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Research Letter

Studies on the Polypropylene Composites Reinforced by Ramier Fiber and $K_2Ti_6O_{13}$ Whisker

Chun-Guang Long,[1,2] Li-Ping He,[2] Zhi-Hua Zhong,[2] and Shu-Guang Chen[1]

[1] *Institute of Material of Science and Engineering, Changsha University of Science and Technology, Changsha 410076, China*
[2] *State Key Laboratory of Advanced Design and Manufacture for Vehicle Body, Hunan University, Hunan 410082, China*

Correspondence should be addressed to Chun-Guang Long, longcg@csust.edu,cn

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Polypropylene composites reinforced by the ramier fiber and $K_2Ti_6O_{13}$ whisker were successfully prepared by means of the torque rheometer blending and transfer molding. Their mechanical properties were tested, and the fracture surface of the composite was analysed by SEM technique. Results showed that the mechanical properties were improved by the addition of 10% of $K_2Ti_6O_{13}$ whisker besides the impact strength. The RF is benefit for improving the mechanical properties of PP after being surface-treated properly.

1. INTRODUCTION

Polypropylene (PP) is a widely used engineering plastic with good mechanical properties, whose consumption is rowed as being number one of all the plastics used for automobiles. Some automakers even think of replacing all other kinds of plastic used for automobiles by the modified PP. Therefore, PP modification is an attractive work for materials scientists and engineers all the time. Potassium titanate whisker was chosen as a filler to modify PP and high mechanical properties were obtained [1]. Lately, the natural fiber-reinforced composites, especially for the automobile and aircraft usage, have got an increasing interest because of the advantages of their low density, relatively high toughness, high strength and stiffness, good thermal properties, and biodegradability over the traditional glass-fiber-reinforced material [2, 3]. But studies on the PP composite reinforced by both the potassium titanate whisker and the natural fiber have not been seen. In this paper, in order to enhance the strength of PP so that it can be more widely used for automobile parts, $K_2Ti_6O_{13}$ whisker (abbreviated as KTW) and ramie fiber (RF) were both chosen as fillers to modify PP, and the effects of different chemical treatments and fiber contents on the mechanical property of the PP composite were studied. It was believed that this work would be helpful for understanding the function of RF as a main filler in PP and providing guidance to the practical application of fiber- or whisker-reinforced PP composites.

2. EXPERIMENTAL

2.1. Materials

The PP powders used, of a diameter smaller than 0.076 μm, were supplied by the Yueyang Chemical Plant, China. The KTWs were produced by the Shanghai Company, Ltd., of whisker with a slenderness ratio of 20∼30. The RFs were supplied by Guangxi Company, Ltd., of ramie. Other materials were bought in the market.

2.2. Sample preparation

Figure 1 shows the procedure of PP multiple composites prepared by the torque rheometer blending and transfer molding. The raw materials, such as PP, KTW, and RF, were dried at 80°C and held for 3∼5 hours. The RF was cut into 3 to 5 millimeters short and was treated by the silane coupling agent, potassium permanganate, and acrylic acid [4], respectively, while the KTW was treated by the silane coupling agent. Then, the raw materials were proportionally weighed and premixed in a blender. According to our previous studies [5], the KTW content should be kept constant at 10% of

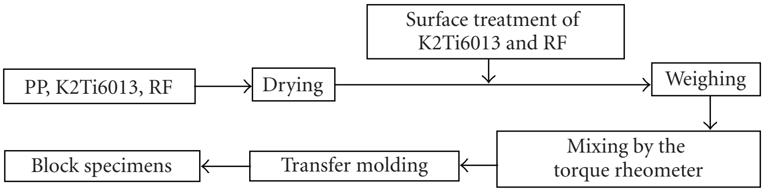

Figure 1: The preparation process of the PP composites.

Table 1: Mechanical properties of PP, KTW/PP, and RF/KTW/PP composites.

	PP	KTW(10%)/PP composites with KTW being treated by silane coupling	RF(20%)/KTW(10%)/PP composites being treated by different chemical solvents				
			By silane coupling agent	By potassium permanganate	By acrylic acid	With RF untreated	RF and KTW untreated
Tensile strength (MPa)	23.5	26.4(12%)	33.2 (41%)	30.1	31.7	24.3	21.6
Bending strength (MPa)	42.3	46.2(19%)	63.5 (50%)	61.2	60.7	45.4	44.8
Compressive strength (MPa)	44.2	48.5(9.7%)	51.5 (16.5%)	50.4	49.2	46.5	42.4
Impact strength (KJ/m^2)	9.5	5.9(−38%)	8.6 (−9.4%)	8.2	9	5.7	5.6

weight in order to get a composite of a good combination property. The content of RF as a filler was changed from 5 to 25 wt%, at intervals of 5 wt%. In order that the filler can be uniformly distributed in the matrix, the mixture was extruded twice by the torque rheometer of type RM-200/300. After that, it was cut into small particles and extruded into specimens by the transfer molding.

2.3. Measurement

The tensile strength, bending strength, and compressive strength were examined on an electron omnipotence tester of type CSS-44020, with rates of 2 mm$\cdot$min^{-1}, 2 mm$\cdot$min^{-1}, and 5 mm$\cdot$min^{-1}, respectively. The impact strength was measured on a tester of type CBL-11J, with no notch in the specimen. All the presented results are the average of five specimens.

The morphologies on the fracture surfaces of PP and composites were observed by a JSM-5600LV scanning electron microscope made in Japan.

3. RESULTS AND DISCUSSION

3.1. Mechanical properties of PP composites

Table 1 shows the mechanical properties of materials (PP, KTW(10%)/PP, and RF(20%)/KTW(10%)/PP) in which the RF was treated by different solvents. When 10% of KTW was added, the tensile compression and bending performance of PP could be improved, with only the impact strength being decreased. Compared to the three chemical treatments, the silane coupling agent shows a relatively good effect for improving the mechanical properties except for the impact strength (in which the acrylic acid shows the best effect). When 20% of unmodified RF was added to the KTW(10%)/PP composite, all mechanical properties were decreased as compared to KTW(10%)/PP composite. If all the fillers are untreated (see the last column of the table), the mechanical properties are a little decreased as compared to PP, with only the bending strength being increased. So the silane coupling agent (KH550) was chosen for the surface treatment of RF. According to Table 1, the tensile strength of the RF(20%)/KTW(10%)/PP composite is higher than that of PP by 41%, the bending strength by 50%, and the compressive strength by 16.5%. The impact strength is increased by 28% when 20% of RF is added to the KTW(10%)/PP composite although it is still lower than that of PP. Therefore, RF is benefit for improving the mechanical performance of PP.

Figures 2 and 3 show the relationship between the RF contents and the mechanical properties in which the abscissa – 10 means the performance value of matrix PP, while the abscissa 0 means that of KTW(10%)/PP composite. The effect of the RF content on the tensile and compressive strengths of the KTW/PP composites is shown in Figure 2. Line 1 shows that the tensile strength is sharply increased and then slowly enhanced with the addition of the RF from 5 to 25%. However, the compressive strength is firstly increased and then decreased with the increase of RF content (see line 2 in Figure 2), and it reaches the maximum value, that is, 17.8% higher than that of PP when the RF content is about 10%.

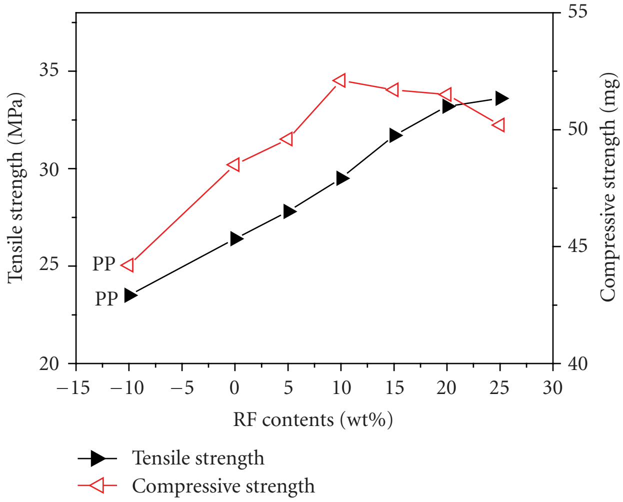

Figure 2: Effect of RF content on the tensile and compressive strengths of PP composites with RF being treated by KH550.

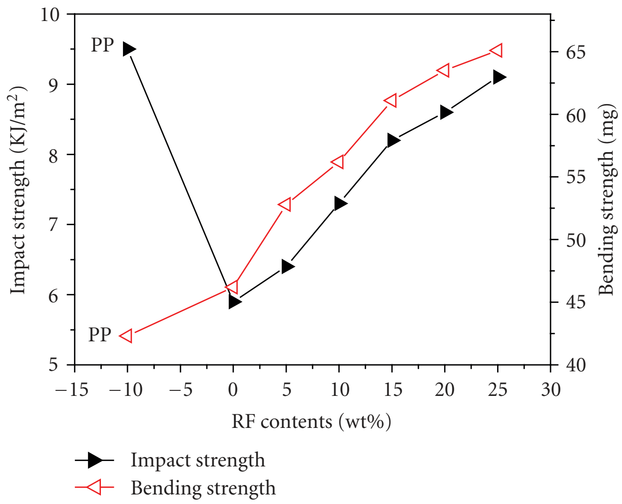

Figure 3: Effect of RF content on the impact and bending strengths of PP composites with RF being treated by KH550.

The relationships between the RF content and the impact and bending strengths are, respectively, shown in Figure 3. Although the impact strength is decreased sharply when 10% of KTW is added, it could be compensated by the addition of RF. That means that the impact strength of PP composites is increased with more RF addition during the experiment range. The relations between the bending strength and the RF content show similar tendency to that of the impact strength and the RF content (see line 2 in Figure 3).

3.2. *SEM observation on the fracture surfaces of PP and its composites*

Figures 4–6 show the SEM morphology on the fracture surfaces of PP and its composites; Figure 6 is the partial enlarged detail of Figure ?? (see the arrow in it). The fracture surface of PP is something dark, and some ductile shear belt can be seen

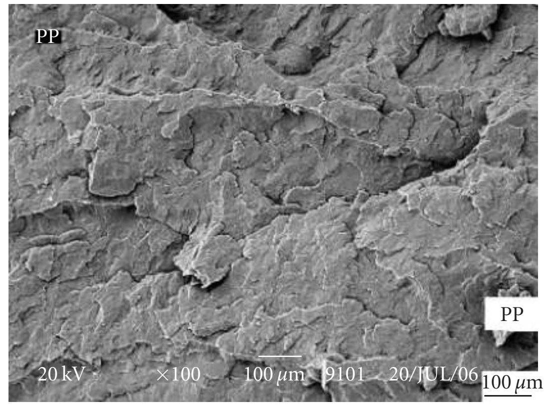

Figure 4: SEM morphology of the fracture surface of PP (100×).

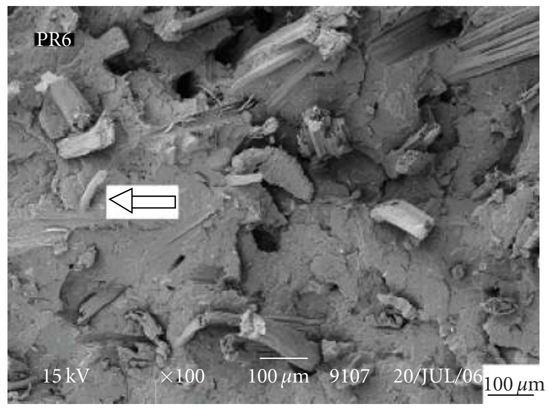

Figure 5: SEM morphology of the fracture surface of RF(20%)/KTW(10%)/ PP composite (100×).

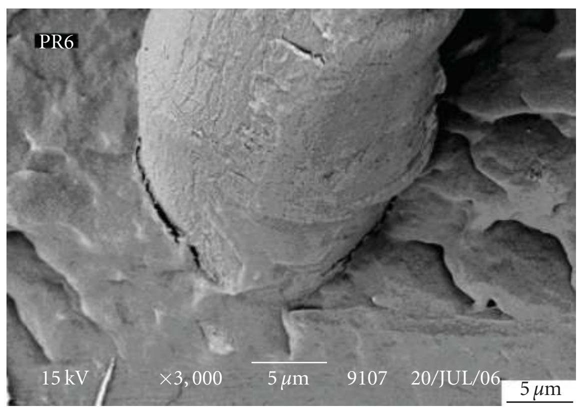

Figure 6: SEM morphology of the fracture surface of RF(20%)/ KTW(10%)/ PP composite (3000×).

from the cross-section in Figure 4, which means that PP is something tough fracture. The fracture surface in Figure ?? is much flat, and almost no ductile shear belt can be seen. That is why the toughness of PP composites is not as good as PP. However, it can be seen from Figure ?? that the RF is almost uniformly distributed in the matrix, and the phenomena of fiber pulling out and fiber breakage can also be seen in it.

Figure 6 shows a relatively good interface bondage between the RF and the matrix. Just as we know that more fibers can bear much great load and transfer much amount of energy [6], this is why the mechanical properties can be improved by adding RF.

4. CONCLUSION

(1) It is possible to prepare PP/RF/KTW composites by the torque rheometer blending and transfer molding, in which the fillers are almost uniformly distributed in the matrix and a relatively good interface bondage can be obtained.

(2) The mechanical properties of PP composites can be effectively improved by the addition of both the RF and a constant content of KTW after they are properly surface-treated, and among the three agents—the silane coupling agent, potassium permanganate, and acrylic acid—the silane coupling agent is a relatively good one for the surface treatment of RF.

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