Sodium Hydroxide and Potassium Permanganate Treatment on Mechanical Properties of Coconut Fibers

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Abstract. The purpose of this research is to determine the tensile stress and interfacial shear stress of coconut fiber that has been treated Sodium Hydroxide and Potassium Permanganate. This research is divided into three stages: soaking for 3 hours, testing, and data analysis. Coconut fiber is soaked in a solution of 5%, 10%, 15%, and 20% sodium hydroxide solution. Then, soaking in a solution of Potassium Permanganate with concentrations of 0.25%, 0.50%, 0.75%, and 1.00%. After that, the coconut fiber is dried in the furnace at 90^{o}C for 5 hours. Then, coconut fiber was tested for tensile stress and interfacial shear stress. Based on the results of the test can be concluded that the treatment of Sodium Hydroxide and Potassium Permanganate affect tensile strength, and the shear strength of coconut fiber. The largest tensile stress was obtained in the treatment of Sodium Hydroxide with a concentration of 20% ie 289.94 N/mm^2, while the highest interfacial shear stress was obtained in the treatment also on Sodium Hydroxide with a concentration of 20% ie 3.09 N/mm^2.

Keywords. treatment, tensile, shear, stress, coir fiber.

1. Introduction

Lignocellulose is the name used for materials containing lignin, cellulose, and hemicellulose. Lignocellulose is a constituent component of plant cell wall especially on the stem section. Hemicellulose and cellulose are polysaccharides that can be decomposed into monosaccharides. The availability of abundant lignocellulosic materials on earth has resulted in the study of the use of lignocellulosic materials to be very attractive[1].

Natural fibers containing hemicellulose, cellulose, and lignin are hydrophilic which is a feature that likes to water. It is this property that causes natural fibers to hardly unite or bind with a hydrophobic matrix of a dislike of water. Therefore, there is a need to improve the properties of the natural fibers in order to establish a good bond with the matrix. Treatment of lignocellulosic materials can be done in several ways as chemically, physically, and microbiologically. Each method has advantages and disadvantages. The efficiency and effectiveness of its use may vary, depending on the source of the material and the purpose of the process. Chemical treatment is the most commonly used method because it is easier, more effective, faster and does not use too high energy. The bond between fiber and matrix has an effect on the mechanical properties of fiber-reinforced composites. Specifically, the composite tensile strength is affected by the efficiency of the load transfer from the matrix to the fiber through shear at the interface. Therefore, a number of mechanical tests have been developed to measure the interface capacity to transfer the stress from the matrix to the fibers in the composite. Several test methods have been used to evaluate the bond capability between fibers and matrices such as: (1) pull outs, (2) microtension, (3) microcompression, (4) fragmentation. The interconnection of the fiber with the matrix consists of several bond models: (a) chemical bonds, (b) ionic electrostatic bonds, (c) molecular reaction interdiffusion, and (d) mechanical bonds (*interlocking*) [2].

The composite mechanical properties are strongly influenced by the bond between the matrix and the fibers. Treatment with sodium hydroxide has the highest effect on tensile strength and tensile modulus, resulting in composites with the best tensile properties. The strength of the composites treated with sodium hydroxide increased significantly by about 53% compared to composites made from untreated fibers and 33% compared to the non-fiber composite [3]. The alkali treatment of the fibers will give two effects to the fibers: (1) increasing the surface roughness of the fibers so as to produce better interlocking, (2) increasing the release of cellulose [4]. The reaction between fiber and sodium hydroxide are [1] [5]:

$$\text{Serat-OH} + \text{NaOH} \rightarrow \text{Serat-O-Na} + H_2O$$

Permanganate is a compound containing MnO4- permanganate groups. Permanganate strengthening is used on cellulose fibers that turn into radicals through the formation of permanganate ions. Then the highly reactive Mn3 + ion as the initiation of the graph copolymerization [6] [8].

Most permanganate strengthening is carried out by using a solution of potassium permanganate (KMnO4) or in acetone with different concentrations within 1 to 3 hours after alkaline strengthening, strengthening the hemp fiber in permangant solution at a concentration of 0.033: 0.0626: and 0.125% in acetone for one minute. As a result of permanganate strengthening is a reduction in the fiber, therefore the water absorption of fiber-reinforced composites increases. The hydrophilic properties of the fibers will decrease with the increase of KMNO4 concentration, but at 1% KMnO4 concentration there is cellulose degradation which will produce polar groups between the fibers and the matrix [6].

2. Material and Methods

The materials used in this research are: coconut fiber, polyester resin, metyl etyl keton peroksida catalyst, sodium hydroxide (NaOH), potassium permanganate (KMnO4), and aquades. The equipments used in this study are digital scales, immersion media, manila cartons, glue, scissors, tensile test equipment. Coconut fiber is obtained from coconut husk with manually method. Coconut fiber is soaked in sodium hydroxide solution for 3 hours with concentrations of 5%, 10%, 15%, and 20%. Then soaked for also for 3 hours in solution 0.25%, 0.5%, 0.7.5%, and 1.00%. Subsequently, coconut fiber was dried in a furnace at 90°C for 5 hours.

The stress occurring at a maximum limit indicates a load capable of being retained by a material called the maximum stress. The maximum stress held by the specimen before break is called the maximum tensile stress that is the ratio between the maximum load and the cross-sectional area of the material. Single fiber tensile specimens were prepared according to ASTM 3379-02 Standard as shown in Fig. 1, whereas the shearing mechanism between fiber and matrix is shown in Fig. 2. The maximum tensile stress value is calculated by using equation 1, while the shear stress value between the fibers and the matrix is calculated using equation 2. The single tensile fiber and pull out test is performed by using the LR10K Plus 10 kN Universal Materials Testing Machine.

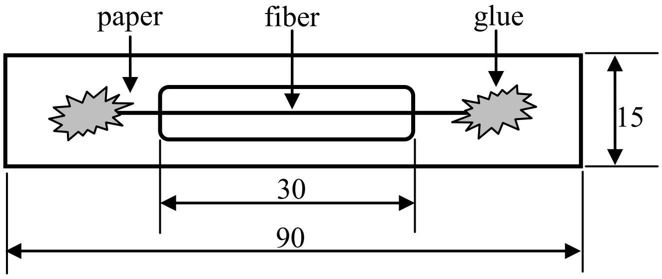

Figura 1. Speciment of single fiber test ASTM 3379-02

$$\sigma = \frac{P}{A} \quad \text{...} \quad (1)$$

with σ = Maximum tensile stress (MPa), P = Maximum load (N), A = Sectional area (m^2).

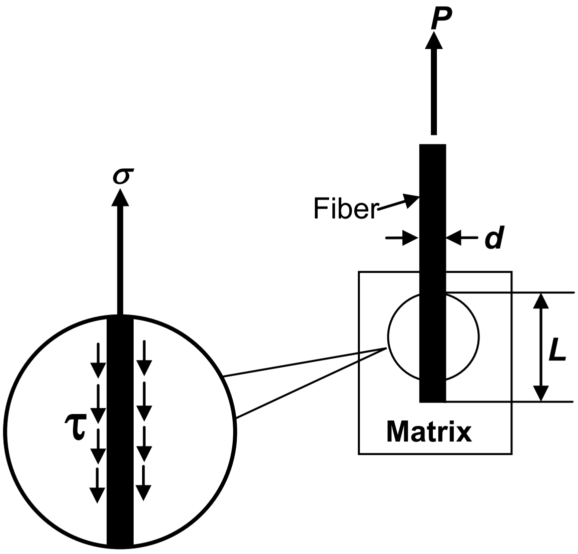

Figure 2. *Single Fiber Pull-Out test* mechanism (Arsyad, 2017)

$$\tau = \frac{P}{\pi d L} \quad \text{..................................} \quad (2)$$

with: τ = Interfacial shear stress (MPa), P = Maximum load (N), d = Fiber diameter (mm), L = Embedded fiber length (mm)

In order for the research to be done well, each research variable is given different notation for each treatment as in Table 1.

Table 1. Nomenclature used for the different coconut fibre treatments

No	Notation	Description
1	WT	Without treatment
2	N05	Soaking in alkali 5%
3	N10	Soaking in alkali 10%
4	N15	Soaking in alkali 15%
5	N20	Soaking in alkali 20%
6	P025	Soaking in Potasium 0,25% after N05
7	P050	Soaking in Potasium 0,50% after N10
8	P075	Soaking in Potasium 0,75% after N15
9	P100	Soaking in Potasium 1,00% after N20

3. Results and Discussion

The results of tensile test are shown in Table 2 and Figure 3.

Table 2. The tensile stress of coconut fiber

No	Treatment	Tensile Stress (MPa)	Strain (%)
1	WT	186,42	28,33
2	N05	144	50
3	N10	113,09	29,17
4	N15	52,65	11,67
5	N20	280,94	11,25
6	P025	138,37	31,25
7	P050	82,7	16,25
8	P075	195,37	16,67
9	P100	102,87	24,58

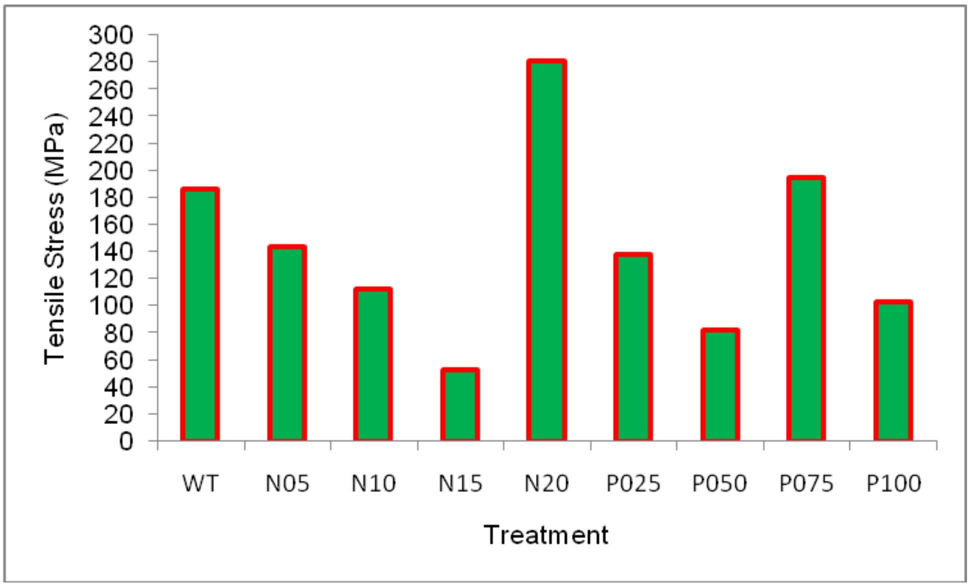

Figure 3. Tensile stress value of coconut fiber

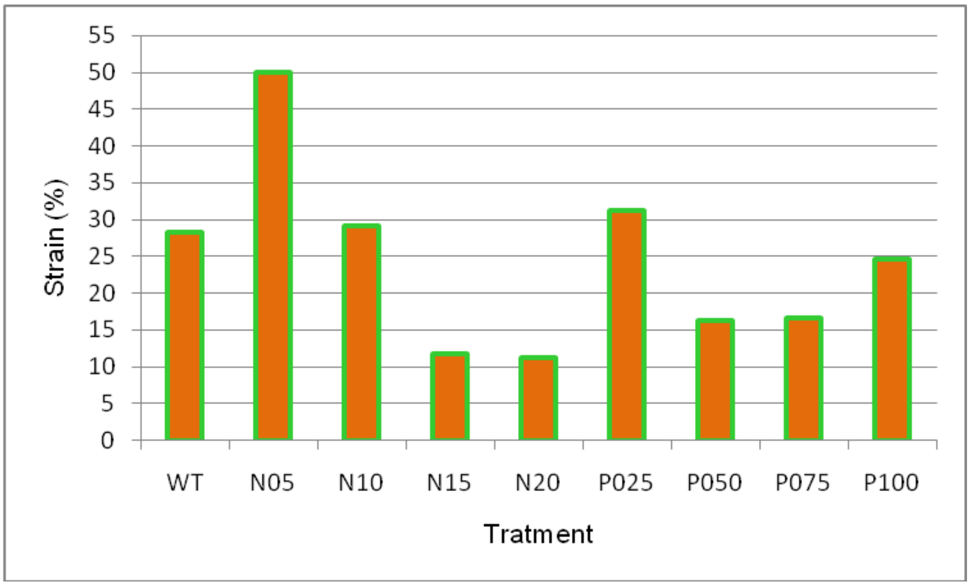

Figure 4. Strain value of coconut fiber

Table 2 and Fig. 3 show that the highest tensile stress is obtained on coconut fiber treatment with 20% alkali which is 280,94 MPa, and this value is higher than coco fiber without treatment ie 186,42 MPa. This indicate that the alkali treatment of coconut fiber can increase the tensile strength of coconut fiber [3][4] [6]. In this treatment coconut fiber contains the lowest lignin that is only 6.1%. This value is lower than the lignin content of coconut fiber without treatment ie 33.5% as shown in table 4 and fig 6. This represent that the alkali treatment of coconut fiber results in lignin degradation so that influence the tensile strength of coconut fiber [7]. While the highest strain of coconut fiber is obtained at 5% alkali treatment which is 50% as shown in fig 4. In this treatment, coconut fiber contains the lowest hemisellulose that is 11% lower than coconut fiber without treatment ie 15.5% . This shows that alkaline treatment degrades the number of coconut fiber hemisellulose [6].

The results of pull out test are shown in Table 3 and figre 5.

Table 3. The interfacial shear stress of coconut fiber

NO	Perlakuan	D	F	τ
		Mm	N	MPa
1	WT	0,31	3,7	1,85
2	N05	0,39	5,43	2,32
3	N10	0,29	3,03	1,72
4	N15	0,33	3,4	1,57
5	N20	0,35	7,38	3,09
6	P025	0,3	4,85	2,42
7	P050	0,35	6,1	2,82
8	P075	0,29	3,4	1,92
9	P100	0,31	2,36	1,19

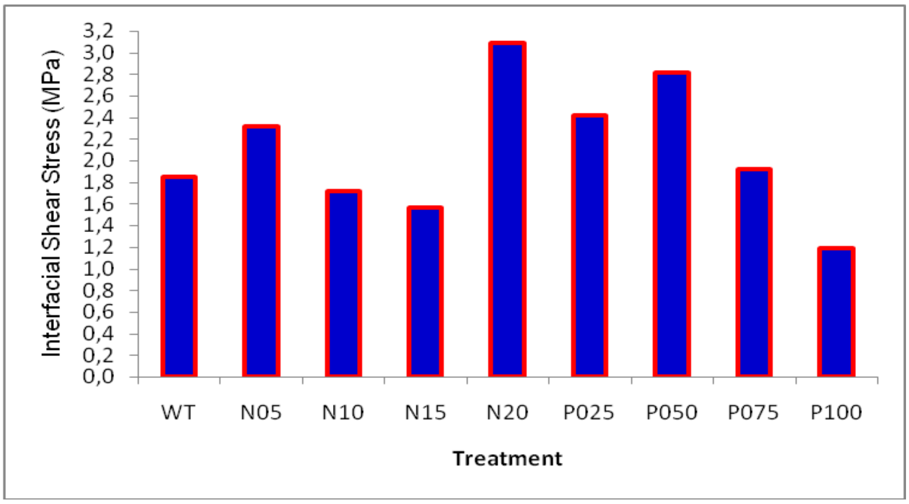

Figure 5. Interfacial shear stress value of coconut fiber

Table 3 and Fig 5 shows the shear stress of coconut fiber, both of which have been treated or untreated. The highest shear stress is found in coconut fiber treated with alkali 20% that is 3.09 MPa. The shear stress value is higher than the value of the shear stress without treatment coconut fiber is 1, 85 MPa. This indicate that the alkali treatment of coconut fiber has compatibility to polyester matrix. While on the other treatment obtained at the treatment of alkali 10% and potassium permanganate 0.50% that is equal to 2.82 MPa. Overall, potassium permanganate treatment after alkali treatment increased the shear stress of coco fiber with a polyester matrix except at 1% potassium permanganate treatment after 20% alkali treatment, the shear stress decreased from 2.09 MPa to 1.19 MPa. The treatment of potassium permanganate caused a reduction in the amount of cellulose, the highest amount of cellulose obtained in coconut fiber without treatment ie 37.9% while the lowest amount of cellulose was obtained in potassium permanganate treatment with 0.75% concentration of 21.6% [6].

Table 4. Content of hemicellulose, cellulose, lignin of caconut fiber

No.	Treatment	Content (% weigth)			
		Hemicellulose (%)	Cellulose (%)	Lignin (%)	Others (%)
1	WT	15,5	37,9	33,5	13,1
2	N05	11	37	29	23
3	N10	11,3	36,8	27,3	24,6
4	N15	12,7	22,2	37,5	27,6
5	N20	40,9	22	6,1	31
6	P025	24,5	37,7	13,2	24,6
7	P050	20,4	29,2	24,8	25,6
8	P075	18,7	21,6	26,6	33,1
9	P100	8,6	35	17,1	39,3

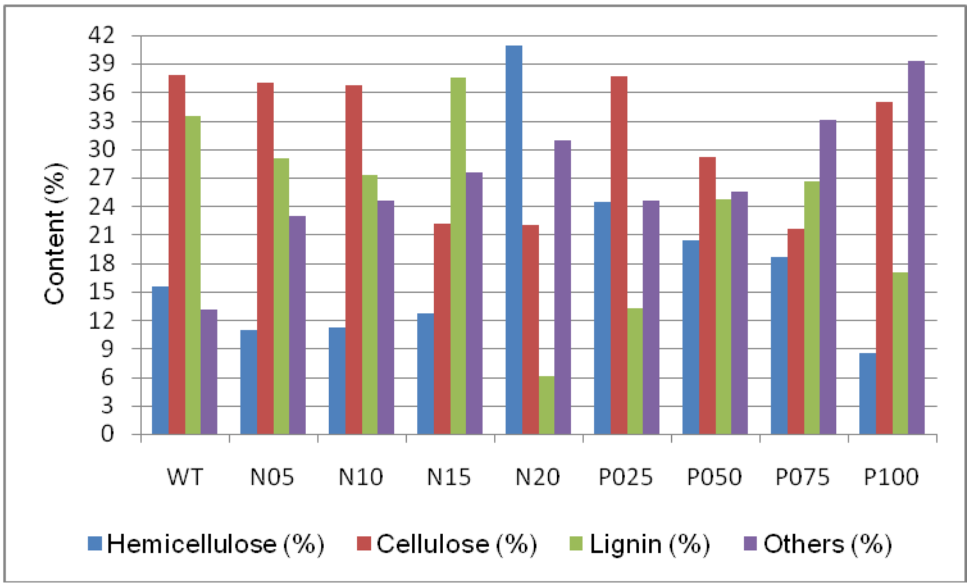

Figure 6. Content of hemicellulose, cellulose, lignin of caconut fiber

4. Conclusion

Based on the testing and discussion that has been done then concluded:

a. The tensile stress of coconut fiber is increased by sodium hydroxide treatment but decreases in potassium permanganate treatment.

b. The treatment of sodium hydroxide, and potassium permanganate increases the compatibility between coconut fiber and polyester matrix.

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