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Modification of Recycled HDPE Composite with OPEFB Microfibers Through the Melt Blend Extruder Process

Zulnazri Zulnazri[1,*], Rozanna Dewi[2], Agam Muarif[3], Ahmad Fikri[4]
Malikussaleh University, Lhokseumawe, Aceh, Indonesia.[1,2,3,4]

*Corresponding Author: e-mail :zulnazri@unimal.ac.id

Abstract. *This study describes the manufacture of modified composites from recycled HDPE plastic waste and TKKS fibers. The comparison of matrix composition with TKKS fibers used is (70:30); (80:20) and (90:10) %. The mixing process of HDPE with OPEFB was carried out using the melt blending method and extruded to obtain composite pellets. Composite characterization obtained high tensile strength in HDPE composites: OPEFB ratio (70:30) % of 36.50 Mpa, while the tensile strength of HDPE: OPEFB ratio (80:20) and HDPE: OPEFB ratio (90:10) % were obtained respectively 23.50 MPa and 26.50 MPa. The results of the surface structure test with SEM showed that there was a bond between the HDPE matrix and TKKS fibers which was marked by a brittle fracture shape on the surface of the composite and the fibers were not uniformly broken. The impact test results of HDPE composite: OPEFB ratio (80:20) % have a high impact value of 0.363168 Joules. The FT-IR test results show deformation of C-H vibrations and pyranose C-O-C which are typical of OPEFB at wave numbers 1070.49 & 1151.50 cm- and intermolecular O-H bending in TKKS at wave numbers 3672.47 cm-. The TGA test results of HDPE composite: OPEFB ratio (70:30) and HDPE: TKKS (80:20) obtained degradation temperature values (Te) of 535.57^{O}C and 529.74^{O}C, respectively.*

Keywords *Plastic waste, HDPE, OPEFB, composites*

1. INTRODUCTION

Plastic waste is a material that is abundant in nature and damages the environmental ecosystem because it cannot be naturally degraded, so that its accumulation continues to increase along with increasing human needs. If burned, this plastic will produce emission gases, causing a greenhouse effect. So that this plastic is a serious threat to living things on planet earth. For this reason, this plastic needs to be processed into economically useful products, one of which is used as a composite using empty palm oil bunches (OPEFB) fiber reinforcement or filler.

10 countries producing the most plastic waste, which has not been managed properly. Where Indonesia is in second place, It takes 400 years to degrade in the soil. (Data: Litbang Kompas 2010).

Potential for Biomass Waste in Indonesia in 2023 is quite promising, OPEFB is one of the most widely produced biomass wastes and has great potential to be used as natural fiber in making composites (Arif Darmawan (2023) dan Rina (2020). Based on the mass balance of materials, each fresh fruit bunches processed at the palm oil mill will produce around 25-26% empty palm oil bunches besides producing palm oil.

This research aimed to reduce the accumulation of plastic waste in the environment. Utilizing HDPE plastic waste and fiber from OPEFB biomass for making composites. Composite is a combined material of two or more materials that has better quality than a single

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material, both mechanically and physically. The previous composite manufacturing of PP and LDPE plastic waste with TKKS filler was carried out through a hot press molding process. The resulting composite product has high tensile strength and can be used as a substitute for wood for furniture, even car interiors, and elastic impact resistance (Zulnazri and Dewi, 2018; Zulnazri et al., 2020). This research was conducted for further innovation development and product refinement so that this innovation can be used as a product that can be applied. In this research study, product refinement was made using the melt blending method and extruder technique combined with composite molding for electronic board applications.

2. LITERATURE REVIEW

HDPE Plastic Modified Composite

Composite is an advanced material product with a combination of two different materials that have better compatibilizers and mechanical properties than single materials. Composites have high impact and tensile strengths and better thermal stability (Zulnazri and Dewi, 2018).

Thermoplastic composites made from lignocellulose fillers from oil palm bunches are currently being developed. Lignocellulose as a fiber has many advantages compared to inorganic fillers, including: low density, high deformability, flexible, does not generate heat on equipment during the process, low price, and comes from renewable resources. Thermoplastic materials and fillers from plant fibers are in principle incompatible materials, due to differences in polarity, so process modifications are needed such as: in situ crosslinking, addition of compatibilizers and copolymerization of functional groups in polymers and fillers (Wirjosentono et al., 2004). Some chemicals developed for compatibility between the two materials are: maleic anhydrate modified-polypropylene, poly [methylene (polyphenyl isocyanate)], poly (propylene-acrylic acid) and silane (Rozman, et, al., 2002).

TKKS fiber is a lignocellulosic fiber that can be used as a filler to produce good PP composites and HDPE composites. The maximum tensile strength of the composite is obtained when the filler content is 20% (weight) although the elongation shows a decreasing trend with increasing filler. The addition of acrylic acid obtained compatibility between the filler and polypropylene (Wirjosentono et al., 2004).

Process modification of plastic polymers with TKKS fibers using extruder techniques can increase the compatibility of polymer materials, where the impact strength, dynamic fracture, water effects on electrical properties, flexural and tensile properties of polymers with TKKS fiber reinforcement are very high (Atmaja et al., 2021).

3. METHODS

The crushed HDPE plastic matrix is mixed with 50 mL of 0.1% BPO initiator. TKKS fiber is mixed with 50 mL of 1% MAH compatibilizer, stirred until smooth. These two materials, HDPE matrix-OPEFB fiber, are mixed with a ratio of (70:30)% to become 100 gr and compatibilizer becomes 100 ml (1: 1). The mixture is homogenized in a melt blending or roll mill to form a hard dough (cross-linking and compatible formation process). Then extruded to obtain a crystal seed composite.

Composite characterization includes: FT-IR test to see functional groups, SEM test to see composite morphology, thermal test to see thermal stability, impact test and tensile test to see the mechanical strength of the composite.

4. RESULTS

HDPE- OPEFB Composite

The specimens from the composite molding of a mixture of HDPE and OPEFB fiber with a ratio of the amount of HDPE and OPEFB fiber as many as 3 variations, it is 70: 30, 80: 20 and 90: 10.

Table 1. HDPE- OPEFB Tensile Test Results

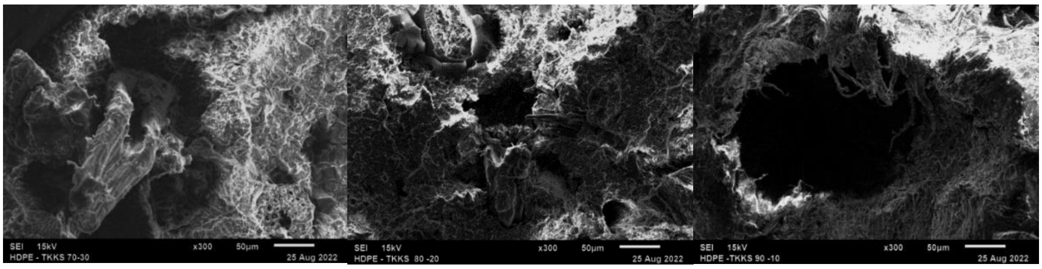
Name	Max. Stress	Max. Force	Break. Force	Break. Disp.
Parameters	Tensile Strength	Maximum Load	Stress at Break	Nominal Strain at Break
Unit	MPa	N	MPa	mm
HDPE : OPEFB (70:30)	40.000	357.000	36.000	0.036
HDPE : OPEFB (80:20)	20.000	235.000	23.000	0.001
HDPE : OPEFB (90:10)	30.000	265.000	27.000	0.043

Based on Table 1 it can be seen that the composite that has the highest tensile test value in this study is a mixture of HDPE: OPEFB as much as 70 : 30 with a Tensile Strength value of 40,000 MPa.

5. DISCUSSION

HDPE-OFEPB Scanning Electron Micrographs (SEM)

The surface structure of the composites was analyzed by SEM. The type of matrix and filler used and the ratio of matrix to fiber will determine the surface shape and fracture shape of the composite when the tensile test is carried out. Figure 1 is the result of SEM analysis showing the fracture morphology of the composite resulting from a mixture of HDPE – OPEFB with a scale of 50μm and a magnification of 300 times. The composite as a whole shows a brittle fracture form, due to the high applied tensile force causing the composite to break irregularly, this shows that the composite has good compatibility between the matrix and the fiber. The HDPE - OPEFB composite also exhibits an irregular morphology due to the influence of the chemical constituents present in OPEFB such as lignin and other inorganic substances.



(a) (b) (c)

Figure 1. Composite HDPE – OPEFB SEM Analysis Results (a) 70:30; (b) 80:20; (c) 90:10

Impact Test for HDPE-OPEFB Composites

Impact test analysis is one of the tests of composite materials to determine the ability of a material to accept impact loads which measure the amount of energy required to break a material specimen. The impact test is also used to study the fracture pattern of the specimen so that it is known that the specimen has a brittle fracture or ductile fracture or a combination of both. Granular fracture or cleavage fracture is a brittle fracture surface shiny and granular while ductile fractures appear more opaque and stringy, also known as fibrous fractures or shear fractures. The impact test analysis method used in this study is the charpy method. The results of the impact test on the 3 types of composites can be seen in Table 2 with euation (1) and (2).

$$W = G \text{ x } R \text{ x } (\cos\beta - \cos\alpha) \quad (\text{Joule}) \ldots\ldots (1)$$

$$\text{Tenacity} = \frac{W}{A} \quad (\text{Joule}/\text{mm}^2) \ldots\ldots (2)$$

W = Impact (Joule)

G = Pendulum weight (N)

R = Pendulum radius (m)

α = The initial angle / angle formed by the pendulum without load

β = The final swing angle/angle that the hammer forms after breaking the test load

A = The cross-sectional area of the fracture (mm^2)

Table 2 Impact test data for HDPE-OPEFB Composites

Composition	Cross-sectional area (A)	Degree		R (meter)	G (Joule)	Impact (W) (Joule)	Tenacity (W/A) (Joule/mm²)
		α	β				
HDPE : OPEFB (70:30)	80	160	153	0.256	25	0.311591018	0.003894
HDPE : OPEFB (80:20)	80	160	152	0.256	25	0.363168179	0.004539

Thermogravimetric Test (TGA) for HDPE-OPEFB Composites

The thermal properties of a material is one of the important factors that must be known so that it can be used optimally. Thermogravimetric analysis (TGA) is a method to determine the thermal properties of a composite material that can be used to study the stability and degradation of composite materials. TGA is a measurement of the change in weight of a material as a function of time. The results of the TGA test on the HDPE : OPEFB composite with a ratio of 70:30 and 80:20 are shown in Figures 2 and 3. Based on the TGA test on the HDPE : OPEFB composite (70:30) the degradation temperature (Te) was 535.57 ^{O}C, and TGA test results on HDPE : OPEFB composite (80:20) obtained a degradation temperature (Te) of 529.74 ^{O}C. This shows that the two composites have very high thermal stability so they are very good as materials for making cassing electronic.

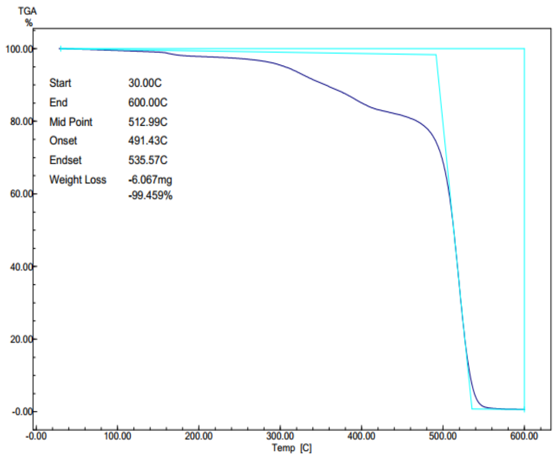


Figure 2. TGA Analysis of Composite HDPE – OFEPB (70 : 30)

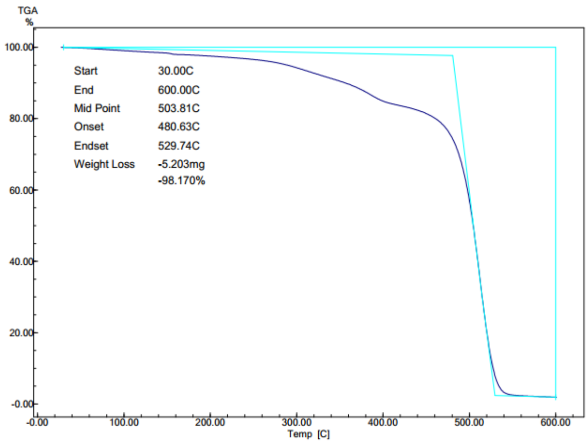


Figure 3. TGA Analysis of Composite HDPE – OFEPB (80 : 20)

FTIR Spectrum for HDPE-OPEFB Composites

The characteristic feature of the FT-IR spectrum of OFEPB fiber is that it displays two main absorption areas, namely in the high wave number and low wave number areas. From the test results of cellulose from empty palm oil bunches, it was found that the high wave number was 2800-3300 cm-1 and the low wave number was 500 -1400cm-1. The spectrum shows a broad absorption peak located at 2800-4000 cm-1 which is a stretch of the –OH group. The absorption peak in the area 2890-2900 cm-1 is related to the -CH_2 group, this is in accordance with a study conducted by Jahan et al., (2011).

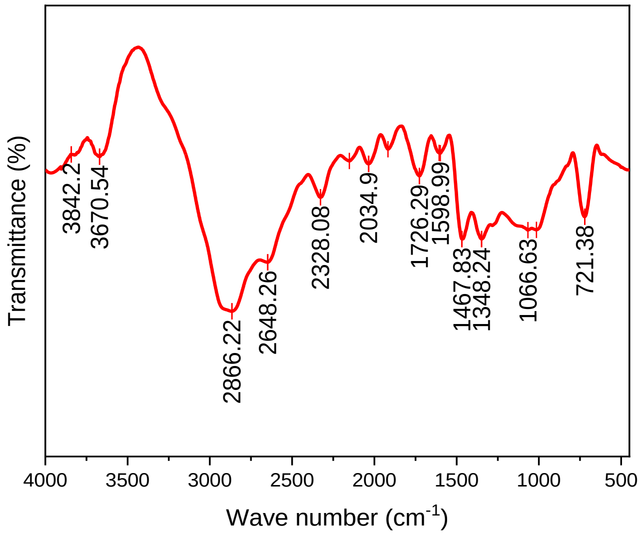


Figure 4. FTIR Spectrum Analysis of Composite HDPE – OFEPB (70 : 30)

The absorption peak in the 2862 cm-1 region is an overlapping of the -CH2 band. The functional group analysis of the HDPE and OFEPB mixed composite with a ratio of 70 : 30 can be seen in Figure 4.

6. CONCLUSION

The tensile test results showing the highest tensile strength value is 40 Mpa, namely the composite of a mixture of HDPE and TKKS with a ratio of 70: 30. Scanning Electron Microscopy (SEM) shows the fracture morphology of the HDPE composite with TKKS with a brittle shape. The impact test results of the composite from a mixture of HDPE: Cellulose 70:30 and HDPE: TKKS 80:20 have the highest impact value of 0.363168 Joules. HDPE and TKKS composites have high strength and have the potential to be used as electronic casing equipment materials.

LIMITATION

It is inevitable that your research will have some limitations, and this is normal. However, it is critically important to strive to minimize the scope of these limitations throughout the research process. Additionally, you need to acknowledge your research limitations honestly in the conclusions chapter.

Identifying and acknowledging the shortcomings of your work is preferable to having them pointed out by your final work assessor. While discussing your research limitations, do not merely list and describe them. It is also crucial to explain how these limitations have impacted your research findings.

Your research may have multiple limitations, but you should discuss only those that directly relate to your research problems. For example, if conducting a meta-analysis of secondary data was not stated as your research objective, there is no need to mention it as a limitation of your research.

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