

Effect of Polyethylene Elastomer and Polypropylene-Grafted Maleic Anhydride on The Mechanical properties of Polypropylene

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Blends of polypropylene copolymer (PP-cp), polyethylene elastomer (PEE) and polypropylene-grafted maleic anhydride (PP-MA) were investigated. SEM was used for the investigation of the phase morphology. The tensile strength and flexural properties of the blends decreased with increasing elastomer content, while the elongation at break and impact strength tended to increase. The effect of PP-MA content was observed by varying the percent weight in PP/PEE blends at 20 wt% PEE and it was found that tensile strength, flexural properties and impact strength of the blends were better than for the blends without PP-MA.

Key words: Polymer blends, polyethylene elastomer, polypropylene-grafted maleic anhydride.

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ผลของโพลิเอธิลีนอิลาสโตเมอร์และโพลิโพรพิลีน-กราฟ แมเลอิกแอนไฮไดรด์ที่มีต่อสมบัติเชิงกลของโพลิโพรพิลีน

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ศึกษาผลกระทบบของโพลิเมอร์ผสมของโพลิโพรพิลีนโคโพลิเมอร์ (PP-cp) ที่มีต่อโพลิเอธิลีนอิลาสโตเมอร์ (PEE) และโพลิโพรพิลีนกราฟแมเลอิกแอนไฮไดรด์ (PP-MA) โดยใช้ SEM ติดตามวิภาคโครงสร้างค่าแรงดึงและสมบัติการค้ำของโพลิเมอร์ผสมลดลงด้วยการเพิ่มปริมาณอิลาสโตเมอร์ในขณะที่สมบัติการยืดหยุ่นและความทนแรงกระแทกมีแนวโน้มเพิ่มขึ้น ได้ทำการสังเกตผลของการเปลี่ยนแปลงปริมาณ PP-MA ในการแปรเปลี่ยนเปอร์เซ็นต์โดยน้ำหนักในของผสม PP-cp/PEE ที่ PEE 20% โดยน้ำหนักและพบว่าค่าทนแรงดึงสมบัติการค้ำของ, ความทนแรงกระแทกของโพลิเมอร์ผสมดีกว่าของโพลิเมอร์ผสมที่ปราศจาก PP-MA

คำสำคัญ โพลิเมอร์ผสม โพลิเอธิลีนอิลาสโตเมอร์ โพลิโพรพิลีนกราฟแมเลอิกแอนไฮไดรด์

INTRODUCTION

Polypropylene (PP) is a thermoplastic with a number of desirable properties that make it a versatile material. It is used in a wide range of applications such as household products, packing materials, and construction material. Moreover, about 20% of PP is used in the automobile industry and furniture as a copolymer. However, poor impact properties limit its applications. Improving the impact strength of PP is a better choice than homopolymer PP for such applications. Polymer blends can be considered the most effective way and have been widely used for the toughening of thermoplastics. To achieve better properties, the impact properties of PP can be improved either by chemical modification or by elastomeric impact modifiers.⁽¹⁾ Chemical modification for impact improvement is not always feasible. Thus, most of the modification of impact properties has involved blending with an appropriate elastomer. Ethylene propylene diene rubber (EPDM) is widely used as an impact modifier.⁽²⁻⁶⁾ Although the addition of rubber phases improves impact properties, the stiffness of the blends seems to be decreased. To compensate for this effect, fillers has been added to reinforce PP containing elastomers such as ethylene-propylene rubber (EPR) and styrene-butylene-styrene grafted with maleic anhydride or PP grafted with maleic anhydride (PP-MA)⁽⁷⁾ and polyethylene.⁽⁸⁾ There is a large amount of data on the impact properties of the blends with elastomers. Paul and Kale studied properties of the blends of PP-cp with polyolefinic elastomer and found that incorporating polyolefinic elastomers in a PP-cp matrix enhanced the impact properties to a large extent.⁽⁹⁾ Also, the processing conditions seem to play an

important role in the resulting blend properties. Petrovic and co-workers investigated toughening of PP by the addition of two types of EPR having ethylene content and three types of EPR containing high density polyethylene (HDPE).⁽¹⁰⁾ It was found that the EPR containing PE was much more efficient in improving impact strength of PP/EPR blends than neat EPR. Blends of PP and EPR rubber were studied by Mehrabzadeh and Nia.⁽¹¹⁾ They found that important factors in controlling the blend properties were the viscosity of PP, rubber content, ethylene content and grafted EPR by maleic anhydride. Moreover, Axtell and co-workers studied blends of polypropylene and *trans*-polyoctenamer at various elastomer levels.⁽¹²⁾ The study illustrated that an optimum blend ratio resulted in improved mechanical properties compared to the polypropylene with a four-fold increase in room temperature notched impact strength and that *trans*-polyoctenamer has a potential use as an impact modifier in thermoplastics.

In this paper, we report the impact properties of polypropylenecopolymer (PP-cp) modified by polyethylene-octene elastomer (PEE) and polypropylene grafted maleic anhydride (PP-MA).

MATERIALS AND METHODS

Materials

Commercially grades of polypropylene copolymer (PP-cp), polyethylene elastomer (PEE) and polypropylene-grafted maleic anhydride (PP-MA) were obtained from Thai Petrochemical Industry (Public) Co., Ltd., Dow Chemical Co., Ltd. and Uniroyal Chemical Co., Ltd., respectively. The materials specifications are listed in Table 1.

Table 1. Characteristics of Polymer Samples

Polymer	Manufacturer	Code	MFI (g/10 min)	Octene Content	Viscosity ML(1+4)121°C
PP-cp	Thai Petrochemical Industry (Public) Co., Ltd.	2500H	2.1	-	-
PEE	Dow Chemical Co., Ltd.	EG8100	1.0	24	23
PEE	Dow Chemical Co., Ltd.	EG8150	0.5	25	35
PP-MA	Uniroyal Chemical Co., Ltd.	PB3150	50	-	-

Blending

A single screw extruder (Axon Ab Plastmaskiner) was used for melt blending the PP-CP/PEE, PP-CP/PP-MA and PP-CP/PEE/PP-CP-MA systems. The screw speed was set at 100 rpm and the temperature profile was set as follows: Zone I: 195°C; Zone II: 210 °C; and Zone III: 230 °C. The composition of all blends are shown in Table 2.

Measurements

The melt flow index of virgin polymer and PP-cp blends were determined using a melt flow indexer according to ASTM D1238.

The tensile tests were conducted at room temperature (23 °C and 54%RH) and crosshead speed of 50 mm/min in a LLOYD LR 30K tensile testing machine, according to ASTM D638.

The flexural tests were determined using a LLOYD LR 30K tensile testing machine, according to ASTM D790M at a crosshead speed of 1.7mm/min.

The impact strength was measured according to ASTM D256 (V-notched) on an Impact Tester. All results were the average of at least six measurements.

Samples were cryogenically fractured in liquid nitrogen and etched with heptane at 25 °C to extract the elastomer phase for 5 days and then dried for about 3 h at 80 °C *in vacuo*, followed by gold coating prior to their installation in the SEM chamber. The morphologies of the impact fracture surfaces of samples were examined using a JEOL Scanning Electron Microscope (SEM), Model JSM-5300.

RESULTS AND DISCUSSION

MFI analysis

The results of MFI analysis are shown in Table 2. It was found that when the percentage of PEE in PP-cp/PEE blends increased, the melt flow index and the viscosity of the blends decreased slightly. It is possible that the PEE could be obstructing the flow and reducing the fluidity of PP-cp. Thus, reduction of melt flow index agreed with the results of Liao and Chang⁽¹³⁾ that the increased rubber content causes a decrease in the melt flow index of a polycarbonate/poly(ethylene terephthalate) (PC/PET) blend system.

Mechanical characteristics of PP-CP/PEE blends

Tensile modulus, yield stress, flexural strength and flexural modulus of PP-cp/PEE blends tended to decrease when the PEE content in the blend increased (Table 2). The elongation at break of the blends increased with increasing PEE content. The effect of PEE concentration on the mechanical properties of PP-cp/PEE blend is influenced by side chain branching of PEE which disrupts the molecular order and the chain regularity of PP-cp, thereby reducing both crystallinity and the melting point. These effects were similar to the result of rubber content and ethylene content in ethylene propylene rubber (EPR) in controlling the polypropylene and ethylene propylene rubber (PP-cp/EPR) blend properties reported by Mehrabzadeh and Nia.⁽¹¹⁾

It can be seen that the elongation at break of PP-cp/PEE8150 blend was higher than that of PP-cp/PEE8100 blend. This may be influenced by addition of lower MFI or higher viscosity of PEE which increase elasticity, flexibility and extensibility of the blends.

The impact test is commonly accepted as a measurement of the material. The results of the Izod tests provide a comparative basis for estimating the relative shock resistance of polymer materials. The impact strengths of PP-cp/PEE8150 and PP-cp/PEE8100 blends, shown in Table 2, were slightly different. Due to the difference in the octene content in PEE, the blends containing PEE 8150 had slightly higher impact strengths than the blend containing PEE 8100. The maximum value of impact strength of the blend appeared at 20 wt% of PEE content at which point the impact strength was increased by 10% and 12.5% compared to PP-cp and respectively. The blends did not break on further addition of PEE up to 30wt%.

Effect of polypropylene-grafted maleic anhydride (PP-MA) on mechanical properties of PP-cp/PEE blends at 20 wt% PEE

Polypropylene-grafted maleic anhydride (PP-MA) was added to improve the adhesion between the phases and enhance the mechanical properties of PP-cp/PEE blends. The effect of increasing PP-MA content on the tensile properties, flexural properties and impact strength of the PP-cp/PEE blends with a fix PEE content at 20 wt% was investigated.

The influence of PP-MA content on the mechanical properties of the blend (PP-cp/PEE, 80/20) is shown in Table 2. It was found that the strength values increased with the increase of PP-MA content. Only 0.5 wt% of PP-MA was enough to remarkably increase the values of tensile modulus, yield stress, flexural strength, flexural modulus and impact strength. PP-cp/PEE blends using PP-MA as an impact strength improver showed the highest tensile modulus and yield stress at 1.0 wt%. Impact strength at 0.5 wt% PP-MA increased slightly. The increase of impact strength of PP-cp/PEE8100 and PP-cp/PEE8150 blends was about 14% and 16% compared to the virgin PP-cp, respectively. Samples did not break at PP-MA concentrations up to 1.0 wt%. This means that the impact properties of PP-cp can be enhanced to a large extent by addition of PP-MA. The maximum values of flexural strength and flexural modulus were achieved when the PP-MA content was 2.0 wt%. The elongation at break of the blends containing PP-MA was less compared to those without PP-MA at the same amount of PEE (20 wt% of PEE). Thus, incorporation of PP-MA in the compounding was not effective in improving the elongation at break.

Figure 1. SEM micrograph of the blends.

Morphology

SEM micrographs of fracture surface of PP-cp and PP-cp blends are shown in Figure 1. The SEM micrographs showed that PEE particles were uniformly distributed in the PP matrix and the size of the elastomer domain increased as the PEE content increased. Increasing PP-MA content of the blends resulted in a noticeable reduction in the minor phase dimension. Using PP-MA 1.0 wt% in PP-cp/PEE blends (Table 2), the SEM micrograph (Figure 1f) showed a finer dispersion of the PEE domains compared to other PP-MA content. Therefore, PP-cp/PEE blend in the presence of PP-MA 1.0 wt% enhanced the adhesion of elastomer and polymer matrix and improved the compatibility of the two phases and enhance, the mechanical properties.

CONCLUSIONS

The impact properties of polypropylene (PP) blended with polyethylene elastomer (PEE) and polypropylene-grafted maleic anhydride (PP-MA) were evaluated. It has been demonstrated that the tensile modulus, yield stress, flexural strength, flexural modulus decreased while the elongation at break and impact strength increased with increasing PEE content. Moreover, PP blended with 20 wt% of PEE and 1.0 wt% of PP-MA showed a significant increase in tensile modulus, yield stress, flexural strength, flexural modulus and impact strength. The elongation at break of the blends containing PP-MA was less compared to those without PP-MA at 20 wt% PEE. Thus, incorporation of PP-MA was not effective in improving the elongation at break of the blends. It was shown that the presence of 1.0 wt% PP-MA in PP/PEE blend enhances the adhesion of elastomer and polymer matrix and improves the

compatibility of the two phases and the mechanical properties.

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