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Mechanical and thermal properties of sodium silicate treated moso bamboo particles reinforced PVC composites

WANG Hui, SHENG KuiChuan*, CHEN Jie, MAO HaiLiang & QIAN XiangQun

School of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou 310029, China

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The main objective of this research was to study the potential of sodium silicate modification on moso bamboo particles as reinforcements for thermoplastic. Moso bamboo particles were modified with sodium silicate aqueous solutions (of 0.5%, 1%, 2%, 5% and 10% concentrations). The mechanical properties of sodium silicate treated moso bamboo particles reinforced PVC composites (BPPC) were calculated and compared with raw bamboo particles filled samples. The thermal characteristics of the BPPC were studied to investigate the feasibility of sodium silicate treatment on moso bamboo particles. The particle morphology and BPPC microstructure were investigated by scanning electron microscopy. Results showed that the tensile strength and modulus of elasticity of the BPPC increased before the concentration of sodium silicate solution reached 5% and got their maximum values of 15.72 MPa and 2956.80 MPa, respectively at 5% concentration. The modulus of rupture obtained the maximum value of 27.73 MPa at 2% concentration. The mechanical curve decreased as the concentration of solution went higher. Differential scanning calorimetric analysis illustrated that the sodium silicate solution treated BPPC possesses a better compatibility. More uniform dispersion of moso bamboo particles in PVC matrix was obtained after the sodium silicate treatment. Hence, the sodium silicate was a feasible and competitive agent of creating moso bamboo particles reinforced PVC composites.

composites, moso bamboo particles, polyvinylchloride, mechanical properties, thermal property

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1 Introduction

There has been a fast growing interest in using natural fibers as reinforcements in resin matrix composites in recent years. Among many of the natural fiber fillers, bamboo was one of the most promising ones, for moso bamboo is of low cost, light-weight and short growth cycle [1, 2]. Study of bamboo fibers as reinforcement of plastics composites has been reported [3–7]. In spite of the advantages of bamboo particles reinforced plastics composites, they also suffer form lower modulus, lower strength and relatively poor moisture resistance. For bamboo fibers are polar and hydrophilic in nature and plastics are nonpolar and hydrophobic, the incompatibility of bamboo and plastics lead to poor adhesion and resulted in poor mechanical properties of the composites [8–14].

One of the most effective methods to enhance the adhesion between the bamboo fibres and matrix was to modify the surface of the bamboo fibres. Some alkali treatment, like NaOH, plays the critical role of removing lignin by means of alkaline cleavage of ether linkages in the lignin [15, 16]. As our research group reported, sodium silicate solution also demonstrates alkali characteristics and it can enhance the water resistance of moso bamboo particles reinforced PVC composites [17]. However, few reports have been done to

*Corresponding author (email: kcsheng@zju.edu.cnng; hwang@zju.edu.cn)

evaluate the integrated effect of sodium silicate as surface modifier of natural fibers, especially the flexural properties of sodium silicate modified bamboo PVC composites.

In this study an attempt was made to prepare bamboo particles reinforced PVC composites using sodium silicate as the particles surface modifier. The mechanical properties of bamboo particles reinforced polyvinylchloride composites (BBPC) such as the tensile strength and the flexural strength upon different treatments were reported, and the DSC and SEM were taken to illustrate the role of sodium silicate treatment in modifying the mechanical properties, thermal properties and fiber-matrix compatibility of the BPPC.

2 Materials and methods

2.1 Materials

Dried sawdust of bamboo was from Lin'an, Zhejiang Province and ground to 200–400 μm with a hammer mill. PVC was obtained from Shanghai Chlor-Alkali Chemical Co., Ltd as polymer matrix.

2.2 Surface modification and composite fabrication

Moso bamboo particles were soaked in the sodium silicate solutions (of concentrations 0.5%, 1%, 2%, 5% and 10%, respectively) at room temperature (20°C and a relative humidity of 65%) for 15min. Then they were washed in very dilute acid to remove the nonreacted sodium silicate solution. Washing was continued with distilled water until the fibers were clean. The washed fibers were then dried in a blast drying oven at 75°C.

The composites were fabricated with a self-designed mould with a size of 152 mm×152 mm×*h* mm (*h* was the thickness of BPPC). The fabrication technique was according to our previous research [18], Bamboo particles were mixed with PVC at a weight proportion of 7:3, and then moulded in a sulfide molding machine (GT-7014-A50C, GOTECH). The mould was preheated at 170°C for 3 min, and pressed at 180°C at a pressure of 10 MPa for 5 min.

2.3 Mechanical properties test

Composites with treated and untreated fibres were tested for their strengths and modulus in a CMT4503 (SANS, Shenzhen, China) machine. Tensile strengths and the flexural strengths of the samples were tested in accordance with ASTM D638 and ASTM D790, respectively.

2.4 Thermal analysis

The differential scanning calculating (DSC 200F3, NETZSCH) equipment was used to test the thermal property of raw bamboo particles and BPPC. A heating rate of 15°C/min and a sample weight of 3–4 mg in an aluminum crucible were used in a nitrogen atmosphere.

2.5 Scanning electron microscopy study

The scanning electron micrographs of the fracture surfaces of the samples were taken with SEM (SIRION-10, FEI). The impact fracture surface was coated with a 20-nm thick gold layer.

3 Results and discussion

3.1 Mechanical properties of BPPC

Figure 1 listed the tensile strengths (TS), modulus of rupture (MOR) and modulus of elasticity (MOE) of all the specimens that were tested, wherever the results of more than one specimen were available. The standard deviations obtained were also included in the figure.

The tensile strength of BPPC increased before the solution reached the concentration of 5% and then decreased. At the concentration of 5%, the tensile strength of the BPPC got a maximum value of 15.72 MPa. The MOR of the BPPC of bamboo particles treated with sodium silicate generally went higher till it reached its highest value of 27.73 MPa when the concentration was 2%, and, after that this value decreased. It was also worth mentioned that the MOR of BPPC treated with sodium silicate decreased at a 0.5% concentration and obtained a lower value of raw bamboo particles reinforced PVC composites. The MOE of the BPPC increased in the whole before it reached the best MOE of 2956.80 MPa at 5% concentration. The MOE of the BPPC treated with sodium silicate was 3 times higher than that of the original bamboo particles. As the concentration went even higher, the MOE of the BPPC reduced.

3.2 Thermal analysis

Differential scanning calorimetry (or DSC) is a technique

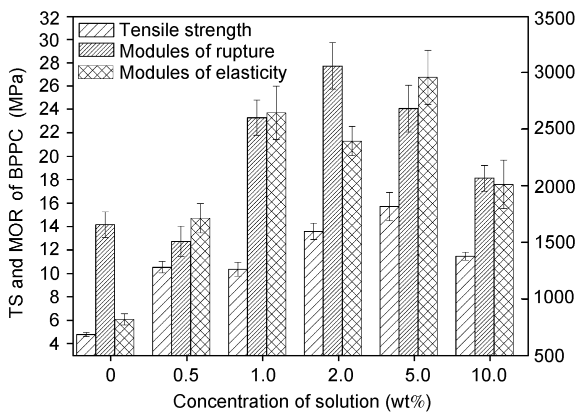

Figure 1 Mechanical properties of bamboo-particle-reinforced PVC composites.

one uses to study what happens to composites when they are heated. The DSC curves obtained for untreated and sodium silicate treated jute fibres reinforced PVC composites were presented in Figure 2. The untreated moso bamboo particles reinforced composites showed two melting peaks in the calefaction process, which conformed parts of PVC (183°C) and cellulose (153°C) crystalloid. While after sodium silicate treatment, the melting peak of cellulose disappeared and the value of PVC peak reduced and just one peak was detected at 180°C, which meant that cellulose and PVC compounded. This phenomenon indicated sodium silicate improved the compatibility between cellulose and PVC. We can conclude that the BPPC treated with sodium silicate possessed a better compatibility in this study.

3.3 SEM analysis

SEM pictures of the fractured surfaces of modified and untreated moso bamboo particles reinforced PVC composites specimens were shown in Figures 3(a), (b). The SEM photograph of the fractured surface of raw moso bamboo particles reinforced PVC composites (Figure 3(a)) indicates poor adhesion between bamboo particles and the PVC matrix. Large spaces of moso bamboo particles were also found at the points where the particles were crossing. It could be assume that moso bamboo particles were bound with each other and a bad compatibility between moso bamboo and PVC matrix was obtained. Hence, the raw fiber was not well interlocked with PVC, and the interfacial adhesive in between them was therefore poor. On the contrary, one could see from Figure 3(b) that the surface of the composites was modified compared with the original one, with the removal of outer cellular layer, and that the internal structure of composites was exposed and prominently rough upon solution treatments. The particles became more disorder and easier to be compatible with PVC granule. Thus better mechanical properties were thus obtained after sodium silicate solution modification.

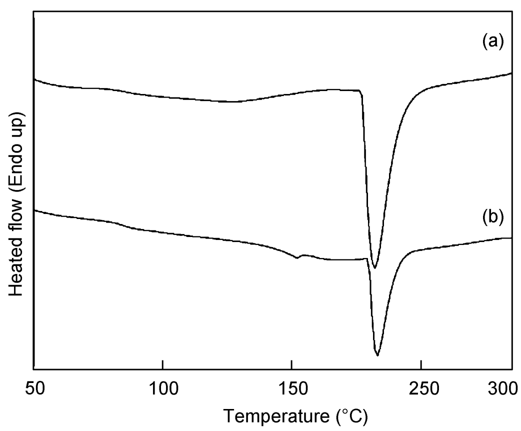

Figure 2 DSC characteristics of bamboo particles reinforced PVC composites. (a) Untreated; (b) treated by 5% Na_2SO_3 solution.

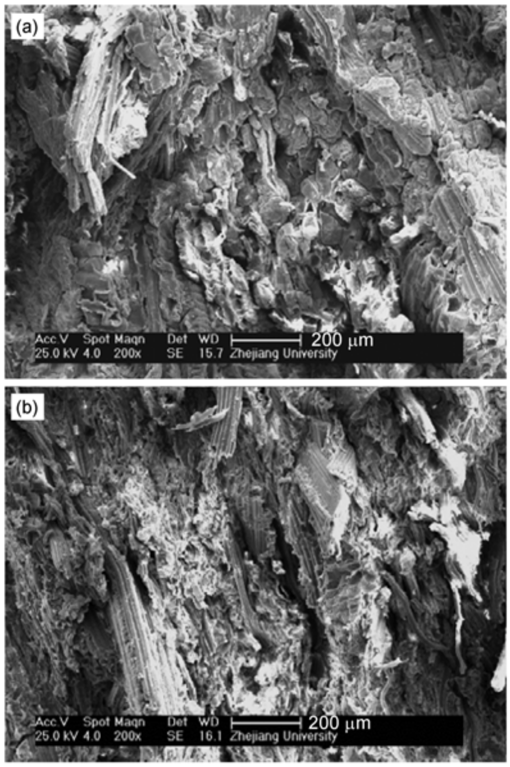

Figure 3 Micro-structure of bamboo particles reinforced PVC composites. (a) Untreated; (b) treated by 5% sodium silicate solution.

4 Conclusion

The effect of surface treatments and the results of different concentrations (0.5%, 1%, 2%, 5% and 10%) of sodium silicate disposal solutions upon the mechanical and thermal properties of the BPPC were demonstrated. After surface treatment of raw bamboo particles, the BPPC definitely showed better mechanical properties. The tensile strength and MOE reached the highest 15.72 MPa and 2956.80 MPa, respectively when raw bamboo particles were treated with 5% sodium silicate solution. MOR got its best performance of 27.73 MPa at a concentration of 2%. Differential scanning calorimetric analysis illustrated that sodium silicate solution treated BPPC pssessed a better compatibility. The micro structure of the composites surface showed that a better uniform dispersion of moso bamboo particles in PVC matrix was obtained after sodium silicate treatment. Results of this study indicated that the use of waste bamboo particles as reinforcement is a feasible and competitive method of creating new materials. Sodium silicate could be used as the surface modifier of moso bamboo particles for the filler of resin matrix.

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