, R. K., Acharya, B., Dutta, A., Mechanical thermal and acoustic properties of hemp and biocomposite materials: a review, Journal of Composites Science, 6(12), 2022.

Diana, L., Ghani Safitra, A., Nabiel Ariansyah, M., Analisis kekuatan tarik pada material komposit dengan serat penguat polimer, Jurnal Engine: Energi, Manufaktur, Dan Material, 4(2), 59–67, 2020.

Farahmand, B., Understanding of composite materials (constituents of composites) bt - fundamentals of composites and their methods of fabrications: pmcs, mmcs, and cmcs, Springer Nature, Switzerland, 2025.

Julian, J., Pengembangan material komposit berpenguat serat alami untuk aplikasi bumper mobil, Jurnal Al Ulum LPPM Universitas Al Washliyah Medan, 10(2), 92–98, 2022.

Koronis, G., Silva, A., Fontul, M., Green composites: a review of adequate materials for automotive applications, Composites Part B: Engineering, 44(1), 120–127, 2013.

Madyaratri, E. W., Ridho, M. R., Aristri, M. A., Adly, M., Lubis, R., Iswanto, A. H., Nawawi, D. S., Antov, P., Kristak, L., Majlingov, A., Fatriasari, W., Recent advances in the development of fire-resistant biocomposites — a review, Polymers, 362(13), 2022.

Mahmuda, E., Savetlana, S., Sugiyanto, D., Pengaruh panjang serat terhadap kekuatan tarik komposit berpenguat serat ijuk dengan matrik epoxy, Jurnal Ilmiah Teknik Mesin, 1(3), 79–84, 2013.

Nguyen, T. A., Nguyen, Q. T., Hybrid biocomposites based on used coffee grounds and epoxy resin: mechanical properties and fire resistance, International Journal of Chemical Engineering, 2021.

Nisa, K. S., Melyna, E., Samida, M. R. M., Sintesis biokomposit serat sabut kelapa dan resin poliester dengan alkalisasi koh menggunakan metode hand lay-up, Rekayasa, 15(3), 354–361, 2022.

Pratama, N., Djusmaini, D., Yenni, D., Pengaruh variasi ukuran partikel terhadapnilai konduktivitas termal papan partikel tongkol jagung, Pillar of Physics, 7, 25–32, 2016.

Saleh, H. M., Dawoud, M. M., Introductory chapter: background on composite materials (H. M. Saleh & M. Koller (eds.)), IntechOpen, 2018.

Saputra, A., Samhuddin, S., Hasanudin, L., Perancangan dan analisis pengujian konduktivitas panas pada tipe material padat, Enthalpy : Jurnal Ilmiah Mahasiswa Teknik Mesin, 7(1), 22, 2022.

Sharma, A. K., Bhandari, R., Aherwar, A., Rimašauskienė, R., Matrix materials used in composites: a comprehensive study, Materials Today: Proceedings, 21, 1559–1562, 2020.

Song, J., Wang, G., Xing, L., Qian, J., Dai, L., Di, H., Influencing factors of rock thermal conductivity and applicability evaluation of its mixing law predictive models, Geothermics, 110, 2023.

https://doi.org/10.29303/dtm.v15i2.1097