Journal of Applied Technology
Volume 9, Number 1, Page 7 – 15, June - November, 2022
ISSN 1693-2536, e-ISSN 2964-3198

Characterization of Eco-Friendly Composite Board as a Heat Insulator Based on Polypropylene Waste with Coconut Coir Filler

Medyan Riza[1*], Sri Aprilia[1], Nasrullah Razali[1], Mukhlishien[1], Muhammad Rabani Fikry[2], Hanif Saputra[2]

[1] Chemical Engineering Department, Engineering Faculty, University Syiah Kuala, Banda Aceh, 23111, Indonesia
[2] Undergraduate Chemical Engineering, Engineering Faculty, University Syiah Kuala, Banda Aceh, 23111, Indonesia

[*] *Corresponding author: medyan_riza@unsyiah.ac.id*

Abstract: Composite boards made of coconut fiber with polypropylene as a matrix are an option in dealing with environmental pollution problems caused by these materials. Coconut coir fiber has pores that can absorb heat, which is one of the global problems now. The process of making this composite is divided into 3 stages, namely the preparation stage of coco fiber into two different sizes, namely 40 and 80 mesh. The second stage is the process of preparing polypropylene into a matrix by heating the polypropylene until it melts and the desired texture is obtained. And finally, the mixing process consists of a predetermined fiber size, a polypropylene matrix (10:90, 20:80, 30:70 (%b fiber/%matrix)), and the resulting mixture is printed. The board was tested for its physical properties, namely water absorption and density, then analyzed for its mechanical properties through the fracture modulus test and analyzed the morphology structure, namely SEM and FTIR, as well as heat resistance testing through the Differential Scanning Calorimetry test and the Thermogravimetric Analyzer test. From the results of the study, it was obtained that a sample with a size of 40 mesh and a ratio of 10:90 had the best density and DSA values, namely 0.794 gr/cm3 and 2.8%. The best sample mechanical properties were obtained by a sample with a size of 80 mesh at a ratio of filler to matrix of 10:90 with an MOR value of 7.75 and an MOE of 1198 MPa. The highest melting point of the composite board was obtained in the f/m3 sample with a filler: matrix percentage of 30:70 and a coir size of 40 mesh, at a temperature of 518 °C. The highest thermal stability was obtained in the f/m6 sample with a filler and matrix percentage of 30:70, with a thermal stability temperature ranging from 290 to 533 and a mass loss of 4.26 mg.

Keywords: Coconut coir, polypropylene, DSC, TGA, Bending Test. Morphology

1. Introduction

Indonesia is a country that has the largest tropical rain forest in the world, as well as abundant natural resources. One of its natural resources is wood. The forest area in Indonesia is decreasing day by day at a very worrying rate. The amount of deforestation that has occurred in Indonesia for decades has resulted in forest shrinkage on a very large scale [1]. In addition, Aceh Province is one of the regions that produces agricultural solid waste on a large scale, which means it cannot be utilized optimally. Solid waste can be used as a new product by mixing it with plastic in order to obtain materials with different basic properties [2].

Due to significant technological developments, the application of materials science in the field of composites continues to grow, and fiber-reinforced composite materials have been widely used in tools that require strong and lightweight material components. Composite materials are not only made of synthetic composites but also of natural fibers and natural composites to reduce environmental pollution. Natural fiber is a material that can produce lightweight, strong, environmentally friendly, and economical composites [3]. In particular, research has been carried out on ceilings made of composite materials, including polypropylene composites reinforced with coconut fiber, which are expected to withstand heat. The United Nations Sustainable Development Summit (KTT) ratified the Sustainable Development Goals (SDGs), which were implemented from 2015 to 2030, with one of the global goals being to encourage and build quality infrastructure innovations and improve sustainable industries [4].

Coconut coir waste is a material containing lignocellulose which can be used as an alternative raw material for the manufacture of heat-resistant particleboard. One of the factors that can affect the quality of the composite board made is the density or the level of coir density on the board. In general, the higher the density of the particle board, the better its physical and mechanical properties [5]. However, based on research conducted by Banon et al. [6], the process of making particleboard can be carried out using polypropylene-based adhesives. Because polypropylene is one of the wastes whose existence is very abundant and difficult to recycle, this can be an important reason for using polypropylene.

Polypropylene is a type of thermoplastic polymer that is widely used in everyday life. There are many variations and types of polypropylene developed based on its use. The possible use of polypropylene (both isotactic and atactic polymers) of polar monomers is a way of increasing the effective polarity of polypropylene [7]. Coconut fiber is one of the most potential materials used as natural composites. Coconut coir fiber itself has advantages such as being anti-moth, mildew, and not easy to rot. Coconut coir fiber can also play a very good role as sound and temperature insulation, being non-flammable and durable [8]. Variations in the size of the coir fibers used in this study also affect the results obtained, as research conducted by Hidayani et al. [7] shows. The hardness of the composites is directly proportional to the density, where the density of each composite depends on the size of the fiber mesh. The ratio between the matrix and the raw material also affects the mechanical properties of the resulting composite. The addition of the filler ratio resulted in a decrease in the strength of the composite. This was due to the large amount of filler resulting in the matrix phase not being able to wet the entire surface of the available fibers [9]. This study presents a modification of the manufacture of composite boards using coconut coir fiber with reinforcing materials made from polypropylene waste, which functions as a natural binder between fibers. The results of this study are expected to provide an environmentally friendly coconut fiber composite board innovation that can reduce heat.

2. Materials and Methods

Materials

The materials that need to be prepared for this research are coconut coir waste, polypropylene waste, aquades, and NaOH.

Method

The process of making composite boards is divided into 3 stages of the procedure. The first step is to clean the coconut coir waste first, then wash it with clean water and dry it. After that, it was soaked with a 5% NaOH compound for 1 hour in order to remove some of the impurity compounds contained in the coconut fiber that were not needed. After that, it was dried again under the sun to obtain a constant mass of coconut coir. Then the coir is cut to reduce the size of the coco coir in order to facilitate the sifting process, until the coir sizes are 40 and 80 mesh. The second step is to make an adhesive (matrix) from polypropylene waste. The waste used is obtained from the remnants of bottled drinking water in the form of glasses that are scattered around the Syiah Kuala University. The polypropylene that will be used is cleaned first from dirt. Then it is weighed according to the needs and heated over the pan until it melts and the desired matrix structure is obtained. The final stage is the mixing stage. The composite is made

by mixing coconut fiber and polypropylene adhesive. The ratios between the coco coir matrices used are 10: 90, 20: 80, and 30: 70 (%wmatrix/wCF). The mixing process is carried out as quickly as possible to prevent hardening during the stirring process. Next is the printing of the board, where the board is printed using a hot press measuring 30 cm x 30 cm x 2 cm and the resulting particle board with a size of 20 cm x 20 cm x 1 cm is compressed for a variable time of 10 minutes at 180 °C.

In the research, six samples of composite boards were tested. The boards vary based on the size and the ratio of the ratio between the coconut fiber and the matrix used. The comparison is varied in the filler: matrix (f/m), namely 10:90 with a size of 40 mesh (f/m1), 20:80 with a size of 40 mesh (f/m2), 30:70 with a size of 40 mesh (f/m3), 10:90 size 80 mesh (f/m4), 20:80 size 80 mesh (f/m5), and 30:70 size 80 mesh (f/m6) of composite board. The analysis carried out includes the physical properties that are reviewed on the board are water absorption. While the mechanical properties of the boards under review are the value of the modulus of elasticity (MOE) and the modulus of rupture (MOR), this value is obtained by applying pressure in the form of a load to the composite board. This process is carried out using the Hung Ta tool, Universal Testing Machines (UTM). in accordance with the testing mechanism of JIS A 5908:2003 Particleboard Value Standard (Indonesian National Standard, 2006). Furthermore, the morphology of the composite board was tested through SEM (Scanning Electron Microscope) and FTIR (Fourier Transform Infra-Red) tests as well. Furthermore, the thermal properties of the composite board were tested by using the TGA (Thermogravimetric Analysis) and DSC (Differential Scanning Calorimetry) tests.

3. Result and Discussion

Analysis of the Physical Properties of Composite Boards

Water absorption

Water absorption is a physical property of the composite board that states the ability of the board to absorb water for 24 hours of immersion [10]. The water absorption value of the composite board produced in this study can be seen in Figure 1 below.

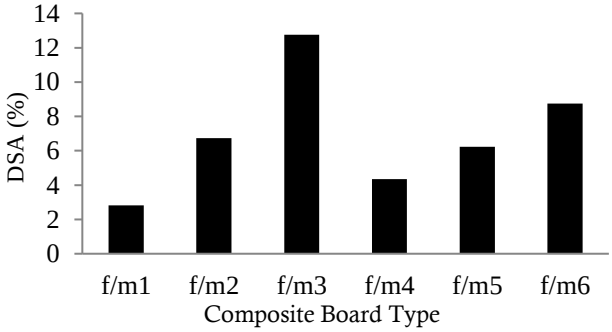


Figure 1. Chart of the influence of sample variations on the value of the moisture content of composite boards

The results of the analysis in Figure 1 show that the f/m^3 sample has the highest water absorption capacity with a DSA content of 12.75%. The lowest absorption is at f/m1 with a DSA level of 2.823%. The high DSA value can be caused because the composite board with a ratio of 30:70 has more filler than the other ratios, so the homogenization process cannot run properly compared to other samples, which will cause more pores and cause absorption to be lower. higher. In addition, the amount of moisture on the board is also influenced by the density of the composite board. However, from the results of the study, it was found that the particle size of 40 mesh had a smaller water absorption value compared to the size of 80 mesh of coconut coir. This could be caused by several factors, including the imperfect mixing process and the poor compression process, causing the bonding process between the particles to be imperfect, resulting in more pores or cavities on the board [11]. This is because the matrix with the base material of

polypropylene is hydrophobic. Hydrophobicity is a condition in which a material rejects the presence of water around it. So, the higher the percentage of coir and the higher the number of pores in the sample, the more water content that can be absorbed by the composite board [12].

Analysis of the Mechanical Properties of Composite Boards

The modulus of rupture analysis

The modulus of repulse, or the firmness of a board to fracture, is obtained simultaneously with an experiment to obtain the modulus of elasticity (MOE) value. The comparison of the MOR values for each tested composite board can be seen in Figure 3 below:

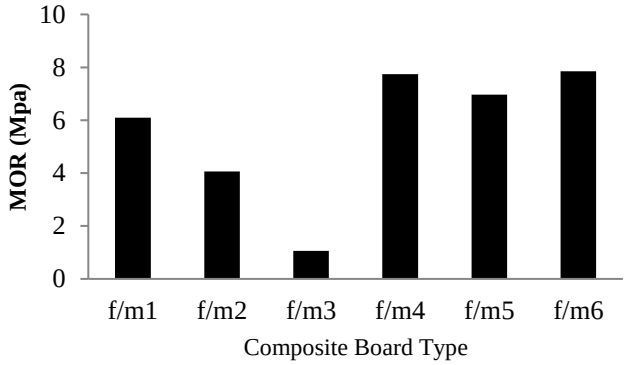


Figure 3. Comparison of the MOE Value of each Composite Board

Based on Figure 3, it can be seen that each composite board has a different elasticity strength. The lowest MOE value is in the f/m^3 sample, which is 0 Mpa. While the highest MOE value is 1226 MPa at f/m^4. This could be due to differences in the ability to bind fibers and matrix on each board. The f/m4 sample has a higher MOE value because it is one of the sample variations with the largest matrix, so that it can be superior to other composite board variations. While the f/m^3 sample has an MOE value of 0, because the sample has the least matrix, it has a high stiffness value. The sample also obtained a high-water absorption value. This was due to the uneven mixing between the matrix and filler, resulting in many pores and causing the board to be more brittle and stiffer. In general, the smaller the fiber size, the higher the density value should be and the fewer votes produced, so the value of the modulus of elasticity will also be greater. However, manual mixing also results in the bond between the fibers and the matrix not occurring perfectly [13]. Based on the value of the modulus of elasticity obtained, it can also be seen that the boards produced in the following research have not yet reached the applicable SNI standard, which is based on the SNI, the value of the expected modulus of elasticity is 1961.33 MPa.

Composite Board Morphological Analysis

Fourier transform infrared analysis

In the manufacture of composite boards, analysis using Fourier Transform Infrared (FTIR) is needed to see functional groups or changes in chemical components contained in the board. FTIR analysis on composite boards can be seen in Figure 4 below.

Journal of Applied Technology
Volume 9, Number 1, Page 7 – 15, June - November, 2022
ISSN 1693-2536, e-ISSN 2964-3198

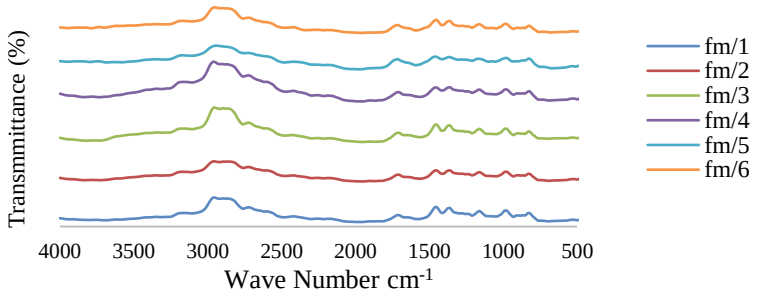


Figure 4. Spectrum of FTIR Analysis on 6 Composite Boards

Table 1. Functional groups in f/m1 composites

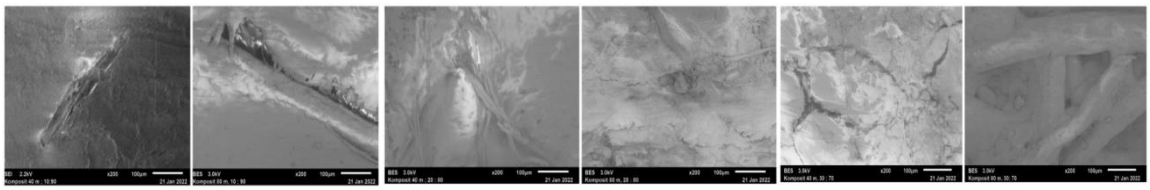
Absorption Area (cm^{-1})	Bonds and Types Functional groups
1161,15	C-O-C stretching
1365,6	H-C-H bending
1708,93	C=O stretching
2185,35	C ≡ C stretching
2603,9	CH_3 stretching CH_2 stretching
3169,04	O-H stretching

Figure 5 shows a spectrum that has almost the same shape, but there are some changes between one sample and another. This is because there are differences in the number of compositions used in composite boards so that it can cause interference from each peak of the functional group [14]. It can be seen that there is a wave shift in the range of 2700 to 3000 cm-1 precisely on the C-H bond from Figure 5. In the figure, it can be seen that the f/m5 composite board has the smallest wave peak compared to other types of composite boards. While the f/m3 composite board has the highest wave peak compared to other composite boards, this shows that the composition of each composite board between the filler and the matrix can affect the wave crest of a spectrum of functional groups that you want to know about. Composite boards with different filler and matrix ratio variations can be seen in the FTIR spectrum with C-O-C stretching at the peak of wave 1161.15 cm-1, H-C-H bending at the peak of wave 1365.6 cm-1, C=C stretching at the peak of wave 1454.33 cm-1, C=O stretching at the peak of 1708.93 cm-1, CC stretching at 2185.35 cm-1, CH3 and CH2 stretching at wave 2603.9 cm-1, and O-H stretching at wave 3169.04 cm-1. Polypropylene has a high peak intensity because it contains a high concentration of polypropylene. This also indicates that there is no chemical reaction between polypropylene and coconut fiber [11].

Scanning electro microscopy analysis

The results of the scanning electro microscopy analysis were carried out to determine the morphology of the resulting composite board. The analysis was carried out at a magnification of 200 times. The results of the analysis can be seen in the following figure.

Journal of Applied Technology
Volume 9, Number 1, Page 7 – 15, June - November, 2022
ISSN 1693-2536, e-ISSN 2964-3198



(a) (b) (c) (d) (e) (f)

Figure 5. Composite board surface structure

The results of this SEM analysis were carried out on 6 composite boards, as shown in Figure 6. The composite boards were analyzed to see the structure and morphology of the boards in each sample. Figures 6 (a) and (b) are comparisons for board morphology for f/m1 and f/m4 samples. Figure (a) is a 40-mesh sample and Figure (b) is an 80-mesh fiber. From the image, it can be seen that the sample has the distribution of filler is less than that of the matrix, so that the density is greater and the DSA value is smaller than the other samples. With so much matrix on the board, the filler can be mixed and bonded completely by the matrix. The large density value of the sample gives a good MOR value as well. The sample also shows that there is an increase in better bonding due to the increasing number of matrices that are able to cover the particles bound to each other so that the particles can unite to form a bond into a board [15]. And in the sample (c) is the morphology of the 40-mesh fiber composite, the picture (d) is the 80-mesh fiber composite morphology. In the picture it can be seen that there are wide cavities and deep cracks, often called porosity. This cavity causes a lack of the ability of the coco fiber particles to fill the empty spaces in the particle board during pressing. Figures (e) and (f) have the lowest density value and the largest DSA value. This is due to the large value of the ratio between the filler and the matrix so that the matrix is not able to fully bind the coir, resulting in many pores and cracks and causing the MOR value in the f/m3 sample to decrease, but there is an increase in the MOR value of the f/m6 sample. This is caused by the uneven mixing and cutting of the part of the board that is sampled for testing.

Composite Board Thermal Properties Analysis

Thermogravimetric analysis

TGA is a measurement of the change in weight of a material as a function of time. The results of the analysis are in the form of a continuous diagram recording where the reaction is decomposed [16]. The results of the TGA analysis of 6 samples of composite boards can be seen in the following figure.

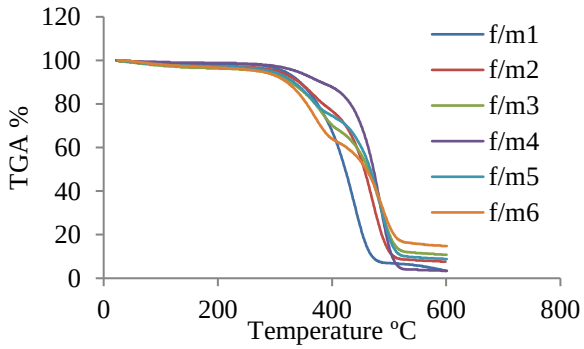


Figure 6. The results of the TGA analysis of 6 samples of composite boards

From Figure 6, it can be seen that there was a decrease in the mass of each composite board sample starting at a temperature range of 280 to 520 ^{0}C. In this temperature range, a decomposition process of the composite board constituent materials occurred. The decomposition of a material is also influenced by the type of material and the heat resistance of the material itself. The f/m1 sample

has thermal stability (onset temperature) at a temperature of 282.26 ^{0}C and a drastic decomposition occurs starting at a temperature of 375–464 ^{0}C, while the f/m2 sample has an onset temperature of 289 and decomposition is at 414–510 ^{0}C, the sample f/m4 has an onset temperature of 289 ^{0}C and decomposition is at 436–506 ^{0}C, the sample f/m5 has an onset temperature at 291 ^{0}C and decomposition is at a temperature of 426–507 ^{0}C, and the sample f/m6 has its onset temperature at 292 ^{0}C and its decomposition at 401–510 ^{0}C. The levels of weight loss in the TGA analysis test were 4.83; 4.62; 4.46; 4.83; 4.56 and 4.26 mg of the total weight of the test sample of 5 mg. The size of the coco fiber on the composite board also affects the thermal stability of the board. The smaller the fiber size, the higher the lignin exposed to the coir surface, the lower the thermal stability of the composite. However, the soaking process with alkali can cause the thermal stability value to be higher. This is because the smaller the particle size, the more lignin that can be removed from the fiber, the greater the thermal stability of a composite board [17]. So it can be concluded that the highest thermal stability was obtained in the f/m6 sample with a filler and matrix percentage of 30:70 with an onset temperature of 292 ^{0}C and a degradation temperature of 401 to 510 ^{0}C with a mass loss of 4.26 mg. Mass shrinkage in polymers occurs due to the release of hydrogen atoms from polymer hydrocarbon bonds. The release of hydrogen atoms is due to the input energy coming from heat [18].

Analysis of differential scanning calorimetry

Samples were analyzed at a heating rate of 20 mL/min in the range of 100 °C-600 °C. The results of this DSC test will be in the form of a thermogram that provides information about Tg (glass transition temperature), Tc (crystallization temperature) and Tm (melting temperature) as shown in Table 2 [19]. The results of the DSC analysis can be seen in the following picture:

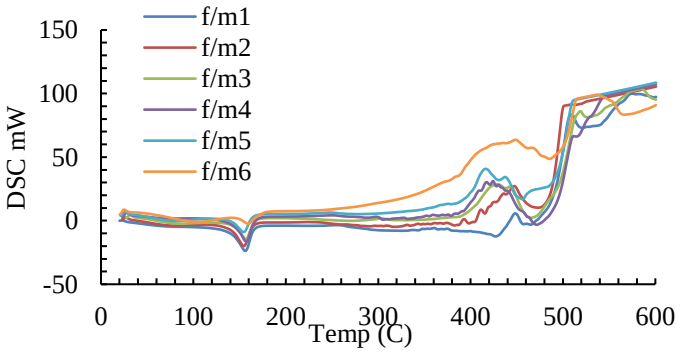


Figure 7. DSC Thermogram on 6 Composite Boards

Figure 8 is a DSC thermogram of the thermal properties of the composite board. In the thermogram, it can be seen that there is a change in the thermogram. Tg (glass transition temperature) is the temperature at which the loss of water groups contained in the composite board occurs at around 150 °C. Furthermore, there is a so-called Tc peak (crystallization temperature) at the peak of this phase change. It can be seen that there are two endothermic peaks at temperatures in the range of about 410 °C to 470 °C. The thermogram at temperature changes between 500 °C and 520 °C is the process of the composite board starting to melt, which at that temperature is called Tm (melting temperature). In general, when the ratio of the filler matrix is higher, more heat is required at the time of melting the composite board [20]. In general, the smaller the particle size of the fiber, the higher the heat required to melt the composite. This is due to the alkaline immersion process, which will cause the loss of lignin content from the fiber and cause the melting point of the composite to be lower. However, from the results of the analysis on the composites that have been made, it is found that the f/m3 sample with a 40-mesh coir size has a heat resistance value of 518 °C. This is due to the uneven stirring process so that the samples tested have unequal adhesive levels, thus causing the

temperature of the heat resistance to decrease. From the thermogram above, it can be seen that the f/m3 sample has the highest value, namely at a temperature of 518 °C. The ability of the composite board to withstand heat can be up to a temperature of 518 °C.

4. Conclusion

From the results of the study, it can be concluded that the composites produced from this study have met SNI 03-2015-2006 in particleboard density standards. The composite board with the highest water absorption is in the f/m3 sample, and the lowest absorption is at f/m1. There is no composite board that meets the MOE and MOR values of SNI 03-2015-2006. The more matrix is used on the composite board, the better the surface structure of the composite board. There is a phase change on the board precisely when the temperature is above 510 °C, which is the melting temperature of the board. The highest thermal stability was obtained by the f/m6 sample with a temperature of 292 and a decomposed mass of 4.26 mg from 5 mg of the total weight of the sample.

References

[1] Makkarennu, dkk., "Analisis kebutuhan bahan kayu bulat pada industri kayu lapis pt. katingan timber celebes," *J. Perennial*, vol.6, no.2, p.116-122,2010.

[2] Setiawati D., " Komposit serbuk kayu plastic daur ulang: Teknologi alternatif pemanfaatna limbah kayu dan plastik," *http://tumoutou.net/ 702_07134/ Dina_Setyawati.htm,* 2003.

[3] A. Rahman, dkk.,"Pengaruh komposisi material komposit dengan matriks polypropylene berpenguat serat alam terhadap morfologi dan kekuatan sifat fisik,"*J. Teknik ITS*, vol. 5, no.2, p.209-211, 2016.

[4] Wahyuningsih, "Millenium Developmet Goals (MDGs) dan Suistainable Development Goals (SDGs) Dalam Kesejahteraan Sosial," *J. Bisnis dan Manajemen,* vol.11, no. 3, p.390-399, 2017.

[5] F. Widyawati, and R. Monica, "Pengaruh ukuran partikel terhadap sifat fisik dan mekanik komposit limbah gergaji kayu jati dengan matrik resin epoxy," *Hexagon J. Teknik dan Sains*, vol.*3, no. 1*, p. 46-52, 2022.

[6] C. Banon, T.D. Sutanto, I. Gustian, I. Koharudin, dan W. Rahmi, "Cangkang Buah Karet Dengan Perekat Limbah Plastik Polipropilena Sebagai Alternative Papan Partikel," *J. Kimia Riset*, vol.1, no.2,p.86-93, 2016.

[7] T.R. Hidayani,"Grafting polipropilena dengan maleat anhidrida sebagai pengikat silang dengan inisiator benzoil peroksida," *Eksakta: Berkala Ilmiah Bidang MIPA,* vol. 19, no. 1, p.56-62, 2018.

[8] T. Indahyani,"Pemanfaatan Limbah sabut Kelapa pada Perencanaan Interior dan Furniture yang Berdampak pada Pemberdayaan Masyarakat Miskin", *Humaniora*, vol. 2, no. 1, p.15-23, 2011.

[9] A.N. Shabiri, R.S. Ritonga, dan M.H.S. Ginting, "Pengaruh Rasio Epoksi/Ampas Tebu dan Perlakuan Alkali Pada Ampas Tebu Terhadap Kekuatan Bentur Komposit Partikel Epoksi Berpengisi Serat Ampas Tebu", *J. Teknik Kimia USU,* vol. 3, no. 3, p.28-31, 2014.

[10] L. Hakim, E. Herawati, and I.Wistara," Medium Density Fibreboard Made of Acetylated Sludge from Paper Mill," *Makara J. Techn.*, vol.15, no. 2, p. 4, 2011.

[11] A. Al Faruqi,"Studi Pengaruh Variasi Komposisi Binder Sampah Plastik Polypropylene (PP) Dan High-Density Polyethylene (HDPE) Terhadap Sifat Fisis Dan Sifat Mekanik Komposit Berpenguat Serbuk Ampas Tebu Untuk Aplikasi Papan Partikel, *Doctoral dissertation*, ITS, 2019.

[12] A. Lestari, M. Mora,"Pengaruh Variasi Massa Batang Pisang dan Cangkang Kelapa Sawit terhadap Sifat Fisis dan Mekanis Komposit Papan Partikel Menggunakan Perekat Resin Epoksi, *J. Fisika Unand*, vol.*7*, no.2, p.124-129, 2018.

[13] H.N. Beliu, Y.M. Pell, and J.U. Jasron,' "Analisa Kekuatan Tarik dan Bending pada Komposit Widuri-Polyester, *LONTAR J.Teknik Mesin Undana (LJTMU)*, vol.3, no.2, p.11-20, 2016.
[14] A. Purbasari, T.A.C. Darmaji, C.N. Sary, H.Kusumayanti," Pembuatan Dan Karakterisasi Komposit Dari Styrofoam Bekas dan Serat Ijuk Aren" *METANA,* vol 15. no. 2,p. 65-70, 2019.
[15] M. Masdani, Y.Dharta,"Potensi Pengembangan Komposit Berpenguat Serat Kulit Gaharu Sebagai Material Pengganti Fiberglass Pada Pembuatan Dashboard. *Manutech: J. Tekno. Manufaktur*, vol.10, no. 1, p.33-38, 2018.
[16] D. Rahmayanti,"Karakteristik Sifat Termal (DTA-TGA) dan Konduktifitas Termal Keramik Cordierite Berbasis Silika Sekam Padi dengan Penambahan Alumina (0, 20, 25, dan 30 wt%)", *Skripsi*. Universitas Lampung, , 2016.
[17] Nanang, Endriatno, "Analisa Pengaruh Variasi Fraksi Volume Terhadap Densitas Dan Kekuatan Tarik Serat Pelepah Psang-Epoksi", *J.Ilmiah Teknik Mesin*, vol 5, no 2, p. 29-34, 2014.
[18] Beyler dan M.M. Hirschler, *Thermal Decomposition of Polymers*, 2002.
[19] U.D. Wiwiek, "Evaluasi Kinetika Dekomposisi Termal Komposit Ap/Htbp Dengan Metode Kissinger, Flynn Wall Ozawa Dan Coats-Redfren," *J. Teknologi Dirgantara*, vol. 15, no.2, p.115-132, 2017.
[20] Farid Mulana, Hisbullah, Iskandar,"Pembuatan Papan Komposit Dari Plastik Daur Ulang Dan Serbuk Kayu Serta Jerami Sebagai Filler"*J. Rekayasa Kimia Dan Lingkungan*, vol 8, no.1, p.17-22, 2011.