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Interfacial Shear Strength of Polylactic Acid-Kenaf Fibre Biocomposites

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Abstract. This paper reported the interfacial shear strength (IFSS) between kenaf fibre (KF) and polylactic acid (PLA) matrix which was measured using microbond tests device. The value of IFSS obtained in PLA-KF is comparable to other polymer with natural fibre reinforcements. The properties of single kenaf fibre was determined from tensile tests and also described in this paper. From single kenaf fibre properties, various mechanical properties can be estimated for various applications.

Introduction

Mechanical performances of biocomposite materials are strongly depend on the properties of the reinforcement fibre and matrix. Excellent properties of each constituent can be transferred from one phase to another if the interface between fibre and matrix is good. Up to-date research on micromechanical and interfacial adhesion of natural fibre and biodegradable matrix are rarely studied until recently reported by Le Duigou and coworkers [1] on flax fibre and PLA matrix. They reported that interfacial region is very complex and can be performed at various scale levels including nanoscopic, microscopic and macroscopic.

Investigation on surface adhesion between single fibre and matrix can be divided into two groups, namely direct and indirect methods [2]. Examples of direct methods comprises of fragmentation [3], Broutman test [4], fibre push-out [5], fibre pull-out and microbond test [6-8]. Indirect methods consist of conventional mechanical testing and acoustic emission. There are various parameters that can be evaluated during characterization of the interface such as the effect of matrix chemistry, fibre surface treatments, and fibre diameter on the behavior of composite materials [7]. Day and Cauich Rodrigez [8] found that the position of the grips which support the microdroplet is important and affects the interfacial shear stress distribution. In addition, they also suggested using two droplets where one of these will be restrained while the other will be displaced.

The purpose of this paper is to investigate the applicability of microbond tests and to determine the surface adhesion of kenaf fibre and polylactic acid matrix by adopted test method developed by Morlin and Czigany [2]. Single kenaf fibre properties has been determined and also reported in this paper.

Experimental

Materials. Polylactic acid, PLA (3051D) used for the experiment was obtained from Nature Works Ltd. The kenaf bast fibre was supplied by Kenaf Natural Fibre Industries Sdn. Bhd. (Kelantan, Malaysia) in the form of long fibre and was harvested at 6 months aged.

Microbond Test. Microbond test is a method which is used to measure interfacial shear strength between fibre and matrix. Microbond tests were conducted using a microbond device and fixed onto the Zwick 005 tensile tester. The device contains of two steel blades that can be positioned with micrometers. The role of the steel blades is to support the droplet and hold them during the debonding process as shown in Fig. 1.

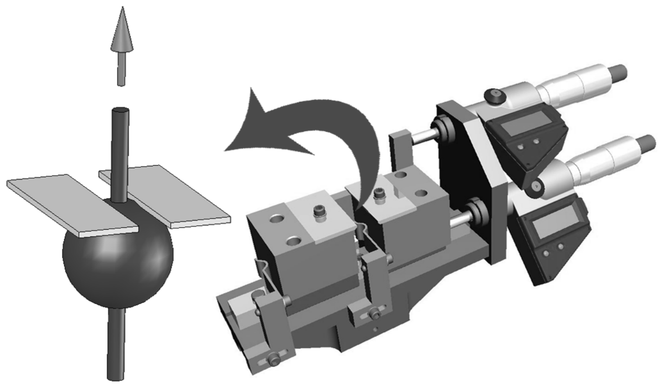

Fig. 1 Schematic diagram shows microdroplet test arrangement.

A microdroplet of PLA is placed onto the kenaf fibre, and then, the diameter of the microbond (D), length of the microbond (L_0) and diameter of kenaf fibres (d_f) were determined using optical microscope (Olympus BX51) attached to photo-camera (C-5060). Fig. 2 shows photomicrograph of kenaf fibre with PLA matrix droplet. Forty specimens were prepared for the microbond tests. Assuming shear stress is constant along the interface, the average values of interfacial shear strength were calculated by using Equation 1. From the microbond tests, the maximum force (F_{max}) was measured during the pull-out of the fibre.

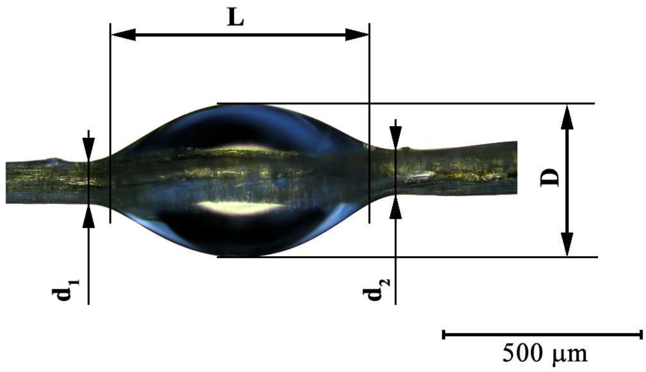

Fig. 2 Kenaf fibres with PLA matrix droplet.

$$\tau = \frac{F_{max}}{d_f \cdot \Pi \cdot L_0} \qquad (1)$$

Single Kenaf Fibre Test. Single fibre test was used to measure the strength and stiffness of the single fibre. This test was carried out using Zwick Z005 tensile tester with 20 N load cell and strain rate used was 0.5 mm/min. Initial length of kenaf fibre based on window frame was 25 mm as shown in Fig. 3. Thirty samples were prepared and tested.

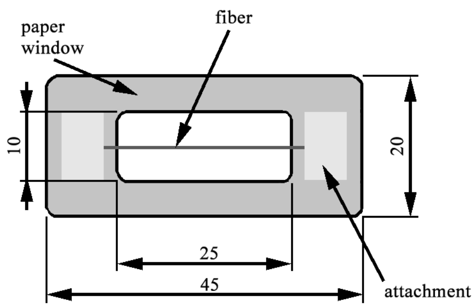

Fig. 3 Window frame used in the preparation for single fibre tests.

Results and Discussion

Microbond Tests. Microbond test was carried out to measure the interfacial adhesion between kenaf fibre and polylactic acid. Details of the diameter of kenaf fibre, dimension of microdroplet, and force needed for pulling-out fibre from the matrix are tabulated in Table 1. It is noted that the force recorded during microbond tests were varied in a wide range. The average interfacial shear strength is 5.41 ± 2.23 MPa. The data obtained is comparable to PP-flax, PP-hemp and PP-sisal as reported by [2]. Tensile strength of the PLA matrix is 63.3 MPa. Hence, interfacial adhesion normalized to the tensile strength of the matrix is 8.55%.

Force-displacement curve of single kenaf fibre and PLA matrix is shown in Fig. 4. Debonding has occurred at maximum force, F_{max}, followed by drastic failure which assign to breakage of the fibre. At the end of microbond tests, friction of fibre-matrix occurred due to uneven and bump surfaces of the kenaf fibre. Generally surface of kenaf fibres are naturally rough and the dimension were inconsistent. Peak in Fig. 4 was due to the debonding of the kenaf fibre and droplet. After kenaf fibre and PLA droplet has debonded, the droplet starts to move on the fibre.

Table 1 Interfacial shear strength according to Equation (1).

	Kenaf Fibre	Microdroplet		Force, F	Interfacial Shear
	Average Diameter, d_f (mm)	Diameter, D (mm)	Length, L (mm)	(N)	Strength, IFSS (MPa)
1	0.18	0.60	0.95	2.71	5.06
2	0.13	0.52	0.92	2.89	7.81
3	0.07	0.45	0.50	0.93	5.23
4	0.14	0.63	1.07	1.88	4.09
5	0.11	0.36	0.44	0.67	4.55
6	0.07	0.32	0.51	0.28	2.62
7	0.09	0.33	0.40	0.95	8.65
8	0.15	0.39	0.74	0.67	1.87
9	0.04	0.24	0.32	0.32	7.27
10	0.11	0.38	0.71	1.72	6.91
				Average	5.41
				Standard Deviation	2.23

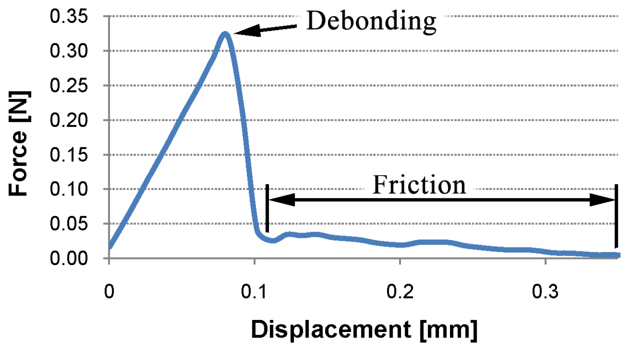

Fig. 4 Force-displacement curve obtained from microbond tests for single kenaf fibre.

Single Kenaf Fibre Test. Single kenaf fibre tests were carried out to characterize stress and elongation at break of kenaf fibre. Table 2 shows properties of single kenaf fibre. Typical force-displacement curve obtained from single kenaf fibre test is shown in Fig. 5. Properties of single kenaf fibre are very useful to predict theoretical values of tensile properties and compare to the true values obtained from experimental. Density of kenaf fibre measured is 1.13 g/cm^3 [9]. Hence specific tensile strength and modulus are 117.30 MPa/g/cm^3 and 9.89 GPa/g/cm^3, respectively.

Table 2 Properties of single kenaf fibre determined from single fibre test.

Force (N)	0.72 ± 0.32
Elongation at Break (mm)	0.39 ±0.13
Strain at Break (%)	1.56 ± 0.53
Tensile Strength (MPa)	132.55 ± 18.80
Tensile Modulus (GPa)	11.18 ± 2.44

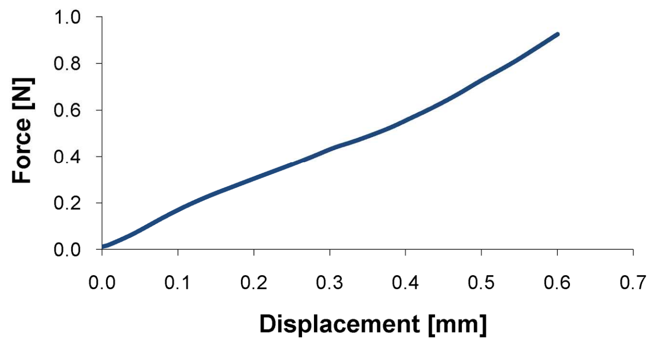

Fig. 5 Typical tensile curve obtained from single kenaf fibre tests.

Summary

The micromechanical properties of PLA-KF biocomposite was investigated using microbond tests. Interfacial shear strength of PLA-KF is 5.41 ± 2.23 MPa. From single fibre tests, tensile strength and tensile modulus of single kenaf fibre are 132.55 ± 18.80 MPa and 11.18 ± 2.44 GPa, respectively.

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