A Method for Directly Measuring the Interfacial Shear Strength between Short Plant Fibers and Thermoplastic Polymer

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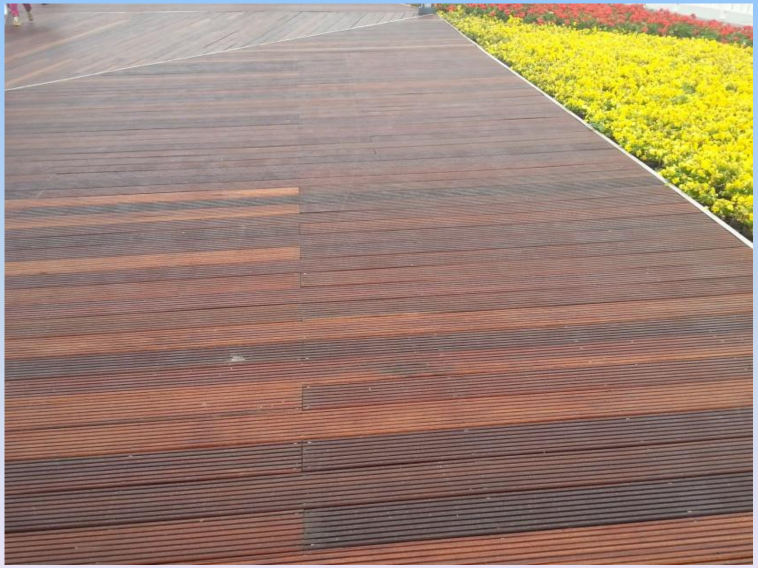
1. Background

● **Plant fiber reinforced thermoplastic polymer composites (PFRTPC) are attracting global interests, especially in the automobile and construction industries.**

● **A problem is the inherent weak interface bonding between the hydrophilic plant fibers and the hydrophobic thermoplastic polymers.**



1. Background

- **Interface improvement:**

✓**Physical approaches:** **Corona treatment; Plasma treatment; Mercerisation; Heat treatment;**

✓**Chemical approaches:** **esterification-based treatments; silane coupling agents; graft copolymerisation; treatments with various chemicals.**

- **How to evaluate the effect of interface improvement?**

✓**The change of bulk properties before and after treatment;**

✓**Time-consuming and sometimes produces inconclusive results.**

1. Background

- **Interfacial shear strength (IFSS) is one of the most direct indicators for evaluating the interfacial properties between fiber and matrix polymer in a composite.**
- **Several micromechanical techniques, such as single fiber pull-out test, push-out test, fragmentation test, microbond test, have been developed for IFSS measurement.**

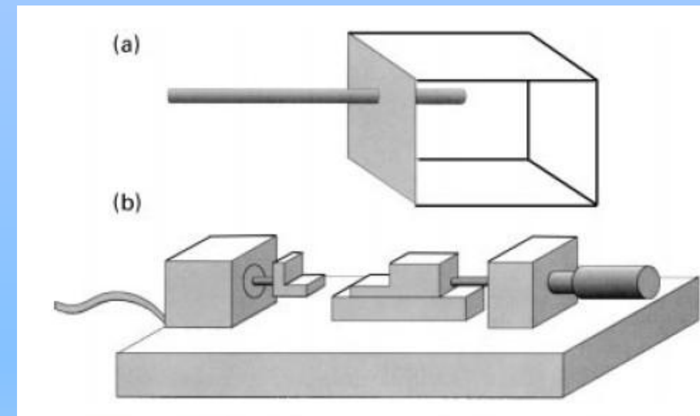
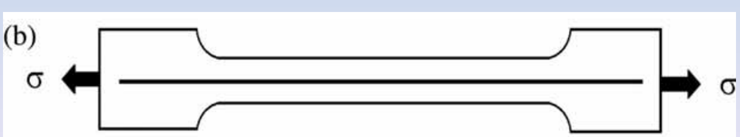
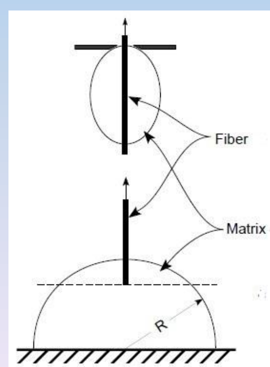


Fig. 1. (a) Single fibre pull-out specimen. (b) Schematic drawing of the loading rig.

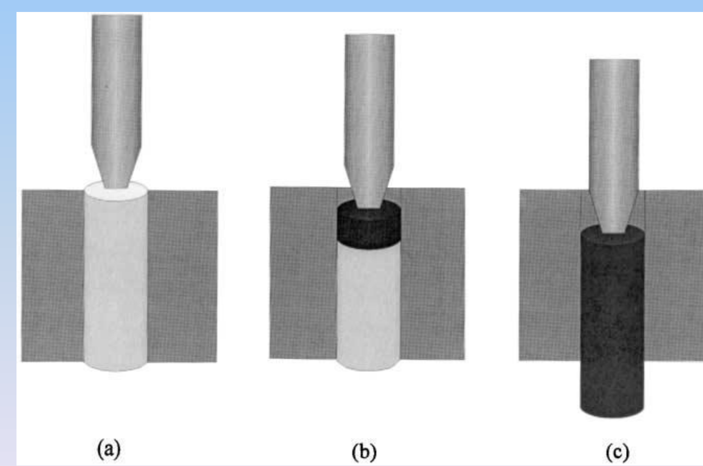
(So et al. 2001)



Franco and Gonza´lez, 2005



Nairn et al 2001



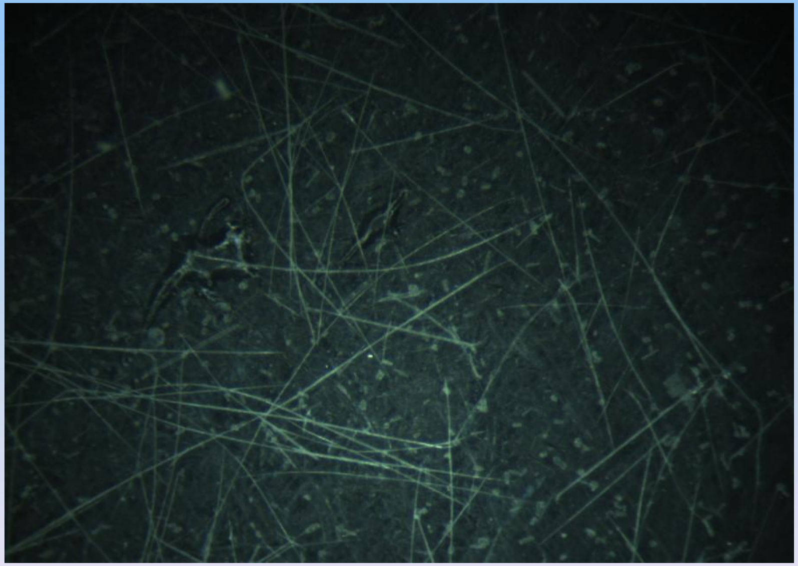
(Zhou et al 2001)

1. Background

- The above mentioned techniques are mainly used for composites reinforced by long synthetic and natural fibers;
- We propose a novel method to directly and quantitatively measure the IFSS between single short plant fiber (wood, bamboo fibers) and thermoplastic polymer;
- This method is principally the same as the well-known "fiber pulling out" methodology;
- As a case study, the IFSS between bamboo fibers and polypropylene (PP) was measured and the effect of embedment length of fiber in the plastic matrix was investigated.

2. Materials and Methods

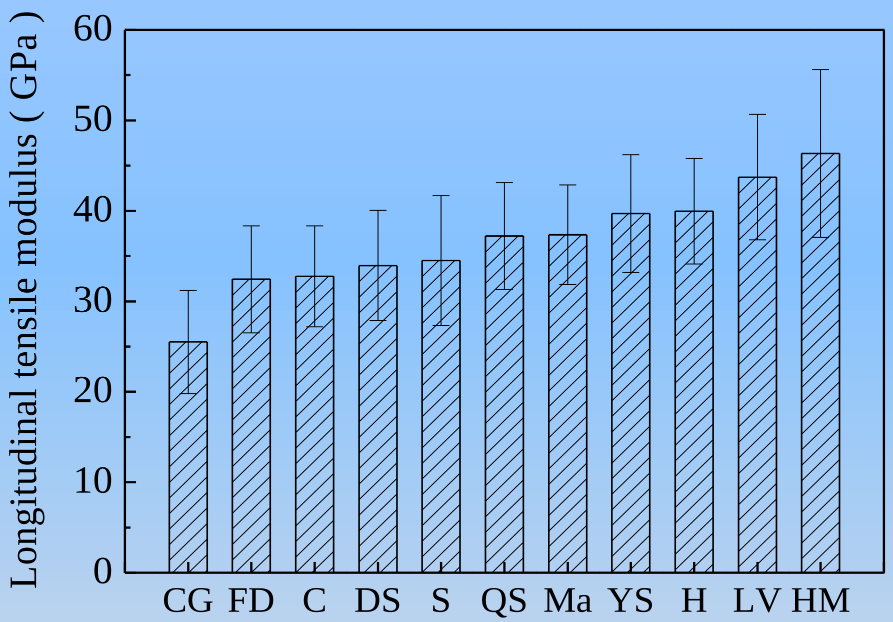
- **Moso bamboo fibers: Chemically macerated with a mixture of hydrogen peroxide and glacial acetic acid;**
- **Polypropylene(PP matrix): melting point 165° C; density 0.905 g cm^{-3}; 10 mm (width) × 25 mm (length) × 0.5 mm (thickness).**

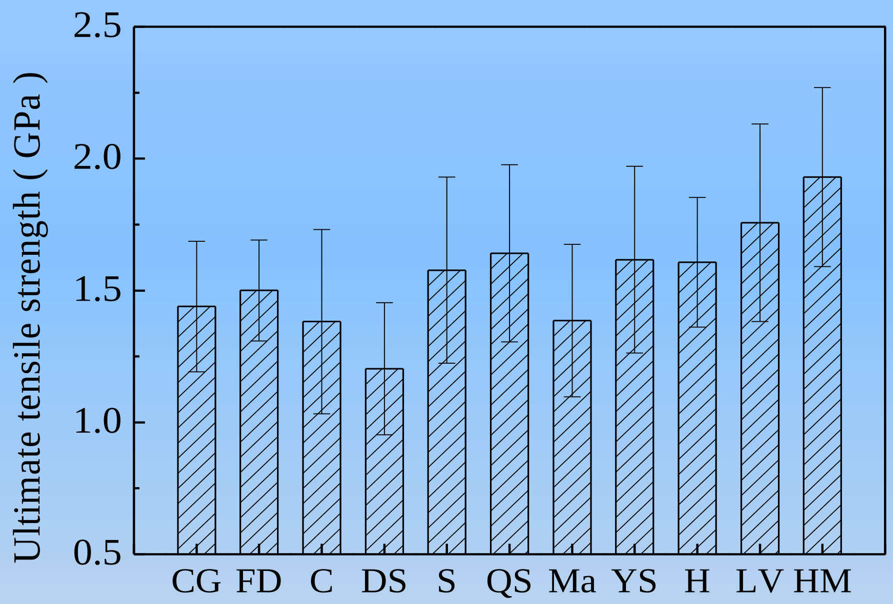


2. Materials and Methods

A commercial microtensile tester combined with a custom-built fiber griping system was used to measure the IFSS. This instrument was initially developed for measuring the mechanical properties of single short plant fibers, such as those found in bamboo or wood.

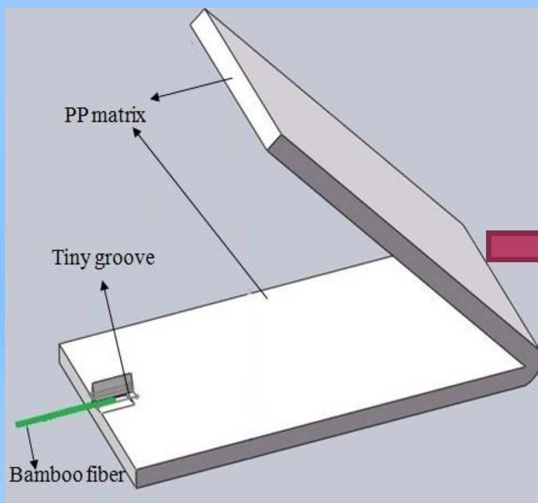
2. Materials and Methods

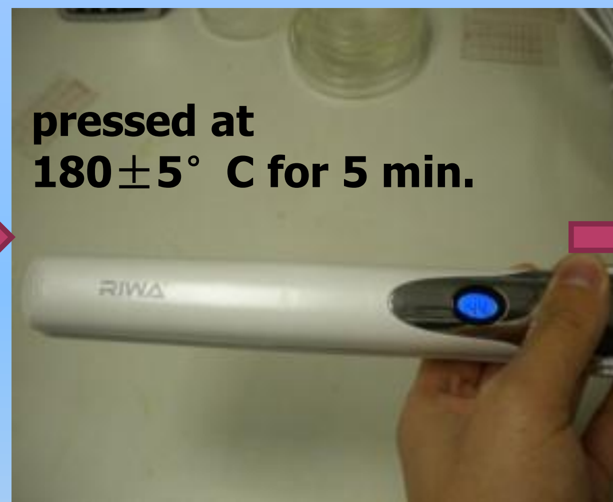


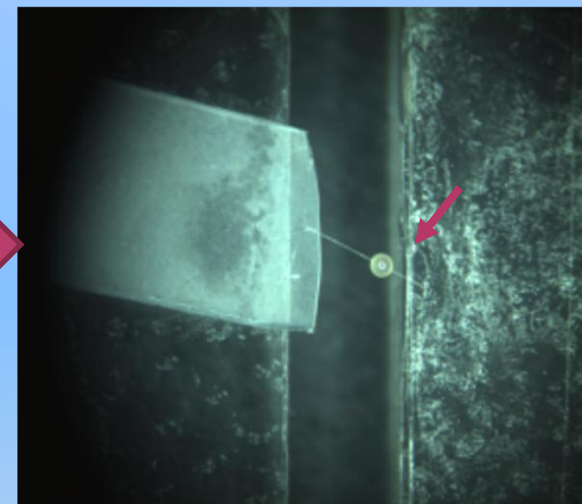


The histogram of (A) tensile modulus (B) tensile strength of 11 kinds of bamboo fibers

2. Materials and Methods





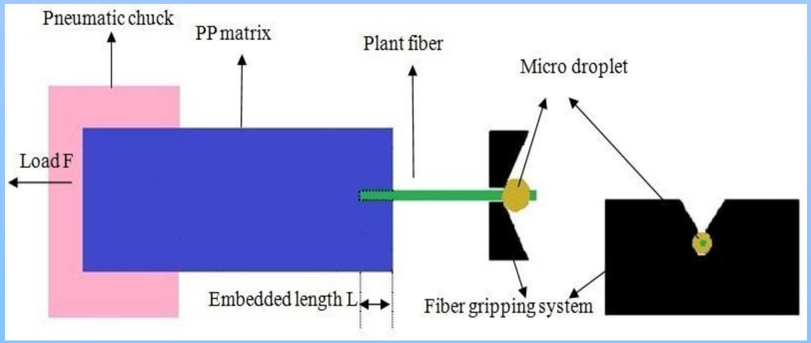


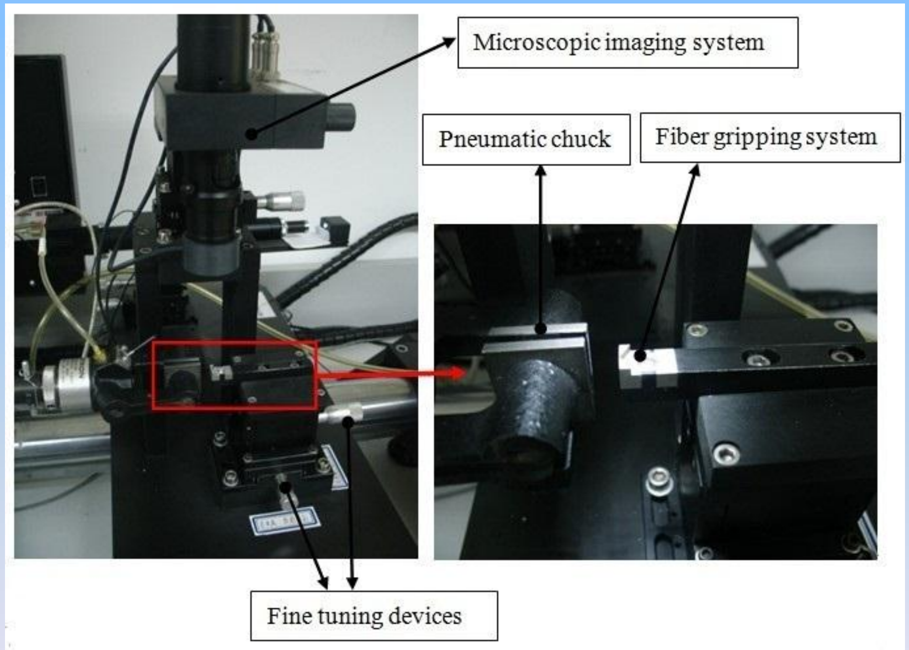
Procedure for sample preparation

The whole assembly was pressed in a small hot-pressing device at 180±5 ℃ for 5 min.

An epoxy microdroplet, approximately 200 μm in diameter, was then placed at the free end of the fiber with an ultrafine tweezers

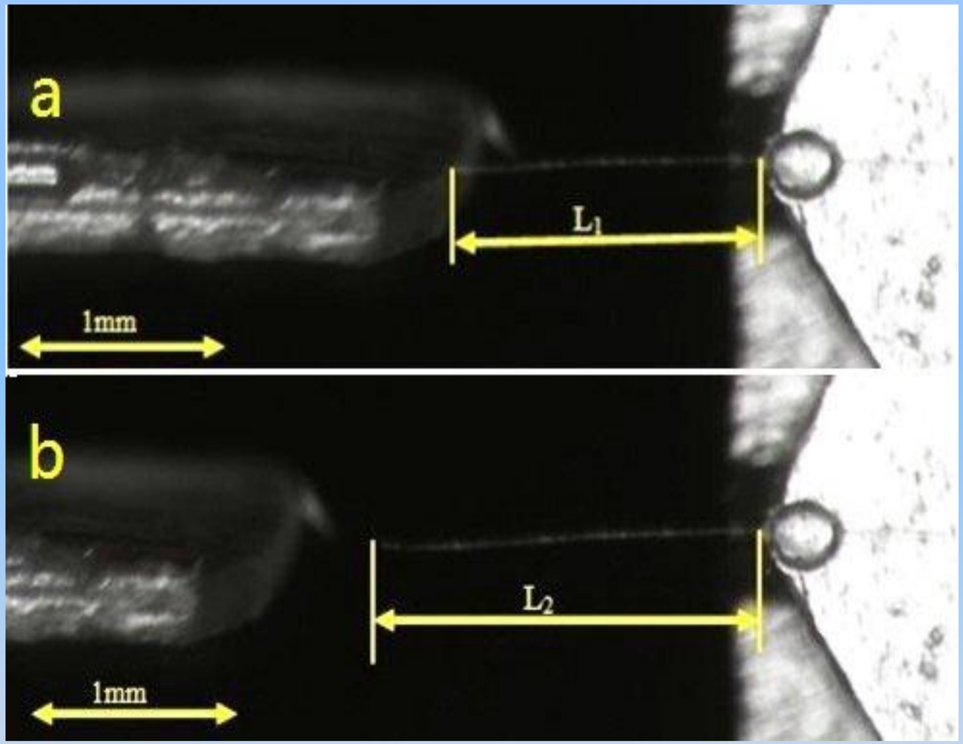
2. Materials and Methods

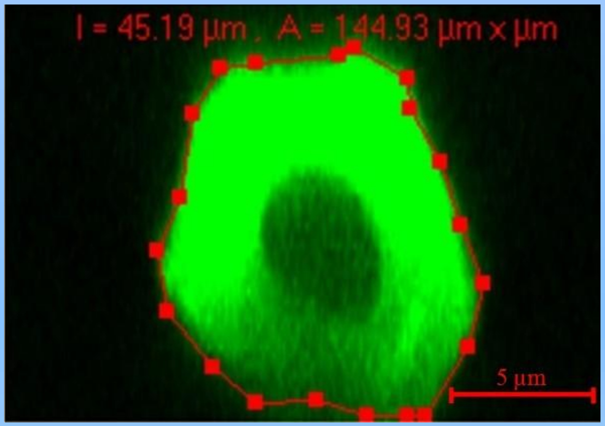




Schematic drawing showing how a single bamboo fiber pull-out test is performed

2. Materials and Methods

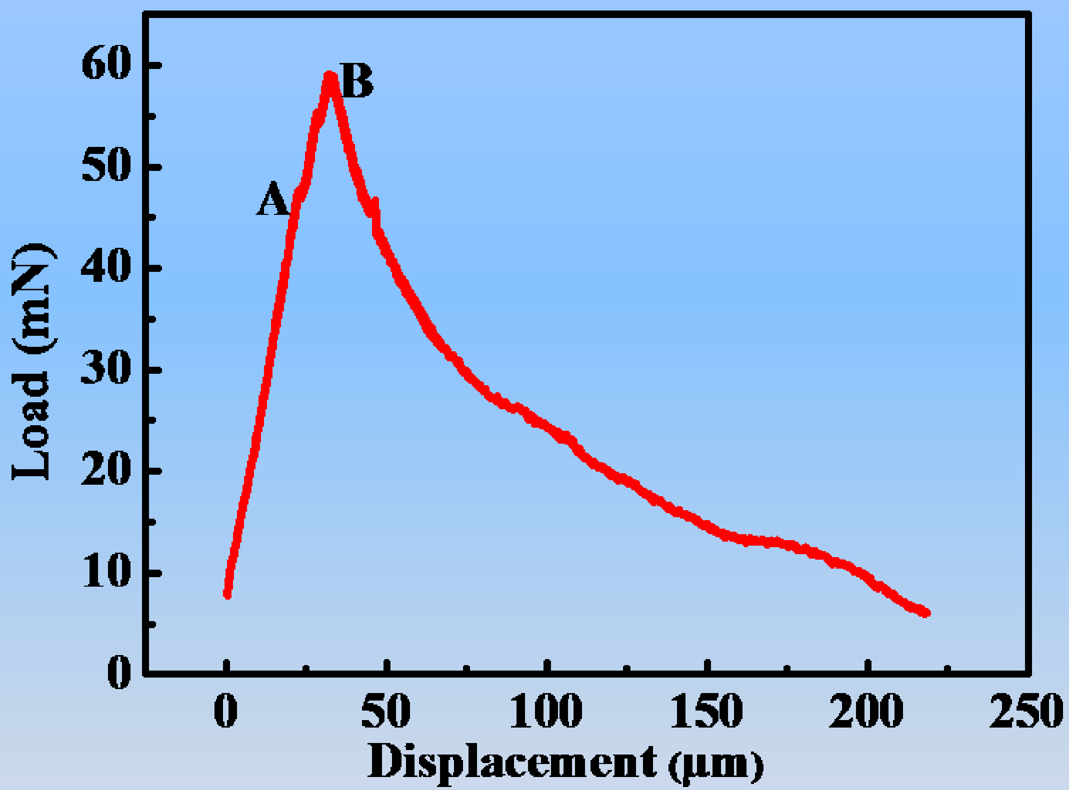




The interfacial shear strength (IFSS) was calculated using the following equation:

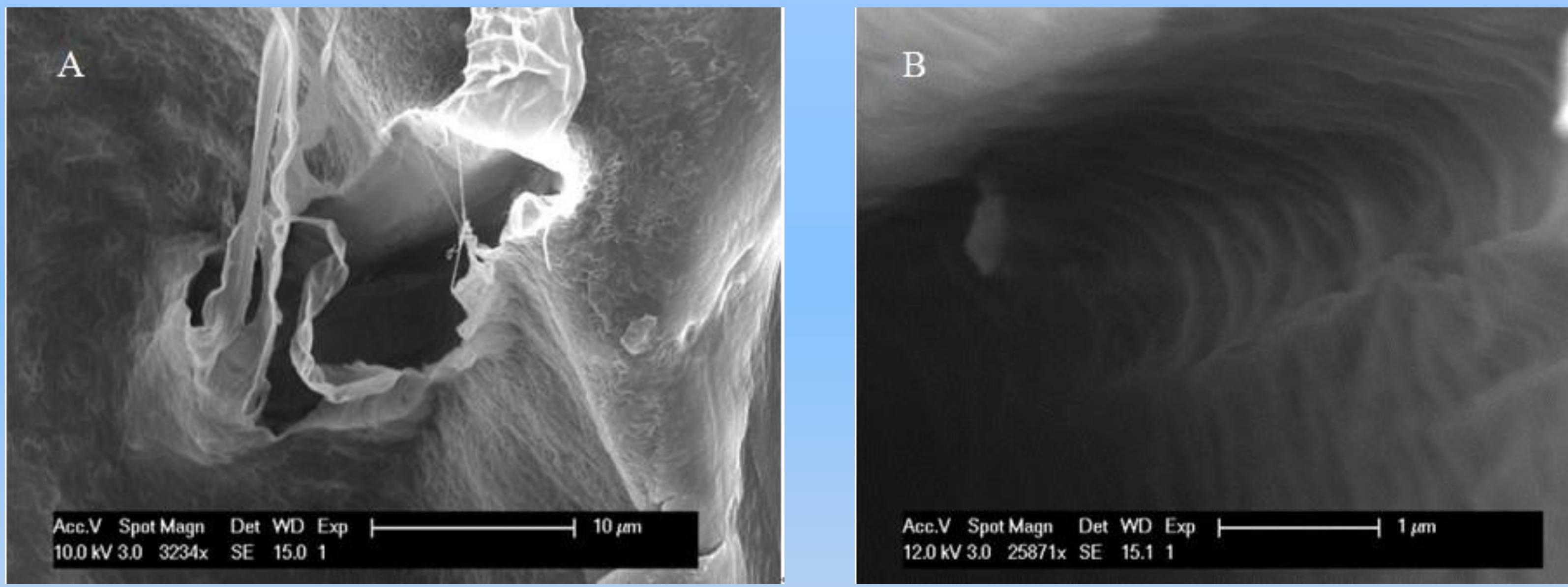
$$IFSS = \frac{F}{l(L_2 - L_1)}$$

3. Results and Discussion



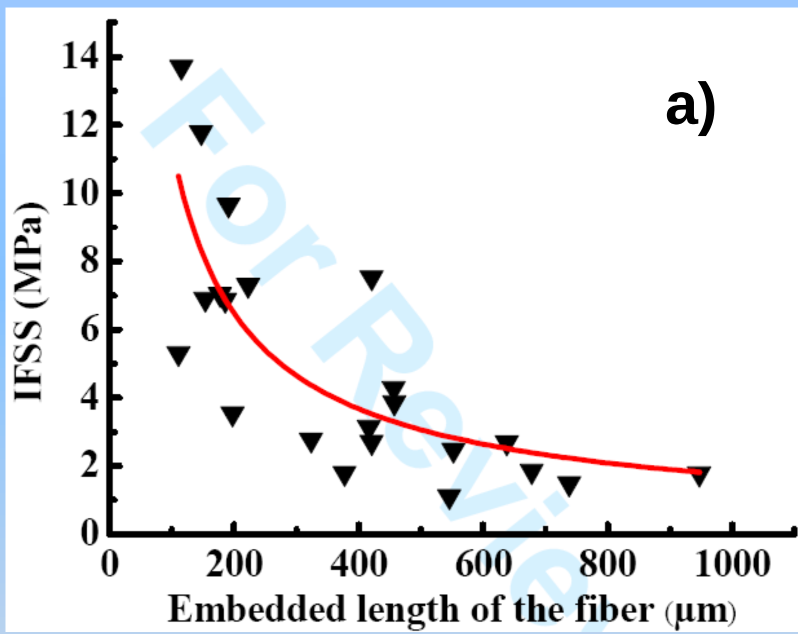
The typical single fiber pull-out curve: Load vs. displacement.

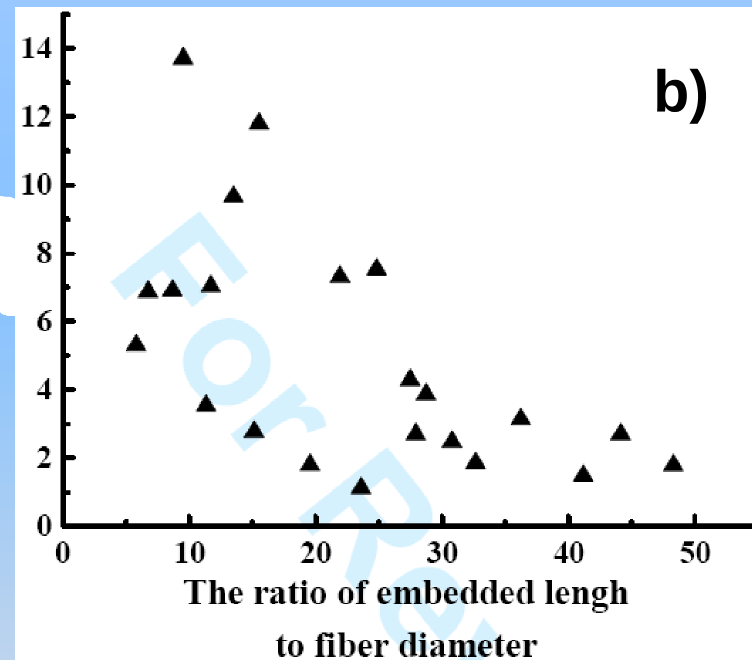
3. Results and Discussion



SEM micrographs: (A) the cavity left in the PP matrix after extraction of the fiber; (B) the inner surface of the cavity

3. Results and Discussion



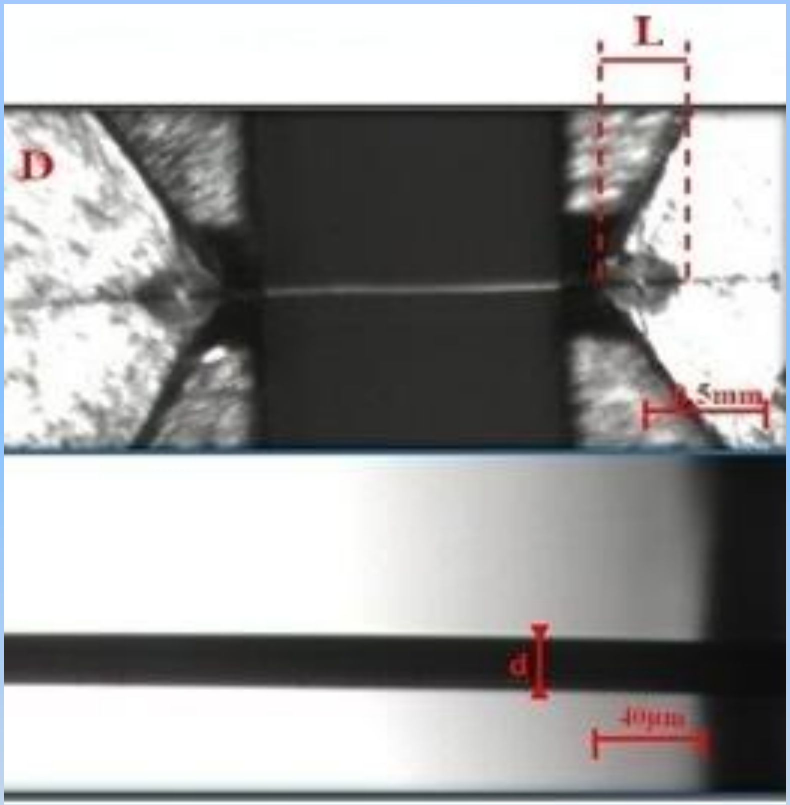


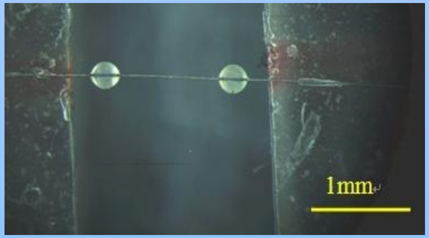
The relationship between the interfacial shear strength (IFSS) and the embedded fiber length (a) and the ratio of embedded length to fiber diameter (b).

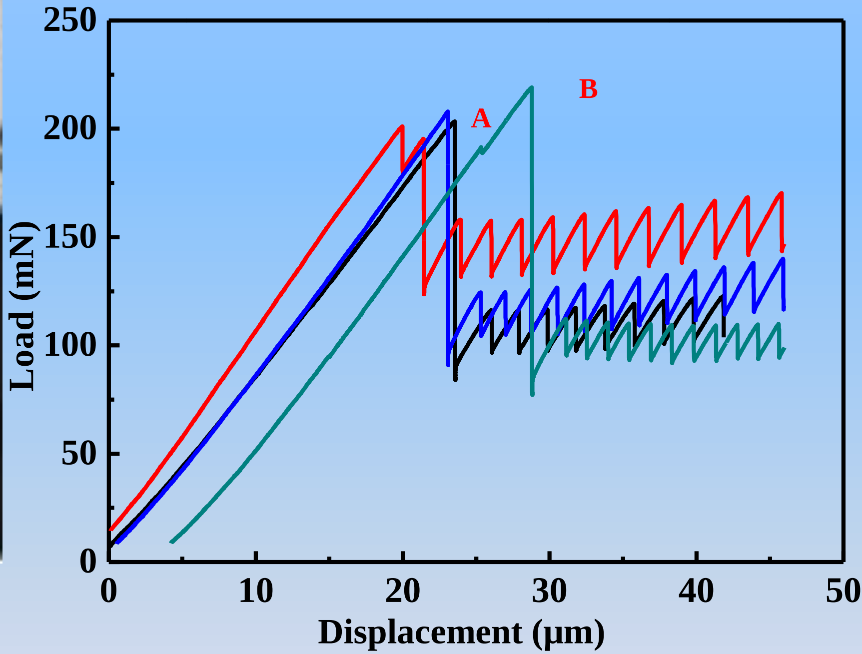
4. Conclusions

- **The single fiber pull-out test method developed in the present study is useful for a direct quantitative measurement of the interfacial shear strength (IFSS) between single plant short fibers (PSF) an thermoplastic polymer ;**
- **The IFSS between a single Moso bamboo fiber and PP matrix varies between 13.7 MPa and 1.1 MPa with an average value of 5 MPa.;**
- **The scattering data are attributable to the huge variation in the embedment length of fibers in the matrix. Moreover, the fiber diameter and sample quality also influence the results. Accordingly, these parameters has to be taken into account for the judgment of interface bonding quality.**
- **The reliability of the pull-out test method must be further improved.**

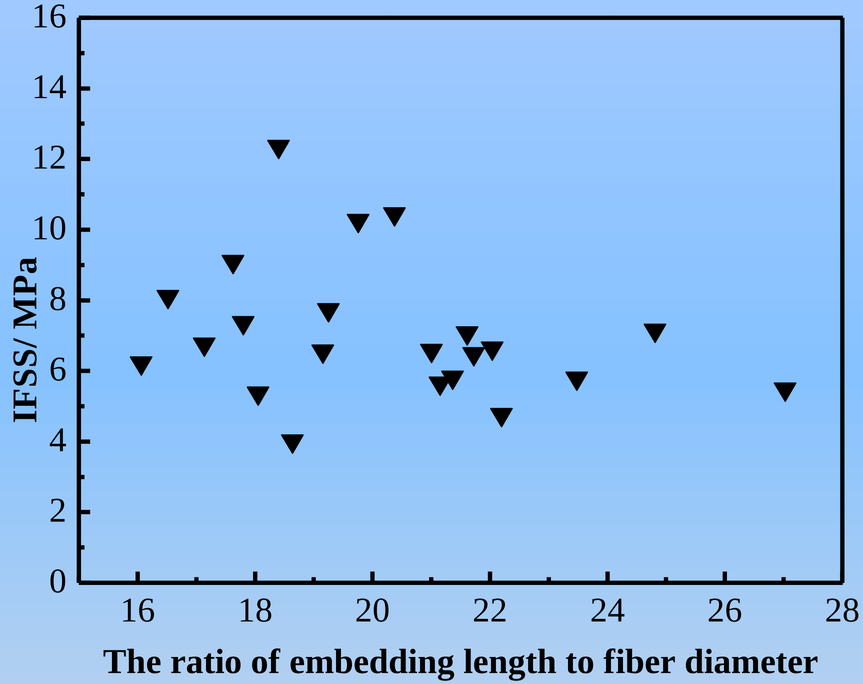
Additional information







Recently, we further demonstrated that this method is highly efficient in measuring the IFSS between carbon fibers and epoxy resin.



	L (μm)	d (μm)	IFSS (MPa)
Max	503.6	22.62	12.36
Min	360.5	16.72	4.01
Average	419.2	20.85	7.08
SD	41.9	1.51	1.98
COV （%）	10	7	28

Relationship between IFSS and the ratio of embedded length to fiber diameter.

Statistical results of IFSS between carbon fiber and epoxy polymer

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