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EFFECT OF FILLER LOADING ON HYBRID COMPOSITES REINFORCED WITH OIL PULP EMPTY FRUIT BUNCHES/FLY ASH: PHYSICOCHEMICAL PROPERTIES AND THERMAL ANALYSIS

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ABSTRACT

Polyester was examined in combination with oil palm empty fruit bunch (OPEFB) and fly ash to create hybrid composites. Various ratios of OPEFB to fly ash were tested, including 10/1, 10/5, 20/1, and 20/5, along with two sizes of OPEFB (80 and 40 mesh). The hybrid composites were fabricated using the hand lay-up method through hot pressing. The density of hybrid composites increased with varying sizes of fly ash. Compared to neat polyester, the hybrid composite exhibited higher water absorption, and thickness swelling was also greater. Despite these differences, the functional groups in the hybrid composites did not show variance from those in neat polyester. The incorporation of OPEFB fibers and fly ash in composite hybrids did not result in a significant difference. The thermal decomposition of hybrid composites at 600°C occurred in two stages. The initial weight loss between 100 and 300°C, followed by a substantial weight loss between 300 and 450°C. Subsequently, the composite hybrid experienced slower degradation after reaching 450°C. DSC analysis revealed that the addition of OPEFB fibers and fly ash as fillers increased the melting point. This is attributed to the thermal stability maintained by the OPEFB fiber filler and fly ash, leading to an elevation in the melting point of the hybrid composites. The shape of molecular symmetry, the molecular weight of the polymer compound, and the degree of crystallinity of the composite also influenced the melting point. A higher degree of crystallinity in the composite material correlated with a higher melting point.

Keywords: OPEFB, Fly Ash, Hybrid Composites of Polyester, Physical Properties, Functional Group, Thermal Properties.

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INTRODUCTION

Environmental issues and the depletion of non-renewable natural resources such as petroleum have increased awareness towards the development of green and sustainable products. The development of green products includes the utilization of bio-resources such as natural fibers for composite applications.[1] Natural fibers are feasible to be substituted into synthetic fibers because of their superior properties such as lightweight, high specific strength, low cost, excellent mechanical properties, bio-degradable, and environmentally friendly.[2] To increase the added value of waste, especially agricultural solid waste, one way is to strengthen polymer composites. In addition, material-based polymers are not very environmentally friendly. By combining agricultural solid waste that contains lots of fiber with polymer as a matrix, the material can become a green material.[3] This means that this material can be degraded in nature and becomes an environmentally friendly material. Natural fibers have several advantages as a renewable resource and have marketing appeal. Fiber-reinforced polymer composites have commercial appeal in the automotive industry, aerospace applications, building and furniture, and panel applications.[4] Fiber-reinforced composites have found increasing application in bridge and building construction in recent years. This is due to the favorable properties of this material, such as low self-weight, high strength, free

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formability, and substantial resistance to corrosion and fatigue.[5] Several researchers have studied the manufacture of hybrid composites with the aim of improving the mechanical and thermal properties of natural fiber-reinforced composite materials. Hybrid composites are made of two or more fibers in one matrix or two matrices mixed with polymer.[4] From the results of previous studies, the hybridization of one type of natural fiber to another type of natural fiber or synthetic fiber in one matrix produces a unique product (hybrid composite) with better mechanical and thermal properties compared to individual fiber reinforcement polymer composite.[1,6] Thus, hybridization provides advantages for composite materials because it is more reliable for different applications and more environmentally friendly. In addition, the hybridization of two or more types of fiber can provide advantages because fiber can complement the weaknesses of other fibers. The reinforcement of filler loading gives advantages for hybrid composites. Some studies have investigated the filler loading in the material matrices. The use of filler such as fly ash and plant fibers, to prepare micro- and nanocomposites for multifunctional applications.[4] Hand layup techniques along with compression molding were used for the preparation of the composites, fly ash and plant fibers were used as reinforcement, and thermosetting polymers such as epoxy were used as matrix materials. In a polymer composite filled with biowaste, the bond between the surface of the filler and the matrix is very important because the mechanical resistance of polymer composites depends primarily on the interfacial properties, also stress concentration occurs in this region because the difference between the properties of the filler and matrix.[7] The addition of filler can provide greater rigidity to the composite. In the study loading empty fruit bunch particles in the matrices, the toughness decreases.[8] A similar trend was shown using palm wood flour with a low-density polyethylene matrix, without fiber-reinforced bio-polyethylene composite treatment, and palm wood fiber polypropylene composite. Poor adhesion or bonding between the reinforcement and matrix formed a weak inter-facial region. As a result, it ended in debonding and frictional pull out of fiber bundles and hindered the ductile deformation and mobility of the matrix, thus lowering the ability of the composite system to absorb energy during fracture propagation. The degree of anisotropy (aspect ratio) of the reinforcement filler plays an essential role. The higher the aspect ratio at its optimum value, the higher the strength of the composite. The aspect ratio should obtain above its critical value for a better stress transfer, thus giving better mechanical properties. It acts to control fiber dispersion and fiber-matrix adhesion. Based on Tien's study, for a given particulate volume fraction, when the particle size of the filler decreases, the strength of the composite increases. Smaller particle sizes with higher total surface area would give a more efficient stress transfer, thus giving higher strength. Small particles will lead to good dispersion and strong particle–matrix interaction while the matrix can fully cover the surface of the fillers under optimum particle loading.[2] The filler loading of 40% was optimum, due to their random orientation, oil palm EFB-based composites empty fruit bunch 50 wt. % with kenaf 0 wt. % showed a higher void content, water absorption, and thickness swelling behavior.[9] The purpose of this study was to develop and characterize the properties of hybrid composites polyester reinforced with OPEFB/fly ash by studying loading and particle size on physical, morphological, and thermal properties. In addition, the void content of the composites was investigated for the hybrid composites.

EXPERIMENTAL

Material

The materials employed in this study included OPEFB with a size of 40 and 80 mesh, fly ash was 250 mesh as reinforcement or filler, polyester resin as a composite matrix, sodium hydroxide (NaOH) for chemical treatment, and methyl ethyl ketone peroxide (MEKP) as a polyester resin catalyst. OPEFB fiber is treated with alkaline from the waste of palm oil plants in West Aceh, Aceh Province, Indonesia. Fly ash is obtained from the Nagan Raya power plant in Aceh Province, Indonesia. OPEFB and fly ash that we used in this research are shown in the Fig.-1.

Fabricated Hybrid Composites

The hybrid composite was manufactured by hand lay-up method using a stainless mold with the size 20 cm x 20 cm x 0.5 cm and pressed with a hot press. Initially, polyester resin was mixed with fly ash and 1% MEKP catalyst for 3 min. OPEFB fibers are arranged in a mold, the resin is poured into the fiber, and then the mold is closed for drying (with curing time) for 24 hours using a press machine. The open mold method

was used in this study. The hybrid composites polyester reinforcement filler in the variations in the composition of OPEFB/fly ash fiber is shown in Table-1. The images of the hybrid composites are shown in Fig.-2.

Fig.-1: OPEFB and Fly Ash

Table-1: Composition Comparison in Hybrid Composites for Size of OPEFB 40 Mesh and 80 Mesh

No.	Name of sample	Particle Size (mesh)	Polyester (wt. %)	OPEFB (wt.%)	Fly Ash (wt. %)
1	PE	-	100	-	-
2	PE/OPEFB10	40	100	10	-
3	PE/OPEFB10/FA1	40	100	10	1
4	PE/OPEFB10/FA5	40	100	10	5
5	PE/OPEFB20 /FA1	40	100	20	1
6	PE/OPEFB20/FA5	40	100	20	5
7	PE/OPEFB10	80	100	10	-
8	PE/OPEFB10/FA1	80	100	10	1
9	PE/OPEFB10/FA5	80	100	10	5
10	PE/OPEFB20 /FA1	80	100	20	1
11	PE/OPEFB20/FA5	80	100	20	5

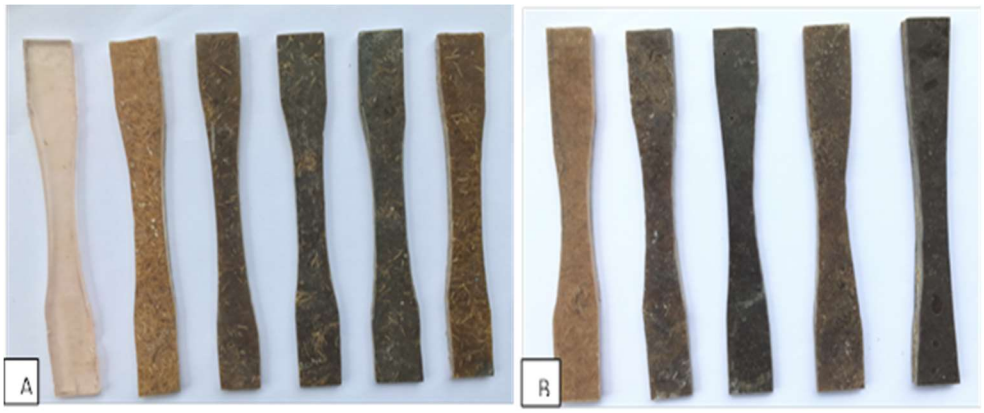

Fig.-2: Image of the Hybrid Composites Neat Polyester, (a.) 40 mesh, (b.) 80 mesh

Characterization

Characterization of the hybrid composites includes physicochemical properties dan thermal analysis. Physicochemical properties of hybrid composites i.e.;

Density was measured by using the ASTM D 1895 standard. Density testing was carried out by weighing composite hybrids using digital scales. Then put in the composite which has been weighed and calculated its volume. The density of the samples was calculated by using the Eq.-1. Where ρ is density, m is the weight of hybrid composites (gram) and v is the volume of hybrid composites (cm^3).

$$\rho = \frac{m}{v} \qquad (1)$$

A water absorption test was carried out to investigate the increase in weight of the hybrid composites after being immersed in water.[10] Specimen weight was measured before and after soaking in distilled water.

Composite samples with a size of 1 × 1 × 0.5 cm^3 were soaked in distilled water for 24 hours at room temperature. Water absorption was calculated with Eq.-2.[11]

$$Water\ absorption\ (\%) = \frac{W_1 - W_0}{W_0}\ x\ 100 \qquad (2)$$

Where; W_0 is the initial weight of the hybrid composites and W_1 is the weight of hybrid composites after immersed in distillate water. The thickness swelling test was carried out by preparing a composite with a size of 1 × 1 × 0.5 cm^3 for thickness swelling evaluation. Samples were measured as T_0 before immersion and T_1 after immersion in water using a vernier caliper. The swelling thickness is determined using Eq.3.[11]

$$Thickness\ swelling\ (\%) = \frac{T_1 - T_0}{T_0}\ x\ 100 \qquad (3)$$

Where; T_0 is the initial thickness of hybrid composites before soaking in the distillate water and T_1 is the thickness of hybrid composites after soaking. Functional group analysis was performed using FTIR (Shimadzu IR Prestige 21) which aims to detect functional groups and identify chemical bonds of organic and inorganic compounds in the composite. The infrared spectrum of the range of wavenumbers is collected and used to analyze fiber clusters. Infrared spectrum measurements using the potassium bromide (KBr) pellet method. Hybrid composites are mixed with KBr according to the specified proportion; and then pressed using a hydraulic press to form a thin film. FTIR spectra were recorded in the range of 400–4000 cm^{-1}.[12,13] The thermal properties of hybrid composites are practically significant in temperature-related studies because they are important for determining the degree of fiber degradation after alkaline treatment. TGA was performed using a TA Instruments Q-series thermal analysis engine model (TGA Q500). The analysis was carried out in a nitrogen atmosphere with a gas flow rate of 50 mL/min at a temperature range of 30 to 600◦c with a heating rate of 10◦C/min.[11] DSC testing was carried out using a DSC analyzer (Shimadzu DSC 60) under an inert gas (nitrogen) atmosphere. This test serves to study the thermal properties of the hybrid composites. A 5 mg powder hybrid composite sample was weighed placed and sealed in an aluminum container. Then the sample is heated in the range of 30 to 300ºC at a speed of 10ºC/minute and with a nitrogen flow rate of 20 mL/minute.[14]

RESULTS AND DISCUSSION

Functional Group of Hybrid Composites

Analysis of composite hybrid functional groups was carried out by looking at the shape of the spectrum at certain peaks indicating the type of functional groups belonging to the compound. FTIR spectra on various hybrid composites with different filler sizes can be seen in Fig.-3. This analysis is carried out by looking at the shape of the spectrum by looking at certain peaks that indicate the type of functional groups belonging to the compound. Figure-3 A shows the spectra of pure polyester composites (PE) and composite hybrids with the addition of various fillers. In general, the spectra shown in the figures appear to have almost the same shape, but there are differences that are not too significant when compared between one composite hybrid board and another. There are several peaks visible in the resulting spectrum. The peak shows the functional group O-H stretching at wavelength 3549.02 cm^{-1}, C-O stretching shown at peaks 2935.66 cm^{-1}, C=O for esters appears at spectrum 1950.03-1872.88 cm^{-1}, C=O stretching comes at wavelength 1782.22 cm^{-1}); C-H for CH_3 asymmetrical bend from polyester (1490.97 – 1450.47 cm^{-1}); C-O stretching (1278.81 – 1070.49 cm^{-1} and SiO show at peaks 744.52 – 702.09 cm^{-1}, it is derived from fly ash. The only visible difference was the intensity of the C-H peaks on the polyester composite, which was steeper than that of the hybrid composite samples that had been added with filler. It can be concluded that the addition of OPEFB fiber filler and fly ash in composite hybrids did not show a significant difference. This is also reinforced by the results of previous studies.

Thermal Properties

Determination of the characterization of the thermal properties of a material is very important because it is used to determine the thermal stability of the material in the temperature range where the material can be used for its degradation.[15] This can be done by testing the Thermogravimetric Analysis (TGA) and Differential Scanning Calorimeter (DSC).

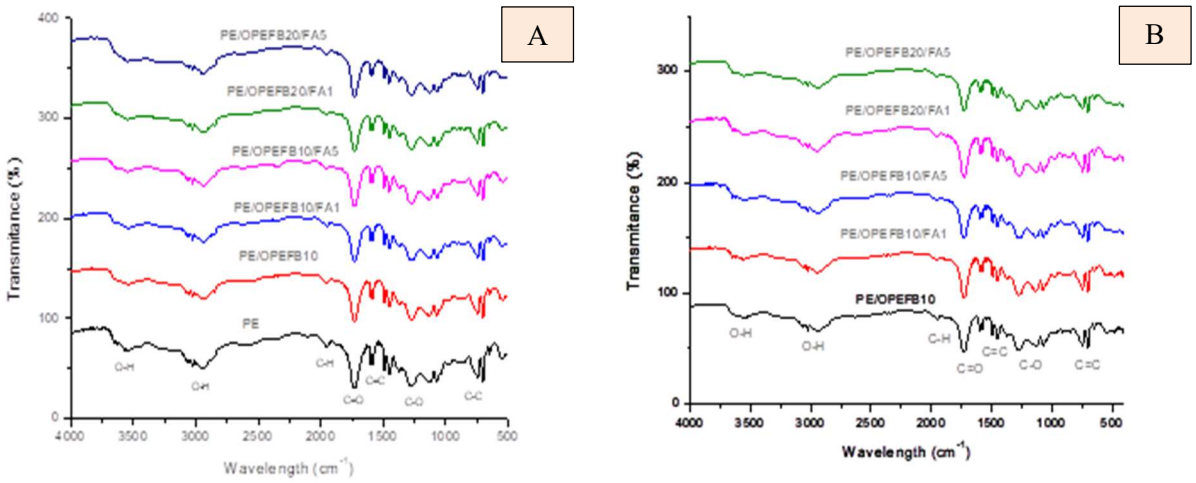

Fig.-3: FT-IR Hybrid Composites PE/OPEFB/FA, 40 (A) and 80 (B) Mesh

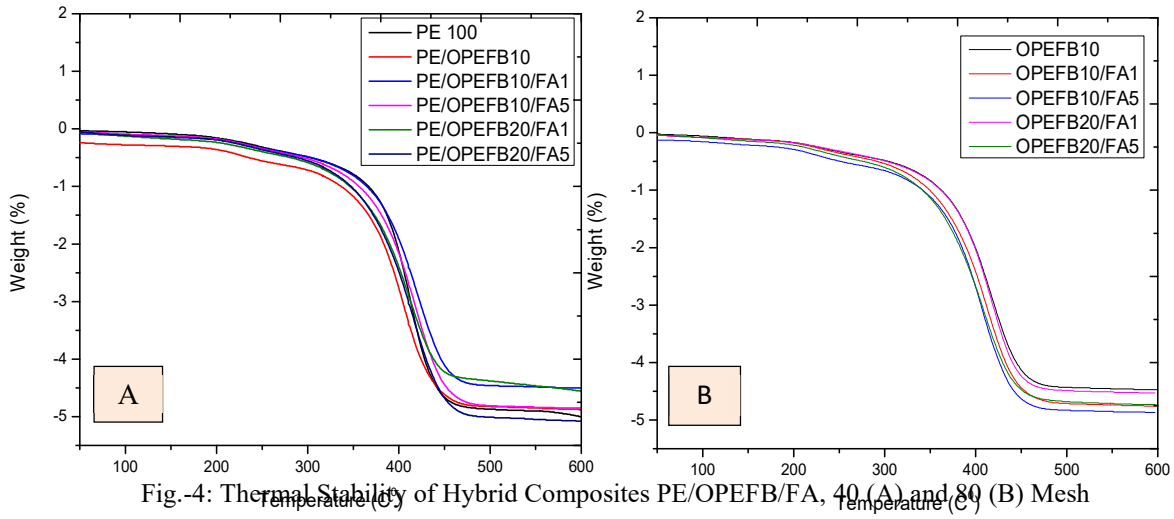

Fig.-4: Thermal Stability of Hybrid Composites PE/OPEFB/FA, 40 (A) and 80 (B) Mesh

Thermogravimetric Analysis (TGA)

TGA is an analytical technique useful for assessing the thermal stability of materials including polymers by recording the loss of sample weight with temperature. The thermal stability of composite hybrids is shown in Fig.-4. The Figure shows the TGA thermogram in the form of a percentage of degraded weight in composite hybrids. Figures-4 A and B show the TGA thermogram with different composite weight percentage reduction processes occurring at different temperatures. Based on the figure, it can be seen that all hybrid composites underwent two stages of thermal decomposition when heated to 600°C. Composite hybrids experienced the first weight loss at temperatures of 100–300°C and a significant weight loss at temperatures of 300–450°C. Then the composite hybrid experienced slower degradation after a temperature of 450°C. The first stage of decomposition occurs due to the evaporation of water in natural fibers which have hydrophilic properties. The weight loss at this stage is very low due to the low water content adsorbed from the atmosphere by the OPEFB fiber surface during the preparation and alkali treatment processes. OPEFB fibers that have been prepared and that have been treated with alkali contributed to the initial decomposition at temperatures of 100°C to 300°C. Furthermore, the second or main decomposition stage is caused by the devolatilization of cellulose, hemicellulose, partial decomposition of lignin, and also the decomposition of polyester resins. Lignin decomposition continues to provide gradual weight loss beyond 450°C. The pyrolysis of hemicellulose and cellulose occurs rapidly in the range of 250–340°C and 340–400°C, respectively, contributing to a sharp decrease in the TG profile. Meanwhile, polyester resin begins

to decompose at a temperature of 330°C.[12] Based on the results in Table-2, each sample variation has a different onset temperature and peak degradation temperature. It can be seen that the residues produced in the various samples produce different percentages. At 600°C, the hybridization of OPEFB fiber and fly ash left a higher amount of residue than the composite containing pure polyester resin. Hybridization of the composite will increase the marked thermal stability of the residue produced compared to pure polyester composites. This high residue is caused by the content of inorganic materials, such as silica contained in OPEFB and also fly ash, where these compounds are not burned and are left as residue. In the variation of the PE/OPEFB20/FA5 composite hybrid samples with a filler size of 40 mesh produced the largest residue of 10.6%. The addition of fly ash into fiber-reinforced composites will result in a decrease in compressive strength but an increase in heat resistance. Previous research also concluded that the addition of fly ash to the resin will increase thermal stability because fly ash has a high silica content.

Table-2: Onset Temperature, Degradation Temperature, and Percentage of Sample Weight Degraded on a Variety of Composite Hybrid Board Samples

Sample	Particle size (mesh)	T Onset (°C)	T Degradation (°C)	Weight % of sample degradation
PE	-	352.66	506.39	0.2
PE/OPEFB10	40	333.78	485.02	2.4
PE/OPEFB10/FA1		323.02	463.74	3
PE/OPEFB10/FA5		310.07	471.20	8.8
PE/OPEFB20/FA1		317.98	455.08	2.2
PE/OPEFB20/FA5		300.01	475.95	10.6
PE/OPEFB10	80	333.97	492.28	5
PE/OPEFB10/FA1		338.75	492.72	4.8
PE/OPEFB10/FA5		330.15	480.55	2.6
PE/OPEFB20/FA1		322.57	466.50	9.4
PE/OPEFB20/FA5		326.75	460.91	5

Differential Scanning Calorimeter (DSC)

DSC analysis is carried out to determine the amount of heat required for a material to reach the melting point. The melting point describes the phase change from solid to liquid without changing the composition. DSC profiles for various sample variations and filler size variations are shown in Fig.-5 A and B. This is because fly ash has a high silica content. Figure-5 shows the melting points of various composite hybrid samples. Pure polyester composites have a melting point of 400°C. Meanwhile, the composite hybrid with the addition of organic filler (EFB fiber) and inorganic filler (fly ash) showed an increase in the melting point to 420-430°C. This is due to the OPEFB fiber filler and fly ash which can maintain thermal stability so that the melting point obtained by hybrid composites increases. In addition, the melting point is affected by the shape of the molecular symmetry and the molecular weight of the polymer compound as well as the degree of crystallinity of the composite material. The higher the degree of crystallinity of the composite material, the higher the melting point of the composition material. Research shows that the presence of a small amount of fiber in the composite will increase the crystallization of the composite hybrid. The increase in crystallinity may be due to the strong interaction between the fibers and the matrix, which exerts a transcrystallinity effect. Figure-5A, B hybrid composites with the addition of filler show high decomposition, this is due to the bonding that occurs between OPEFB filler and fly ash so that the energy required to decompose the polymer chain is also high when compared to polyester composites without filler. The increase in melting point is also due to the silica content in OPEFB fibers and fly ash which will maintain thermal stability. The higher the silica in a material, the higher the melting point.

Density of Composite Hybrid

Density is a measure of the mass per unit volume of a material. The density of a material is directly related to its weight, which means that when the density decreases, the importance of the material will decrease.[17] The density of the composite hybrid board was determined by dividing its mass (m) by its volume (v). The

density of each composite hybrid board generated in this investigation is represented in Fig.-6. Figure-6 shows the difference in density for each sample, composite board with polyester composition without adding filler has a density value of 1.418 gr/cm^3.

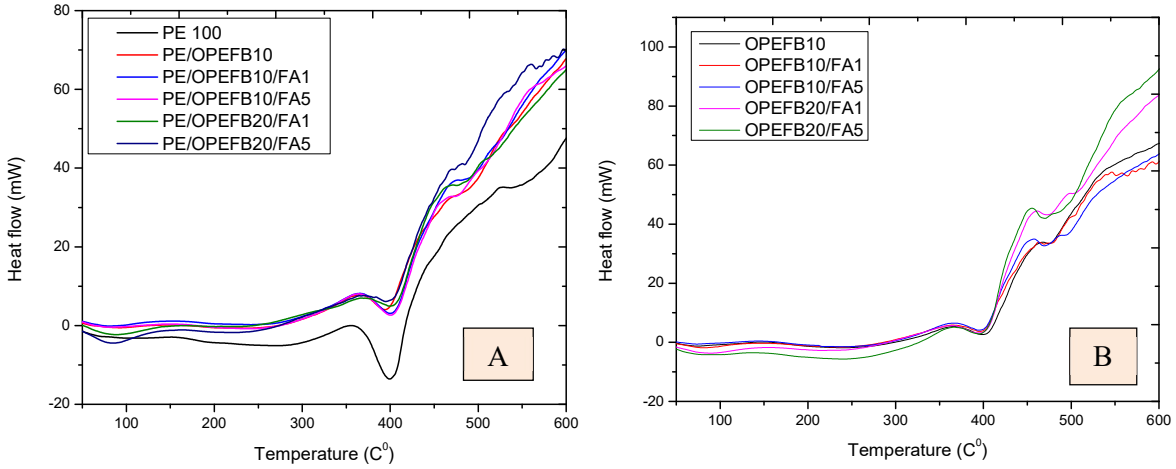

Fig.-5: DSC Thermograms of Various Sample Variations with 40 (A) and 80 (B) Mesh Filler Sizes

Table-3: Classification of Panel Fiberboard Products

Board Type	Density (gr/cm^3)
Insulation board	0.16 – 0.5
Medium density fiberboard	0.64 – 0.8
Medium density hardboard	0.5 – 0.8
Hardboard	0.5 – 1.450
High-density hardboard	0.8 – 1.280

However, incorporating a 10% OPEFB filler, characterized by a particle size of 40 mesh, resulted in a significant reduction in the density value of the hybrid composite to 1.344 gr/cm^3. The decrease in density of the hybrid composite is attributed to adding filler, which possesses a relatively lower weight than the polyester resin. Including fiber in the hybrid composite presents difficulties in achieving consistent impregnation of the fiber by the resin, creating empty spaces inside the composite. Faults that arise at the interface between the fiber and matrix, or faults inside the fiber, will impair the performance of the hybrid composite and reduce its density.[18] The most common cause of cavity formation is the inability of the matrix to displace air trapped within the fiber during impregnation into the matrix.[19] Hybrid composites with the addition of fly ash to the OPEFB fibers increased in density value. The density value increases with the amount of fly ash composition added. This increase is due to the high density of fly ash, which ranges from 1.3 - 4.8 gr/cm^3, more significant than the density of polyester and OPEFB fiber. The size of the filler particles utilized is the determining factor for density. This investigation employed several filler particle sizes, precisely 40 and 80 mesh. Figure-6 demonstrates that the density value of the composite hybrid particle board is higher when an 80 mesh filler size is used compared to a 40 mesh filler size. The reduction in filler particle size will decrease the interparticle spacing, resulting in a significant increase in density. The smaller filler particle size exhibits a more uniform distribution inside the matrix.[20] Based on SNI 03-2105-2006, the density value for particleboard is 0.5 - 0.9 gr/cm^3, so from the research results, the composite hybrid board obtained has a density value that exceeds the quality standard value that has been set. However, the density value of the composite hybrid board obtained in this study can be categorized into the hardboard type particleboard, which can be seen in Table-3.

Swelling Degree

The swelling degree is essential because natural fiber polymer composite materials are utilized in diverse industrial applications under varying site conditions. Hybrid composites made from natural fibers typically

exhibit a high degree of sensitivity to water. Hence, examining the water absorption properties in this investigation is imperative.

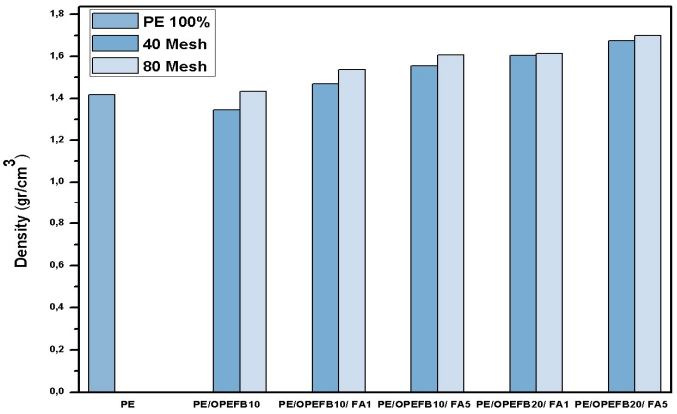

Fig.-6: Effect of Material Composition Ratio on Density of Composite Hybrid Board

The test was performed on the hybrid composite board to analyze its crucial physical property of water absorption under specific conditions and time. Various parameters, including voids, moisture, temperature, fiber volume fraction, matrix viscosity, and the bonding structure between fiber and matrix, influence the percentage of water absorption.[10,11] Figure-7 displays the water absorption % in the composite hybrid board. Figure-7 demonstrates a positive correlation between the duration of soaking time and the percentage of water absorption. The water absorption % of the composite board made of pure polyester exhibited a comparatively minor growth and reached a steady state on the seventh day. This is due to the hydrophobic nature of polyester, meaning it repels water. The reduced water absorption is also a result of the decreased porosity on the surface of the composite. The composite hybrid board with OPEFB fiber filler exhibits significant water absorption on the graph. After seven days of soaking, the hybrid composite with the highest water absorption value was 4.83% for the PE/ OPEFB20/FA1. This was followed by 4.35% for the PE/OPEFB10/FA1, 4.30% for the PE/OPEFB20/FA5, 3.98% for the PE/OPEFB10/FA5, 3.27% for the PE/OPEFB10, and 0.52% for the PE. The results showed that water absorption exhibited a more rapid rate during the first phase and subsequently decelerated as the soaking duration increased. The composite's water absorption capacity and thickness are directly correlated with its density, the existence of voids, and the adhesion between the fiber and matrix.[20] The weight of the composite hybrid is subsequently increased due to the entrapment of water in the cavities. Insufficient interfacial adhesion exists between the OPEFB fibers, fly ash, and polyester matrix, permitting a significant quantity of water molecules to diffuse into the composite hybrid, as evidenced by the high water absorption in the composite hybrid.[10] The more OPEFB fibers are used, the more the composite's water absorption capacity is affected. Natural fibers such as OPEFB contain hydroxyl groups and oxygen groups in the fiber cell wall, which will attract water through hydrogen bonds.[10] Based on SNI 03-2105-2006, the value of particle board moisture content is not allowed if it exceeds 14%. Therefore, composite hybrid boards with various sample variations with 40 and 80 mesh filler particle sizes meet the existing particle board SNI requirements.

Thickness Swelling

The hybrid composite thickness development test was conducted to examine the effect of water vapor diffusion on the thickness of the composite specimens. The percentage change in the thickness of the composite hybrid board from various samples with different filler sizes can be seen in Fig.-8. Figure-8A shows the results exhibit a consistent pattern with water absorption, as the thickness of the composite hybrid board grows after being immersed in distilled water for seven days. After seven days of soaking, the composite hybrid board achieved the maximum thickness development value of 1.72% for the PE/OPEFB20/FA5 composition.

This was followed by 1.65% for PE/OPEFB20/FA1, 1.30% for PE/OPEFB10/FA1, 1.09% for PE/OPEFB10/FA5, 1.10% for PE/OPEFB10, and 0.92% for PE. Based on Figure 8B, it is evident that both the composite hybrid boards with 40 mesh and 80 mesh particle sizes exhibited a similar trend in which the

percentage of thickness increased rapidly during the initial stage of soaking and slowed down as the soaking time increased.

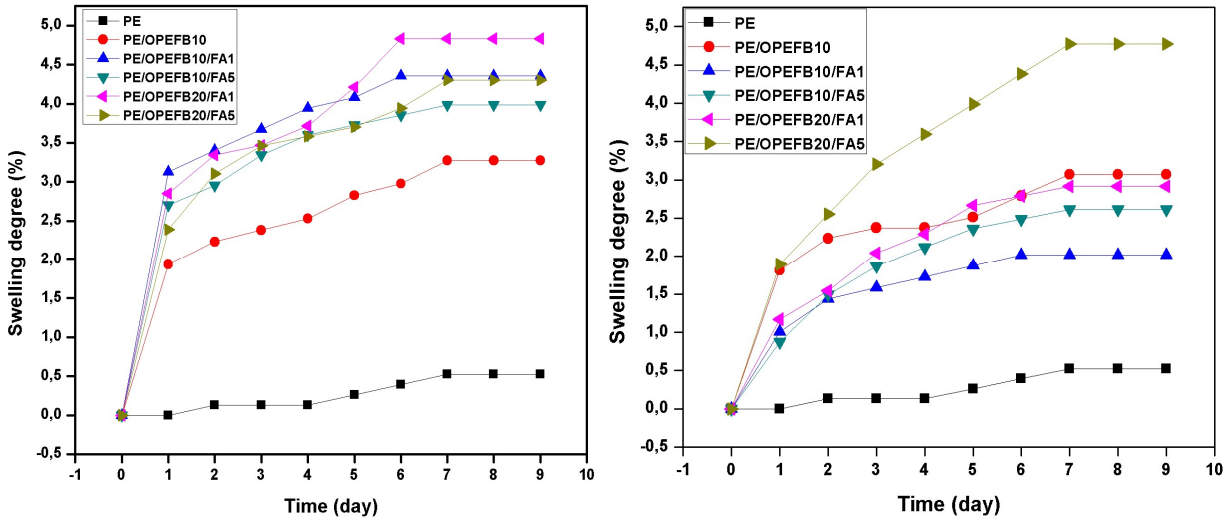

Fig.-7: Percentage of Water Absorption of Composite Hybrid Boards of Different Sample Variations with 40 (A) and 80 (B) Mesh Filler Particle Sizes

The composite hybrid board's thickness development at 80 mesh particle size achieved the highest thickness after seven days of soaking: 1.98% PE/OPEFB20/FA5. The succeeding values were 1.75% PE/OPEFB20/FA1, 1.30% PE/OPEFB10/FA1, 1.21% PE/OPEFB10/FA5, 1.09% PE/OPEFB10, and 0.92% PE. The results indicate that an increase in fiber and fly ash fraction leads to a more significant percentage of thickness in the composite material. Further observations reveal that the thickness development is faster in the initial stage and decelerates as immersion time increases. Pure polyester composites exhibit high dimensional stability, evidenced by minor changes in thickness. The minimal increase in thickness observed in pure polyester composites results from the material's hydrophobic nature. Polyester composites generally have fewer voids and smaller pores, resulting in only minor swelling in the composite's thickness. Conversely, hybrid composites containing OPEFB and fly ash fillers exhibit more significant thickness development due to the addition of hydrophilic OPEFB fibers. The hybrid composite's surface and the OPEFB fiber contain voids and a high porosity, which will ultimately cause alterations in dimensional stability.[21]

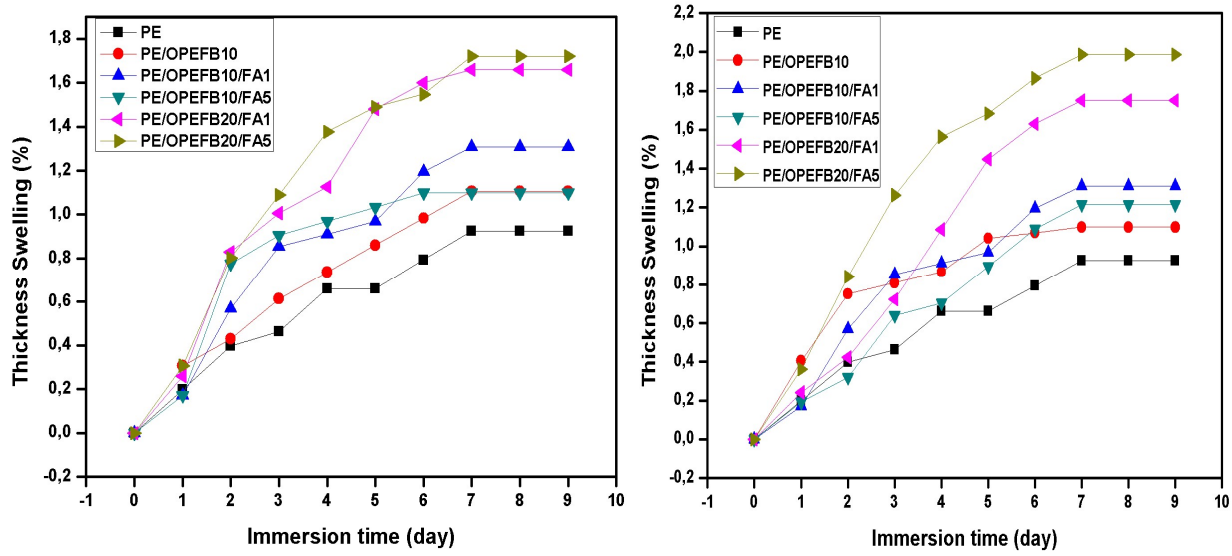

Fig.-8: Percentage of Thickness Swelling in Composite Hybrid Boards of Different Sample Variations with 40 (A) and 80 (B) Mesh Filler Particle Sizes

Adding 20% fly ash to the resin will create an interlocking system and a stiffer matrix by restricting chain mobility. As a result, the lower void content reduces water absorption.[22] In this study, it was found that the addition of fly ash at levels below 20% led to significant water absorption. It was also observed that the size of the filler particles had a significant impact on water absorption, with hybrid composites containing 80 mesh particles exhibiting greater absorption than those containing 40 mesh particles. This result can be attributed to the larger surface area of smaller particles, which leads to more significant water application.[23] Based on the SNI 03-2105-2006 standard, the maximum allowable thickness increase for composite particle board is 12%. As such, it can be affirmed that the produced composite hybrid board meets current industry standards.

CONCLUSION

Incorporating OPEFB fiber filler and fly ash in hybrid composites does not exhibit substantial variations in functional groups. The sole discernible distinction is in the magnitude of the absorption band's intensity. The thermal stability of the hybrid composites was enhanced and the melting point was raised by incorporating OPEFB fibers and fly ash, as demonstrated by TGA and DSC studies. Incorporating OPEFB fiber and fly ash fillers enhanced the mechanical characteristics, specifically the tensile strength. The hybrid composite board examined in this study possesses a density that surpasses the standards set by SNI 01-4449-2006 and is classified as a hardboard-type particleboard.

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CONFLICT OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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