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Characteristics polyester matrix composite reinforced hybrid *Musa acuminata* stem-*Hibiscus tiliaceust* bark fiber as rear vehicle bumper material

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Abstract

In this study characterizing the polyester matrix composite material reinforced with hybrid fibers (*Musa acuminata* stem fiber (MASF)-Hibiscus tiliaceus bark fiber (HTBF). The aim is to increase impact toughness and shrinkage due to temperature changes. The fiber length is 10 cm, arranged randomly, with the volume fraction ratio of MASF and HTBF is 5%:25%, 10%:20%, 15%:15%, and 20%:10%. The fiber was treated with alkali by soaking it in 5% NaOH solution for 2 days. The matrix used was polyester BQTN type 157 and was catalyzed by MEKPO. To determine impact toughness and fiber shrinkage due to temperature degradation, impact tests and thermogravimetric analysis (TGA) were carried out. Specimens were prepared by the vacuum infusion method. The results of this study indicate the highest impact toughness was 0.102 J/mm2 at the volume fraction ratio of the MASF-HTBF hybrid fiber 20 %:10%. If the volume fraction exceeds 20%, the collision energy will again decrease. Based on the TGA test the polyester composite specimens with the best heat resistance were hybrid fiber reinforcement with volume fraction ratio: 5% MASF, with the lowest weight loss of about 73.16%.

Keywords: Polyester matrix composite; *Musa acuminata* stem fiber; *Hibiscus tiliaceust* bark fiber; Hybrid fiber; Impact toughness; Thermogravimetric analysis

1. Introduction

The rear bumper is one part of the vehicle that has a very important role. The rear bumper serves as a shock absorber from behind that occurs in the vehicle in the event of a collision. Therefore, we need a material that has good impact toughness, light weight, low heat shrinkage and corrosion resistance. Recently, polyester matrix composite materials have begun to be used in the automotive industry for exterior parts such as bumpers, extenders and followers [1]. The reason is that compared to composite material steel plate, it is low density, light weight and corrosion resistance. However, the polyester composite material. cannot withstand shock and crash loads compared to metal. The impact toughness of polyester bumpers is low when compared to steel plate bumpers and high shrinkage. Several studies to improve the mechanical and physical properties have been carried out.

Research [2] natural fibers are used as reinforcement for polyester composite materials, to increase impact toughness, chemical attack resistance, and thermal resistance. The reasons for using natural fibers over synthetic fibers (Kevlar, boron, carbon, nylon and fiber glass) are low cost, biodegradable, recyclable, non-toxic and combustible. Natural fibers have attracted the interest of engineers, researchers, professionals and scientists around the world as an alternative reinforcement for fiber-reinforced polymer composites, due to their superior properties such as high specific strength, low weight, low cost, quite good mechanical properties,characteristics of non-abrasive, environmentally friendly and

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bio-degradable. In this light, a brief review of the use of natural fibers (such as abaca, banana, bamboo, cotton, coir, hemp, jute, pineapple, sisal etc.) was carried out [3] . Glass Fiber Reinforced Polymers are hybridized with natural fibers to enhance Engineering and Technology applications.

In the matrix composite material functions: to protect the fiber surface from abrasion damage that will cause fracture, adhere to the surface to transfer the forces that have been applied to the same fiber, to separate the fibers from each other to increase the resistance of transverse crack propagation to other fibers according to the study [4] [5].

Work [6] compared the impact strength, cost and weight of jute-based composite bumpers with carbon steel bumpers. Composite bumper was developed by applying a series of layers of jute fiber and a layer of liquid resin. The results of the Charpy impact test, the observed impact toughness of the composite bumper was 7.14 J/mm^2. When compared to steel bumpers, the cost of composite bumpers is 58% lower and a weight reduction of 56.1% is achieved.

Research [7] hybrid kenaf fiber/glass fiber is used as a reinforcement for composite materials to improve the mechanical properties of composites as car bumper beams. The specimens without any modifier were tested and compared with a common bumper block material called glass mat thermoplastic (GMT). The results showed that some mechanical properties such as tensile strength, Young's modulus, flexural strength and flexural modulus were similar to GMT, but the impact strength was still low.

The works [8] design optimization of bumper systems has focused on one single impact loading. This study aims to address this issue by developing a multiobjective optimization approach, in which multiple impact loading scenarios are considered to optimize the intrusion and energy absorption of the bumper system. Modeling of real-life impact scenarios is first validated by comparing the numerical results with the experimental data.

The study [9] proposed a structural design and optimization method for a commercial front bumper system made of carbon fiber woven reinforced composites. The structure of the integrated bumper system is presented taking into account the manufacturing process of composite materials. Then, an optimization procedure that combines the Kriging modeling technique and the modified particle swarm optimizer (PSO) algorithm is proposed to find the optimal combination of design variables. Real-vehicle experiments prove that the optimized bumper system meets all strength and crash-worthiness requirements with a weight reduction of 31.5%. The results show that the proposed design method is an efficient and effective way to design composite structures.

At present, there has not been found in the literature describing the results of research using hybrid fibers (MASF and HTBF) as reinforcement for polyester composites, so that their impact toughness and shrinkage properties are suitable as a rear bumper material.

2. Material and methods

2.1. Materials

The natural fibers used as research materials were *Musa acuminata* stem fiber (MASF), Hibiscus tiliaceus bark fiber (HTBF) as shown in Figure 1. The composite matrix consisted of BQTN type 15 polyester, MEKPO catalyst, and 5% NaOH, fiber treatment. The equipment used are impact test equipment, thermogravimetric analysis (TGA), Scanning Electron Microscope (SEM FEI inspect S50), vacuum pump, composite mold made of silicon, with a standard thickness of 6 mm and composite fabrication equipment.

2.2. Methods

Composite specimens were made using the vacuum infusion molding method. The variables of this study are the variation of the volume fraction of MASF and HTBF with the ratio of is 5%:25%, 10%:20% and 15%:15%. The dimensions of the composite impact test specimen are 12.7 mm thick according to the ASTM D 256 standard, as shown in Figure 2. The change in mass or shrinkage as a result, was tested by TGA.

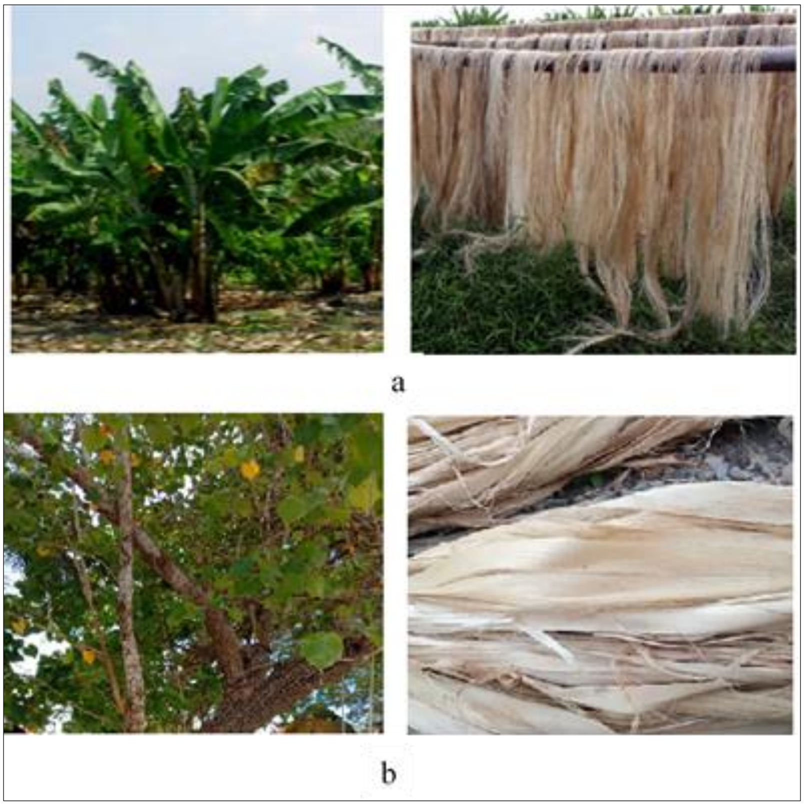

Figure 1 a. *Musa acuminata* stem fiber (MASF). b. Hibiscus tiliaceus bark fiber (HTBF)

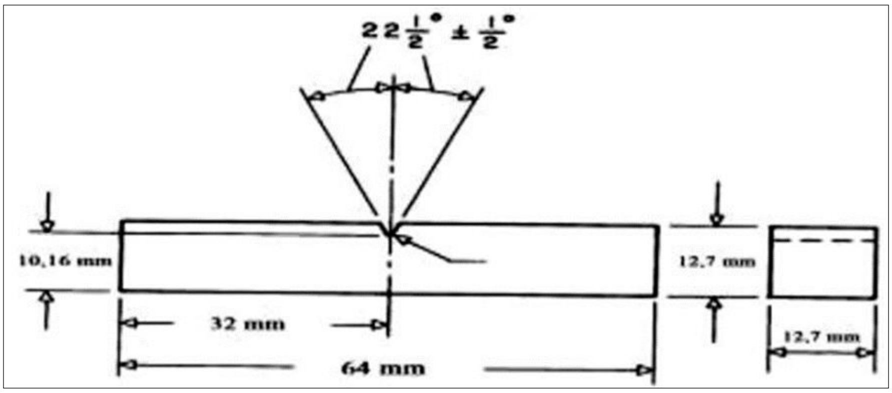

Figure 2 Impact test specimen ASTM D 256 standard

3. Results and discussion

3.1. The toughness impact of polyestre matrix compocite reinforced fiber hybrid

The impact test was carried out to determine the effect of the application of hybrid fiber (MASF-HTBF) on the impact toughness of the hybrid fiber reinforced polyester composite. From the results of the impact test, the impact toughness and impact energy are obtained as shown in Figures 3 and 4.

Based on the results of the study, the impact toughness of the polyester composite specimen reinforced with hybrid MASF-HTBF increased compared to the non-hybrid fiber (only MASF fiber), as shown in Figure 3. The lowest impact toughness was 0.021J/mm^2, at the volume fraction ratio of the hybrid fiber MASF-HTBF; 5%:25%, the highest 0.102 J/mm^2 occurred in polyester composites with a volume fraction of 20% MASF, the addition of a volume fraction of MASF exceeding 20% tends to decrease the impact toughness, shown in Figure 3. Because MASF contains more lignin than HTBF. The physical properties of lignin are hard, strong and tough. In accordance with the results of the study [10].

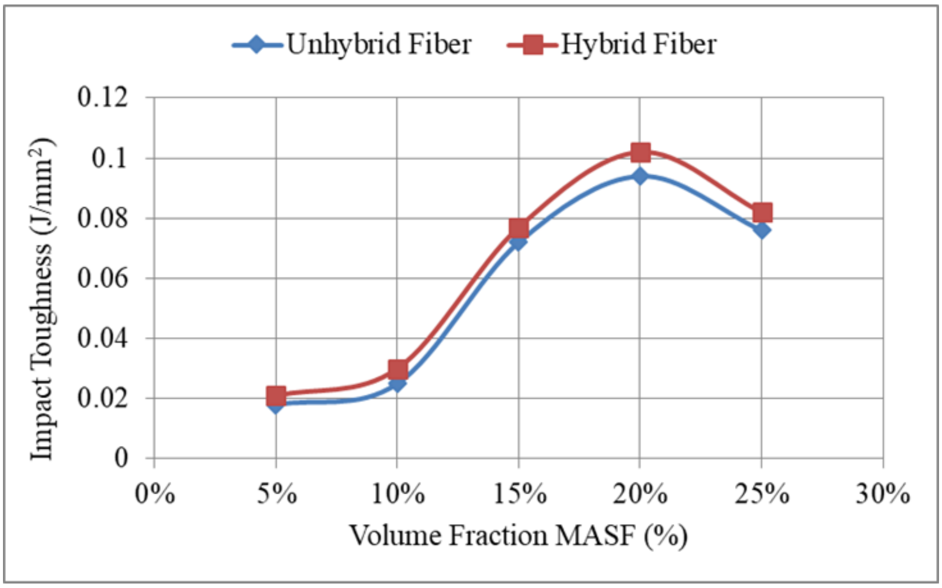

Figure 3 Impact toughness of polyester compocite reniforced fiber hybrid (MASF-HTBF)

Furthermore, in terms of the absorbed impact energy, the characteristics are also the same. The use of MASF-HTBF hybrid fiber also increases the impact energy, as shown in Figure 4. At a volume fraction ratio of 5%:25%, the lowest specimen impact energy is around 3.75 J, and the highest is 15.49 J at a volume fraction ratio of 20 %:10%. If the volume fraction exceeds 20% the impact energy will again decrease.

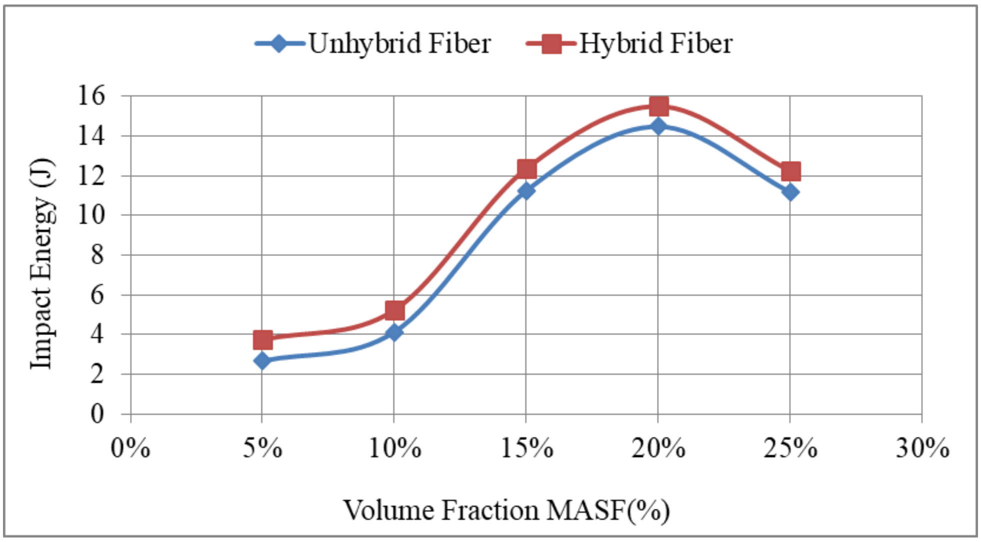

Figure 4 Impact energy of polyester compocite reniforced fiber hybrid (MASF-HTBF)

3.2. Thermogravimetric test results of hybrid fiber reinforced composite

To determine the heat resistance, which causes shrinkage, a thermogravimetric (TGA) test is carried out. Conducted to determine the effect of temperature on the weight loss of composites with volume fractions MASF: HTBF: 5%:25, 10%:20, 15%:15%, 20%:10%, and 25%:5%, with random fiber orientation. The test results are shown in Figure 5.

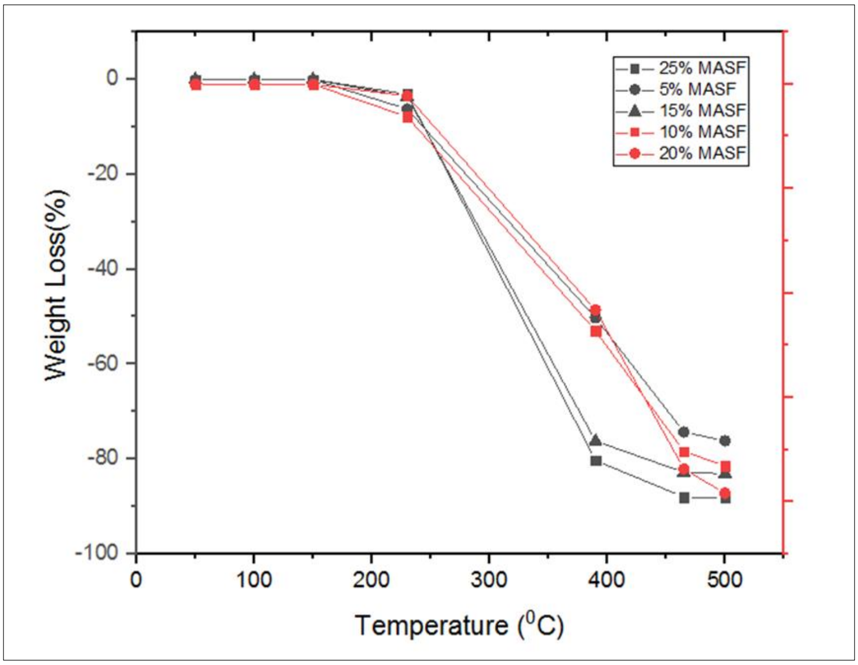

Figure 5 The heat resistance of polyester compocite reniforced fiber hybrid (MASF-HTBF)

From Figure 5. it can be seen that the rate of mass reduction will be higher as the temperature increases, causing the composite to decompose as the heating rate increases. In the graph it can be seen that there are 2 stages of mass decline. The first stage occurred at an initial temperature of 230°C with a mass decrease in each percentage of 3.1%, 3.61%, 2.23%, 6.23 and 6.23%, respectively for the volume fraction 5%, 10%. 15%,20%, 25% MASF. In this first mass reduction stage, the composite is dehydrated due to evaporation of the water contained therein. The mass decrease of the first stage can be observed before the temperature reaches 230 °C which causes the mass to decrease. Evaporation of water causes a weight loss of about 5%, this is in accordance [2].

Then the second decrease in weight loss begins at a temperature of 230 °C - 390 °C, in this second stage the weight loss occurs significantly, which is 80.3%; 76.2%; 43.26%; 50.24%; and 47.24%; respectively. In this temperature range, chemical bonds break thermally which causes the formation of carbon charcoal in the decomposition process of this peak.

Based on Figure 5. it can be seen that after the second stage of weight loss occurred, the third stage of weight loss still occurred in the temperature range of 465 °C-500 °C. Weight loss occurs slowly, caused by the occurrence of thermal oxidation of charcoal which runs slowly in this decomposition process, according to the results of the study [11]. The weight loss at third stage: 73,16%; 76,16%; 78,37%; 82,8%; and 88,15% respectively for rasio fraction volume MASF: HTBF : 5%:25%; 10%:20%; 15%:15%; 20%:10%; and 25%:5%.

3.3. The Microstructure of material polyester composite reinforced hybrid fiber

Microstructural testing using a scanning electron microscope (SEM) was carried out after testing the impact strength to determine the bond structure between hybrid fibers (MASF-HTBF) as reinforcement with polyester as a binder (matrix). The test results are shown in Figure 6. Figure 6a. The polyester composite looks just reinforced MASF. The bond between MASF and polyester occurs well, although there are still voids due to the presence of air or impurities.

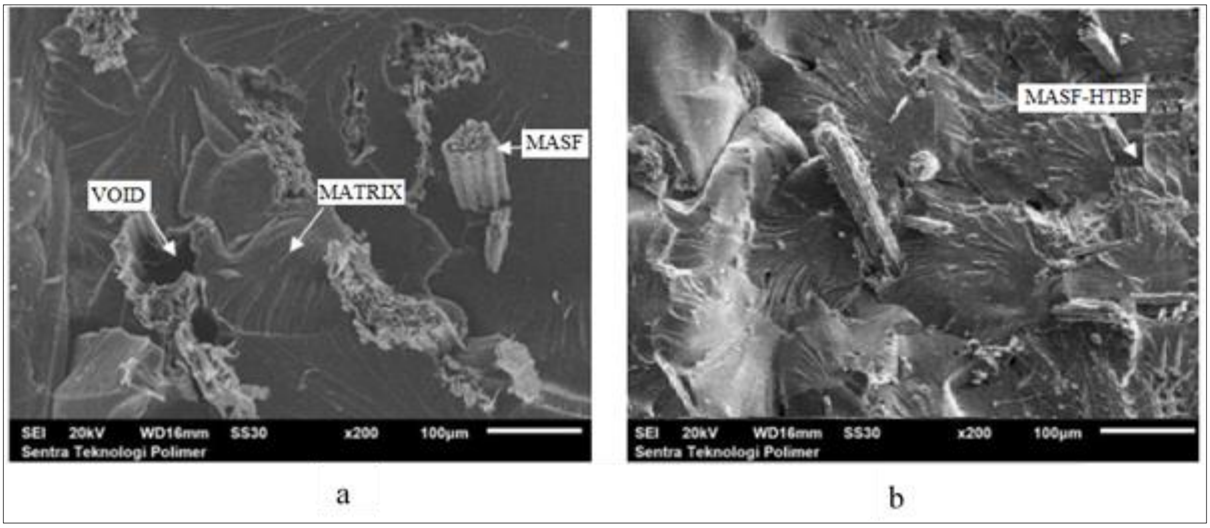

Figure 6 The microstructure of material polyester composite (a).Unhybrid fiber, (b). Hybrid fiber (MASF-HTBF)

The microstructure of the MASF-HTBF hybrid fiber reinforced polyester composite specimen with a ratio of 20%:10% is shown in Figure 6b. The polyester matrix with a volume fraction of 70% adhered well to the MASF-HTBF hybrid fiber. In the fracture after the impact test, only a few hybrid fibers were pulled out, a few pores appeared, indicating that the bond strength between the matrix and the hybrid fibers was getting better. In contrast to Figure 6a. Showed that the strength of the matrix bond was decreasing and it was seen that the fibers were uprooted, as well as many pores, this was because the bond between the fibers and the matrix in the composite material was not so strong. Based on the study [7] showed that polyester and natural fibers have good interfacial adhesion and can provide better mechanical strength to the composite. Research activities on integrating natural fibers into polyester are aimed at minimizing the consumption of synthetic fibers and to increase the strength and impact resistance of composite materials.

4. Conclusion

The impact toughness, impact energy of the MASF-HTBF hybrid fiber reinforced polyester composite with random fiber arrangement is better than the MASF reinforced polyester composite. The best heat resistance (lowest shrinkage) is the use of hybrid fibers with a volume fraction ratio of MASF and HTBF ; 5%:25%. The microstructure shows a strong bond between the fibers hybrid and polyester matrix. Based on the fracture after the impact test, it shows that there are few pull outs and voids. This fact indicates that there is an interfacial bond between the MASF-HTBF hybrid fiber and polyester.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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