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Characterization of Polymeric Foam Composite Reinforced with Empty Fruit Bunch

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Abstract. The use of organic fiber in composite materials has recently become an exciting research object done because it has superior mechanical and thermal properties compared to synthetic fiber. Some of the advantages of using organic fiber on composite materials compared to synthetic fiber are low density, the fiber made from renewable materials that require less energy to produce, lower production costs, less risk on manufacturing processes. The use of Oil Palm Empty Fruit Bunches (EFB) as fiber in this study due to the abundant availability and as an alternative to reducing waste in the palm oil processing industry. The purpose of this research is to know the mechanical, morphological and thermal characteristics of the polymeric foam composite reinforced with empty fruit bunch. Using 10%, 15% and 20% EFB fiber, polyurethane (PU) as a blowing agent and unsaturated polyester resin 157 BTQN-Ex series as a matrix. The tensile test results show the best tensile strength is specimen B (70 wt% resin, 15 wt% polyurethane and 15 wt% EFB). The morphological analysis using Scanning Electron Microscope (SEM) shows that the addition of the percentage of EFB fiber up to 20 wt% affects the cavity formed of polymeric foam composite material where the cavity looks uneven, and it appears that EFB and resin fibers are not well mixed and there are agglomerations of fibers. The result of thermal stability testing using Thermogravimetry Analyzer (TGA) showed that the best thermal stability was specimen C with peak temperature (Tpeak) 356,7 °C in 30 minutes with a mass decrease 66,506%.

1. Introduction

The development of advanced composite technology led to the increasing need for composite materials in the field of industry, such as aviation, shipping, automotive, military equipment, sports equipment, medicine, to household appliances [1].

The advantages and disadvantages of Natural Fiber Composites (NFCs) are : [2], [3]

Advantages:

- Low density and high specific strength and stiffness
- Fibers are a renewable resource, for which production requires little energy, involves CO₂ absorption while returning oxygen to the environment



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- Fibers can be produced at lower cost than synthetic fiber
- Low hazard manufacturing processes
- Low emission of toxic fumes when subjected to heat and during incineration at the end of life
- Less abrasive damage to processing equipment compared with that for synthetic fiber composite.

Disadvantages:

- Lower durability than for synthetic fiber composites, but can be improved considerably with treatment
- High moisture absorption, which results in swelling
- Lower strength, in particular, impact strength compared to synthetic fiber composites
- Greater variability of properties
- Lower processing temperatures were limiting matrix options.

Oil Palm Empty Fruit Bunch (EFB) is a solid waste generated by the production process of Crude Palm Oil (CPO) in the palm oil processing industry. The use of EFB fibers in addition to easy to obtain, cheap, and easy to engineer, is also an attempt to exploit waste. Waste material is one of the alternative materials that need to study in the development of replacement material used as reinforcing material on composite material [4].

Based on data and research results of Center for Data and Information System of Agriculture, Secretariat General of Ministry of Agriculture of Indonesia, in 2014 about projection of oil palm commodity 2014-2019 which is based on data of average growth of palm land since 1980-2014 equal to 11,51 % and the average data of 1980-2014 production growth of 11,95%, and other supporting data, hence projected growth of Indonesian palm oil commodity production until 2019 with potential EFB fibers of 37 million ton [5].

The potential of waste EFB especially in Aceh is also quite abundant then it needs another alternative to utilize the TKKS waste into a more efficient material. In Aceh, there are 25 units of Palm Oil Processing Plant (PKS), located in eight districts with the total operating capacity of 551.12 tons per hour. From the data, using the assumption of 20% Fresh Fruit Bunches will produce solid waste in the form of EFB in a day as much as 110,224 Tons [6].

In general, EFB waste in Palm Oil Factory is used as feed boiler for procurement of electrical energy in internal of Palm Oil Factory and compost fertilizer making material [7], [8]. The chemical composition is known that the fiber content in EFB is the most content and has been used as alternative materials of wood substitute such as bulkhead panel/wall and paper [3].

Assessment of mechanical properties has been done where tensile strength of EFB as a (single) fiber is still lower than other natural fibers ie sisal, jute and hemp, but better than coir and bamboo fiber [9]. Tests have been done by classifying of EFB fibers and showing that the fiber stem fiber is the best part of EFB which has the best tensile strength compared to the primary stem fiber and upper stem fiber [10].

Investigation of EFB fiber by comparing the thermal and physical properties of EFB fibers treated with chemicals and those not being chemically treated. TGA & FTIR testing showed better thermal properties of EFB fibers treated with chemicals, as well as SEM & EDX physical properties also better of EFB treated chemically [11].

Similarly, the study of the mechanical properties of composites by investigating the mechanical behaviour of polymeric foam composite materials is reinforced by EFB (in particles form) fibers due to static and impact loads where the toughness of the composite polymer increases with the addition of EFB fibers [12].

Bio nanocomposite hybrid polyurethane foam reinforced with EFB and nanoclay feedstocks has been performed [13] has a positive effect on improving the compressive strength and thermal stability of this composite material compared to the bio composite which only uses EFB fibers but the production cost to make nanofibers and nanoclay is very high.

The study of nanocomposites with epoxy as a matrix showed that the addition of 3% nano EFB as a filler was able to improve the physical, structural and thermomechanical properties of nanocomposites with epoxy as a matrix because of proper distribution and dispersion in the epoxy matrix [14].

The addition of cellulose from EFB carried out on film bio composites resulted in improved tensile strength and modulus of elasticity as well as good morphology in bio composites [15].

The study of the mechanical properties of woven braid fibers / empty bunches of hybrid palm oil reinforced polyhydroxybutyrate bio composites as non-structural building materials. The results of tensile and bending test of hybrid woven fibers KBFw/EFB reinforced bio composite polyhydroxybutyrate (PHB) with 11 layers have the ability as an alternative material to replace some wood species as non-structural building materials [16].

Some research on the use of EFB fiber application on composites has also been carried out, such as parking bumper redesign response analysis of polymeric foam reinforced EFB fibers due to static press load where bumper parking redesign pressure is better than before but less both accept shear stress [17].

The research that has been done using EFB fiber as a sustainable acoustic/sound absorbent material with sound absorption performance of EFB fiber proved to be comparable with commercial synthetic stone wool and feasible as an alternative of sound absorbing material [18].

Other studies have been carried out where the results of the design and manufacture of polymeric foam traffic cones with EFB fibers and the unsaturated polyester resin as a matrix with the impact test result in the same structural stability as the commercial traffic cone and the lighter product weight [19]. However, the stability of the structure is still better with traffic cones with rubber mats and commercial strips [20].

The study has also been conducted by analyzing the mechanical properties of the lightweight brick from the cut waste of marble boulder reinforced EFB with compressive strength test which produces a lightweight composite brick from fine cut waste marble reinforced EFB fibers [21].

The addition of oil palm empty fruit bunches (EFB) fiber as fillers at a certain percentage of polymeric foam composites can increase the tensile strength of the composite [22]. The smaller the particle size of oil palm empty fruit bunches (EFB) on polymeric foam composites can improve the tensile strength of the composite to be better due to good mixing between the polyester resin and EFB fiber [21].

2. Methodology

2.1. Materials

Oil empty fruit bunch was obtained from palm oil mill at PTPN I Kota Langsa-Aceh. Unsaturated polyester resin, blowing agent (polyurethane), Catalyst Methyl Ethyl Ketone Peroxide (MEKP) and Sodium Hydroxide (NaOH) was supplied by PT. Justus Kimiaraya Jakarta, Indonesia. The material used in this research is contained in table 1.

Table 1. Material researches

No.	Material	Specification	Information
1.	Unsaturated Polyester Resin	BQTN 157-EX	
2.	Waste EFB Fiber		fiber
3.	Blowing Agent	Polyurethane	
4.	Catalyst	MEKP	
5.	Fiber rinse	NaOH, 1M	1%
6.	Lubricant	WAX	For Molding

Table 2. Composition of specimen

Material	Composition (wt %)		
	A	B	C
Unsaturated Polyester Resin	75	70	65
Polyurethane	15	15	15
EFB (fiber)	10	15	20

2.2. Specimens Preparation

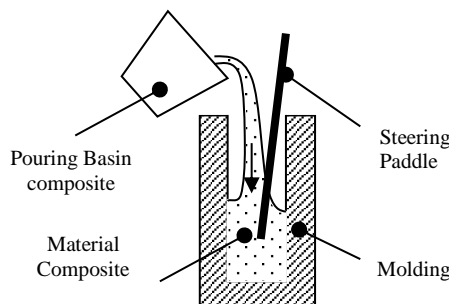


Figure 1. Pouring molding process

The initial treatment of EFB obtained from Palm Oil Factory is to immerse with NaOH solution for 24 hours. Then washed with clean water to remove the remnants of fat and dirt. Furthermore, EFB drained and carried drying with the hot sun to dry. EFB fiber is cut and chopped and then filtered to the size of 0.8 scale mesh. The technique of making foamed polymer composite material with EFB fiber as this amplifier using the casting method (Figure 2). Polyester resins, EFB fibers, polyurethane is mixed with compositions as in Table 2 and hardened with catalyst (Butanone Peroxide).

2.3. Tensile Test

The form of test specimens used in this study has used specimen tensile test specimen prepared following ASTM D-638 test standard and conducted using RTF Series Tensilon Universal Testing Machine.

2.4. Morphology Study

The morphology study of polymeric foam composite reinforced with empty fruit bunch was carried out using a scanning electron microscope (SEM), Hitachi model SU 3500 at a voltage of 10 kV. The surface was sputter-coated with a thin layer of gold before observation.

2.5. Thermal Measurement

The thermal stability of polymeric foam composite reinforced with empty fruit bunch measured by Linseis Thermal Analysis Model Simultaneous Thermal Analysis (STA) PT1600 TG-DSC/DTA from room temperature to 600 °C with a heating rate of 10 °C/min using 8-10 mg of samples.

3. Results and Discussion

3.1. Tensile Properties

Figure 2 shows the ratio of tensile strength between the three test specimens with different compositions. Specimen with label A (10 wt% of EFB), the mean maximum voltage value is 4,941 MPa,

with a strain value of 0.032 mm/mm. For specimens with composition 15 wt% of EFB (label B) obtained the average maximum strength of 9,014 MPa with a strain of 0.025. While the specimens with label C (20 wt% of EFB) contained a maximum value of 2,127 MPa, a strain formed of 0.021.

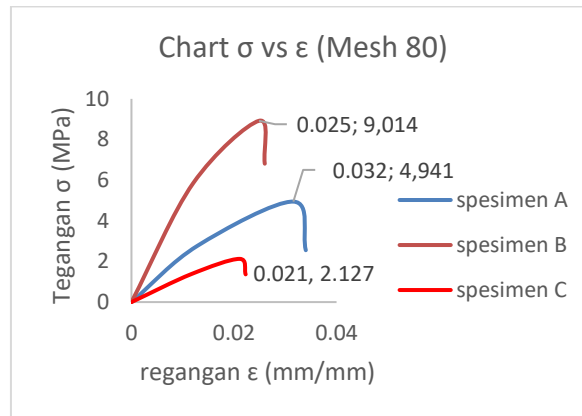


Figure 2. Tensile strength ratio of the specimens

Figure 3 shows that the best average tensile strength of the three specimens is specimen B with a composition of 70 wt% resin, 15 wt% polyurethane and 15 wt% EFB which indicates that the bond between the resin and the EFB particle in the composition is excellent. While the tensile strength of C specimen has decreased dramatically compared to specimens' B and A., This shows that the composition of EFB to 20 wt% in composites has an unfavourable bond between the resin and EFB particles due to the excessive amount of EFB fiber concentration thereby reducing the absorption capacity of the EFB fiber.

The test resulted by tensile testing machine on the specimen with the composition of labels A, B, and C can be concluded the average value of the test results as shown in table 3.

Table 3. Stress and strain average

No	Specimen	Average			
		ΔL (mm)	F (N)	ϵ (mm/mm)	σ (MPa)
1	A	2.684	484.522	0.032	4.941
2	B	2.115	874.267	0.025	9.014
3	C	1.792	208.399	0.021	2.127

3.2. Analysis of Morphology

Figure 3a of SEM results of the specimen A shows that the formation of cavities in this composite material was strong form. These suggest that the polyurethane reaction as a blowing agent function to produce a hollow composite can react and mix with a polyester resin as a matrix and EFB fiber well.

Figure 3b shows that the mixture of polyester resin, polyurethane, and EFB fibers is still well mixed. It was indicated by the formation of a bubble (cavity) on the composite material is quite good and the spread of the fibers evenly and homogeneously.

Then figure 3c depicts the result of SEM specimen C, it can be seen that the addition of the percentage of EFB fiber up to 20 wt% affects the cavity formed in the polymeric foam composite material where the visible cavity is uneven, and it appears that the EFB fiber and resin do not mix well.

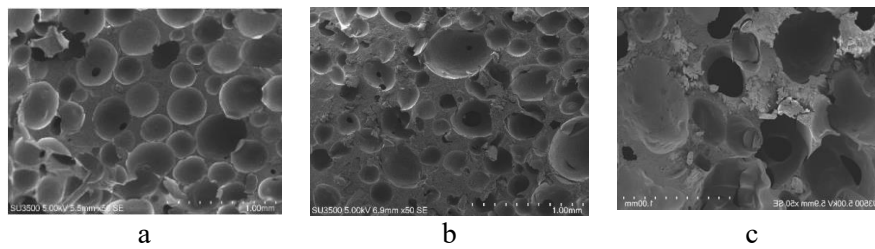


Figure 3. SEM micrograph of polymeric foam composite with EFB fibers

3.3. Thermal Properties

Figure 5 is the TGA curve of all three test specimens with different compositions. Thermal properties of these three specimens are not significantly different results.

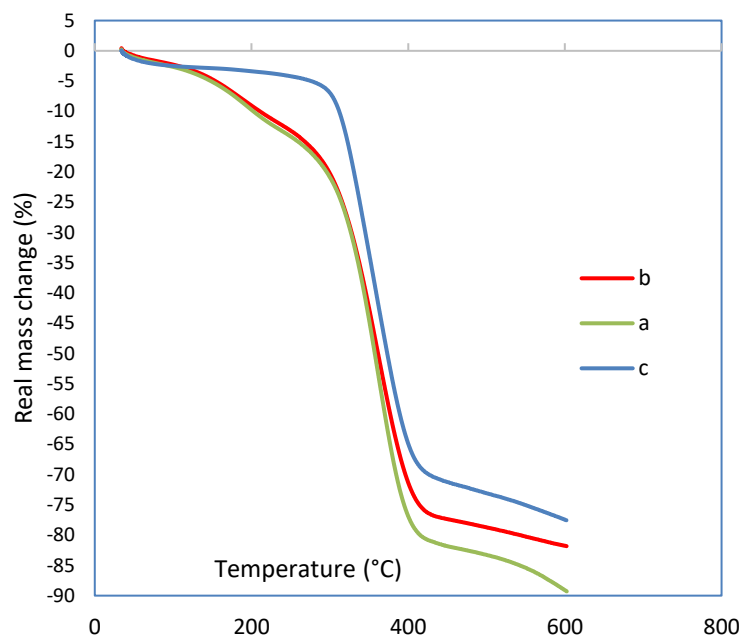


Figure 5. Thermogravimetry Analysis Curve

The TGA curve of specimen A shows that the initial reaction of mass change (9.72%) of the specimen occurred at a temperature of 162.9 - 189.9 °C within 11 - 13 minutes, then a significant decrease in mass began at a temperature of 332.2 °C and peak at a temperature of 362 °C within 27-30 minutes (67.686%). Composite materials continue to decline in mass and decompose at temperatures above 600 °C.

In specimen B the TGA curve shows that the mass decrease starts at a temperature of 141.6 - 177.5 °C in 11 - 13 minutes at 9.432%. Then the mass change occurred significantly by 64.748% at a temperature of 327.5 °C and peak at a temperature of 361.9 °C within 27 - 30 minutes. This specimen B also decomposes at temperatures above 600 °C.

The result of thermal analysis on specimen C shows that the thermal stability of this composite material is better than specimen A and B. This is seen on the curve where the test specimen did not decrease the mass up to temperature 312.2 °C within 27 minutes. The peak temperature (T_{peak}) occurs at 356.7 °C in 30 minutes with a mass reduction percentage of 66.506%. Composite material decomposition occurs at temperatures above 600 °C as well as specimen's A and B.

4. Conclusion

Composite polymeric foam using empty fruit bunch (EFB) oil which has the best tensile strength is specimen B with composition (70% Resin, 15% Polyurethane and 15% fiber) with a tensile load of 874,267 N, the stress of 9,014 MPa and strain of 0,025 mm / mm.

The result of thermal analysis on specimen C shows that the thermal stability of this composite material is better than that of A and B. This is seen on the curve where the test specimen did not decrease the mass up to temperature 312.2 ° C within 27 minutes. The peak temperature (Tpeak) occurs at 356.7 ° C in 30 minutes with a mass reduction percentage of 66.506%. Composite material decomposition occurs at temperatures above 600 ° C as well as specimen's A and B.

The addition of a percentage of EFB fiber amounts to 20% (composition C) results in a mixture of resins, fibers, and polyurethanes to be unfavorable so that the resulting SEM image of the cavities formed is obstructed by EFB fibers.

The thermal test results of the three composite material compositions show that specimen C has the best thermal stability visible on the curve, the specimen does not decrease mass to 312.2 ° C in 27 minutes. The curve between the percentage decrease in weight vs. temperature also showed a less significant difference in the results of the three specimens. The highest peak temperature (Tpeak) is composite with composition A of 362 ° C with the percentage of composite weight reduction of 67.686%.

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