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EFFECT OF ALKALI TREATMENT ON THE COCONUT FIBER SURFACE

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ABSTRACT

The purpose of this study was to determine the effect of treatment Alklali (NaOH) on the surface of coconut fiber covering the surface roughness, tensile strength, and the ability of bonding between coconut fiber with polyester matrix. Coconut fiber soaked in a solution of alkali with a concentration of 5%, 10%, 15%, 20%, and then dried in an oven at a temperature of 90 ^oC for 5 hours. Fiber surface roughness testing is done in two ways namely SEM and surface roughness measuring instrument. Single fiber tensile strength and fiber pull out test was performed with a tensile test. Based on these test results, it was concluded that concentration solution of alkali to give effect to the surface roughness of coconut fiber, increasing the tensile strength, and improve bonding with the fiber and polyester matrix. The alkali treatment increase of the surface roughness of coconut fiber until 3.96 μm. In the 20% alkali treatment obtained tensile and shear strength is highest, respectively 280, 94 N/mm^2 and 3, 09 N/mm^2.

Keyword: coconut fiber, chemical treatment, tensile strength, surface roughness.

INTRODUCTION

The use of natural fibers as reinforcement composites have been mostly used, and is still studied for its development in various fields. The advantages possessed by natural fibers such abundant, environmentally friendly, low production cost, and elastic. Besides these advantages, natural fibers also have disadvantages including: the quality is not uniform, high water absorption, low strength, difficult to bond to the matrix (which are hydrophilic). Natural fibers also called lignocellulosic fibers because of natural fibers contain many elements of lignin, hemicellulose, and cellulose (Brigda, 2009). The natural fiber content depending on conditions, places and climates where the natural fiber grown. On growth, the plants need chemical compounds in the form of primary and secondary macro-molecules such as C, H, O, N, P and K. In addition to a macromolecule plants also need micro elements such as iron, magnesium, and others. Cellulose and hemicellulose is a polysaccharide compound while the lignin is a polyphenolic compound macromolecule (Muensri, 2011). The strength or toughness of composite influenced by the bonding between the surface of the fiber with the matrix, how to prepare the fiber, reinforcing component should have a higher elastic modulus of the matrix. Compatibility between natural fibers with the matrix will determine the properties of composites (Rozman, 2000). Rout (2001) said that the chemical treatments improve the surface topogrophy, tensile strength of coconut fibers.

Several methods of treatment have been done to improve the compatibility of natural fibers. The treatment of physically and chemically, aims to modify the fiber surface. Chemical treatment can change the surface morphology of coconut fiber to become rougher though its mechanical strength decreases slightly (Arsyad, 2015).

Therefore, the goal of this study was to determine the roughness surface, tensile strength and bonding ability of coconut fiber under alkali treatment. For this aim, there are different concentrations chemical treatments were used: 5%, 10%, 15%, and 20% for alkali.

LITERATURE REVIEW

The main component of wood molecule are cellulose, hemicellulose, and lignin. Cellulose is a long-chain compounds and are crystalline, hemicellulose is a branched-chain compounds which are non-crystalline and non-fiber, while the lignin is an amorphous compound. Fiber has a natural properties are hydrophilic, meaning that likes to water. Whereas matrix is hydrophobic, meaning do not like water. Alkali treatment on fibers is able to reduce hydrophilic properties of the fiber (Arsyad, 2015). The reaction between the fiber with NaOH are:

$$\text{Fiber-OH} + \text{NaOH} \longrightarrow \text{Fiber-O-Na} + H_2O$$

The method used to determine the amount of hemicellulose, cellulose and lignin in coconut fiber is a Chesson method (Mahyati, *et al.*, 2013). A mixture containing 1 g of dry samples (A) and 150 ml of distilled water was heated in a glass tube at a temperature of 90-100 °C for 1 hour. The mixture was filtered and the residue washed with 300 ml of hot water. The residue was dried in an oven until its weight is constant (B). Dry residue (B) mixed with 150 ml of 1 N H2SO4 and heated in a glass tube at a temperature of 90-100 °C for 1 hour. The mixture was filtered and washed with 300 ml of distilled water and then dried residue (C). Dry residue (C) soaked with 10 ml of 72% H2SO4 at room temperature for 4 hours. After that, 150 ml of 1 N H2SO4 was added to the mixture and refluxed in a glass tube at a temperature of 90-100 °C for 1 hour. The solids are washed with 400 mL of distilled water, heated in an oven at 105 °C and weighed to constant weight (D). Finally the solids (D) is heated until become ashes and weighed (E). The percentage of hemicellulose (H_c), cellulose (S_c), and lignin (L_c) are calculated using the following equation:

$$H_C = \frac{B - C}{A} X100\% \tag{1}$$

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$$S_C = \frac{C - D}{A} X100\% \tag{2}$$

$$L_C = \frac{D - E}{A} X100\% \tag{3}$$

There are two main aspects to be obtained from test Shear Force Pull Out (SFPO) are (a) the initiation of the behavior of the release fibers from the matrix, and (b) the release of fibers from the matrix that failed against the friction between the surface of the fiber and the matrix as a result of the tensile load. Figure-1 shows SFPO test procedure in which a single fiber embedded in the matrix with a depth of L and given axial tensile load of F. Load F is expected to pull out the fibers are embedded assumed shear stress along the surface of the fibers are embedded is uniform.

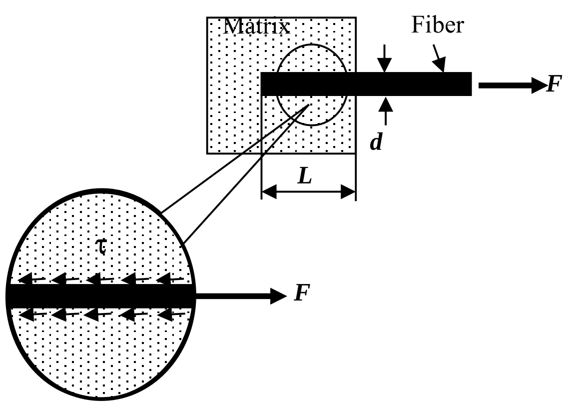

Figure-1. The mechanism test of single fiber pull-out (Arsyad, 2015).

The shear stress between the fiber and the matrix can be calculated from the magnitude of the load used to pull out the fibers from the matrix using the equation:

$$\tau = \frac{F}{\pi d L} \tag{4}$$

with: τ = shear stress (MPa), F = maximum load (N), d = fiber diameter (mm), L = embedded fiber length (mm)

Tensile test is one of the mechanical tests that aimed to determine the strength of the material to tensile force. By doing tensile tests can be seen how the material reacts to tensile force and determine the extent to which the material has been elongation. If the material is pulled up to break up, will pull a complete profile obtained in the form of curves. This curve shows the relationship between tensile force with a elongation. Concern in the curve is the ability of materials to hold maximum loads. To determine the tensile stress, and elongation, use the following equation:

$$\sigma_{maks} = \frac{F_{maks}}{A} \tag{5}$$

$$\varepsilon = \frac{L_1 - L_o}{L_o} x100\% \tag{6}$$

with: σ_{maks}=Maximum Tensile Strength (N/mm^2), F_{max}= Maximum load (N), A=sectional area (mm), ε=elongation (%), L_o=initial length (mm), L_1=end length (mm). The model of specimens for single fiber tensile test in accordance with the ASTM 3379-02 is shown in Figure-2.

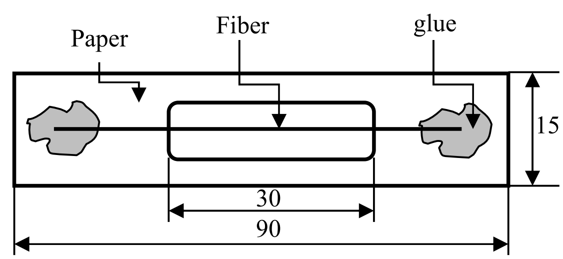

Figure-2. Single fiber tensile test specimens to ASTM 3379-02.

MATERIALS AND METHODS

Materials used in this research that coconut fiber, alkali (NaOH), polyester matrix, and distilled water. Coconut fiber is obtained by separating the fiber from coconut husk, then the corks are still attached to the fibers are separated manually by hand. The coconut husk is obtained from public of Sidenreng Rappang Regency of South Sulawesi province. Coconut fiber soaked in a solution of alkali (5%, 10%, 15%, 20%) for 3 hours. Then coconut fiber is dried in an oven at a temperature of 90° C for 5 hours. Single fiber tensile test coconut fiber length of 30 mm in accordance with ASTM 3379-02 standard by using a tensile test LR10K Plus 10 kN Universal Materials Testing Machine. Stress values (MPa) and strain (%) is automatically calculated by the tensile test equipment. To determine the the form of the surface roughness coconut fiber used Vega3 Tescan electron microscope (SEM, Scanning Electron Microscope). Each sample was cut short in the size of preparations, then the sample is placed over the preparation. Samples were observed using Vega3 Tescan at 5kV voltage to determine surface roughness. Measurement of surface roughness be done also using Mitutoyo surface roughness measuring instrument SJ.301. For easy of the implementation of the study, each treatment is given notation as shown in Table-1.

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Table-1. Testing notation.

Notation	Treatment
UT	Untreatment
A5	5% NaOH Treatment
A10	10% NaOH Treatment
A15	15% NaOH Treatment
A20	20% NaOH Treatment

RESULT AND DISCUSSIONS

Table-2. Content of coconut fiber.

Treatment	Content (% weight)		
	Hemicellulose	Cellulosa	Lignin
UT	15,5	37,9	33,5
A5	11,0	37,0	29,0
A10	11,3	36,8	27,3
A15	12,7	22,2	37,5
A20	40,9	22,0	6,1

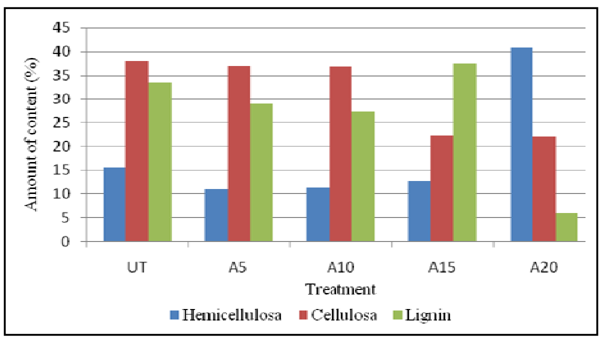

Figure-3. Amont of content of coconut fiber.

Testing of chemical composition by using Chasson method conducted and equation (1), (2), and (3) to determine the percentage of the amount of lignin, cellulose and hemicellulose coconut coir fiber, both fibers without treatment or with treatment. The composition of the test results can be seen in Table-2 and Figure-3.

Fiber surface roughness is determined using two methods: Mitutoyo surface roughness measuring instrument and SEM. The results of the fiber surface roughness measurements by using a roughness measuring instrument shows in the Table-3 and Figure-4, and the results of measurements of fiber using SEM can be seen in Figure-5.

Table-3. Value of surface roughness by Mitutoyo SJ. 301.

No	Treatment	Roughness value
		µm
1	UT	1,62
2	A5	3,96
3	A10	3,63
4	A15	3,48
5	A20	2,53

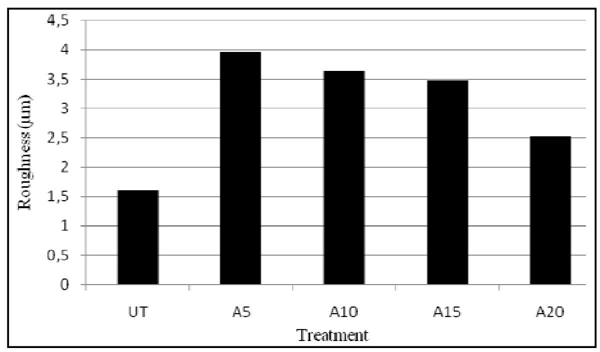

Figure-4. Roughness of coconut fiber surface.

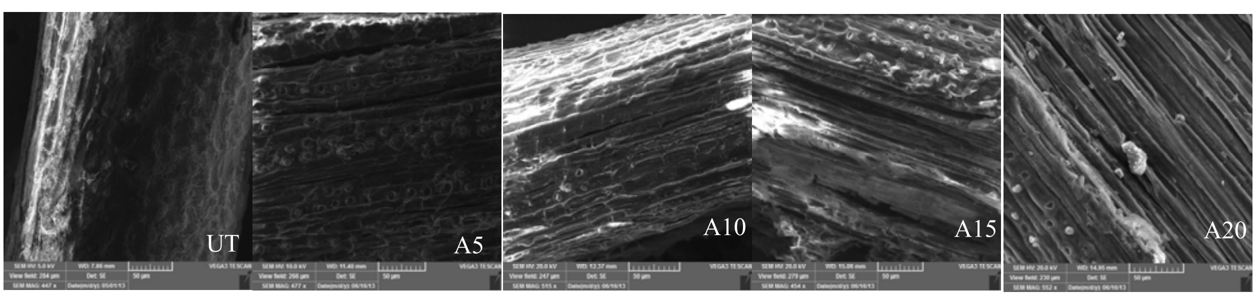

Figure-5. SEM of coconut fiber surface untreated and after treatment.

As shown in Table-3 that the surface roughness coconut fiber increased after being treated alkali. Coconut fiber without treatment, the value of roughness only 1.62 µm, while after the alkali treatment roughness values increased to 2.53 µm to 3.96 µm. The roughness value in accordance with Figure-5. Figure-5 shows the results of SEM photograph of coconut fiber surface. Figure-5 (UT) shows coconut fiber surface without treatment, the surface still looks fine as it is still filled with various elements and impurities. While Figure-5 (A5 - A20) shows a slightly rough surface as the effect of alkali treatment. After alkali treatment, important modification done is the disruption of

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hydrogen bonding in network structure, thereby increasing surface roughness (Karthikeyan, 2012). Alkali treatment on the fiber will give two effect to the fibers which are (1) increasing the surface roughness of the fiber so that it will produce a better interlocking, (2) will increase the amount of cellulose that apart (Mohanty, 2005).

Table-4 shows the tensile strength, elongation, and shear strength coconut fiber before and after treatment. The maximum tensile strength values obtained on A20 treatment as shown in Figure-6 is 280.94 MPa, an increase of approximately 33.6% of the untreated fiber (UT) is 186.42 MPa. In the treatment A20 (20% alkali) causes the degradation of lignin greatest, so that the lignin content of at least, as shown in Table-2. The lignin will affect fiber strength, fiber strength will be high if the number of lignin is low because lignin is stiff and brittle (Daulay, 2009).

Table-4. Tensile strength, elongation and shear strength of coconut fiber.

No	Treatment	σ (N/mm^2)	ε (%)	τ (N/mm^2)
1	UT	186,42	28,33	1,85
2	A5	144,00	50,00	2,32
3	A10	113,09	29,17	1,72
4	A15	52,65	11,67	1,57
5	A20	280,94	11,25	3,09

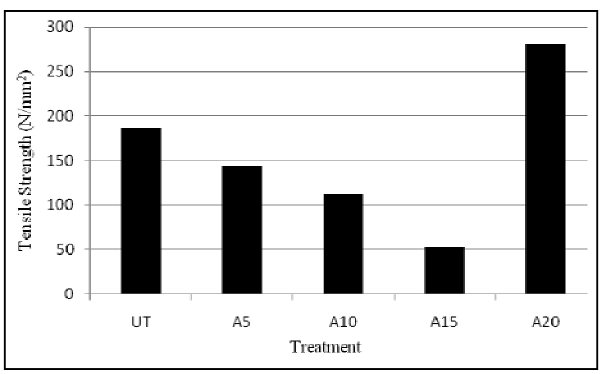

Figure-6. Tensile strength of coconut fiber.

Moreover, as shown in Figure-2, in the treatment of A20 hemicellulose content of the highest of 40.9% where the hemicellulose is a compound that is non-crystalline (Arsyad, 2015). Average elongation of fiber that given first treated is higher when compared to fiber by other treatments, as shown in Figure-7. Figure-7 shows that the highest strain coconut fiber obtained on A5 treatment, namely by 50%, but for the other treatments tend to decrease compared with the elongation of coconut fiber without treatment.

Based on the value of the tensile load and equation 4, the obtained value of interfacial shear stress (IFSS) or shear strength as shown in Table-4 and Figure-8. Figure-8a shows the grooves on a matrix which is the former site of the fiber. While Figure-8b shows the reaction of the bonding between the fibers with the polyester matrix. The Figure-8a shows the former grooves coconut fiber in the matrix as a result of alkali treatment, where there are deposits of sodium attached to the matrix. This indicates that there has been a reaction between the fiber surfaces with a matrix that can increase the bonding between the fibers with the matrix.

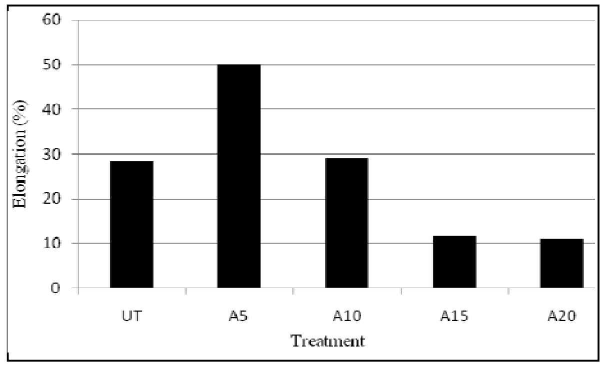

Figure-7. Elongation of coconut fiber.

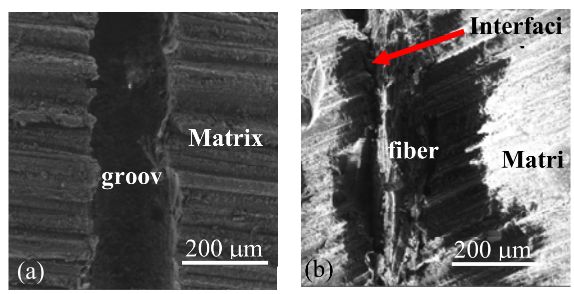

Figure-8. SEM of coconut fiber (a) untreated and (b) after treatment

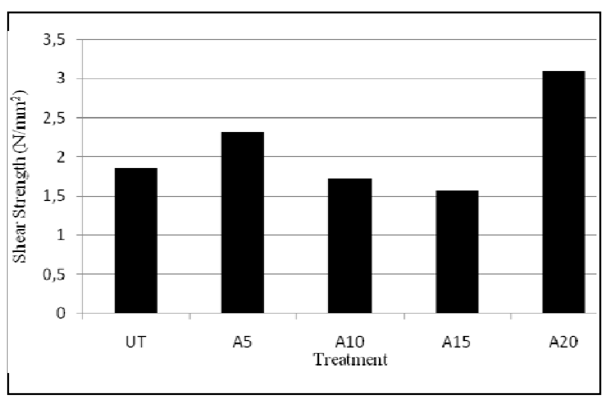

Figure-9. Shear strength of coconut fiber.

Coconut fiber soaking treatment in alkaline solution resulted in a decrease in the content of hemicellulose, cellulose and lignin. Coconut fiber without treatment contains hemicellulose, cellulose, and lignin, respectively 15.5%, 37.9% and 33.5%. The value in accordance with the results of Agopyan 2005. Mohanty

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(2005) also says that the alkali treatment reduces the amount of cellulose in the fibers as compared of untreated coconut fiber. Khan (2012) says that the alkali treatment will reduce the amount of hemicellulose compared with coconut fiber without treatment. Decrease in cellulose and lignin is proportional to the increase in the concentration of alkali solution. In the coconut fiber treated with alkali 5% decrease of cellulose from 37, 9% to 37% and for lignin from 33, 5% to 29, 0%, and for the treatment of 20% alkali respectively 22% and 6, 1%. The reduced lignin and cellulose means alkali solution managed to damage the structure of lignin and disconnect carbon chain of cellulose. Coconut fiber surface in the alkali treatment seemed rougher than the surface coconut fiber untreated. The value of surface roughness highest obtained in 5% alkali treatments are is 3.96 μm, and the lowest in coconut fiber without treatment with a value is 1.62 μm. The roughness is marked by the presence of granules on the fiber surface. The higher the alkali concentration of the grain size is getting smaller, but more solid than the granules in the treatment with a low alkali concentration. The granules are integrated solid and coating the fiber surface so it can be slow the rupture of fiber when given tensile load. In the alkali treatment, the average values of the highest tensile strength obtained in 20% alkali treatment are 280.94 MPa. At the time, the lignin content its lowest is 6%, where lignin is stiff and brittle, so the strength of the fiber will increase when lignin content is low (Daulay, 2009). At 20% alkali treatment obtained the highest shear strength between coconut fiber with a polyester matrix are 3.09 MPa. This means that the surface roughness of the fiber by small granules are unite with one another and sturdiness can react either with the polyester matrix increasing the ability bonding between coconut fiber with polyester matrix Carvalho (2010), and Mulinari (2011). Chemical modification of natural fibers is necessary for increased bonding between the fibers and polyester matrix (Kumar, 2011).

CONCLUSIONS

Based on the testing and discussions have been conducted, it is concluded that:

a) The alkali treatment increase of the surface roughness of coconut fiber. The values of highest roughness of obtained in 5% alkali treatment are 3.96 μm.
b) In the 20% alkali treatment obtained tensile and shear strength is highest, respectively 280, 94 N/mm^2 and 3, 09 N/mm^2.
c) In the 20% alkali treatment, obtained the lowest lignin content are 6.1%.

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