Scanning Electron Microscopy Morphology Failure Analysis of Rattan Fibers

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ABSTRACT

Today, rattan yarns are developed in the furniture industry because they are readily available, inexpensive, harmless to health, and biodegradable to the environment; hence, by utilizing it as a hybrid composites fibre, it will be able to resolve the environmental problem in the future [1,2]. The development of rattan yarns as composite materials is quite well recognized, considering the availability of natural fiber (rattan) raw materials in Malaysia and Southeast Asia. This study was carried out to get a technical examination of the tensile strength of rattan yarns fibre composites using polyester resin as the matrix.The goal of this study is to determine the tensile strength composite of rattan yarns fibres that influences the diameter of the fibres from 1 mm to 5 mm maximum. For varied angles of cross section area, single fibre bundles were studied using a scanning electron microscope for fractography study, which revealed comparably heterogeneous ruptures linked with more existence of microfibrils. Tensile tests were performed at different diameters (1–5 mm) and gauge lengths consistently at 5 mm/min to assess the effects of diameter and gauge length on tensile properties. The tensile strength (310 MPa) and Young's modulus (7.4 GPa) of rattan yarn fiber at 5 mm width showed the highest value compared to the others. The tensile strength and Young's modulus increased with the increase of width of rattan fiber bundles.

Keywords: *fiber diameter, morphology, mechanical properties, Young's modulus, tensile strength*

1. INTRODUCTION

Natural fibres offer excellent mechanical properties, are renewable, ecologically benign, and cost-effective. As a result, they've gotten a lot of attention in recent decades as polymer matrix composite reinforcements. In recent years, significant number of research are carried out on natural fiber composites including jute [3-5], kenaf [6-9], pineapple [10-12], sisal [13,14], hemp [15-17], coir [18-20], henequen [21, 22] fiber as reinforcement in composites. However, study on rattan fiber based epoxy composites is limited. Therefore, the specialty of this study is to explore the new sources of natural fiber. Rattan, a plant abundantly available in Malaysia or other neighboring country is investigated in this paper for making natural fiber composite. The mechanical properties of rattan fiber composites are for the possible structural application such as ceiling sheets, partitioning board and wall or floor tiles. The ability to accurately and reliably quantify the tensile strength of natural fibres using a practical approach is thus critical for comparing different types of fibres and predicting the mechanical properties of their composites.

In this article, morphology and lamination bonding between single fibre rattan fibers and the epoxy are discussed. The rattan yarns from the species of Calamus caesius supplied by AFR Craft Enterprise address Plot A, Mile 7, Bukit Gedong, Tg.Kling, Melaka while the resin supplied by Chemibond Enterprise Sdn. Bhd, Petaling Jaya, Selangor was used to validate the method, and the results of the measurements are reported. This study emphasize on the objectives to evaluate the morphology and lamination bonding between single fibre rattan fibers and the matrics bonding. Although some progress has been made towards rattan fibre, further research is needed in the upgrading potential rattan fibre especially from the family of Calamus caesius. Customarily, Calamus caesius has been utilized by rural community for making baskets, mats, and crafted works. The circular cane, skin peel and hyperbolic shape give significantly critical high-quality materials for the very advanced rattan furniture fabrication. Commonly use for tide and reinforcement for bigger diameter rattan canes. The tone of the rattan influenced by components such as age, dampness substance and the light conditions during development [23-27]. The prototype sample for this study includes the original structure from the natural composite of rattan fibre.

2. METHODS OF MICROSTRUCTURE AND FRACTURE ANALYSIS

A scanning electron microscope (Leo Supra, 50 VP, Carl Zeiss, Germany) was used to examine the microstructure of rattan fibre bundles and shattered fibres following tensile testing. Using secondary electrons and a beam voltage of 15 kV, scanning electron microscopy examination was conducted on silver palladium sputtered samples and an operating pressure of 1 Pa. The cross-sectional area was calculated from the diameter of the fibre to get the tensile strength. The fibre bundle's cross-sectional area was estimated by measuring the diameter of the bundle and assuming that the fibres were completely semi cylindrical and homogeneous along their length. The effective cross-sectional area was calculated by using the Equation 1:

$$A = d^2 . \theta \text{ (radian)} / 4 \quad (1)$$

where, A is cross-sectional area, π. θ = 180^0, and d is the diameter of the fiber.

A. Tensile Test

Tensile properties (Young's modulus, tensile strength, and elongation at break) of the rattan fiber bundles were tested according to ASTM D3039 standard by using an Instron 5969 Widespread Testing Machine equipped with a 50 kN load capacity at room temperature (23^0C). This test conducted as per ASTM D3039 assurance. The cross section views of rattan fiber specimen is shown in **Figure 1**. The thickness is 1 mm and thw width is 5 mm. The fiber was loaded at a constant crosshead displacement rate of 100 mm/min until rupture. A total of 30 samples for each diameter of fiber tested. Mechanical properties like tensile strength, Young's modulus, and elongation at break are presented in Table 1. Rattan fiber at 5 mm width showed the highest tensile strength and Young's Modulus, while, rattan with 1mm width showed the lowest value for both the properties. Meanwhile, tensile strength for rattan fibers at 2 mm were second highest after 5 mm which was 23.279MPa. Fibers with higher cellulose content and lower microfibrillar angle have higher mechanical characteristics, however cellulose content was not perfectly associated with measured strength of natural fibres [28,29].

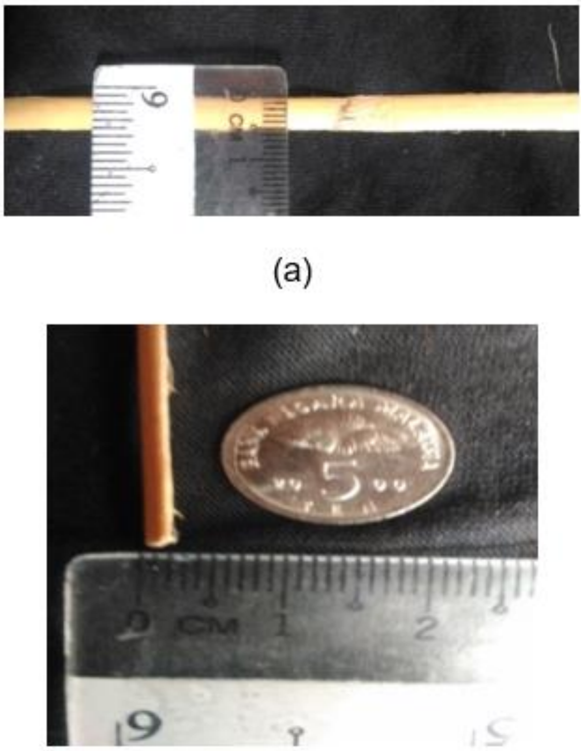

Figure 1: Rattan yarn from (a) plan view and (b) side view

B. Fracture Analysis

The fractography examination using scanning electron microscopy (SEM) of tensile-ruptured fibres is shown in **Figure 2**. The fracture mechanism of rattan fibre revealed a fibre pullout failure mode with relatively heterogeneous rupture linked with more microfibrils. It is important to note that microfibrils are made up of cellulose chains and are the most powerful component of the fibre bundle. As a result, the relative number of microfibrils (cellulose composition) and lignin determines the strength differential between fibres. It is also influenced by the spiral angle of the microfibrils around the fibre axis. A thicker fibre

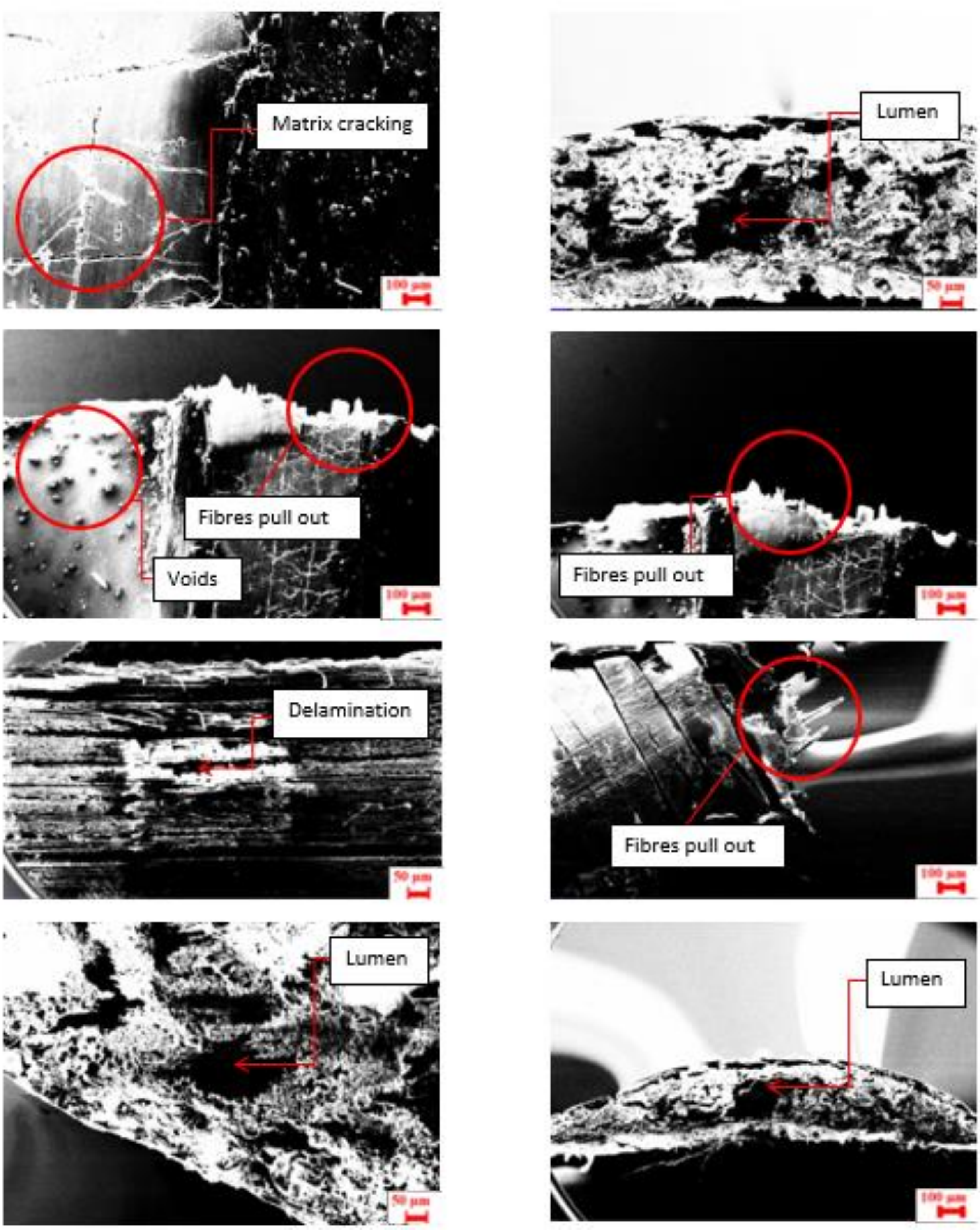

Figure 2: The SEM image of single rattan fibers that illustrates the irregular shape of rattan fiber by which the optical magnification observation of cross setion could depending on what angle the fiber was looked up.

with more microfibrils had a more even distribution of weaker and stronger microfibrils [33]. As a result, the weaker microfibril in the broader fibre may break at lower stress than the weaker microfibril in the narrower fibre. When the weakest microfibril is broken, the fibre structure is weakened. The defect may behave as a microcrack, propagating rapidly in a brittle mode till final rupture. Furthermore, various fibre cells do not shatter at the same stress level, which might be owing to the presence of cell wall flaws along the fibre length, which produces stress intensities that eventually lead to failure [34].

C. Sputtering plasma Paladium Coating

In this study, the sputtering machine brand Quatron model SC7620 uses magnetron sputter head with a simple-to-replace disc target Electrical safety interlocks are included into the sputtering head, which is hinged. The system may be switched between sputter coating and glow discharge modes through a panel-mounted switch. The plasma current may be controlled by adjusting the vacuum level with an argon leak valve, while the plasma voltage is fixed. The gas injector mechanism guarantees that argon gas enters the chamber near to the plasma discharge, ensuring optimum sputter coating efficiency. The SC7620 is also intended for coating specimens prior to inspection in tungsten filament SEMs. [35]. For conducting SEM in this study, a silver coating is necessary on surface of breakage samples. To interact with the bombarded electron beam, a conducting surface is necessary otherwise the interaction of the electron beam with the sample surface electron will be very poor. Then only the images can be magnified into desired zooming. In Figure 2, the fibres are magnified between 50 µm to 100 µm. There were failures of bonding include matrix cracking, delamination, fibres pull out and voids as the residues and debris might fluctuating in the air during experiment.

D. Rattan Fiber Surface Morphology

The morphologies of the rattan composite samples found that the structure was formed by several bundles of elementary or ultimate cells overlapped and bonded together by lignin along the bundle length. **Figure 3** shows the sample of rattan embedded with unsaturated thermoset resin made of ApoxiAmite consist of fiber bundles used in this study. This rough and uneven surface provides good adhesion to polymer matrix of composites by providing good fiber-resin mechanical interlocking [30]. From this study, the effect of rattan fiber diameter on tensile properties was positive correlation between tensile strength and fiber diameter, i.e., tensile strength increased with the increase of rattan fiber diameter. The relationship was statistically significant for most of the cases (**Figure 4**).

Figure 3: Composite sample for tensile test

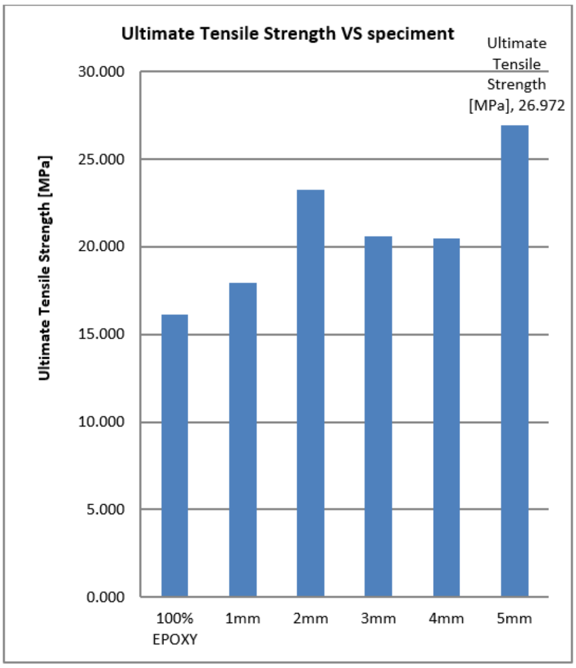

Figure 4: Tensile strength based onrattan width respectively

Due to its difficulty in determination, the lumen is not commonly used to calculate cross-sectional area, and the fibre bundle is assumed to be a perfect cylinder, which may introduce some inaccuracies when calculating tensile properties [31]. The origin, maturity, species, and extraction procedures all influence the interior structure and characteristics (chemical composition and mechanical properties) of lignocellulosic fibres. In addition, test circumstances, microfibril angle, and the density of weak links or defects all influence fibre strength. [32]. Lumen exists in some part of rattan fibre as shown in **Figure 2**.

3. CONCLUSIONS

The microstructure and tensile characteristics of single rattan fibres of five different widths were studied and assessed for use as reinforcement in polymeric composites. Fiber bundles had a semi-circular form and were made up of a bundle of ultimate fibres linked together in a thermoset epoxy resin matrix. The width range of varied between 1-5 mm, respectively. Single fibre in 5 mm width showed the highest tensile strength and Young's modulus while the highest elongation was observed for 2 mm. With increasing width and gauge length, mechanical characteristics of fibres showed rising trends. The brittle behaviour of fibres, as well as fibre dragged out with microfibril debonding on the surface of fibre fracture, were demonstrated using SEM fractography. The overall mechanical characteristics of the fibres were higher than in earlier research, which might be due to a variety of factors such as plant age, location, and environment. As a result, this analysis of different fibre widths will aid in optimising the manufacturing process and selecting the best end use. SEM picture of a single technical fibre showing splitting and misalignment of primary fibres.

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