Study on the properation and properties of PP/mental aluminium power composites

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Abstract. In this paper, polypropylene (PP) was blended with aluminum powder, porous powder and EVOH reinforcing agent in different proportions by melt blending method. The infrared spectrum analysis of the blending components was carried out to study the tensile strength, impact strength, ball indentation hardness and heat resistance of the composites with different proportions. The results show that when the content of aluminum powder is 2 wt.%, the content of porous powder is 9 wt.%, and the content of EVOH is 4 wt.%, the heat resistance of the composite is the best. The tensile strength, impact strength and hardness of the composite are 21.33 MPa, 1.83 MPa and 74.78 N/mm², respectively. At this time, the composite has the best comprehensive properties.

1. Introduction

In recent years, the application of plastics in various industries has been growing steadily. As a general thermoplastic, polypropylene has low density and good heat resistance. In addition, its products have good luster, non-toxic, tasteless and chemical resistance, so it is widely used in the fields of electrical appliances, packaging and daily necessities[1]. However, polypropylene also has some shortcomings, such as brittle fracture at low temperature, large shrinkage during product molding, insufficient impact property and low hardness, which limit the further application of polypropylene in some fields[2-4]. With the application demand of food packaging, pure polypropylene material can not meet the demand of packaging products. It is necessary to modify polypropylene. The common modification methods are filling and blending. Due to its low cost and simple process, blending modification has become a hot spot in the research of toughening and reinforcing properties of polypropylene materials in recent years[5].

EVOH resin is a copolymer of ethylene and vinyl alcohol, which has excellent gas barrier performance, good mechanical properties, strong moisture absorption, etc., and has been widely used in the field of food packaging[6]. However, because EVOH resin is hydrophilic, its gas barrier is affected by humidity, and its high production cost further limits the application scope of EVOH resin[7]. In order to improve the properties of EVOH resin, PP was blended with EVOH resin of different proportions. Due to the poor compatibility between PP and EVOH resin and the insufficient mechanical properties of the blend system, a certain amount of compatibilizer was added during blending[8]. Among them, inorganic particles have been widely studied and applied in recent years because of their low cost, good compatibility with PP / EVOH blends, good reinforcing and toughening effects, and improving the heat resistance of polymer matrix. In this paper, inorganic powder and aluminum metal powder were used as compatibilizers and added to PP / EVOH blends with different
proportions in a certain proportion to study the mechanical properties and thermal stability of PP / EVOH blends with different proportions.

2. Experimental section

2.1 Materials
PP, T30S, produced by PetroChina Daqing Petrochemical Plant; Aluminum metal powder, Dongguan Jinrong hardware decoration materials Co., Ltd. Shinelintm environmental protection new functional additive, 990 multifunctional additive, Shenzhen xuanlin Metal Pigment Co., Ltd. EVOH enhancer, E1058B, Shanghai Yishang International Trade Co., Ltd.

2.2 Preparation of composite materials
Aluminum metal powder equivalent to 2 wt.% and inorganic porous powder equivalent to 9 wt.% of PP mass were added to 100 g polypropylene (PP) material, and then 0 wt.%, 1 wt.%, 2 wt.%, 3 wt.%, 4 wt.%, 5 wt.% of EVOH were added into the above mixture, stirred the mixture at a certain speed for 10 minutes, after that the composite was taken out, the sample was used for testing.

2.3 Performance test
(1) Infrared spectrum analysis: Test with German Brooke company TENSOR-27 infrared spectrum analyzer.
(2) Tensile property test: WSM-5kN computer-controlled electronic universal testing machine of Changchun intelligent instrument and Equipment Co., Ltd.
(3) Impact performance test: JC-25 pendulum impact test machine of Chengde precision testing machine Co., Ltd. was used to test the notchless samples according to GB 1043-1993.
(4) Hardness test: QYS-96 plastic ball indentation hardness tester of Changchun Shengzu testing instrument development Co., Ltd.
(5) Thermogravimetric analysis (TGA): T15-218 microcomputer thermobalance of Beijing Hengjiu scientific instrument factory was used to test in N2 atmosphere.

3. Results and discussion

3.1 Infrared spectrum analysis
The ATR analysis diagram of EVOH is shown in Figure 1. The wide peak at 3295cm\(^{-1}\) is -OH-stretching vibration absorption peak, at 2923cm\(^{-1}\) and 2851cm\(^{-1}\) are -CH\(_2\)- stretching vibration absorption peak, at 1426cm\(^{-1}\) and 1330cm\(^{-1}\) are -CH\(_2\)- bending vibration absorption peak.

Figure 1. ATR analysis of EVOH.
3.2 Tensile strength of composites
The tensile strength diagram of the composite is shown in Figure 2. It can be seen from the diagram that with the increase of EVOH content, the tensile strength first decreases, then increases, and then decreases. The tensile strength of composites is mainly determined by the bonding force between phases. The greater the bonding force is, the greater the tensile strength is. With the increase of EVOH content, the particle size of the dispersed phase gradually increases, and the interfacial force becomes worse [9]. When the content of EVOH reaches 2 wt.%, the tensile strength is the lowest. When the content of EVOH is more than 2 wt.%, the tensile strength shows an upward trend. At this time, the increase of the content makes the compatibility increase and the bonding force between interfaces increase. When the content of EVOH is 4 wt.%, the tensile strength reaches the maximum. Further increasing EVOH content makes EVOH disperse unevenly and agglomerate in the blends, which leads to the decrease of tensile strength.

![Figure 2. Tensile strength diagram of composite.](image)

3.3 Impact strength of composites
The impact strength results of the composite is shown in Figure 3. It can be seen from the figure that with the increase of EVOH content, the impact strength trend of the composite is consistent with the tensile strength trend. EVOH can disperse in the blend system as regular and fine phase. When the content of EVOH is less than 2 wt.%, the distance between the dispersed phase particles is large, and the surrounding stress between adjacent particles has no superposition effect [10], resulting in the decrease of impact strength. With the increase of EVOH content, the distance between the dispersed phase particles is small, and the stress field around the adjacent particles has superposition effect. When the EVOH content reaches 4 wt.%, the notched impact strength of the blends increases greatly. Further increasing the content of EVOH makes EVOH disperse unevenly in the blend system, resulting in the decrease of impact strength at the notch.
3.4 Hardness of composites
The hardness diagram of the composite is shown in Figure 4. It can be seen that with the increase of EVOH content, the hardness value of the composite surface first increases and then decreases. This is due to the increase of EVOH content, the hardness of inorganic powder and EVOH resin is higher, which is helpful to improve the overall surface hardness of the composite. When EVOH content reaches 4 wt.%, the hardness is the highest. Further increasing the EVOH content, EVOH dispersed unevenly in the blend system, and its strength was lower than that of the blend system, resulting in a significant decrease in the surface hardness of the blend system.

3.5 Heat resistance test of composites
In order to study the thermal stability of the composites, the thermal stability of the composites with different EVOH content was studied in this experiment. It can be seen from Figure 5 that the thermal decomposition process of the blends is mainly distributed in the temperature range of 400 ℃ ~ 480 ℃. With the addition of EVOH, the thermal decomposition temperature of some blends increases. According to the data in Table 1, when the content of EVOH is 4 wt.%, Te, Ti, Tc and Tr increase by 9.7 ℃, 5.1 ℃, 4.5 ℃ and 14.7 ℃ respectively compared with those without EVOH. Therefore, for a certain proportion of EVOH component, it is helpful to improve the thermal stability.
Table 1. DTG parameters of blends.

| EVOH content | Te (°C) | Ti (°C) | Te (°C) | Tr (°C) |
|--------------|--------|--------|--------|--------|
| 0%           | 428.1  | 455.0  | 467.5  | 575.3  |
| 1%           | 422.9  | 448.3  | 465.3  | 572.5  |
| 2%           | 436.5  | 457.8  | 471.3  | 587.7  |
| 3%           | 422.5  | 453.8  | 467.7  | 576.0  |
| 4%           | 437.8  | 460.1  | 472.0  | 590.0  |
| 5%           | 406.8  | 438.8  | 455.4  | 561.5  |

Figure 5. DTG composite curve.

4. Conclusions
(1) With the increase of EVOH content in the system, the tensile strength decreased first, then increased, and then decreased. When the EVOH content was 4 wt.%, the tensile strength of the composite was the highest, with the maximum value of 21.33 MPa.

(2) With the increase of EVOH content in the system, the impact strength and tensile strength have the same trend. When the EVOH content is 4 wt.%, the impact strength of the composite reaches the maximum value of 1.83 MPa.

(3) With the increase of EVOH content in the system, the hardness first increases and then decreases. When the EVOH content is 4 wt.%, the hardness of the composite reaches the maximum value of 74.78 N/mm².

(4) With the addition of EVOH content in the system, the thermal stability of the blends with certain proportions is obviously enhanced. When the EVOH content is 4 wt.%, the thermal stability of the composites is the best.

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