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Development of a Hybrid Coconut Fibre and Multi Reinforcement Epoxy Composite for High Impact Strength

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Abstract. The use of natural fibers as reinforcement in polymer composite materials provides several advantages due to its low density, biodegradable, easily recycled, low price and able to be renewed. To improve the mechanical properties of composites reinforced natural fibres, it needs to substitute with a type of synthetic reinforcement. The purpose of this study was to obtain the impact characteristics of epoxy composite hybrids through multi reinforcement. The hybrid composites fabricated by three variations, namely variation I (Coconut fibre + Eglass + Fabric + Rubber), variation II (Coconut fibre + Eglass -Fabric), and variation III (Coconut fiber + Eglass + Rubber). Short coconut fibre is produced by fibrillation process. Hand layup process was used to prepare the specimens. In each variation, the first layer consists of coir+ Epoxy + Alumina. Impact test is performed to determine the mechanical properties. The results showed that the variation 1 had the highest impact strength of 58.02 kJ/m^2 while the lowest impact strength in the variation II, which is 41.13 kJ/m^2. The fracture occurred in the form of brittle fracture.

1. Introduction

Growing environmental awareness has resulted in a renewed interest in the use of natural material for many applications. This paradigm has forced to search for new materials to make the conventional composite materials be an environmentally friendly material. Polymeric composites reinforced with natural fibres have been developed in recent years. It shows significant potential for various engineering applications due to their intrinsic sustainability, low cost, low weight and mechanical strength. The interfacial adhesion between natural fibres and polymeric matrices is critical to the composite performance [1-3].

Coconut fiber is as a suitable candidate to reinforce polymeric matrix in a composite. It is easily and widely available like Indonesia and Malaysia. Coconut fiber as a reinforcing element greatly determines the mechanical properties of the composite because it will be able to continue the load distributed by the matrix. Coconut fiber, which is combined with a polymer as a matrix, will produce alternative composites that are very beneficial to the industrial application. It is expected to produce maximum composite mechanical properties to support the application of alternative composites.

Several studies on the mechanical properties of coconut fiber have been carried out. Asasutjarit, et al [4] investigated the mechanical properties of coir based green composites were prepared using coir fiber treated with varying pre-treatment condition. The changes in the proportion of chemical composition and morphological properties of coir fibres with different coir pre-treatment condition were discussed. It is observed that the mechanical properties of coir-based green composites; modulus of rupture and internal bond, increase as a result of chemical composition modification and surface modification. Scanning electron microscopy (SEM) investigations show that surface modifications improve the fiber/matrix adhesion. B.Bakri [5] investigated the mechanical properties of coir rope-glass fibers reinforced polymer hybrid composites. These results mechanical properties of impact energy and impact strength of coir rope and glass fiber as reinforcement in polymer hybrid composite is 15C15G is higher than 10C20G and 20C10G that is 12.8 J and 177.1 kJ/m² respectively. The possibility of surface chemical modification of Coir fibers has been extensively used in a wide variety of application, e.g., packaging, furniture etc. [1]. Sakthivel, et al. [6] studied the mechanical properties of epoxy composites with natural fiber reinforcement (banana, coir, sisal). His research produced the impact energy for each fiber, namely coir 4 joule, banana 5, sisal 4 joule. Karthikeyan et al [7] compared the impact property of sodium lauryl sulphate (SLS) and NaOH treated coir fiber reinforced epoxy composites. The result shows SLS treated coir fiber reinforced composite shows more impact energy than NaOH treated coir fiber reinforced composite. According to Akash et al [8] hemp fiber/epoxy resin composite exhibits more tensile strength than coir fiber/ epoxy resin composite and coir fiber/epoxy resin composite exhibits more bending strength than hemp fiber/epoxy resin composite.

The strength of natural fiber composites is highly depends on mechanical bonding between fibers and matrices. Alex.S, et al, [9] stated that the strength of hybrid composites depends on the properties of fiber, the aspect ratio of fiber in composites, orientation of fiber, intermingling of fiber and fiber matrix interfaces. The interface bonding increased by adding the coupling agents and chemical treatments. The NaOH is often used because it is relatively easy to do and more economical.

Narendra et al[10] suggested the presence of nylon fabric and chemically treated pith can contribute to longer durability of the panels in moisture condition. Zhi Wang et al. [11] studied the effects of integrating micro-Al_2O_3 onto carbon fiber surface and its contents on mechanical properties of carbon fiber reinforced polymer composites were investigated. Mode II interlaminar fracture toughness, impact strength, flexural properties and initial modulus were determined by mechanical test machines and dynamic mechanical analyzer. The reason for performance improvement was discussed based on scanning electron microscopy. The mode II interlaminar fracture toughness, impact strength, and flexural strength of composites without the addition of micro-Al_2O_3 were 348 J/m^2, 118 kJ/m^2 and 682 MPa, respectively. However, the mechanical properties of modified composites were improved significantly. The mechanical properties were optimum when the areal density of micro-Al_2O_3 particles reached 15 g/m^2 at which the mode II interlaminar fracture toughness, impact strength, and flexural strength reached 522 J/m^2, 161.7 kJ/m^2 and 759 MPa, respectively. Leandro José da Silva et al. [12] studied a full factorial design was used to investigate a hybrid composite reinforced with natural fibre and silica microparticles. The microsilica addition did not affect significantly the flexural strength; while the interaction between fraction of fibres, silica particles and maleic anhydride addition played a major role not only on the flexural strength, but also on the flexural modulus. The volume fraction of sisal fibres exhibited significant effects on the bulk density, apparent density, apparent porosity and water absorption of the composites. Isik et al. [13] verified that the nanoclay addition of 1 wt.% provided higher impact resistance and tensile strength. However, the modulus of elasticity was gradually increased with the nanoclay addition. Satender et al [14] has examined the use of coir as an epoxy composite reinforcement. Composites were prepared with a different weight ratio of coir fibers with epoxy resin. To find the effect of coir fibers on the mechanical properties of composite, tensile test, impact test and hardness test were conducted on the prepared specimens. Experimental result shows that the addition of coir fibers increase the strength of composite; the composite with 7.5% fiber content shows the maximum tensile and impact strength. Seenivas et al [15] in the present work, mechanical properties (tensile, flexural, compression and hardness) are tested for sisal/coir; sisal/hemp and sisal/flax fibers reinforced epoxy hybrid composites according to ASTM standard. Sisal/hemp fibers reinforced hybrid composite exhibits more tensile and flexural strength than sisal/coir and sisal/flax fiber reinforced hybrid composites. I Mawardi [16] This study aims to develop fiber-reinforced epoxy resin composites. This study presents the effect of fiber fibrillation on the impact and flextural strength of the epoxy hybrid composite reinforced by coir fiber. Coir is soaked in 5% NaOH solution for 5 hours. Then fiber is processed using a blender of 2000 rpm density fibrillation. The length of time the fibrillation varied for 10, 20 and 30 minutes. Volume fraction of 30% fiber and matrix 70% composited. The composite uses a matrix of epoxy by hand layup method. The implemented tests are impact and flexural tests. The test results showed fiber fibrillation treatment improve the composite mechanical properties. The highest impact and flexural strength, 24.45 kJ/m and 87.91 MPa produced by fiber fibrillation for 10 minutes.

The mechanical properties of the hybrid composite are strongly influenced by its constituent materials, fibers and matrices. The variations of reinforcing types need to examine for obtaining the optimal mechanical properties. This study aims to obtain the mechanical characteristics of impact strength of epoxy composite hybrids through multi reinforcement.

2. Experimental

2.1. Materials

Reinforcement materials consist of coconut fibers, which were collected from local resources in Aceh, E-glass fibers, rubber and fabrics (Figure 1). Alumina (Al_2O_3) with 99% purity is applied as a filler. As a matrix, the epoxy resin is used.The Eposchon type A for epoxy resin (bispenola epichlorohydrin) and type B for epoxy hardener (polyaminoamide) with a ratio of 1: 1 were used. The epoxy resin is supplied by PT. Justus Kimia Raya-Indonesia.

Coconut fiber E-glass Rubber Fabrics Epoxy resin

Figure 1. Reinforcement materials and matrix

2.2. Microfibrillation of coconut fiber

Coconut coir fiber is sorted for uniformity in diameter and cut for 10-20 mm. Pre-treatment is done by boiling fiber in a 5% NaOH solution at a temperature of 80 ° C for 10 minutes. The fiber that has been decreed is then carried out by the fibrillation process. The process of fiber fibrillation is carried out by semi-mechanically, using a high-speed blender. Coconut fiber is blended at 20000 rpm for 10 minutes. This process aims to reduce fiber diameter. Fibrillated fibers are then washed with distilled water and dried for 3 days before composite molding. This process has been conducted by I Mawardi et al [16] who performed fibrillation for coconut fiber using a high-speed blender. The results show fiber fibrillation treatment can improve the composite mechanical properties. The highest impact and flexural strength, 24.45 kJ/m and 87.91 MPa were obtained by fiber fibrillation of 10 minutes.

2.3. Hybrid composite fabrication

A hybrid composite was prepared by molds made of steel. The various composite materials were fabricated by hand lay technique at room temperature. Epoxy resin, alumina and hardener were mixed in a bowl to prepare the matrix materials. A well-mixed mixture of matrix and coconut was poured into the mold. The first layer composition (Coconut fiber + Alumina) based on the volume fraction of coir and matrix are 30:70, with the percentage of alumina as much as 5% of the weight of epoxy. Hybrids composite reinforced by coconut fiber, ceramic, Eglass fiber, synthetic fabrics, and rubber were varied by the reinforcement arrangement (Figure 2), namely; 1. Coconut fiber + E-glass + Fabric + Rubber; 2. Coconut fiber + E-glass + Fabric; 3. Coconut fiber + E-glass + Rubber.

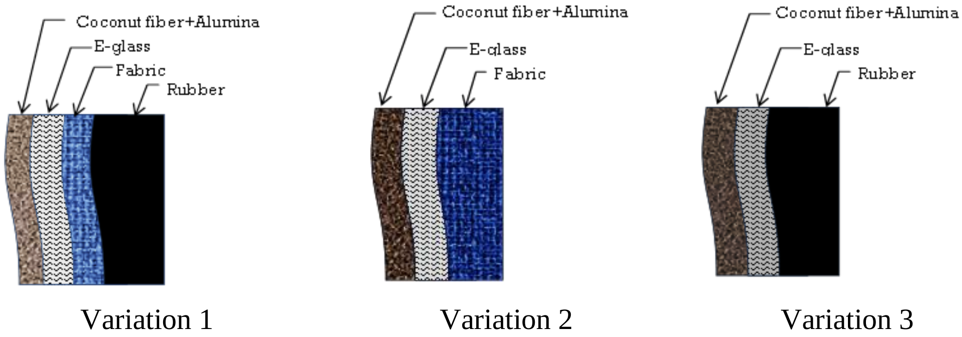


Figure 2. Hybrid composites variation based on the reinforcement arrangement

2.4. Testing of the composites

Fabricated hybrids composite is formed into impact test specimens. The impact test was carried out according to ASTM D 6110-02 standard (Figure 3) The fractured surface morphology of composite specimens was examined using digital microscopy.

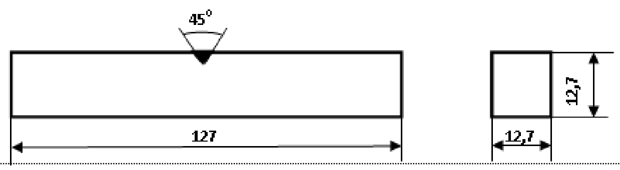
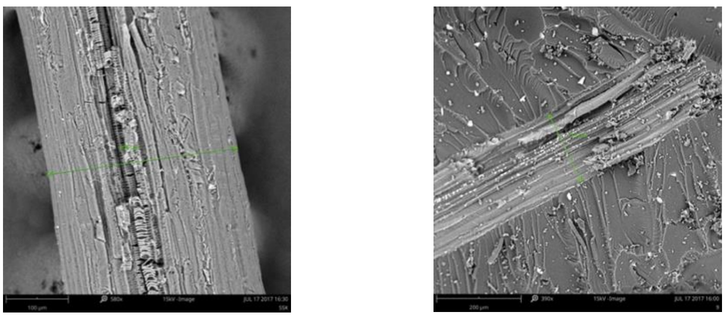


Figure 3. Standard specimens for impact test

3. Results and Discussion

The treatment of fiber with NaOH and followed by a fibrillation process using a high-speed blender can change the dimensions or morphology of the coconut fiber. After the fibrillation process, the fiber diameter is reduced to 40%. It will improve the matrix-fiber interface. This phenomenon will increase the properties of the composite. The results of fibrillation treatment in modifying the surface of the coconut fiber observed by Scanning Electron Microscopy (SEM) as shown in Figure 4.



Coconut fiber before fibrilation Coconut fiber after fibrilation

Figure 4. Coir before and after fibrilation

Hybrid composite reinforced by coconut fiber and other multi-reinforcement (E-glass, rubber and fabric) has been formed into impact test specimens (Figure 5).

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Figure 5. Hybrid composite impact test specimen

Hybrid composites with various multi reinforcement have been performed by impact test. The results of various reinforcement arrangement to impact strength can be tabulated in Table 1.

Table 1. Mechanical properties of hybrid composites

Hybrid composite reinforcement	Variation	Impact energy (joule)	Impact strength (kJ/m^2)
Coconut fiber + E-glass + fabric +rubber	V-1	18.8	58.02
Coconut fiber+ E-glass + fabric	V-2	13.3	41.13
Coconut fiber+E-glass + rubber	V-3	16.4	50.62

Impact energy and impact strength produced by hybrid composites with multi reinforcement are shown in Figures 6 and 7. Figure 6 shows a hybrid composite with a variation of reinforcement 1 (V-1) produces the highest impact energy absorption compared to two other variations, which is equal to 18.8 joules. Where the lowest impact absorption value is produced in variation 2 (V-2), which is 13.3 joules. Combining fabric and rubber reinforcement in hybrids composite can increase the impact energy up to 41%.

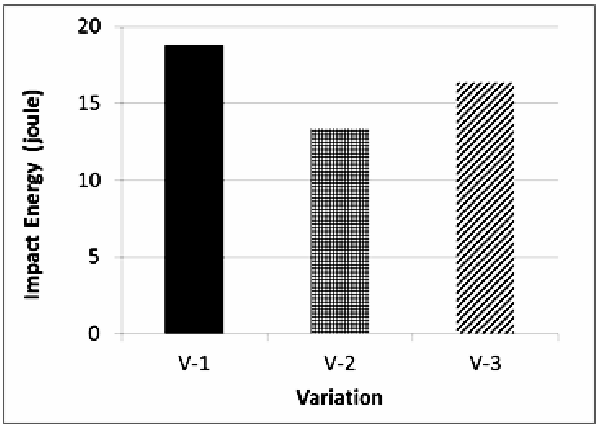

Figure 6. Hybrid composite impact energy with multi reinforcement variations

The highest impact strength of hybrids composite occurs in variations 1 (V-1), which is equal to 58.02 kJ / m^2. The decrease in impact strength occurs in variations 3 (V-3) and variation 2 (V-2). The decrease in impact strength at the lowest value occurs in variation 2 (V-2), which is 41.13 kJ / m^2 (Figure 7). The results show that the type and the arrangement of the reinforcement influence the impact strength. The use of rubber as a reinforcement greatly effects on the impact strength.

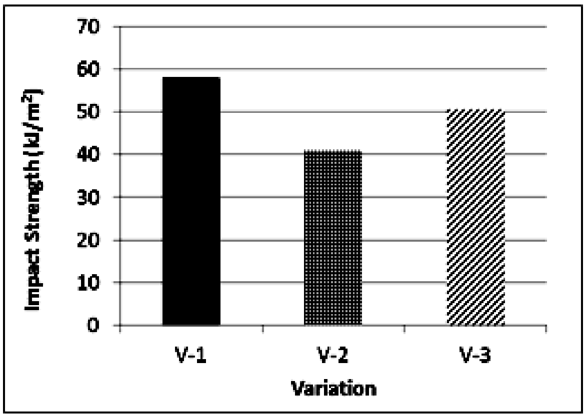

Figure 7. Impact strength of hybrids composite with multi reinforcement variations

The impact strength of a coir fiber reinforced epoxy composites is a measure of the ability of the composites to resist the fracture failure at high velocity under sudden applied force. Impact energy also defined the toughness of the composites. In this case, the increase in the value of impact strength is inseparable from the multi-reinforcing factor and the reduced diameter of the fiber after experiencing the fibrillation process. By comparing from the previous studies conducted by Indra [16], where hybrid composites reinforced with coconut fiber that had been fibrillated (boiling 10 minutes and 10 minutes blender) without the addition of rubber and fabric resulted in the impact strength of 24.45 kJ / m^2. The fabric and rubber reinforcement can increase the impact strength up to 137 %. From the hybrid composite fracture cross section, it is showing that a brittle fracture occurred. On the fracture surface, it is found that there is no visible hole from the fiber (pull outs bonding), no fiber or reinforcement uprooted. This phenomenon shows that the epoxy matrix can strengthen the reinforcement (Figures 8).

Figure 8. Fracture surface section from impact testing

4. Conclusion

Successful fabrication of coir fibers reinforced hybrid composites multi reinforcement can be achieved by hand layup method. The highest impact strength is produced by hybrids composite with variation 1, (Coconut fiber + E-glass + Fabric + Rubber), which is equal to 58.02 kJ / m^2. The use of rubber as reinforcement can increase impact strength of hybrids composite. The form of fracture that occurs on hybrids composite is a brittle fracture. The fabric and rubber reinforcement can increase the impact strength up to 137 %.

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