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Green composites of natural fiber bamboo/pineapple leaf/coconut husk as hybrid materials

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Abstract. Natural fiber reinforced polymer composite materials have been investigated for mechanical properties using by Universal Testing Machine (UTM) and structures of the fractured surfaces through optical and electron microscopy scanning with materials from natural fiber synthesis are bamboo fiber, pineapple leaf and coconut fiber mixed in polyester resin to be a hybrid composite material to see the best characteristics of tensile test properties. Mixing of natural fibers (filler) with polyester (matrix) has been developed as a renewable material. The results showed that the incorporation of bamboo-pineapple leaf-husk fiber have optimum tensile strength value 366 Mpa with flexural strength 0.302 Mpa. This is due to the presence of bamboo fiber has a high content of cellulose that can to replaced the failure in pineapple leaves and coconut fiber and make the hybrid composites not only as a strong material but biodegradable too.

Keywords. Flexural strength; Hybrid composite; Natural fiber; SEM; Tensile strength.

1. Introduction

In recent years, composites are more environmentally friendly while synthetic fibers can be a source of environmental pollution [1]. Composites are currently considered the most promising materials in the community due to their distinctive mechanical properties, biodegradable and abundant raw material availability. Many researchers have shown increased interest in the development of biodegradable polymer fiber reinforced (BFRP) composites as a substitute for conventional materials, especially in the fields of automotive, marine, packaging, furniture and the building construction industry. The production of natural fibers of composite materials becomes highly appealing and widely applicable, due to global warming problems and reduced petroleum availability. Natural fibers play an important role in developing biodegradable composites to solve ecological and environmental problems [2].

Natural fibers such as bamboo, hemp, sisal, pineapple, abaca and coir have been studied as reinforcement and filler in composite. Bamboo is a plant that can grow quickly, so it is potentially a source of abundant fiber included in the family Bambusae, under the genus Gramineae. Pineapple leaf



fiber (pineapple leaf fiber), which is rich in cellulose, is relatively inexpensive and widely available having the potential to strengthen polymer composites [3]. Coir is a residue of coconut production in many areas, which produces coarse fiber coir. Coir is a natural fiber of ligno-cellulose. It is a fruit fiber obtained from the outer shell, or the skin of a coconut. This fiber is widely used to make various kinds of flooring materials, furniture, yarn, rope and others. Therefore, research and development efforts have been underway to find new uses for coir, including the utilization of coir as a reinforcement in polymer composites [4].

Various utilization of fiber as a hybrid composite in thermoset resin is found in Table 2. Several studies have shown that polymer mechanical properties such as tensile strength and stiffness can be enhanced by combining three different plant fiber types with different mechanical properties, suggesting the potential to switch to 100% plant fiber composites [3]. The combination of two or more plant fibers in a matrix is known as a hybrid green composite. The high mechanical properties of this composite have shown progress on material designs as they overcome the failure of old products. To improve some of the good characteristics of bamboo fiber, pineapple leaves and coconut husk, some treatments such as fiber extracting using hand-lay up and hot compression molding methods are used as polymer boosters in unsaturated polyester resins to be tested for increased tensile strength and bending properties of the fibers using the Universal Testing Machine (UTM) 1 and observed effects on composite microstructures through optics and electron microscopy scanning. From this research hoped that the combination of bamboo, pineapple leaf and coir fiber in isothalic polyester resin composites can increase high tensile strength and good flexibility in the resulting composite material.

2. Experimental

2.1. Material

In this present investigation Bamboo, pineapple leaf and coconut Husk fibers are used for fabricating the composite specimen. The Bamboo, Daun nanas and Cococnut Husk fibers are obtained from North Aceh. Isothalic polyester resin and the catalyst Methyl Ethyl Ketone Peroxide (MEKP) are obtained from sigma aldrich. The accelerator used for the investigation is Cobalt Napthanate and is added as 1% with the resin and the catalyst.

2.1.1. Natural fiber. Based on the origin of natural fibers composed of plant fibers, animals, or minerals. According to several studies, among the most popular natural fibers are plant fibers used as reinforcement in fiber-reinforced composites. Plant fibers such as bamboo, sisal, kenaf, cotton, hemp, coir, pineapple, banana, etc., are ideally widely used as reinforcement for NFRP composites due to the physical and chemical properties of natural fibers that are bio-degradable. Table 1 shows the physical and chemical properties of bamboo fibers, pineapple leaves and coconut husk and table 2 reports of a fiber-proof hybrid thermoset composite [5].

Table 1. The physical and chemical properties of bamboo fiber, pineapple leaves and coconut husk.

Fiber	Bamboo	Pineapple leaf	Coconut husk	References
Cellulosa (wt.%)	48.2-73.8	71.6	32-43	[6, 7]
Lignin (wt.%)	30	5-12.7	0.15-0.25	[6, 7]
Hemicellulosa (wt.%)	21-31	4.58	40-45	[3, 5]
Microfibril angle ($^{\circ}$)	2-10	14	30-49	[6, 7]
Density (gr/cm^3)	1.23	1.3	1.2	[6]
Tensile strenght (Mpa)	500-575	150-1627	170-230	[8]

Table 2. Work reported on mechanical characteristics of thermoset hybrid composites.

Natural/glass hybrid fiber	Matrix polymer	Fabrication technique	References
Coir/glass fiber	Polyester	Close mold	[9]
Oil palm empty fruit bunch/glass fiber	Phenol-formaldehyde (PF)	Hand lay-up	[10]
Banana/glass fiber	Phenol-formaldehyde (PF)	Hand lay-up, compression molding	[11]
Biofiber (pineapple leaf fiber/sisal fiber)/glass fiber	Unsaturated polyester	Hand lay-up	[12]
Palmyra/glass fiber	Rooflite	Mixing and sandwiching	[13]
Jute/glass fabric	Isothalic polyester	Hand lay-up	[14]
Glass/natural fiber	Epoxy vinyl ester	Hand lay-up	[15]
Kenaf/glass fiber	Epoxy	Modified sheet molding compound (SMC)	[16]
Sisal/jute/GFRP	Epoxy	Hand lay-up	[17]
Curaua/glass fiber	Orthophthalic polyester	Compression molding	[18]
Sisal/jute/GFRP	Isothalic polyester	Hand lay-up	[17]
Sugar palm/glass fiber	Unsaturated polyester	Hand lay-up	[19]
Flax/glass fiber	Phenolic resin	Compression molding	[20]
Banana/Hemp/glass fiber	Epoxy	Mold lay-up	[21]

2.1.2. *Bamboo fiber.* The bamboo fiber was extracted by cutting into small pieces by crusher machine to obtain bamboo powder. Wash bamboo powder using water then immersed in sodium hydroxide (NaOH) at a concentration of 6% of water volume for 3 hours at room temperature. Then fiber washed twice with water. Fiber was dried at room temperature for 8 hours and then was re-branded at 50 °C for 2 days. Fibers are saving in plastic bag to avoid contamination of atmospheric moisture before composite formation.

2.1.3. *Pineapple leaf.* The first stage, Pineapple Leaf was feeding into the decortication machine to obtain fiber and then fiber were cut into a small pieces. Fiber then soaked in 5% NaOH solution for 1 hour at room temperature. The last fiber was rinsed several times, then dried at room temperature for 48 hours [2].

2.1.4. *Coconut husk.* Coconut fiber is washed with water and dried. Then the coir fiber is cut into short. The powdered fiber is soaked in 5% NaOH solution for 2 hours. The fiber is then thoroughly washed with water to remove the excess NaOH attached to the fiber. Coir fiber was dried at room temperature for 3 hours for composite formation [4].

2.2. Preparation of composite specimen

Material composite hybrid polyester was fabricated by hand lay up methode and hot compression molding. the mixture of raw material bamboo, pineapple leaf and coconut husk as filler in Isothalic polyester resin according with volume frakction and and 1 % catalyst Methyl Ethyl Ketone Peroxide (MEKP) from total weight of matrix. the rule of mixture such as pineapple leaf-coconut husk and bamboo-pineapple leaf fiber, each fiber type consisted of 30 wt.% of the composite, while for 3-fiber types each fiber type consisted of 20 wt.% of the composite and then feeding into a hot compression with a temperature of 850°C [22] with the modification of the pressing for 15 minutes. Specimens

have been removed from the mold were cutting according with ASTM D638 for tensile and D790 flexural strength standard method.

2.3. Mechanical testing

2.3.1. Tensile and flexural test. Figure 1 (a) and (c) testing of tensile properties for hybrid composite materials refer to the ASTM D 638 standard. Tensile strength is measured using a universal testing machine (UTM) EXCEED Model. E43. Dimensions, gauge length and cross-head speed are selected according to standard ASTM D-638. Figure 1 (b) and (d) Tests of bending strength using three point bending with specimen samples referring to ASTM D 790 standard. The specimen test sample is repeated several time and the average results taken to be discussed as the characteristic properties of the composite.

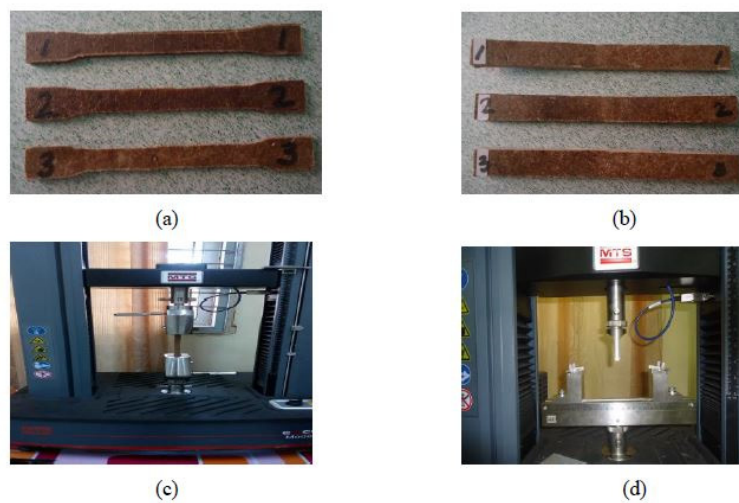


Figure 1. (a) Sample specimen ASTM D-638, (b) Sample specimen ASTM D-790, (c) UTM EXCEED model E-43 for tensile test, (d) three point flexure test.

2.3.2. Analysis scanning electron microscopy. To analyze the effect of treatment on fiber surface structure was done by SEM microscope. The fiber surface structure was observed using a JEOL-T20 microscope. Electron scanning analysis is carried out at a voltage of 5-20 KV [17].

Tensile testing of natural fiber reinforced polyester composite materials was analyzed using Universal Testing Machine (UTM) Model E43 with sample specimens used ASTM D-638 shown in figure 1. The result of tensile strength and flexural composite test of hybrid polyester composite is shown in table 3.

Table 3. Mechanical properties of different composite samples.

Sample	Tensile strength (MPa)	Flexural load (kN)
Pineapple leaf + coconut husk	183	0,21
Bamboo + Pineapple leaf	246	0,24
Bamboo + Pineapple leaf + coconut husk	366	0,302

3. Results and discussion

3.1. Tensile properties

The tensile strength test of the hybrid polyester composite material increased significantly against the mixture of each reinforcing material in the polyester resin shown in figure 2. The results showed that bamboo-pineapple leaf-coconut husk fiber mixture has higher tensile strength compared to bamboo-pineapple leaves and Pineapple leaves-coconut husk is due to the good mechanical properties of bamboo fibers associated with natural fiber compositions as shown in table 1. Thus, making polyester composite hybrids of pineapple-coconut bamboo-coconut leaves capable of producing a value of 366 MPa. The polyester hybrid composite has a higher tensile strength than the research conducted [17], 229.54 Mpa and [21] which reported the results of its investigation of the Banana-Hemp-Glass fiber-hybrid composite obtained the highest tensile strength of 39.5 MPa.

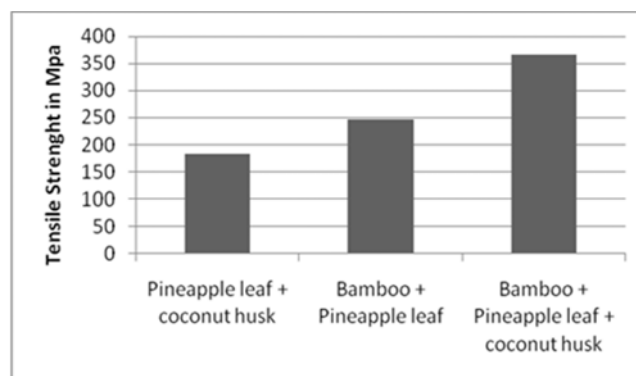


Figure 2. Tensile load comparison of different composite materials.

This research has result a good tensile properties material of polyester hybrid composite. The tensile strength increase with removal of hemicellulose, wax, lignin and other impurities resulting in a rough topographic surface of bamboo fiber and offers better interface adhesion properties to fiber / matrix and good stress transfer as shown in figure 3. Alkaline treatment also lead to increased surface area of fibril fibers to be effective when moistened with resin. From these results it is concluded that the hybrid composite plays a role in forming a composite material which has a better value and tensile strength characteristics and this is proved by the results of scanning electron microscopy analysis contained in figure 4. which shows bamboo mixture of pineapple leaf –coconut husk has a good surface structure [23].

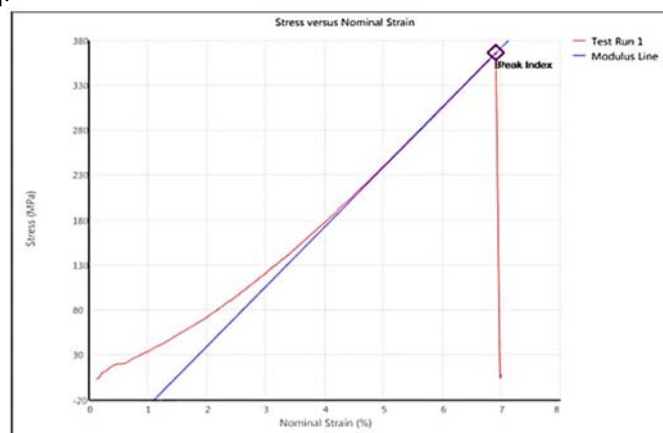


Figure 3. Sample graph generated from the machine for stress versus strain for tensile test of bamboo-pineapple leaf-coconut husk composite.

3.2. Tensile properties

The bending strength properties of hybrid polyester composites which have been tested and obtained by the average results are shown in table 3. Load vs crosshead generated by the machine during hybrid polyester composite testing are found in figure 5. Comparison of the different flexural strengths of hybrid polyester composite can be seen in the figure 4. From the picture it is stated that bamboo- pineapple leaf-coconut husk composite is better than composite bamboo-pineapple leaves and pineapple leaf-coconut husk fiber composite. The results show that polyester composite polyester fiber-bamboo fiber-coated fibrous fibers improve the mechanical properties of composites [24].

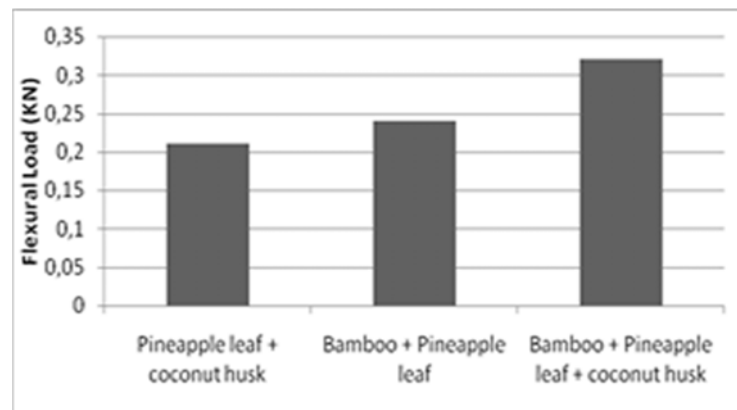


Figure 4. Flexural load comparison of different composite materials.

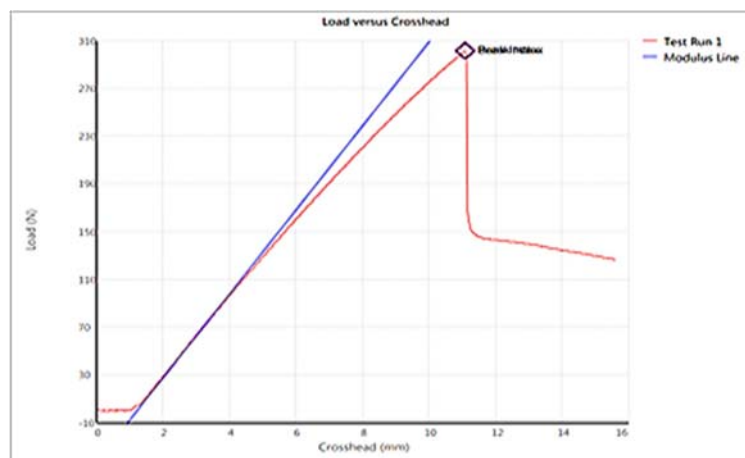


Figure 5. Sample graph generated from the machine for load vs crosshead for tensile test of of bamboo-pineapple leaf-coconut husk composite.

3.3. Scanning electron microscopy

The morphology of the hybrid composite shown in figure 6 (a), (b) and (c) observed at 100x and 500x and 1000x magnifications indicates increased adhesion of fibers and matrices distributed evenly throughout the composite section so as to show the optimal interface attachment between the fibers and matrix. Interlocking is one of the bonding mechanisms that occur between fiber and fiber-reinforced polymer matrix. The interlocking properties shown by bamboo-pineapple-coconut husk involve diffusion of the polymer matrix into the surface of porous fibers. The polymer matrix will flow into the surface of the porous fiber and the polymer is embedded and solidified to form a strong bond between the fiber and the matrix as show the optimum value as has been reported in the previous flexural test results [25].

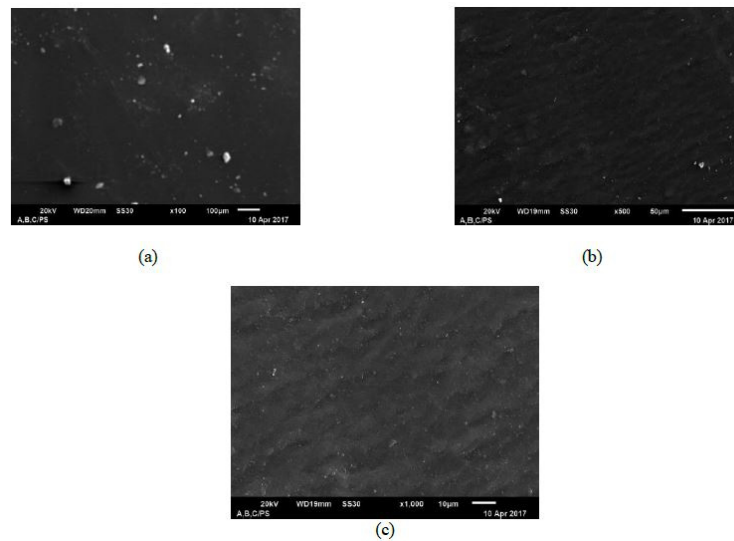


Figure 6. (a) bamboo-pineapple leaf –coconut husk 100x, (b) bamboo-pineapple leaf –coconut husk 500x dan (c) bamboo-pineapple leaf –coconut husk 1000x.

4. Conclusion

Pineapple leaves / coconut husk, bamboo / pineapple leaves and bamboo / pineapple leaves / coconut husk which has been fabricated into hybrid composites performed several tests such as tensile, flexural and SEM analysis. Based on the results obtained it can be concluded:

- The results noticed that the bamboo-pineapple-coconut husk fiber composite material has a maximum tensile strength 366 MPa.
- The bamboo-pineapple-coconut husk mixture is capable of producing a bending strength of 0.302 kN.
- The composite morphology structure shows a flat surface and interlocking the filler interface with a matrix thus affecting the mechanical properties of the composite.
- Cellulose content in fiber plays an important role to the characteristics of composite tensile and compound properties.

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