Study on Mechanical Properties of Flake Graphite Filled Polypropylene Composites

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Abstract. The surface modification of flake graphite (FG) was made by coupling agent, and then it was filled with polypropylene (PP). After mixing with an open mixer, the FG/PP composites were prepared by compression molding. The experiment results showed that the compatibility and the mechanical properties of FG/PP composites can be improved by the modification of FG with titanate coupling agent NDZ-201. With the increase of the amount of NDZ-201, the strength, tensile modulus and tensile strain at fracture of FG/PP composites first increased and then decreased, while the bending modulus showed a downward trend and the fracture bending strain continued to increase. When the dosage of NDZ-201 was 0.7wt%, the mechanical properties of FG/PP composites were the best. Furthermore, with the increase of FG content, the tensile strength and bending strength of FG/PP composites firstly decreased and then increased, the tensile modulus and bending modulus increased, the fracture tensile strain and fracture bending strain decreased correspondingly. FG with small particle size and large specific surface area was easy to mix with PP evenly, which was conducive to improving the mechanical properties of FG/PP composites.

Keywords: Flake Graphite; Polypropylene; Composites; Mechanical Property.

1. Introduction

Polypropylene (PP) is one of the most promising general-purpose polymer materials. PP has many advantages such as good chemical stability, corrosion resistance, scale inhibition, light weight, low price, fatigue resistance, strong thermal conductivity, easy processing and many other advantages. It can be used between -10℃~125℃[1-4]. Due to the non-polar linear structure and high crystallinity of polypropylene, its compatibility with other polymer materials, fillers, additives, and other compatibility is not good, which affects its mechanical properties, thermal conductivity, electrical conductivity and so on, so that its application is limited [5-8]. At present, academia and the business community are particularly concerned about flake graphite/polypropylene (FG/PP) composites. However, the compatibility of PP and FG is very poor, it is difficult to be mixed uniformly, and it is easy to appear holes, cracks and other defects. When the materials are subjected to stress, it will crack or even fracture, which will affect its mechanical properties [9-11].

In this study, the coupling agent was used to modify the surface of FG, and the mixing process was optimized by using the shearing force of the open mill to improve the dispersion of FG in PP. The mechanical properties of the composites were improved by adjusting the filling amount of FG in PP, so as to expand the application of FG/PP composites in chemical industry, construction, electronics, seawater desalination, new energy and other fields [12-16].

2. Experimental Methods

2.1 Materials

Flake graphite (FG, 99%, particle size 17μm, 27μm, 37μm, 74μm and 148μm, Hebei Haoteng Trading Co., Ltd); Polypropylene (PP230#, Sinopec Maoming Petrochemical Company); Silane coupling agents (KH-560, KH-570) and Titanate coupling agent (NDZ-101, NDZ-201) were bought from Dinghai Plastic Chemical Co., Ltd; Absolute ethanol (analytical pure, Tianjin Yongda Chemical Reagent Co., Ltd); Antioxidant 1010 and Zinc stearate were obtained from Shanghai Aladdin Biochemical Technology Co., Ltd.

2.2 Equipments

Double-roll open mill (ZG-180, Dongguan Zhenggong Electromechanical Equipment Technology Co., Ltd); Electric drying oven (101-3AB, Tianjin Taisite Instrument Co., Ltd); Flat vulcanizer (ZG-200T, Dongguan Zhenggong Electromechanical Equipment Technology Co., Ltd); Universal prototype (WZY-240, Chengde Hengtong Test Instrument Co., Ltd); Thermal constant analysing (TPS-2500S was produced by Sweden Hot disk Co., Ltd); Electronic universal testing machine (104C, Shenzhen Wance Testing Machine Co., Ltd.).

2.3 Preparation of FG/PP Composites

The coupling agent was dissolved in anhydrous ethanol, and then mixed well with FG. The mixture was dried in an oven at 140℃. A certain amount of PP, zinc stearate, antioxidant and treated FG were pre-mixed in a high-speed mill, then mixed in a double-roll open mill, and finally molded by the flat vulcanizer to prepare FG/PP composites. (Opening mill conditions: front roller 180 °C, rear roller 175 °C. Molding conditions: upper template 193 °C, lower template 190 °C, pressure 12 MPa).

2.4 Testing Methods

The tensile properties of the FG/PP composites were tested according to GB / T 1040.1-2006. Sample size and shape: 170mm×10mm×3±0.2mm, 1B. The bending properties of the composites were tested according to GB / T 9341-2008. Sample size: 80mm×10mm×3±0.2mm. Testing speed: 2mm/min.

3. Results and Discussion

3.1 Types of Coupling Agents

The coupling agent can connect the filler and the resin together closely, improve the interface between the filler and the resin, so as to improve the performance of the composite materials effectively. When FG content of 17μm was 50wt% and the coupling agent dosage (measured by FG content) was 1wt%, the FG/PP composites were prepared and their mechanical properties were tested (Tab.1).

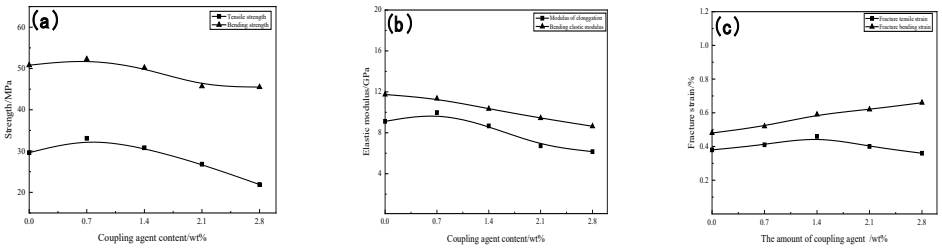
As shown in Tab.1, the tensile and bending strength of FG/PP composites prepared by FG treated with coupling agents don't change much. The tensile strength of composites prepared by FG treated with KH-570 and NDZ-201 increase by 10.7% and 12.3%, the bending strength increased by 1.8% and 22.7%, respectively. At the same time, the modulus and strain are also improved obviously. In particular, the fracture tensile strain of the composites prepared by FG treated with NDZ-201 reaches a maximum of 0.86%, and the bending modulus reaches a maximum of 11.1 GPa. In a word, the compatibility of PP and FG is greatly improved after the treatment of FG with NDZ-201, so FG/PP composites have better mechanical properties.

Table 1. Effect of coupling agent on mechanical properties of FG/PP composites

Coupling agent	Tensile strength /MPa	Tensile modulus /GPa	Fracture tensile strain /%	Bending strength /MPa	Bending modulus /GPa	Fracture bending strain /%
None	30.0	6.73	0.64	50.2	8.61	0.76
KH-560	30.4	6.56	0.86	49.8	6.04	0.95
KH-570	33.2	7.75	0.67	51.1	8.51	0.78
NDZ-101	29.7	6.89	0.62	48.5	8.96	0.74
NDZ-201	33.7	6.85	0.86	61.6	11.1	0.71

3.2 Content of Coupling Agents

When the FG content of 37μm was 70wt%, the FG/PP composites were prepared by changing the amount of NDZ-201 and their mechanical properties were tested (Fig.1).

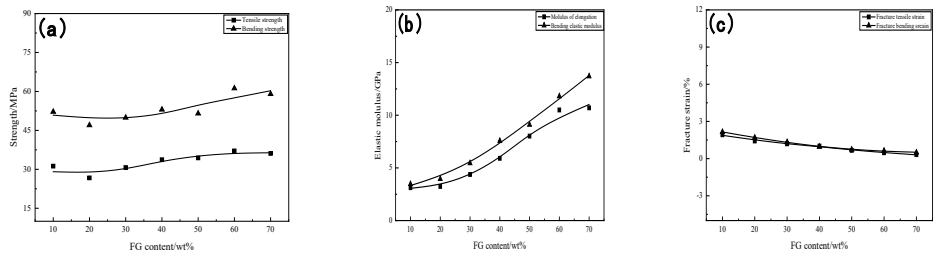


(a) Strength; (b) Modulus; (c) Fracture strain

Fig 1. Effect of coupling agent dosage on mechanical properties of FG/PP composites:

With the increase of the amount of coupling agent, the strength of FG/PP composites increase first and then decrease. When the amount of NDZ-201 is 0.7wt %, the tensile strength and bending strength of the composites reach the biggest, which are 11.8% and 3.0% higher than those of the composites without coupling agent, Fig.1(a). Fig.1(b) shows that with the increase of the amount of NDZ-201, the tensile modulus increases first and then decreases. But the bending modulus of FG/PP composites shows a downward trend. From Fig.1(c), it can be seen that with the increase of the amount of NDZ-201, the fracture tensile strain of the composite increases first and then decreases, and the fracture bending strain continues to increase. In summary, when the amount of NDZ-201 is 0.7wt%, a monolayer can be formed between PP and FG, the mechanical properties are the best.

3.3 Content of FG



(a) Strength; (b) Modulus; (c) Fracture strain

Fig 2. Effect of FG content on mechanical properties of FG/PP composites

In order to investigate the effect of FG content on the mechanical properties of the composites, FG/PP composites with different FG content were prepared by 17μm FG and 1wt% NDZ-201. Fig. 2 shows the results.

With the increase of FG content, the strength of FG/PP composites decrease first and then increase. When the FG content is 60wt%, the tensile and bending strength of the composites are the largest, which are 37.1MPa and 61.2MPa, respectively, Fig.2(a). Fig2(b) shows that the modulus of FG/PP composites increase with the increasing of FG content. Furthermore, the fracture strain of FG/PP composites display the opposite results, Fig.2(c). On the one hand, when the content of FG is low, the PP matrix bears most of the stress, and the plastic deformation energy absorbed by the composites is small. On the other hand, less FG content makes the composite easy to produce defects and fracture when subjected to external forces.

3.4 Particle Size of FG

To explore the effect of FG with different particle sizes on the mechanical properties of composites, FG with particle sizes of 17μm, 27μm, 37μm, 74μm or 148μm were selected to prepare FG/PP composites under the condition of FG content of 50wt%, NDZ-201 dosage of 1wt% and the mechanical properties were tested (Tab.2).

Table 2. Effect of FG particle sizes on mechanical properties of FG/PP composites

FG particle size / μm	Tensile strength / MPa	Tensile modulus / GPa	Fracture tensile strain/ %	Bending strength / MPa	Bending modulus / GPa	Fracture bending strain / %
17	34.4	7.85	0.70	53.0	9.87	0.69
27	32.5	6.74	0.91	50.4	7.79	0.93
37	30.5	6.53	0.77	49.0	8.01	0.86
74	27.9	6.48	0.80	44.3	7.35	0.87
148	25.1	6.83	0.54	43.0	7.12	0.86

Tab. 2 shows that both the strength and modulus of FG/PP composite gradually decrease with the increase of FG particle sizes. When the particle size of FG is 17 μm, the tensile strength, tensile modulus, bending strength and bending modulus of the composites are 34.4MPa, 7.85GPa, 53MPa and 9.87GPa, respectively. FG with small particle size has a larger specific surface area and is more evenly mixed with PP. The internal stress generated after molding cooling is small, and cracks are not easy to occur when under stress. On the contrary, it is difficult to mix well between FG with large particle size and PP, and it is easy to appear defects such as large holes, cracks and so on, thus reducing the mechanical properties of the composites.

4. Conclusion

(1)The modification of FG with titanate coupling agent NDZ-201 not only improved the compatibility of FG and PP, but also improved the mechanical properties of FG/PP composites. With the increase of NDZ-201 content, the strength, tensile modulus and fracture tensile strain of the composites increased first and then decreased, the flexural modulus showed a downward trend, and the fracture bending strain continued to increase. When the amount of NDZ-201 was 0.7wt %, the mechanical properties of FG/PP composites were optimum.

(2)With the increase of FG content, the strength of FG/PP composites firstly decreased and then increased, the modulus increased accordingly, the fracture strain decreased correspondingly. The increase of FG particle size reduced the mechanical properties of FG/PP composites.

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