Properties of Non-Wood Plant Fiber Bundles and the Development of Their Composites

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Among the natural fibers obtained from annual non-wood plant fibers. In order to promote some plant fibers and to develop their composites, it is necessary to understand their mechanical properties. The mechanical properties of plant fibers depend on their physical, chemical, and morphological properties, such as fiber orientation, cellulose content, crystal structure and diameter/cross-sectional area of the fiber. The fiber cross-sectional area strongly influences to the evaluation of fiber strength [1]. To establish the procedure for determined of fiber cross-section area, the evaluation of the reliability of diameter measurement of fiber bundles by using optical microscope is needed. However, the methods used for determining the fiber cross-sectional area have not been fully exploited.

In recent years, chemical, thermal and physical treatments had been used for fiber surface treatment. Alkali solution and steam refining process had been used for the treatments [2][3], while only cotton fiber has been coated by chitosan solution to improve their properties [4]. However, the investigations of mild steam treatment with low temperature and steam pressure, and chitosan coated plant fiber have not been exploited.

On the other hand, the steam pre-treated exploded Miscanthus sinensis with the low temperature and steam pressure showed higher mechanical properties of binderless fiberboard than that of high temperature and steam pressure of pre-treatment [5]. However, the utilization of long fiber bundles treated with mild steam and layered with different orientation on mats have not been fully exploited.

The objectives of this study were to evaluate the method of measuring the cross-sectional area as parameter to determine of mechanical properties of plant fiber bundle. Then, the fibers were treated with alkali, mild steam and chitosan treatment to improve their properties. The oriented boards were manufactured with steam treated fibers using hot pressing system.

In order to evaluate the method for measuring of fiber cross sectional area; abaca, pineapple, sansevieria, sisal, coconut, kenaf and ramie fiber bundles from Indonesia were used as materials. The cross-sectional area of each fiber bundle was observed using a scanning electron microscope (SEM). The coefficient factor as parameter to evaluate the method of measuring cross-sectional area is defined as the ratio of the cross-sectional area determined from a representative SEM image (Sr) selected for each fiber by image analysis software, to the cross-sectional area of each fiber determined by using the circle equation (Sc) based on average value of five locations diameter measurement by using optical microscope (So).

The coefficient factor of fiber cross-sectional area was in the range of 0.92-0.96. The values of Sc shows to evaluate 4-8% lower values than those of Sr. Thereby, the coefficient factors of each fiber have little influence to evaluate So. Based on the result, So has been used directly for the determination of fiber strength [6]. In addition, ramie, pineapple and sansevieria fibers provide higher values of the average tensile strength than other fibers i.e. 849 MPa, 654 MPa and 562 MPa, respectively.

Therefore, ramie, pineapple and sansevieria fibers were treated by alkali, mild steam and chitosan solution to improve their properties. The fibers were immersed in a NaOH solution of 2% (w/v) at 95°C for 2h for alkali treatment, while for mild steam treatment; the fibers were steamed by using boiling water in the screen-covered bath at steam pressure about 0.1 MPa for 2h. In addition, the fibers were immersed to 4% and 8% chitosan solution at room temperature for 2h. Degree of crystallinity, crystallite size and crystallite orientation of fibers were determined by x-ray diffraction method.

The fiber after steam treatment showed the higher value of degree of crystallinity than untreated and alkali treatment. The steam treatment for all fiber provided a higher value of crystallite orientation than untreated and alkali treated fibers. It was observed that the steam treatment for all fibers gave slightly higher value of crystallite size than untreated and alkali treated fibers. Alkali and steam treatments remove a certain amount of wax and oils covering the external surface of the fibers and its surface become slightly smoother than untreated fiber, and the monofilament can be visible. On the other hand, the chitosan 4% was more uniformly covered on the fiber surfaces than the chitosan 8%. Steam-treated and chitosan 4%-coated ramie fiber provides higher values of the average tensile strength than other fibers i.e. 892 MPa and 875 MPa, respectively. The decrease in tensile strength and Young's modulus of alkali treated fibers was probably due to the decrease in the degree of crystallinity and crystallite orientation [7]. In addition, high water absorption causes the swelling of cellulose fibers, resulting poor mechanical properties. This fact also may attribute to fiber damage.

Furthermore, in order to utilize the steam-treated ramie, pineapple and sansevieria fibers, each fiber were used on board manufacturing. Phenol–formaldehyde resin solution was chosen for impregnation and adhesive purposes. The uni-oriented direction (0° fiber orientations) board and cross-oriented direction (90° fiber orientations) board developed from the untreated and mild steam-treated fibers with a target density of 800kg/m^3.

The result showed that the internal bond of oriented boards increases when the fibers treated with mild steam. The high internal bond was 1.33 MPa for uni-oriented steam-treated sansevieria board and the lowest one was 0.45 MPa for cross-oriented untreated pineapple board. The boards made from steam-treated fibers provided higher properties in modulus of rupture (MOR) and modulus of elasticity (MOE). The uni-oriented boards showed higher average values of MOR and MOE compared to cross-oriented boards. The high values of MOR and MOE were 403 MPa and 39.2 GPa for uni-oriented steam-treated sansevieria boards (Fig. 1). The differences for board MOR and MOE were found mainly due to the differences on the ratios of fiber substances on board to density of fiber bundles [8]. Based on the results of this study, when the ratios of fiber fraction to fiber density are one, it was calculated that: the values of the MOR parallel to the fibers of the uni-oriented boards without adhesives reach 80% of the fiber's strength. Mild steam treatment of fibers imparts the dimensional stability of boards. The dimensional stability of steam-treated boards has been increased compared to untreated board.

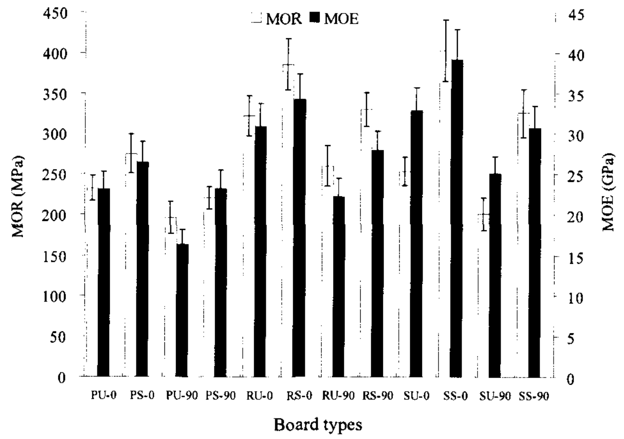

Fig. 1. MOR and MOE parallel to the fiber of the boards. PU-0, uni-oriented untreated pineapple board; PS-0, uni-oriented steam-treated pineapple board; PU-90, cross-oriented untreated pineapple board; PS-90, cross-oriented steam-treated pineapple board; RU-0, uni-oriented untreated ramie board; RS-0, uni-oriented steam-treated ramie board; RU-90, cross-oriented untreated ramie board; RS-90, cross-oriented steam-treated ramie board; SU-0, uni-oriented untreated sansevieria; SS-0, uni-oriented steam-treated sansevieria; SU-90, cross-oriented untreated sansevieria; SS-90, cross-oriented steam-treated sansevieria.

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