Effect of fiber fibrillation on impact and flexural strength of coir fiber reinforced epoxy hybrid composites

I Mawardi¹,², Jufriadi¹ and Hanif ¹
¹Department of Mechanical Engineering, Politeknik Negeri Lhokseumawe, Lhokseumawe, 24301, Indonesia
E-mail: ddx_72@yahoo.com

Abstract. This study aims to develop fiber-reinforced epoxy resin composites. This study presents the effect of fiber fibrillation on the impact and flexural 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% composites. The composite uses a matrix of epoxy by hand lay up method. The implemented tests are impact and flexural tests. The test results show fiber fibrillation treatment can improve the composite mechanical properties. The highest impact and flexural strength, 24.45 kJ/m² and 87.91 MPa were produced with fiber fibrillation for 10 minutes.

1. Introduction
Composites with synthetic fiber reinforcement materials have been used in various aspects of life, starting with household needs, land, air and sea vehicle industries, sports equipment, health and bulletproof vests. However, the use of synthetic fibers as a composite amplifier has a negative impact on the environment since its waste is unable to decompose naturally but able to interfere with up to several generations. The development of composite technology is now begin to experience a shift from composite materials to synthetic fibers to composite materials of natural fibers. This technological trend shift is based on the nature of the composite fiber-making nature that is more environmentally friendly, because natural fibers are able to decompose naturally and renewable. Although not completely shifting synthetic fibers, the utilization of environmentally friendly natural fibers is a wise move to save the environment. Natural fiber-loaded composites also have a high density strength ratio so that the resulting components are lighter. Many varieties of natural fibers are available such as coconut fiber, hemp fiber, pineapple fiber-nanasan, fibers, and banana fiber.

Coir fiber is one of the natural fiber materials that can be forgiven in the manufacture of composites. This coconut fiber is being used because it is easy to obtain and widely available. Coir fiber as a reinforcing element greatly determines the mechanical properties of the composites as it forwards the loads which is distributed by the matrix. Coir fiber which is combined with polymers as a matrix, will produce alternative composites that are useful for the industrial world. The initial treatment of coco fiber is expected to produce maximum composite mechanical properties to support the utilization of alternative composites.

² To whom any correspondence should be addressed.
Some research on the mechanical properties of coconut fiber has been done. Udaykumar, et al [1] in their research work stated that short coir fibers reinforced polymer composite have been developed by hand layup techniques with varying fiber percentages (5%, 10%, 15%, 20%, 25% by weight), natural fiber (coir) reinforced polymer matrix (vinyl ester). The developed coir fiber reinforced composites were then tested for their flexural properties. The result shows that a flexural property increases with increases in fiber percentage; however after a certain fiber weight percentage the properties are decreased. From the data of tested results conclude that 20% of coir reinforcement at 4mm thickness of polymer composite exhibited higher percentage of elongation. The coir fiber in the present study could be used as an effective reinforcement for making composites, which have an added advantage of being light.

Sarocha Charoenvai, et al [2] 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. Bakri [3] has investigated that the mechanical properties of coir rope-glass fibers reinforced polymer hybrid composites. These results mechanical properties of impact energy and strength of coir rope and glass fiber as reinforcement in polymer hybrid composite is 15C15G, it is higher than 10C20G and 20C10G also 2.8 J and 177.1 kJ/m², respectively. The possibility of surface chemical modification of Coir fibers have been extensively used in a wide variety of application, e.g., packaging, furnitures etc. [4]. Sakthivel, et al [5] have conducted a research of the mechanical properties of epoxy composites with natural fiber reinforcement (banana, coir, sisal). His research yielded impact energy for each fiber ie, coir 4 joule,banana 5, sisal 4 joule. Karthikeyan et al [6] compared the impact property of sodium lauryl sulphate (SLS) and NaOH treated coir fiber reinforced epoxy composites. Result shows, SLS treated coir fiber reinforced composite shows more impact energy than NaOH treated coir fiber reinforced composite. Haishal et al [7] have analysed the mechanical properties of randomly oriented coir fiber/epoxy resin composite. The result shows tensile strength of 31.08 MPa, impact strength of 11.49 kJ/m² and suggested for low load applications. 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 fiber and matrix. It is supported by Alex.S, et al, [9] which have stated in their works of the strength of hybrid composites depends on the properties of fiber, aspect ratio of fiber in composites, orientation of fiber, intermingling of fiber and fiber matrix interface. The bond interface is improving by the addition of coupling agents and chemical treatments. Chemical treatment is relatively easy to do and more economical. Commonly the chemical element is using NaOH. Narendra et al [10] suggested that the presence of nylon fabric and chemically treated pith could contribute to longer durability of the panels in moisture condition. 18% NaOH treated sisal fiber reinforced composite shows higher tensile and flexural strength than 5%, and 10% NaOH treated sisal fiber reinforced composites [11]. The tensile strength, tensile modulus and creep resistance of composite increases with increasing of the sisal fiber content in composite up to a certain limit [12].

In addition, the use of fiber as an amplifier in natural composites is very high by diameter and fiber length. The smaller the fiber diameter will be the more matrix bonds with the fibers so as to improve the composite properties and the properties of the composite structure. Reducing the fiber size is not sufficient by chemical treatment (soaking the fibers in NaOH solution) however; it is required further treatment such as fibrillation process or reducing fiber size. One study to minimize fiber diameter has been done by Gery P [13] examining the manufacture of flax fiber nanofiber. First, the fibers were processed pre-treatment chemically with 5% NaOH solution at 105 °C for 60 minutes followed by mechanical fibrillation process with blender at 13,000 rpm for 20 minutes. From the above process it
is able to change the diameter of the hemp fiber from > 10um to 100-300 nm in size. This study aims to examine the effect of coir fiber fibrillation on the impact and flexural strength of epoxy hybrid composites reinforced by coir fiber.

2. Experimental

2.1. Materials
The coir fibers were collected from local resources, Bireun, Aceh, Indonesia (Figure 1). The epoxy resin is used Eposchon type A for epoxy resin se (bispenola epichlorohydrin) and type B for epoxy hardener (polyaminoamide) with a ratio of 1:1. PT. Justus Kimia Raya has supplied the epoxy resin.

![Figure 1. Coir](image1)

2.2. Fiber pre-treatment
The Coir fiber is first sorted in uniformity of diameter and length. Fibers cleaned and dried ± 2 days. The fibers are cut with a length of 30-50 mm. Coir fiber is soaked in 5% NaOH solution for 5 hours [14] (Figure 2). The function of this treatment is to reduce soluble cellulose, hemi cellulose, pectin, lignin, etc., from fiber.

![Figure 2. Soaking fiber in 5% NaOH solution](image2)

2.3. Fiber fibrillation
Fiber that has been pre-treatment is further process of fibrillation. Fiber fibrillation process is done semi-mechanically; it is by blending fibers at 2000 rpm for 10, 20 and 30 minutes (Figure 3). This process aims to reduce fiber diameter. The fibrillated fibers are then washed with distilled water and dried for 3 days prior to composite fabricating.
2.4. Composite preparation
The formation or printing of composite hybrid panels is carried out using a mould made of steel. Various composite materials were fabricated by hand lay up technique at room temperature (Figure 4). Epoxy resin and hardener were mixed in a bowl to prepare the matrix materials. Coir fibers were mixed and added into matrix. Hybrid composite was fabricated with 30% volume fraction of fiber and 70% volume fraction of matrix. A well-mixed matrix and fibers is poured into the mould. Steps involved in fabrication of hybrid composites are shown in Figure 4.

2.5. Testing of the composites
The fabricated composite is formed into a specimen for mechanical testing; they are impact and flexural test. The flexural test (three-point bend) was carried out according to ASTM D790 standard and impact test with Charpy method used ASTM D6110 standard. The fractured surface morphology of the composite specimens was examined using digital microscope. Each variation was made 5 specimens. Figure 5 shows samples of impact and flexural test specimens that have been formed.
3. Results and Discussion

Composites with a ratio of volume fraction of 30% fiber and 70% epoxy matrix with various variations of fiber treatment have been tested impact and bending. From the results of hybrid composite test of epoxy reinforced coconut fiber for various variations of fiber treatment to impact and flexural strength can be tabulated in Table 1.

### Table 1. Mechanical properties of epoxy and coir composites

| Type of composites                  | Fibrillation (minute) | Impact strength (kJ/m²) | Flexural strength (Mpa) |
|-------------------------------------|-----------------------|-------------------------|-------------------------|
| Fibrillation Untreated Coir Fiber (FUCF) | 0                     | 9.63                    | 42.81                   |
| Fibrillation Treated Coir Fiber (FTCF) | 10                    | 24.45                   | 87.91                   |
|                                     | 20                    | 18.96                   | 72.42                   |
|                                     | 30                    | 17.46                   | 51.37                   |

#### 3.1. Impact strength

Figure 6 shows coir fiber reinforced composite without fibrillation treatment (FUCF) having a significantly lower impact strength compared with fiber treatment with fibrillation (FTCF), reaching 100%. In the composites with fiber fibrillation treatment there is a decrease in the value of impact energy and impact strength as the fibrillation time increases. The highest value of impact energy measured is 14.06 joule, which is induced by the 10 minutes of fiber fibrillation. Meanwhile, the lowest value of impact energy measured is 10.04 joule that is induced by the 30 minute of fiber fibrillation.

![Impact energy](image1)

![Impact strength](image2)

**Figure 6.** The effect of fiber fibrillation on impact energy and strength of composites

The mean impact strength of FTCF composites is increased by 110% against FUCF composites. The highest increase of 153.75% occurred in FTCF composites around 10 minutes of fibrillation, followed by fibrillation of 20 and 30 minutes (96.75% and 81.23%). The highest impact strength was
obtained on the composite with FTCF for 10 minutes, i.e. 24.45 kJ/m². Decrease in impact strength occurs in FTCF for 20 and 30 minutes. Decline in composite impact strength value with FTCF for 30 minutes as 8% against FTCF for 20 minutes. From the impact strength result, there is a significant effect of fiber treatment with fibrillation using a blender on the impact strength of the epoxy composite hybrid.

Impact strength of a coir fiber reinforced epoxy composites is a measure of the ability of the composites to resist fracture failure at high velocity under a sudden applied force. Impact energy also defined the toughness of the composites. In this case, the increase in impact strength value is unable to be separated from the reduced factor fiber diameter after experiencing the process of fibrillation using blender. The contribution is longer will damage the fiber structure thereby decreasing the value of the impact strength of coir fiber reinforced polymer hybrid composites.

Treatment of fiber with NaOH and followed by fibrillation process using blender. After fibrillation due to the reduced diameter of the fibre, the aspect ratio of the fiber increases and yields rough surface topography, which in turn offers a better fibre-matrix interface. This also results when obtaining the enhanced properties. The effect of fibrillation in modifying surface of fibre can be observed by digital microscopy as shown in the fig 7. On the fracture surface, Visible fiber break and no visible hole marks due to fiber release (pull outs bonding).

Figure 7. Surface morphology of the hybrid composite epoxy

3.2. Flexural strength
The result of flexural strength testing for various fiber fibrillation treatment variations on composite hybrids has been tabulated in table 1 and shown in Figure 8. In Figure 8, the flexural strength trend is similar to the impact strength. Composites with FTCF have a higher flexural strength of 51% compared to composites with FUCF.

Composite with FTCF for 10 minutes has the highest flexural strength, which is 87.91 MPa and the lowest in FTCF for 30 minutes, i.e. 51.37 MPa. Flexural strength will decrease with increasing time of fibrillation. Flexural strength decreased 17.62% and 29.1% in 20 and 30 minutes of fiber fibrillation. Decreased flexural strength at 20 and 30 minutes of fiber fibrillation due to fiber damage due to blender or fibrillation process. Therefore, to increase flexural strength in composites with FTCF compared to FUCF indicates the presence of fiber fibrillation treatment. The fiber diameter becomes smaller so that it can increase the interface between fiber and matrix.
4. Conclusions
The results of the impact and flexural test by varying the length of fiber fibrillation treatment in coir fibers reinforced epoxy hybrid composites can be concluded that the successful fabrication of coir fibers reinforced hybrid composites can be achieved by hand lay up method. It is also shown that the highest impact and flexural strength was produced by composite with FTCF for 10 minutes, i.e. 24.45 kJ/m$^2$ and 87.91 MPa. In addition, for 10 minutes fiber fibrillation can produce better impact and flexural strength than 20 and 30 minutes. Treatment of Fiber fibrillation treatment can improve the fiber-matrix interface, so that it is able to raise the composite mechanical properties.

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