Characteristics of mechanical properties of coir-fibre/rubber composite

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Abstract. Indonesia has the largest coconut land in the world with area of 3.88 million hectares producing 3.2 million tons of coconut. It produces a large amount of coir fibre and it is potential as reinforcement of composite material. The country also has large rubber forest land with industry investment opportunity of US $ 3 billion. The investigation of mechanical properties with different composition of coco fibre and rubber is needed to find its optimum properties of the porous natural composite. The specimens were varied in weight fraction between coco fibre and rubber (30:70; 50:50; 70:30). All specimens were tested with tensile testing in longitudinal and transverse direction to get its tensile properties and observed by macro photo. The result shows that the increasing of fibre reduces the strength and strain and it has optimum modulus for 50% fibre. This can be used as engineering consideration in producing of product, such as mattress and carpet.

1. Introduction

Indonesia has the largest coconut plantations in the world with an area of 3.88 million hectares (97% is community plantations). Land capable of produced 3.2 million tons of copra equivalent. Over the past 34 years, coconut area has increased from 1.66 million hectares in 1969 to 3.89 million hectares in 2005. Although the area has increased, crop productivity has tended to decline (in 2001 an average of 1.3 tons / Ha, in 2005 an average of 0.7 tons / Ha). Indonesia's coconut productivity has still low compare to India and Sri Lanka [1]. Indonesian coconut exports continue to showed a declining trend. Based on data from the Indonesian Coconut Processing Industry Association (HIPKI), the value of coconut exports in 2014 was US $ 1.55 billion. Coconut exports in 2015 fell US $ 1.36 billion and fell again to US $ 1.32 billion in 2016 [2]. One factor of decline of coconut has the increase in number of exports of fresh coconut without added value. During this time, Indonesian coconut exports required around 59.5% -62% coconut oil products, dry grated coconut 8.8% -11%, coconut cake and the rest other processed coconut products. Coconut coir products in Indonesia have the second exporter in the world after the State of Vietnam. The export volume of Indonesian coconut fiber in 2016 was around 27,992 tons. Coconut coir exports have the potential to contribute national income of IDR 13 trillion [2].

Indonesia's rubber land area has the largest in the world with an area of around 3.4 million hectares [3]. The Indonesian Rubber Council (Dekarindo) states that in 2015 Indonesia has the opportunity to
absorb at least US $3 billion in investment in the downstream rubber industry [4]. Domestic production has only reached one ton, inferior to Malaysia already producing 1.3 tons per hectare, Thailand 1.9 tons per hectare. National production has only around 3.4 million tons and only 600,000 tons absorbed in the local industry and the rest is exported. The rubber industry sector absorbed a workforce of 2.1 million people. Indonesia has the second largest natural rubber produce country in Thailand. Unfortunately, around 85% of domestic rubber production has still exported in the form of raw rubber and the rest is for domestic consumption. Other challenges besides productivity and employment also the need to foster community plantations. This activity has been benefit for increasing productivity. Increased rubber production has become a latex and crumb rubber product. Downstreaming product has been increased added value latex. Coconut coir has part of a coconut plant ($cocus$ $mucifera$ $L$) [5,6].

Coconut coir fiber has divided into two: white fibers and brown fibers. White fibers come from the inside of the coconut while brown fibers come from the outer skin of the coconut. White fiber has softer properties, and strong but brittle. While brown fiber has strong, abrasion resistant but short fiber [6]. Coconut fiber can be extracted from the outer portion or in the coconut fruit. Part of the coconut fruit there are 3 layers, namely: exocarp, mesocarp, endocarp. The outside has called the exocarp, the middle has mesocarp, and the inside has endocarp [7]. The exocarp part that will be used in making coconut fiber. Coconut coir fiber has the advantage that it has anti-dumping properties, high stress strain values and is easier to manufacture [8]. The process has been make coconut fiber as follows: fiber uptake, separation of fiber and matrix, chemical treatment, drying, and fiber separation again [9.10]. The processed of extract fiber begun by separate the endocarp, mesocarp, and exocarp coconut parts. Next separated the fiber with a fiber grinding machine, and brown fiber has obtained.

Natural rubber has a type of plant and the Latin name Hevea Brasiliensis. This plant originate from Brazil and has been cultivated throughout the world. This plant produced rubber that has useful for the rubber industry in the world [11]. Rubber produced rubber called latex. This latex has been used for the world's rubber industry to be processed into products such as rubber gloves, tires, absorbers, and more. The used of natural composite from coconut fiber and natural rubber has various advantages: abundant raw materials and widely used for the industrial sector.

2. Materials And Methods
This research make using materials coconut coir fiber used straight fiber processed from farmers in Kebumen, Indonesia. This coconut fiber was processed from $cocus$ $mucifera$. The processed included softening, sifting fiber separation, and drying. So, produced coir fiber straight. The fibers, then selected with a length range of 10-20 cm or medium-long fibers. Short fibers were ignored / removed. Natural latex was obtained from PT. Nusantara IX Semarang. Latex processing used a high speed centrifugation system, so as to obtained concentrated latex. Latex disperse materials in the form of sulfur, ZDEC, ZMBT, ionol, ZnO Bentomite, Darvan, KOH, BHT, Potassium laurate and Water. This material was obtained from Richest group LTD (Shanghai Ruizheng Chemicals).

2.1. The process of making Latex Compound
Making latex compound has mixing liquid latex with chemical disperse material. These chemicals consist of 4 types, namely stabilizers as stabilizing latex rubber, accelerators and activators as activators and speeding up the latex disperse process, antioxidants as inhibiting rubber oxidation and finally a curing agent as a process of delaying thickening of the rubber. The four types of material have been dispersed before the process of making latex compounds. The chemical disperse processes begun with the process of make a 50% disperse formula, namely sulfur, ZDEC, ZMBT, ionol, ZnO using a mixture of Bentomite, Darvan and Water with a ratio of 50%: 50%.

2.2. Manufacture of composite straight coconut fiber and concentrated latex
The processed of make this composite with the spray up technique. The straight coir fiber that has been cleaned, then placed on a 25x 25 cm mold. After that the spray processed with a latex
compound that has been mixed with chemicals. The spray proceed has been carried out using 2 stages of spraying. Spraying a stage 25 cm away and a stage near 5 cm with coir fiber. A composite was tested by tensile test using standards ISO 13934-1 Textiles. Tensile properties of fabrics. Part 1: Determination of maximum force and elongation at maximum force using the strip method. And macrography test with the stereo microscope.

2.3. Experimental Specification
For composite coir fibre with rubber, test standards, e.g. EN ISO 13934-1, aim to measure the maximum tensile or breaking force. And with two-direction, e.g. longitudinal direction and transverse direction.

Material testing used a material tensile test. The machine used UTM Testometric with a maximum capacity of 5 KN. This testing used a reference using the strip test method at EN ISO 13934-1 [12]. Tensile speed of 200mm / min and 2N pretension. Tensile test specimens with dimensions of 5cm x18 cm with 10 gage length. Observation of fractures and macro-fiber structure used Nikon Ocular Microscope with serial number 3115990. Tensile testing aims to determine the maximum tensile strength of the composite and modulus of elasticity. Macro photo were useful for knewed the bond between fiber and rubber whether bonding occurs completely or not.

3. Result And Discussion
This research predicted the tensile strength of three specimens of fraction weight. Weight of coir fiber fraction : 30%; 50%; 70% and there are two data : longitudinal and transverse direction. Each direction with five sample/fiber content treatment. Transverse direction of coir with in the same direction of rolling force. Then, the resumed of experimental data obtained in accordance with Tables 1a and 1b. Specifications of tensile testing results could be seen in Tables 1a and 1b. The tensile strength of a large heavy fraction is 30 w/w and the low is 70 w/w for longitudinal direction. The tensile strength of a large heavy fraction is 50 w/w and the low is 70 w/w for transverse direction.

Difference of fiber between transverse and longitudinal fibers have various differences values. Where the direction of the longitudinal fiber has a smaller tensile value than the directional fiber tensile test. The fiber used for the material printing processed. Position of sample was a random fiber. And will be compared with the direction of the force results from the rolling machine process. Fiber in the direction of the force of the rolling machine has a value more stable and better. Longitudinal direction has a un-stable values because The direction of the force forming differs from the direction of the force questioning the tensile test.

Rolling machines produced a significant force between the three types. The tensile strength of transverse direction was better than longitudinal direction. Modulus elasticity between transverse and longitudinal direction fibers increases with increasing weight fraction. Modulus Elasticity could be seen in Figures 1a and 1b. The value of the strain between transverse and longitudinal fibers increases with decreasing weight fraction.

| Fiber content (w/w) | Tensile strength (MPa) | Modulus Elasticity (GPa) | Strain (Є) |
|---------------------|------------------------|--------------------------|------------|
| 30                  | 3.2624                 | 0.005707578              | 1.9914     |
| 50                  | 2.509                  | 0.006760161              | 1.0842     |
| 70                  | 0.71568                | 0.002749945              | 0.69118001 |

| Fiber content (w/w) | Tensile strength (MPa) | Modulus Elasticity (GPa) | Strain (Є) |
|---------------------|------------------------|--------------------------|------------|
| 30                  | 2.4607                 | 0.005068109              | 1.6098     |
| 50                  | 2.5699                 | 0.008211296              | 1.1896     |
| 70                  | 0.588                   | 0.00120215               | 1.1484     |
The tensile strength of natural rubber reinforced coconut fiber composites can be seen in Figures 1.a and 1.b. In this graph showed that the highest tensile strength values in transverse direction obtained a weight value of 30% fraction. And the lowest weight fraction of 70%. This showed that coconut fiber with 30% fraction weight has a good bonding between rubber and fiber. So, fraction weight 30% fiber has a good strength. This decreases because the bonding between rubber and coconut fiber does not bind well. Thus, the tensile strength of composite coconut and rubber has decreased. Both transverse and longitudinal direction composites. In Figure 1.b for the weight of 50% fraction the tensile strength increases. This is because, the composition of the fiber and rubber are balanced. So that the bond between the fiber and rubber can blend well.

Modulus of elasticity of fiber and rubber material composites can be seen in Figures 2.a and 2.b. The weight of the fraction tends to increase from 30% fiber to 50% fiber. But there is something interesting, namely the weight of 70% fraction has decreased. Because the bond between the rubber and the fiber has not been able to blend well. Transverse and longitudinal directions have values that tend to be the same. This value used to see the strength of the material against the strength of plastic deformation. The optimum value was coconut fiber with 50% fraction weight that is 0.006760161 GPa for longitudinal direction and 0.008211296 GPa for transverse direction.

Strain of coconut coir and rubber composite material has a tendency to go down which closely related to the weight of the composite material fraction. Material strain was closely related to tensile
strength. Where the tensile strength of the material will always be related to the material strain. The strain value of curve 1.b has a good tendency compared to curve 1.a. this is because the curvature of the curve between 1a is neater than 1b. The decrease that occurs between coconut fiber 1a which has a directional direction has good ang results. This is because the bonding between rubber and fiber is good when compared to coconut fiber transverse direction.

This test used a stereo microscope with 50x magnification. The results obtained in the form of surface images between coir fiber and rubber. This analysis has been used to see the existing fiber and rubber. An overview of Macrography Test results could be seen from Figure 4.

![Figure 4. Macrography Test (a) fraction weight 30%; (b) fraction weight 50%; (c) fraction weight 70%](image)

Macrography test showed between rubber and fiber bonding. Figure 4.a showed the weight of 30% fraction. Where between coconut fiber and rubber has a less strong bond. Indicated by coconut fibers that have cavity. The rubber showed was also not evenly and tends to gather in one place. Figure 4.b shows a good bond between rubber and fiber. Fiber and rubber could binded to one another. So that the fiber was not too hollow and rubber was evenly distributed. Figure 4.c showed the weight of 70% rubber fraction wherein this picture showed that the fibers that accumulate on one side make it difficult for the rubber to get inside, so the bond between the rubber and the fiber was low. The many black area indicate fibers that accumulate on one side. Based on macro observations of coconut and rubber fibers which show a strong bond was coconut fiber with 50% fraction weight.

| Fiber content (w/w) | Weight (gr) |
|---------------------|-------------|
| 30                  | 39.6        |
| 50                  | 50.3        |
| 70                  | 52.6        |

Table 2. Matt Fiber content

Table 2. Showed the weight of matt fiber. Where 50% fraction weight indicated weight that tends to be light. Where for the 25x25 cm specimen where the weight of rubber : 39.5 gr and 39.5 gr fibre. Based on the results of the analysis of tensile strength and photo macro observation obtained the results of an efficient comparison that : 50% fraction weight. Table 2 also shows that the weight of 50% fraction showed good weight. Where between the fiber and rubber can be fused to form a bond.

4. Conclusion
The results of this study concluded that increasing fiber content can reduce the mechanical strength of composites. Good mechanical strength has in the composition of the 50% fiber content. This mechanical strength obtained from the material tensile test. The difference in the direction of the fiber also has an influence in determining the magnitude of the mechanical strength of the composite. Longitudinal direction coir fibre have good mechanical strength.
Acknowledgments
This research was supported by The Research Grant of Master Thesis RISTEKDIKTI in 2019.

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