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Tensile Strength and Fracture Behavior of Single Abaca Fiber

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ABSTRACT

An experiment device has been designed and fabricated to investigate the tensile strength and fracture behavior of Abaca fiber. The single fiber with a nominal length of 30 mm was pulled with a loading rate of 0.46 N/s. Results shows that the tensile stress of the fibers failure ranges from 56 MPa to 1118 MPa. This result was estimated from the breakup diameter of the fiber, assuming it has a circular cross sectional area. The fiber's failure can be classified into two types; uniform failure at cross section and non-uniform failure initiated by partial tearing of the fiber segment.

1. Introduction

Natural fibers in engineering applications are rapidly gaining popularity because of their environmental advantages such as renewable and reducing waste. Natural fibers such as jute, flax, hemp coir, and sisal are found to produce good reinforcement in thermoset and thermoplastic matrices and are being used in automotive applications, construction as well as in packaging industries [1].

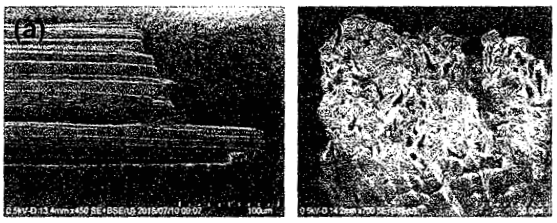

Figure 1 SEM images of Abaca single fiber (a) and its cross sectional area (b).

As a composite material, one of the most important factors determining the strength is individual's fiber strength. This is particularly due to a wide distribution in individual Abaca's strength caused by the non-uniformity of the fiber's width and length. This difference could cause wide distribution of the tensile strength of the composite, restricting the application of the composite in wider engineering application especially in those subjected to loading rate variation. The mechanical properties of the fiber composite are also affected by the physicochemical properties caused by fragment height in the fiber stem [2]. To date, the mechanical properties of single abaca fiber have not been much elaborated yet. Therefore, in this study, the tensile strength and fracture behavior of single abaca fiber, shown in Figure 1, are evaluated. As the results, a standard deviation for the tensile strength of single abaca fiber can be determined and their fracture behavior can be elucidated.

2. Methodology

An experiment apparatus for investigating the tensile strength of single Abaca fiber has been designed and used, as shown in Figure 2. The apparatus consists of an electric motor, an xyz stage, a linear guide, specimen holders, and a cantilever spring equipped with a strain gage.

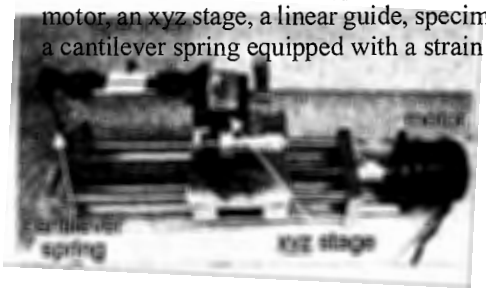

Figure 2 Abaca single fiber tensile test experiment setup

A single broken fiber is shown in Figure 3(b). The specimens considered for the tensile stress analysis were those broken at a location between x and x', as indicated in Figure 3. The specimens broken at other location were excluded because the failure could be resulted by causes other than the tensile force.

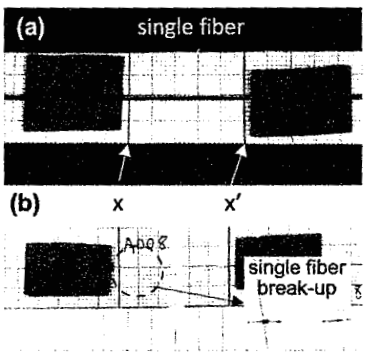

Figure 3 Abaca single fiber specimen (a) and specimen after tensile test showing the fiber break-up failure (b)

In a tensile test, the single fiber specimen, Figure 3(a), is installed at the specimen holder and aligned using the xyz stage. The fiber is pulled as with a loading rate of

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0.46 N/s. The pulling force, N is acquired by using a strain gage connected to a data acquisition system. The tensile force, N, is calibrated from the deflection of the cantilever spring.

3. Results and Discussion

Several results of tensile tests are shown in Figure 4. It is shown in this figure that the single fibers broke at various tensile force ranging from 2.8 N to 9.8 N. The data were acquired with a sampling frequency of 1 kHz. In order to evaluate the tensile strength, it is necessary to evaluate the nominal area of the fiber's cross section at break-up location. In this analysis, the cross sectional area of the single fiber is estimated by measuring the fiber width at break-up location, as shown in Figure 5, assuming the cross section area is in circular shape. Measurement for the real area of the cross section requires individual evaluation of each fiber's cross section in an SEM chamber to achieve a more precise value of the tensile strength.

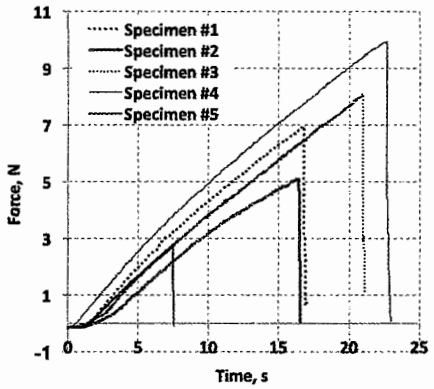

Figure 4 Several results of abaca fiber tensile test

A total of 36 specimens have been tested and the results are summarized in Figure 6. The fiber broke at the tensile force ranging from 2.19 N to 10.46 N, resulting in the maximum tensile stress at failure ranging from 56 MPa to 1118 MPa. The evaluation of the real cross sectional area at breakup point will be conducted to achieved a more representative value of the tensile strength. The number of specimens will be increased up to 100 specimens to achieve a statistically representative value of the tensile strength. Weibull analysis method will be used for the analysis.

Figure 5 shows the fracture behavior of fiber specimens Nos. #1, #2, #3, and #4 indicated in Figure 4. The fiber failed in various manners but in general it can be classified into two main groups; uniform failure across the section and non-uniform failure involving prior break-up or tearing of fiber segments. A uniform fiber failure across the section is shown in Figure 5(c) while non-uniform failure of the fiber is shown in Figure 5(a), (b), and (d). The width of the analyzed fibers ranges from 81 μm to 263 μm. Microscopic observation reveals that uniform failure occurs for thinner fibers. However, a more detail analysis is still required to understand the fracture mechanism. One of the causes for non-uniform failure is the existence of weak point [2], as indicated in Figure 1(a).

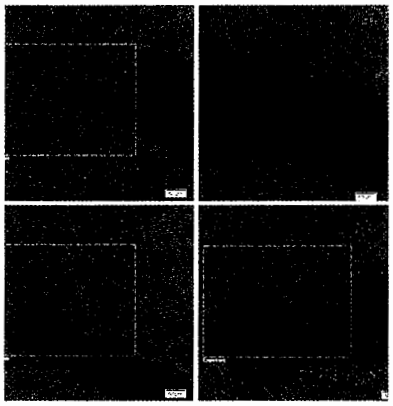

Figure 5 The fibers' width of several specimens

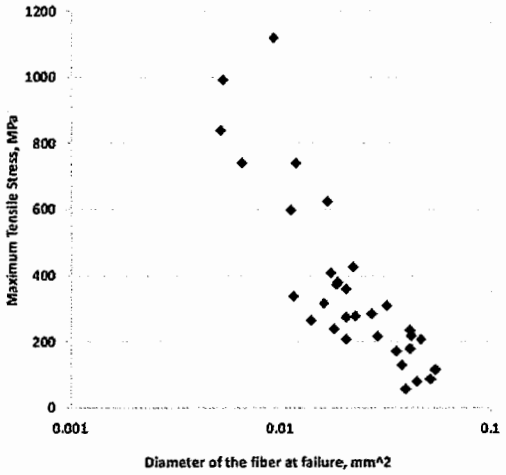

Figure 6 Tensile strength of the abaca fiber

4. Concluding Remarks

A tensile test experiment setup has been used to evaluate the tensile strength of the single abaca fiber. It is found that the tensile stress of the fiber at failure ranges from 56 MPa to 1118 MPa. Further analysis is still required to determine the Youngs modulus, clarify the failure mechanism, and investigate the resin-fiber bonding strength.

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