Effects of Calcium Sulfate Whiskers on the Mechanical Properties and Light Transmittance of PE Greenhouse Films

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Abstract. Calcium sulfate whisker (CSW) is a kind of fiber crystal material with high orientation structure. The major goal of this research is to study the changes of mechanical properties and light transmittance of PE greenhouse film with different proportions of CSW. The experimental results show that the mechanical properties and light transmittance of PE/CSW films are enhanced compared with the pure PE. For PE/2%CSW, it shows a 18.6% increase in tear strength, a 3.1% increase in luminous transmittance and 17.7% increase in haze. The PE/5%CSW demonstrates a 12.8% higher in tensile strength, a 20.5% higher in tear strength, a 23.9% lower in luminous transmittance and a 53.0% higher in haze. This article gives a new formula to strengthen the mechanical properties of PE greenhouse films and finds the direction for the research and development of astigmatic covering film.

1. Introduction

Whisker is a kind of fiber formed naturally or grown in the form of single crystal under artificial control. Its diameter is very small (micron order) and its structure does not contain defects in common materials, such as grain boundaries, holes, etc. [1-2] Because its atoms are highly ordered, its strength is close to the theoretical value of a complete crystal. The highly oriented structure of whiskers not only makes them have high strength, high modulus and high elongation, but also has electrical, optical and magnetic properties [3-4]. Calcium sulfate whisker (CSW) is a kind of whisker, which refers to the fibrous single crystal synthesized from gypsum through a specific process. With the advantages of high strength, low toxicity, high temperature resistance and good organic compatibility, [5-6] it can be used in the fields of polymer composites, such as PP and PE.

Greenhouse film is a plastic agricultural film used to make plastic greenhouses and greenhouses. It is an important agricultural resource with good heat preservation, moisture retention and plant growth promotion. And the polyethylene greenhouse film is the main agricultural film material in agricultural greenhouse film. With the development of agricultural production, the development of functional agricultural greenhouse film with high light transmittance, high thermal insulation, high strength and long service life is becoming a research and development hotspot. Therefore, the purpose of this study is to study the changes of mechanical properties, luminous transmittance and haze of PE greenhouse films by adding different amounts of calcium sulfate whiskers. It lays a foundation for prolonging the service life of greenhouse film, developing astigmatic covering film and promoting crop growth in the future.
2. Experimental

2.1 Materials
LLDPE (Linear Low Density Polyethylene, DFDA-7042), the density is 0.915 ~ 0.940 g/cm³, purchased from Sinopec Zhenhai Refining & Chemical Company (Zhejiang, China). CSW (Calcium Sulfate Whiskers), provided by Jiangxi Fengzhu New Material Technology Co., Ltd (Jiangxi, China).

2.2 Preparation of PE/CSW Composite Films
First of all, PE was mixed with 2% and 5% CSW in a mixer, respectively. Then the compounds were squeezed out by a double-screw extruder (LTE-26-44, Labtech Engineering, Thailand) and pelletized through a pelletizer (LZ-120/vs, Labtech Engineering, Thailand) to form masterbatchs. The pure PE was used as control and without pelletizing. Afterward, the PE, PE/2%CSW and PE/5%CSW greenhouse films were produced by using a blown film machine (LF400-COEX, Labtech Engineering, Thailand) at about 180°C. And the thickness of the three films was 100μm.

2.3 Property Tests

2.3.1 Mechanical properties
The films' mechanical properties included tensile strength and tear strength. A universal testing machine (Labthink Co. Ltd., China) was used to test and all operation steps met the GB/T 1040.3-2006 (tensile strength) and QB/T 1130-1991 (tear strength). The tensile strength and tear strength shall be tested at least five times respectively, and then averaged.

2.3.2 Light transmittance
The WGT-S transmittance/haze tester (Shanghai Precision Instrument Co., Ltd, China) was employed to determine the luminous transmittance and haze of the greenhouse films, and the operation process conforms to the GB/T 2410-2008. The films samples shall be tested at least three times and averaged.

3. Results and Discussions

3.1 Mechanical Properties Analysis

![Figure 1](image)

Figure 1. Mechanical properties for PE and PE/CSW films

Figure 1 shows the mechanical properties of the three films. The tensile strength of PE, PE/2%CSW and PE/5%CSW films were 25.3, 25.0 and 29.0MPa, respectively. It can be analyzed that compared with pure PE film, adding 5%CSW to PE film can increase the tensile strength by 12.8%, while the tensile strength is almost unchanged when adding 2%CSW. Besides, the tear strength of PE film was the lowest, PE/5%CSW film was the highest, while that of PE/2%CSW film was in the middle. They were 97.4, 119.6 and 122.4kN/m, respectively. With the addition of CSW in the PE films, the tear
strength of the films was increased by 18.6% and 20.5%, respectively. The results indicated that the addition of CSW improved the mechanical properties of PE and will be instrumental in the extension of the service cycle of greenhouse films. It was because the high orientation structure of CSW was conducive to enhance the strength of PE greenhouse film.

3.2 Light Transmittance Analysis

![Figure 2. Light transmittance for PE and PE/CSW films](image)

The light transmittance analysis was used to analyze the luminous transmittance and haze of the greenhouse films. From Figure 2(a), the results of the luminous transmittance were 88.4%, 91.2% and 67.3%, which correspond to PE, PE/2%CSW and PE/5%CSW. This showed that 2%CSW can improve the luminous transmittance of PE film by 3.1% while 5%CSW reduces the luminous transmittance by 23.9%. As for haze, it's not hard to see that adding 2%CSW and 5%CSW all raised the haze of PE film compared with pure PE film. The haze values of the three films were 38.6%, 46.9% and 82.2%, respectively. In the presence of 2%CSW and 5%CSW, the haze value of PE film enhanced by 17.7% and 53.0%.

The astigmatic covering film refers to the greenhouse film with light transmittance ≥85% and haze ≥50%. The results of this study proved that the PE film with 2% and 5%CSW didn’t belong to the astigmatic covering film. It can also be concluded that in order to successfully prepare astigmatism film, the addition of CSW can be more than 2% and less than 5%. Therefore, the formula of greenhouse films needed further research.

4. Conclusions

PE/CSW greenhouse films were prepared by twin-screw extrusion in this research. The effects of CSW with different amounts on the mechanical properties and light transmittance of PE greenhouse films were studied. Adding CSW was helpful to improve the mechanical properties of PE greenhouse films. Compared with PE, the tear strength of PE/2%CSW increased by 18.6%, while the tensile strength of PE/5%CSW raised by 12.8% and the tear strength enhanced by 20.5%. However, PE/2%CSW and PE/5%CSW didn’t achieved the requirements of astigmatic covering film, and further research was needed.

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