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Effect Of Liquid Smoke on The Morphology and Compatibility of Sago Fiber-Matrix

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Abstract - *The study aims to identify the effect of liquid smoke treatment on the surface morphology of sago fibers and its influence on epoxy matrix bonds. The proposed study is divided into two steps: fiber treatments and property tests. In the first treatment, sago fiber is immersed in the liquid smoke solution for 1, 2, 3, 4, and 5 hours, then dried inside an oven at 43 ^oC for 1 hour. Next, surface morphology and fiber compatibility to the epoxy matrix is observed by Vega3 Tescan Scanning Electron Microscope (SEM). Findings indicate the hat surface morphology of sago fiber with no treatment is relatively smooth, while those with immersion treatments became rough and grooved along with crystallization on the fiber surfaces. The crystallization index is increased throughout increasing immersion durations; leaving more grooves on fiber surfaces which are enhanced the binding quality of sago fiber to the epoxy matrix.*

Keywords-*liquid smoke, sago fiber, surface morphology, binding compatibility*

1. INTRODUCTION

Previous studies have tried various treatments on natural fibers, including heating with a turmeric solution, soaking in a solution (KMnO4, NaOH, H2O2, and seawater), and steaming. Changes in the physical properties of the fiber include cleaning and forming grooves by immersion in KMnO4 and H2O2, decreasing levels of coco coir lignin by immersion in NaOH.[1]. Soaking the palm fiber in seawater also reduces the lignin layer while providing a rougher surface [2],[3],[4]. The increase in the content of cellulose compounds and the decrease in the lignin content, due to heating treatment of Akaa midrib fiber with turmeric solution increased the surface strength of the fiber[5]. Changes in the surface morphology of the pineapple leaf fiber, the surface is harder and grooved, increasing the interfacial shear stress between the fiber and the epoxy matrix due to fumigation. [6]. The surface morphology of the Pineapple Leaf Fiber (KPLF) is rough and grooved, the fiber density is increased, and the tensile strength of single fibers is mainly increased at the base of the leaf after fumigation. [7]. When natural fibers are immersed in alkali (NaOH 5%), most of the layer of lignin and other non-cellulose substances on the surface is removed, making the surface cleaner, rougher and more porous. [8]. The improvement of the morphological, chemical, and mechanical properties of the fiber is strongly influenced by the liquid smoke treatment[9][10][11][12][13][14].

Of the various natural fiber treatments so far, only a few are considered eco-friendly. Meanwhile, environmentally friendly materials such as liquid smoke are unique and attractive materials for use in fiber processing. Liquid smoke is a product of the pyrolysis process of natural ingredients from coconut shell raw materials, is quite inexpensive and environmentally friendly. It has almost the same content as other natural fibers which consist of lignin, hemicellulose, and cellulose. Liquid smoke has been widely used as a wood preservative, protects wood from termites and makes it odorless because it contains tar and carcinogens. [15]. In the current application, liquid smoke is used as a natural preservative because of its phenolic and acid content that functions as antibacterial and antioxidant. Liquid smoke compounds have hydrophilic properties because the OH group molecule is classified as a polar compound with negative electrons; Therefore, it is easy to bind lignin fibers to form other compounds[9].

Fiber compounds and liquid smoke are formed during the soaking process. Lignin compounds react with liquid smoked acid, increasing the composition of elements C, H, and O in the compound. Lignin compounds on the fiber surface are easily degraded by the heating process so that they become smaller, harder, grooved and porous. Furthermore, decomposition occurs in the fiber compounds, increasing the density of element C, resulting in increased adhesion between the fibers and the matrix[13]. Therefore, this study applied the treatment of sago fiber with liquid smoke containing phenol, carbonyl, acid, and others. With its liquid content, researchers hope that sago fiber can reduce lignin, hemicellulose, and cellulose compounds while cleaning dirt, bacteria, and other substances through prolonged soaking. In addition, heating the fiber must reduce the H and O elements in the sago fiber, make the surface of the fiber wider, grooved, and porous, and improve the physical properties of the fiber. Meanwhile, the combination of soaking time and heating treatment must form an optimal surface morphology of the fiber to improve the bonding quality of sago fiber and the epoxy matrix.

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2. METHODOLOGY

Sago fiber is separated from the leaf midrib and cambium; then immersed in a liquid smoke solution for a certain period of time, as shown in Table 1.

Table 1. Study notation

No	Notation	Code	Remarks
1	Untreated	WT	Untreated
2	Treatment in liquid smoke by duration of 1, 2, 3, 4, and 5 hours, then 1 hour heating at 43℃	T1J	1 hour Immersion
		T2J	2 hours Immersion
		T3J	3 hours Immersion
		T4J	4 hours Immersion
		T5J	5 hours Immersion

The test object groups were coded and treated as listed in Table 1. After Immersion, the fibers were dried in an oven at 43ºC for one hour, then removed for slow cooling at room temperature. The fiber surface morphology of each group was then observed using a Vega3 Tescan Scanning Electron Microscope (SEM) at a voltage of 5kV, 30 kV, X-ray diffraction (XRD) 15 mA with a scanning speed of 2,000 deg/min. Compatibility and bonding quality tests are carried out by inserting a piece of fiber into the epoxy matrix. Immediately after drying, the fiber-matrix bonding was then observed under SEM microscopy and the same procedure as previously mentioned. The crystallization index (IC) was calculated according to the Segal empirical method, applying I002 as the maximum reflection intensity of the 002 grid and I101 for the diffraction intensity.

3. RESULTS & DISCUSSION

Figure 1 shows the surface morphology of the sago fibers. Figure 1a is the surface morphology of the untreated fiber while Figures 1b to 1f show the surface of sago fiber with liquid smoke treatment, resulting in grooves, porous and an increase in the surface of the coarse fiber.

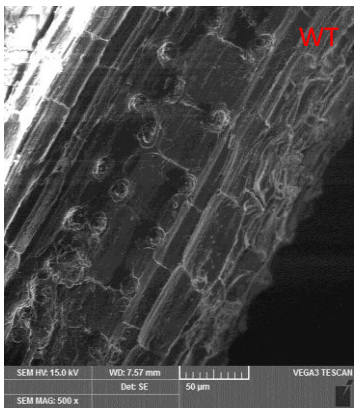

Figure 1a. The fiber surface of the untreated fiber

Figure 1a shows the surface of sago fiber without treatment is quite smooth. This indicates that the surface of the fiber is still filled with dirt; The lignin content is still abundant, coating the fiber surface. The figure shows a regular rectangular pattern on the surface of the sago fiber, which is smooth, as shown by the arrows.

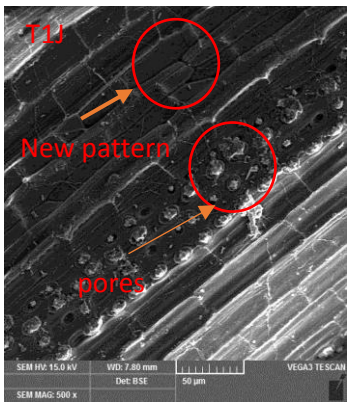

Fig. 1b. Fiber surface with 1 hours immersion

After being treated with liquid smoke for 1, 2, 3, 4, and 5 hours, as shown in Fig. 1b - 1f, each rectangular surface pattern is gradually rougher than the untreated one. The duration of the liquid smoke treatment will form roughness in the fiber.

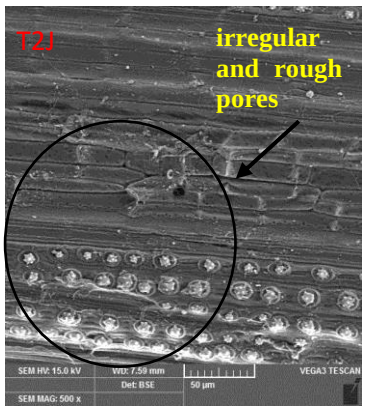

Fig. 1c. Fiber surface with 2 hours immersion treatment

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Figure 1b shows a new pattern on the sago surface; coarse and porous fiber as indicated by arrows. The altered surface identified by moat like longitudinal grooves in rectangular patterns.

The rectangular pattern of 1 hour immersion looks similar with the surface of untreated fiber. However, after 2 hours of liquid smoke immersion, the rectangular pattern becomes irregular, the direction of groove patterns were not longitudinal with cleared fiber pores as shown in Figure 1c.

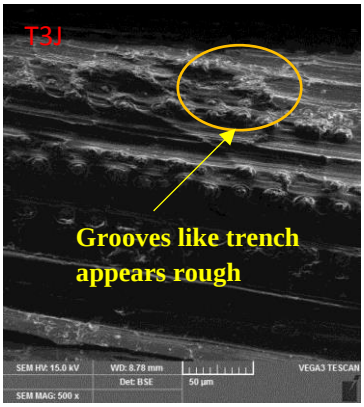

Fig. 1d. Fiber surface with 3 hours immersion treatment

The morphology of fiber surface with 3 hours immersion looks similar to the 2 hours treatment. The longitudinal patterns were still observed in the rectangular patterns along with the non-longitudinal pattern as shown in Figure 1d. The groove patterns were rougher with more porous compared to fiber with 2 hours treatment. The arrow shows coarser and pores pattern were more obvious. Although the rectangular patterns still existed after treated for 4 and 5 hours, the longitudinal paths were disappeared. In this case, the grooves become irregular and rough. The irregular pattern and larger pores were expected because it facilitates matrix compound to fill in the pattern so that it can improve the bonds between fiber and matrix and strengthened the composite bonds.

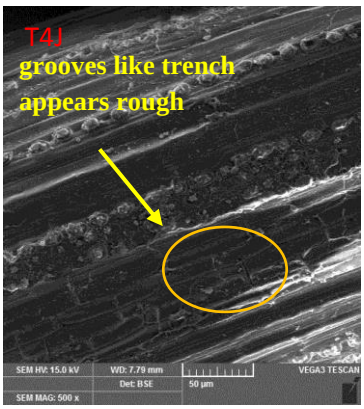

Fig. 1e. Fiber surface with 4 hours immersion treatment

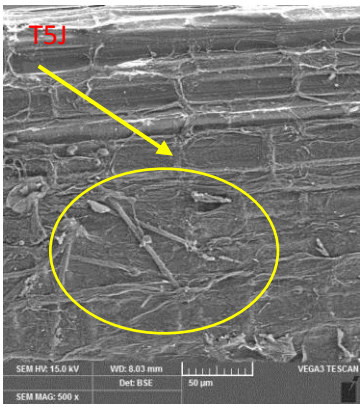

Fig. 1f. Fiber surface with 5 hours immersion treatment

Figure 1b - 1f show the coarse surface as the lignin content on fibers surface have been degraded, and the surface becomes coarse, grooved, porous and crystallized due to liquid smoke effect. Crystallization with large beads occurred on all treated fiber surfaces, whereas in Fig. 1e small crystals were firmly grouped. The liquid smoke treatment causes the surface roughness of the fiber to be very different from that of the untreated fiber. The increase in roughness was caused by the growth of lignin on the fiber surface, enriched with the composition of H and O elements in the lignin compound and the density of C bonds in the fiber, which was also found in other studies[8].

Figure 2 indicates the compatibility between fiber and matrix for all treatments. According to morphology images obtained from SEM, there was a clear difference in crystallizations occurred after fibers were treated in liquid smoke due to the presence of chemical reactions on fiber surface. Crystallization phenomenon during treatment caused by reactions among liquid smoke and fiber compounds, resulted from additional C elements on the surface of sago fibers [20]. Crystallization wraps the fiber surface and makes it stronger. Consequently, the binding between fibers and matrix become more compact compare to fibers without treatment. Coarse, pores and grooved surfaces were predominant as shown in Fig.2 b-e, which are promote the absorption of matrix, filling the grooves and pores, thus increase the compatibility of fiber and matrix. The above phenomenon indicates that immersion of sago fibers in liquid smoke have significant effect on fiber surface morphology, resulted in strong bindings between matrix and fibers.

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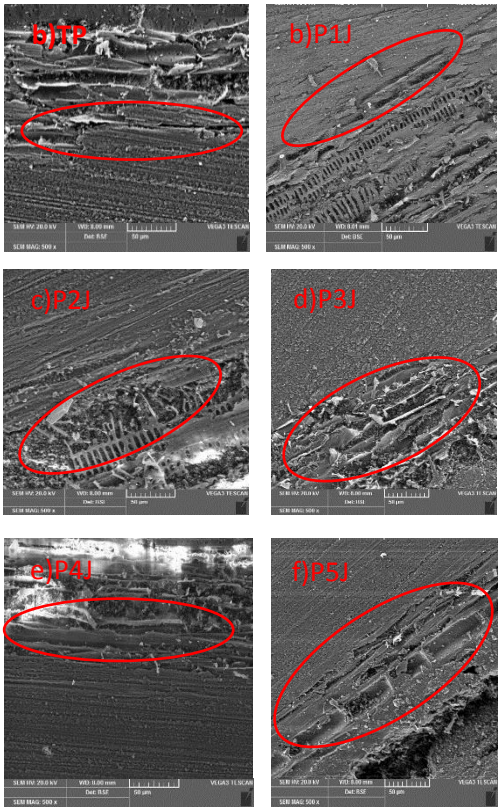

Figure 2. Observation of compatibility between fiber and matrix : a) not treated b–f) treated

4. CONCLUSIONS

The effects of sago fibers treatment in liquid smoke can be explained as follows:

1. Immersion in liquid smoke had altered the surface morphology of sago fiber to become harder, porous and grooved; effectively improved the compatibility of sago fiber and epoxy matrix.
2. Chemical reactions due to liquid smoke treatments-initiated crystallization on fiber surface and formation of groove trenches, pores, along with increasing solidity of surface roughness of sago fibers.

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