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PENYELIDIKAN PERILAKU MEKANIK MATERIAL *POLYMERIC FOAM* DIPERKUAT SERAT TANDAN KOSONG KELAPA SAWIT (TKKS) AKIBAT BEBAN STATIK DAN IMPAK

INVESTIGATION OF MECHANICAL BEHAVIOR OF POLYMERIC FOAM MATERIALS REINFORCED BY OIL PALM EMPTY FRUIT BUNCHES (OPEFB) FIBERS DUE TO STATIC AND DYNAMIC LOADS

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Abstract

Polymeric composite foam with EFB fiber reinforced is new material that can be utilized as an alternative engineering material. EFB fiber utilization becomes the center of subject in this research. Moreover, these composites are unique with the presence of cavities (foam) in the matrix of unsaturated polyester resin. It results a decrease in density of the material that formed, and obtain a thermoset polymer composite material lighter than any else similar type. The objective of this study is to obtain the best manufacturing techniques of composite material, the mechanical behavior of these materials due to tensile static loading and high strain rate impact, and the distribution of foam that occur in the material that formed as a result of blowing agent (BA) from the type of polyurethane (PU). In this research, the sample formed into standard specimen of testing, such as ASTM D638 for static tensile test, and impact test specimen. Mechanical's behaviors that are obtained in this research are density, tensile strength, modulus of elasticity (E), the incident stress, and dynamic modulus of elasticity of the material. For static testing was performed according to standard ASTM D638 tensile and impact test using the Kolsky's method. To know the distribution of foam that occur in the material, were observed using Scanning Electron Microscope instrument (SEM). Calculation of the cavity numbers in specimens was worked by Adobe Photoshop CS5 Extended software. Determination of the stress distribution in this material, then conducted a computer simulation using Ansys. The best result obtained by the composition of this material based on material composition, which resin consumption can be reduced by the presence of BA as well as mechanical strength, good enough for molding. The best composition in this study (20% BA, 60% resin, 10% catalyst, and 10% fiber) will be used in subsequent studies, namely the design and manufacture of traffic cones from this material.

Keywords*: polymeric foam, EFB fiber, mechanical's behavior*

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INTRODUCTION

Oil palm empty bunches (OPEFB) are solid waste products from the processing of oil palm fruit at the Palm Oil Mill (PKS). In Indonesia, the amount of waste produced is quite large, reaching 1.9 million dry tons per year, equivalent to 4 million tons per year. In particular, in the area of North Sumatra, PT. Perkebunan Nusantara III (PTPN-III) produces OPEFB to reach around 1,350 tons per day (Purnomo et al., 2018). If processed creatively, this waste will have good potential, especially because of the availability of abundant raw materials so that it can be utilized and developed into alternative engineering materials

In general, this waste is used as organic fertilizer on plantation land by being burned or thrown back into the land and allowed to experience the natural fermentation process (Tao et al., 2018). But the utilization of this waste for material engineering processing technology is still very limited in number. Some of the studies that have been carried out include: making activated carbon materials (Nb, Shamsuddin, & Uemura, 2016), and epoxy composite fillers (Saba, Jawaid, Alothman, & Almutairi, 2018). In this study, OPEFB fibers will be used to reinforce polymeric foam composite materials.

OPEFB fibers are natural fibers made from oil palm empty bunches which are waste in the processing process in an oil palm mill. Each OPEFB fiber content was physically composed of 16.19% lignin, 44.14% cellulose, and 19.28% hemicellulose (David et al., 2016). This composition is similar to wood constituent chemicals (Ramage et al., 2017). Based on the results of a study (Yargicoglu, Yamini, Reddy, & Spokas, 2014), the composition of chemical ingredients is dominated by fiber material, which reaches an average of 35% per kg.

Composite materials are defined as two or more separate materials are combined on a macroscopic scale to form a structural unit for various engineering applications (Qin, 2015). This material is composed of two main components, namely: matrix and reinforcement. Based on the matrix, this material is divided into polymer matrix composites (PMC), metal matrix composites (MMC), and ceramic matrix composites (CMC). Based on the reinforcement, this material is distinguished by composite reinforcing fibers, particles, fillers, and flakes (Corvette, 2015).

Blowing agent (BA) is a material used to produce a hollow structure in a composite material formed. BA type polyurethane is a chemical reaction between isocyanates and polyols. This isocyanides reaction will produce amine compounds and carbon dioxide (CO2) gas. This gas will then form foam on the polymer material formed (Prociak et al., 2018).

The mechanical properties of the polymeric material are typical with their dominant viscoelastic behavior (Gover, Oloyede, Thambiratnam, Thiyahuddin, & Morris, 2015), so this material has high elastic properties. In addition, this material has a shear and bulk modulus as the nature of the viscos. The Maxwell model for viscous materials was chosen in this study because it aims to observe the stress distribution that occurs due to certain loads.

This study aims to: (1) obtain the technique of making polymeric foam material (PF) which is reinforced by OPEFB fibers, (2) investigating the mechanical behavior of this material due to static and dynamic static loads. Mechanical behavior observed in this study were: tensile strength, specific gravity, elastic modulus (E) static tensile, and fracture patterns due to impact loads, and (3) to obtain the best microstructure of PF material for variations in its constituent materials. Thus, the best material composition is obtained with better distribution of foam distribution.

METHODOLOGY

The materials used in this study are: (1) Unsaturated resin polyester, (2) polyurethane (PU), (3) OPEFB fiber, and (4) MEKPO catalyst. These ingredients are mixed based on certain composition variations, namely: 35% - 80% resin, 10% - 15% OPEFB fiber, and 0% - 40% PU.

Specimens are formed into 3 types of testing, namely: tensile test, impact test, and microstructure. Tensile test specimens followed ASTM D638, impact test specimens based on the Kolsky's bar method (19 mm diameter and length based on Lagrange diagram calculations, ie 200 mm), and microstructure tests using Scanning Electron Microscope (SEM) test equipment.

Static tensile testing and microstructural observations were carried out at the Polymer Technology Center - BPPT, Tangerang, Indonesia. The tensile static test equipment is Shimadzu Servopulser AGS-G 10 kN. Microstructural observations were carried out using SEM tools from EDAX (Energy Dispersive X-Ray Spectroscopy) types. Impact testing was carried out at the Impact and Fracture Research Center, Department of Mechanical Engineering, Faculty of Engineering, University of North Sumatra, with the Air Gun Compressor (AGC) test equipment. To obtain the stress distribution that occurs in the static and impact static test results, a simulation is carried out using Ansys software.

The process of making specimens is preceded by making OPEFB fibers which are visually shown in Fig. 1.

The process of OPEFB refining into fiber is carried out in dry conditions. The results obtained in this process are then filtered with a mesh size of 1x1 mm, so that fibers with diameter sizes ranging from 0.05 to 0.4 mm are obtained, and the length ranges between 0.5 - 2 mm.

The method used for making specimens is by casting method which is accompanied by gentle stirring on the material poured with the position of the slope of the mold between 60^o - 90^o to the work table, as illustrated in Fig. 2.

The desired composite product requirements are: even distribution of OPEFB fibers in composites, foam equalization in composites, closed surface forms, and relatively harder and stiffer surfaces for ease in disassembling the mold. The process of making tensile static test specimens is shown in FIG. 3.

Fig. 1. Process for preparing OPEFB fibers

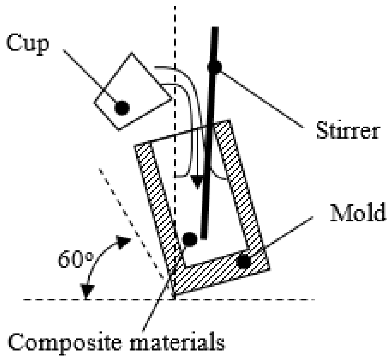


Fig. 2. Casting method

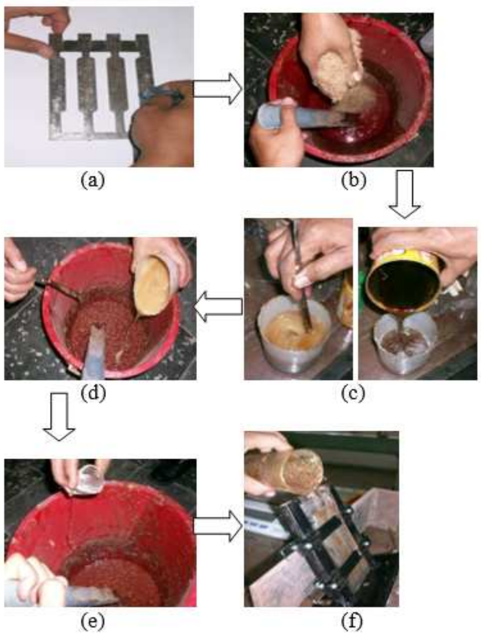


Fig. 3. The process of making test specimens: (a) giving a separation layer; (b) Mixing Resin and OPEFB fibers (C1); (c) Giving PU; (d) Mixing C1 and C2 solutions; (e) Giving a catalyst; and (f) Cast into the specimen mold.

Variations in the composition of composite materials for tensile static test specimens are divided into 3 (three) types, namely: 1). Variations in the composition of Resin-vs-PU, coded V1, 2). Variations in composition of resin-fiber-OPEFB fibers, coded V2, and 3) Variation in composition of PU, OPEFB fibers, and resins, coded V3. These variations are shown in table 1, 2, and 3.

Table 1. Composition in variation V1

No.	B.A.	Resin	Serat	Katalis
1	20%	60%	10%	10%
2	30%	50%	10%	10%
3	40%	40%	10%	10%
4	0%	80%	10%	10%

Table 2. Composition in variation V2

No.	B.A.	Resin	Serat	Katalis
1	20%	65%	5%	10%
2	20%	55%	15%	10%

Table 3. Composition in variation V3

No.	B.A.	Resin	Serat	Katalis
1	40%	35%	15%	10%
2	10%	70%	10%	10%

The physical form of the specimen in each variation is shown in succession in FIG. 4 - 6 for the composition of materials V1 - V3.

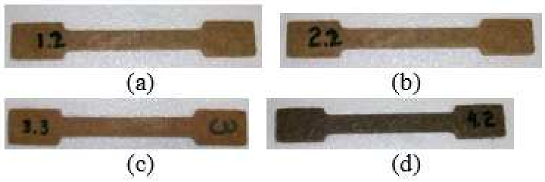


Fig. 4. Specimens for the composition of variations in table 1: (a) V1.1, (b) V1.2, (c) V1.3, and (d) V1.4

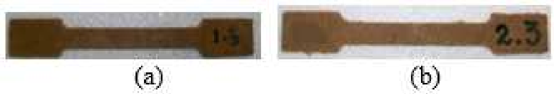


Fig. 5. Specimens for the composition of variations in table 2: (a) V2.1, and (b) V2.2

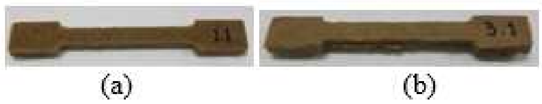


Fig. 6. Specimens for the composition of variations in table 3: (a) V3.1, and (b) V3.2

The physical shape of the impact specimen is shown in Fig. 7.

Fig. 7. Impact test specimen

RESULT AND DISCUSSION

The results of measurement data for specific gravity (ρ) in each variation are shown in Fig. 8. In this study, the desired specific gravity is density which is close to the density of water, which is 1000 kg / m^3. Thus, the resulting composite product is expected to be quite light, stable, and easy to mobilize. Based on the results of measurements and calculations, the specific gravity of the product is: composition for 50% resin ρ = 945 kg / m^3, 55% ρ = 1077 kg / m^3, 60% ρ = 1096 kg / m^3, 65% ρ = 1108 kg / m^3, 70% ρ = 1122 kg / m^3, and 80% ρ = 1124 kg / m^3.

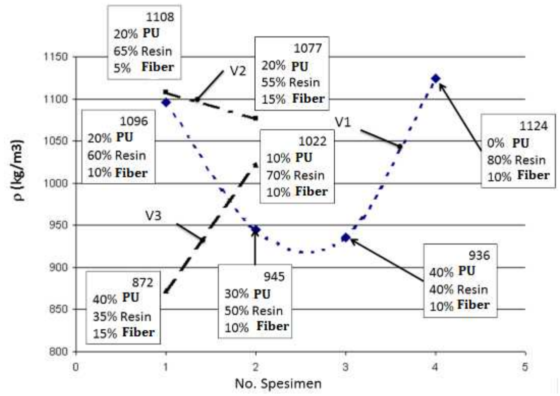
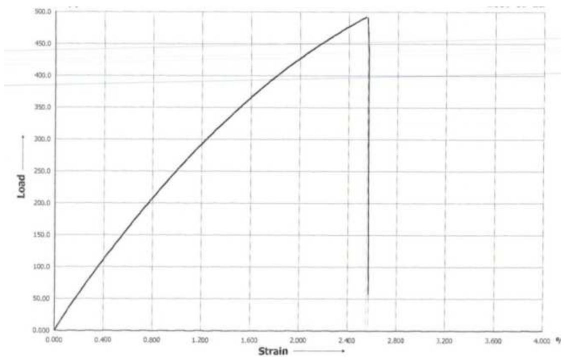
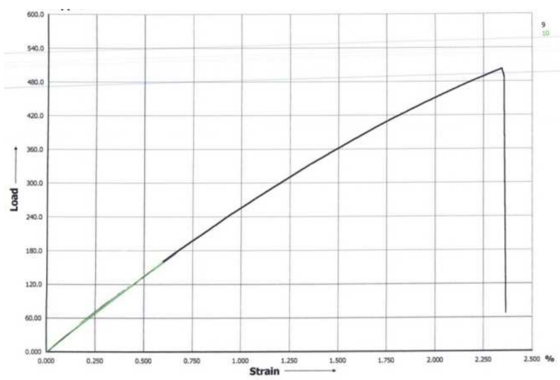


Fig. 8. Specific gravity based on each composition variation

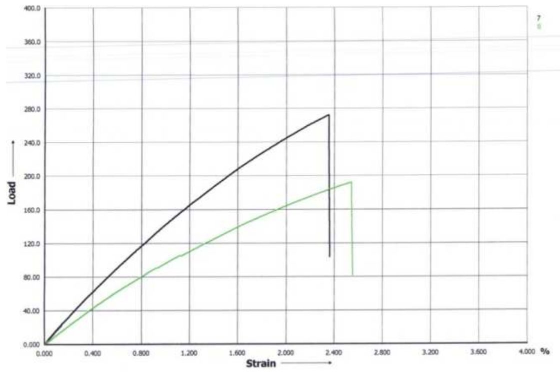
The tensile static test results are shown in the load change chart for length increments. The test results are shown in Fig. 9.



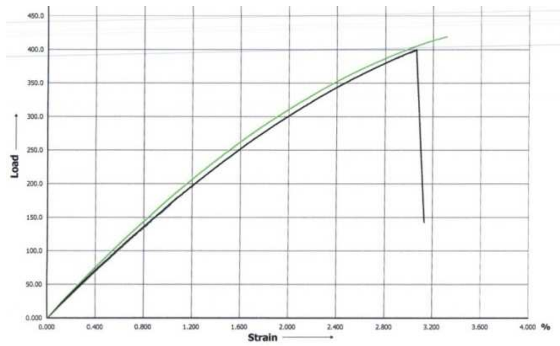
(a)



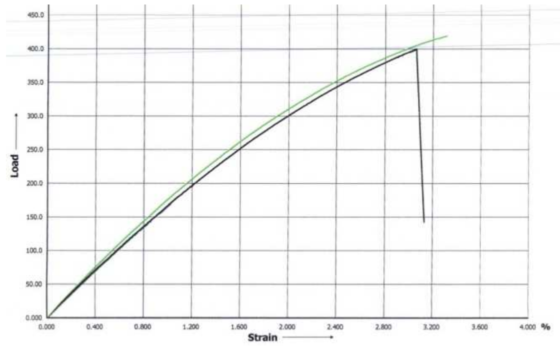
(b)



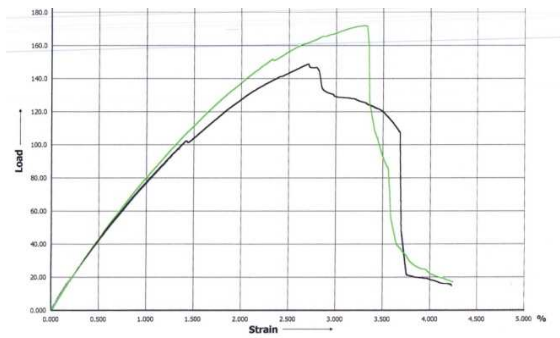
(C)



(D)



(E)



(F)

Fig. 9. Graphs of tensile test results: (a), (b), and (c) specimens with compositions V1, (d) and (e) specimens with composition V2, and (f) specimens with composition V3.

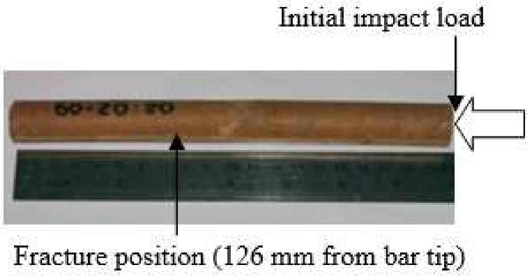
The mechanical data from the static tensile test results are tabulated in table 3.

Table 3. Mechanical data from static tensile test results

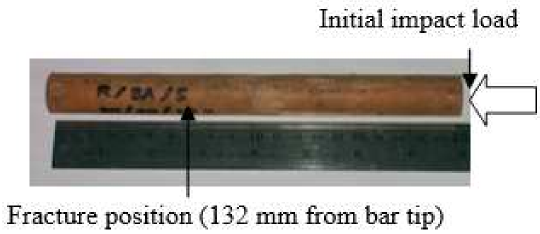
Comp.	N.Sp.	S_{yt} (MPa)	ε	E (MPa)
V1	1	7.427	0.02571	288.8759
V1	2	8.049	0.02363	340.6263
V1	3	2.531	0.02454	103.1377
V2	1	4.628	0.0322	143.7267
V2	2	1.715	0.03589	47.7849
V3	1	1.871	0.04234	44.18989

Based on static tensile test results, the highest tensile strength of the material is found in variation V1.1 with a resin composition of 60% and yield stress of 8.049 MPa, and V1.2 with a composition of 50% resin and a yield stress of 7.427 MPa. Based on the static tensile test results, the strength of the best material is found in the resin composition of 50% or more (V1.1).

Therefore, specimens have been prepared for these compositions for impact tests. The composition variation tested in the impact test was a variation on resin compositions V1.1 and V1.2. The test is carried out by giving an impact pressure of 0.4 MPa, an impact distance of 500 mm, a striker length of 100 mm, and the input bar length of 1500 mm. The position of decay due to impact loads is shown in Fig. 10 and the impact strength is shown in table 4.



(a)



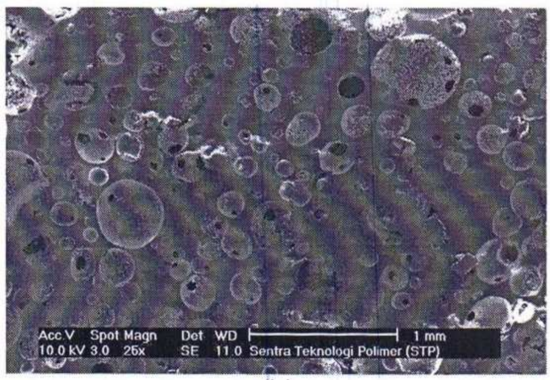
(b)

Fig. 10. Fracture locations in the specimen: (a) 60% resin, and (b) 50% resin

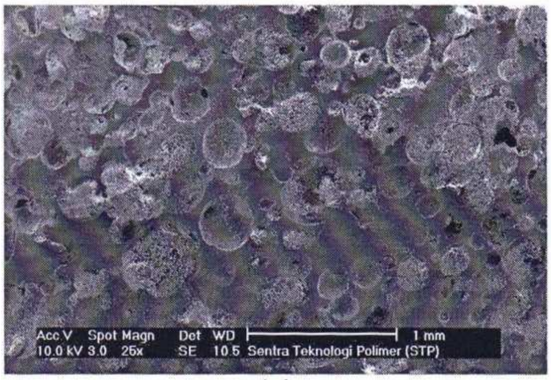
Table 4. Impact fracture position

Spec. No.	Composition (R:BA:S:K) (%)	L / Dia (mm)	Fracture Pos. (mm)
1	60:20:10:10	200 / 19	126
2	50:30:10:10	200 / 19	132

The microstructure (SEM) observation of the surface of the composite material is shown in Fig.11.

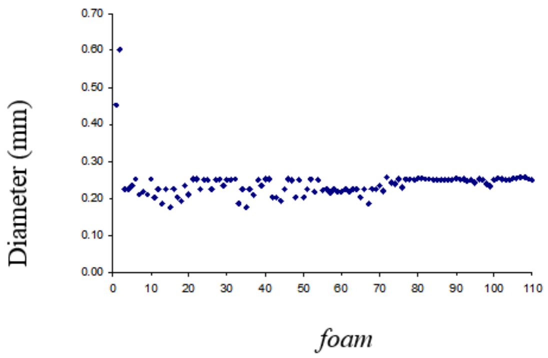


(a)

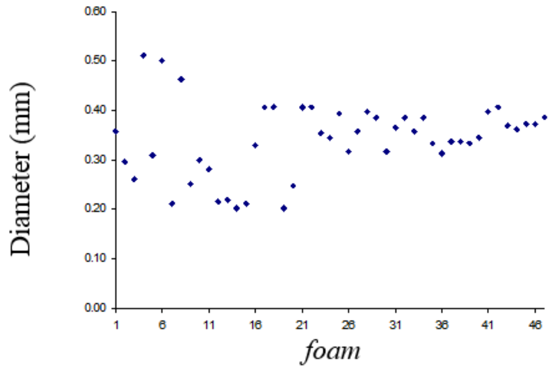


(b)
Fig. 11. Microstructural observations: (a) composition V1.1, and (b) composition V1.2

The amount of foam contained in each composition is calculated using the help of Adobe Photoshop CS5 Extended software. For the composition of V1.1, there are 110 foams in the observation area of 7 mm2 and the foam diameter averages 0.24 mm. In composition V1.2, the amount of foam formed in the same area of observation was 47 foams, with an average diameter of 0.34 mm. The graph of the calculation of the diameter of the foam in each composition is shown in FIG. 12.



(a)



(b)
Fig. 12. Diameter of foam

Based on observations, the amount of foam in composition V1.1 is more evenly distributed in the composite material formed, which is about 70%, with the resulting diameter relatively more uniform compared to composition V1.2. Thus, composition V1.1 can be recommended as a better composition for the manufacture of various components with this type of composite material.

CONCLUSION

The fabrication and testing of the strength of composite materials has been done and has been explained in the results chapter. The conclusion of this study is:

- The technique of making OPEFB fiber reinforced polymeric foam composite materials has been found and tested well. Based on the results of this study, the best technique is to use the casting method which is accompanied by slow stirring. In this method it is possible to remove gas bubbles trapped in the matrix. The slope position of the mold is recommended between 60° - 90° to the workbench.

- The mechanical behavior of PF composite material reinforced by OPEFB fibers from the test results is: the static tensile strength of this material is 7.427 MPa, density is 1096 kg / m3, and the modulus of elasticity is 288.8759 MPa. The location of decay in the specimens resulting from the impact test is as far as 126 mm from the initial impact tip for composition V1.1, and 132 mm from the initial impact tip for composition V1.2. This is in accordance with the approximate location of decency using the Lagrange diagram, which occurs in an area along 198 mm from the starting point of impact.
- Based on the observation of material microstructure, the best distribution of foam is found in the composition V1.1 which is equal to 70% of the observed cross-sectional area, with an average diameter of 0.24 mm. Whereas for Composition V1.2 only 60% with an average diameter of 0.31 mm. In addition, the distribution of foam diameter in composition V1.1 is more uniform compared to composition V1.2.

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