

Effect of CaCO_3 on the Mechanical Properties of Polyethylene Terephthalate/Polypropylene Blends

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Abstract: The aim of this work was to study the influence of CaCO_3 in both tensile and flexural mechanical properties of a PET (polyethylene terephthalate)/PP (polypropylene). Four compositions of PET/PP/ CaCO_3 blend were prepared by injection molding with CaCO_3 content of 0, 2, 4 and 6 wt%. The samples were cut according to the ASTM (American Society for Testing and Materials) standard and tested by using universal testing equipment. The results show that the mechanical properties of the PET/PP/ CaCO_3 composites with 2% and 4 wt% of CaCO_3 composition were better than that of the PET/PP composites. While the content of CaCO_3 is 6 wt%, the serious phase separation between PET and PP resulted in poor mechanical properties of the PET/PP/ CaCO_3 samples. This study shows that CaCO_3 has played a role to improve the tensile and flexural properties of the mixing product if it is present only in a small amount.

Key words: PET, PP, CaCO_3 , PET/PP blend, mechanical properties.

1. Introduction

PP (polypropylene) and PET (polyethylene terephthalate), which are the most popular, are widely used in many fields as to produce the bottle, plastic box, plastic bag... to contain food and water. Recently, the recycling of polymers such as PET after use is attracting the attention of many kinds of research aware of environmental problems and wishing to find ways to save earth resources [1]. PET/PP is expected to be a chance of having better properties than PP and PET. But mixing PET and PP together generally does not guarantee good interfacial adhesion between the two phases. The incompatibility of PET and PP can be reduced by introducing an additive known as a compatibilizer [2, 3]. Besides compatibilizers, lately many fillers have been commercially produced and the effect of filler content on the mechanical properties of polymer blends is of particular interest and significance [4-6]. Among the promising fillers

which have stirred much interest among researchers include clay, silica, and calcium carbonate (CaCO_3). CaCO_3 is one of the most important fillers for industrial production, due to its high performance, cost reduction, enhancing stiffness, induced toughening, and recyclables. There have been many previous studies using CaCO_3 to enhance the properties of PET/PP. Xie et al. [5] successfully synthesized PVC/ CaCO_3 nanocomposites via *in-situ* polymerization technique with a filler loading of 2.5, 5.0 and 7.5 wt%. Their studies found that the toughness and stiffness of PVC were simultaneously improved with the addition of 44 nm-sized CaCO_3 filler. In the work of Hanim et al. [6], PP/ CaCO_3 nanocomposites were prepared at filler loadings of 5, 10 and 15 wt%. The impact strength and modulus of PP showed some improvement with the addition of the CaCO_3 while the tensile strength deteriorated. Incorporation of CaCO_3 shifted the crystallisation exotherms of PP towards higher temperatures, indicating that the introduction of CaCO_3 has acted as a nucleating agent for PP. Besides, Thumsorn et al. [7]

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successfully developed blending sequence on CaCO₃ reinforced recycled PET/PP blend. The researchers used the ratio of RPET/RPP blend, which was 95/5; the content of CaCO₃ was fixed at 2.5 wt%. This research showed that the addition of CaCO₃ revealed the reduction of tensile modulus and yield strength of the blends, but the rigid and impact strength increased.

The main objective of this work is to evaluate role of CaCO₃ and to find the best ratio of PET/PP/CaCO₃ based on the highest flexural test strength, tensile mechanical behavior, and microstructure of the specimen.

2. Materials and Methods

Materials and chemicals were used in this study: polyethylene (SABIC-LDPE 4024, Saudi Arabia) is provided by Thuan Thang Plastics Co., Ltd; ethylene vinyl acetate is supplied by Dong Nhat Phat Co., Ltd. The composition of PET and PP was mixed by using weight measuring container. PET/PP was mixed with CaCO₃ according to its weight compositions which are given in Table 1. CaCO₃ was mixed with PET/PP in the weight composition of 0% to 6%. The mixing process was mixed by using TKC series-vertical injection molding machine. Base on the previous studies about PET/PP blends, ratio of PET/PP is kept fixed 90/10 and EVA (ethylene vinyl acetate) is kept

fixed with constant ratio 5%.

Specimens were produced by using injection mold machine according to the composition decided. The ASTM (American Society for Testing and Materials) D638 was used to measure plastic tensile strength. They were according to the size which is shown in Fig. 1. The specimen geometry is of width = 19 mm, overall length = 113 mm and thickness = 4 mm. The samples were mixed and pressed by using TKC series-vertical injection molding machine. In order to ensure the mixing material is melting, the machine screw extruder is heated to 195 °C. The injection parameters were chosen on basis of the PP supplier recommendations.

Then, each specimen is tested using tensile test machine. The tensile strength of specimens was analysed by using tensile test instrument. The tensile properties were determined using three samples for each composition to study the effect of CaCO₃ weight composition on tensile properties. The constant cross speed used is 50 mm/min at room temperature and mounted on the test machine. The experiment was carried out on Shimadzu Autograph AG-X Plus 20 kN (Japan) with longitudinal extension, a high resolution (1.8 μm) camera without contact with the specimen and basic specifications as following: the maximum test power was 20 kN, in range of speed 0.001-1,600

Table 1 Compositions of the samples (wt%).

Sample	Component (wt%)			
	PET	PP	CaCO ₃	EVA
S0	85.5	9.5	0	5
S1	83.7	9.3	2	5
S2	81.9	9.1	4	5
S3	80.1	8.9	6	5

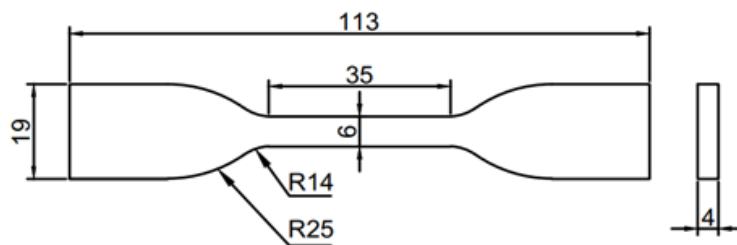


Fig. 1 Specimen of the tensile test according to ASTM standard.

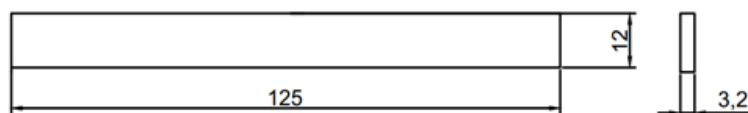


Fig. 2 Sample size for bending strength testing.



Fig. 3 HITACHI S-4800 machine.

mm/min, speed accuracy $\pm 0.1\%$ test speed, operating temperature at 5-50 °C, data acquisition speed 1,000 Hz.

The analogous test to determine bending strength of materials in the ISO system is ISO 178. Test specimens for bending strength were mixed and pressed using a Shine Well SW-120B Injection Machine. Each group of samples was placed in the drying chamber of the machine with temperature of 100 °C for 10 minutes to 15 minutes. Pressing temperature was 180 °C. The size of the sample was tested in this experiment which processed according to the parameters: 125 × 12 × 3.2 mm (Fig. 2). The testing device was used in this method, which is the Instron 5566 Materials Testing Machine with load capacity 10 kN (2,250 lbf); maximum power is 200 VA, and weight of load frame is 136 kg (300 lb).

The fracture surface of each specimen in bending strength test was observed by HITACHI S-4800—high resolution scanning electron microscope (SEM), with acceleration 5.0 kV (see Fig. 3). The surface of the samples used for all SEM was platinum-sputtered with a conductive layer before

observation.

3. Results and Discussion

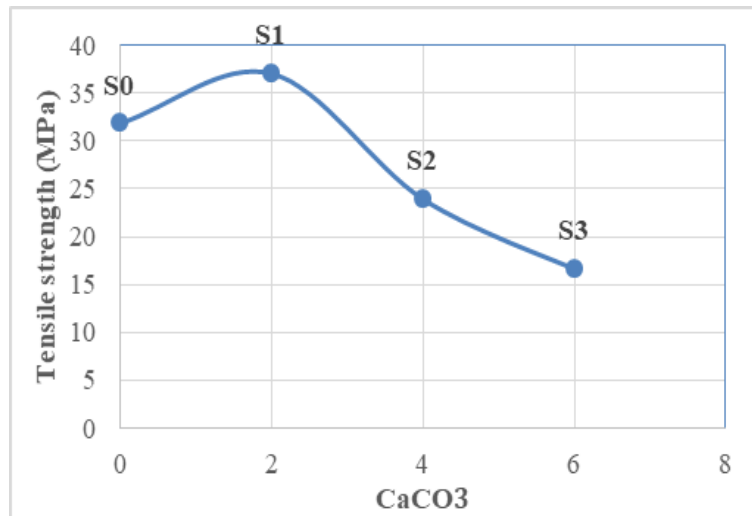
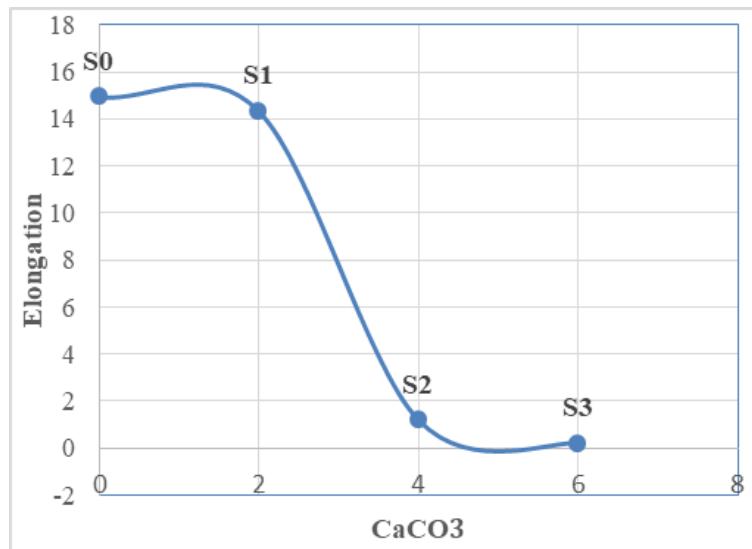
3.1 Tensile Mechanical Behavior

The results of the tensile tests performed with PET/PP and CaCO₃ are shown in Table 2. Fig. 4 shows the tensile strength increases gradually until the composition of 2% CaCO₃, but at 4% CaCO₃, tensile strengths are a drop down. For the PET/PP blends, the addition of 2% of CaCO₃ gave a significant improvement in the tensile strength; the corresponding tensile strength is 37.05 MPa. However, with CaCO₃ from 4% to 6%, the tensile strength became even lower with the addition of CaCO₃, changing from 31.8 MPa (0% CaCO₃) to 24.0 MPa (4% CaCO₃) and 16.6 MPa (6% CaCO₃). This means that 2% of CaCO₃ is sufficient, and larger amounts of CaCO₃ are not warranted for improvement in tensile strength. It happened because the increase in CaCO₃ dramatically decreases the strength of the material and is more brittle.

Fig. 5 shows the effect on elongation in a different

Table 2 Comparison of measured roughness data of tensile strength.

Sample	CaCO ₃ (wt%)	Break-strain (%)	Max-stress (MPa)	Elasticity (MPa)
S0	0	14.9192	31.8237	2,537.90
S1	2	14.3145	37.0462	3,267.26
S2	4	1.18373	23.9329	2,840.77
S3	6	0.20278	16.6142	1,467.71

**Fig. 4** Effects on tensile strength in different composition of CaCO₃ filler.**Fig. 5** Effects on elongation in different composition of CaCO₃ fillers.

composition of CaCO₃ fillers. From Fig. 5 we can observe the incorporation of larger contents of CaCO₃ did not lead to a successive increase in elongation. This shows that CaCO₃ fillers have influenced the ductility of PET/PP blends. The reason for limited ductility is the tendency for the extension of the voids

perpendicularly to axial stress [1].

From Fig. 6 we can observe a great increase in elastic modulus with the addition of 2% and 4 wt% of CaCO₃, but the incorporation of larger contents of CaCO₃ has lower elastic modulus than the PET/PP blend without CaCO₃.

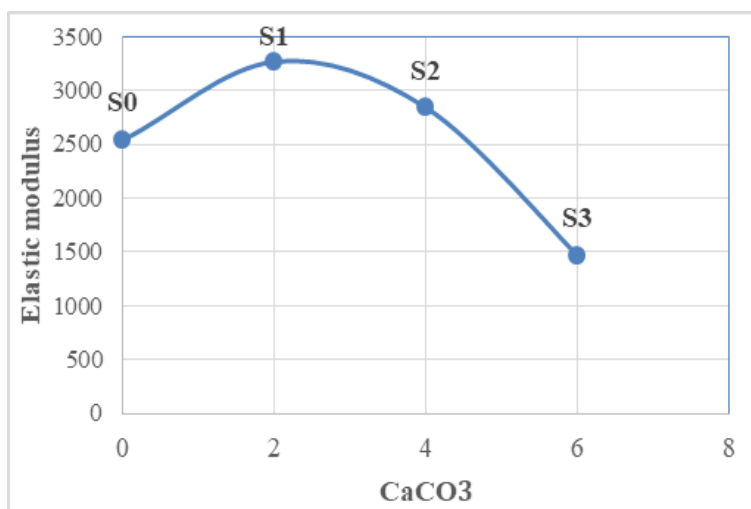


Fig. 6 Effects on elastic modulus in different composition of CaCO_3 fillers.

Table 3 Comparison of measured roughness data of flexural tests.

Sample	CaCO_3 (wt%)	Max-stress (MPa)	Max-strain (%)	Elasticity (MPa)
S0	0	51.9034	6.06355	1,830.05
S1	2	66.0524	5.69094	1,951.53
S2	4	57.1853	5.50371	1,846.01
S3	6	46.5180	5.07828	1,641.34

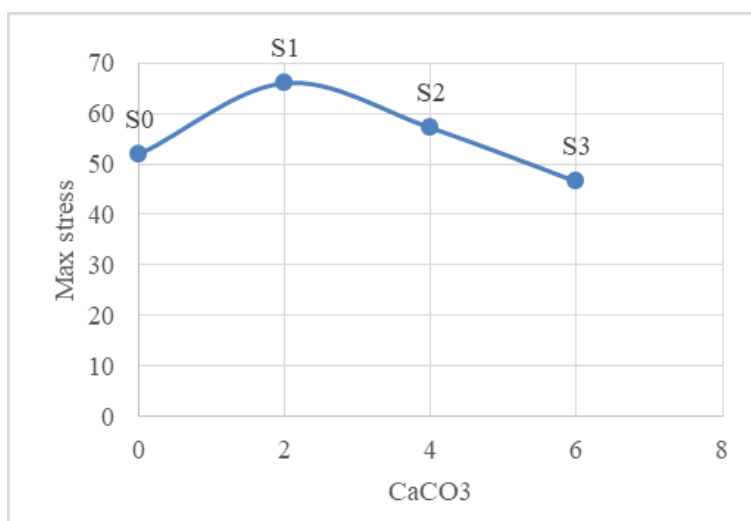


Fig. 7 Effects on flexural strength in different composition of CaCO_3 filler.

3.2 Flexural Mechanical Behavior

The results of the flexural tests performed with PET/PP and CaCO_3 are shown in Table 3 and Fig. 7. From Fig. 7 we can see that the addition of CaCO_3 is found to improve the strength of the blends at loadings of 2% CaCO_3 until the composition of 4% CaCO_3 ,

with flexural strength 57.19 MPa and 66.05 MPa, respectively. But at 6% CaCO_3 filler, CaCO_3 has the opposite effect of slightly reducing the flexural properties.

Fig. 8 shows the results of elasticity. It shows the elasticity has increased gradually from 2% to 4% CaCO_3 . This shows that CaCO_3 filler has influence on

the elasticity of composite material but at a maximum level of 4% CaCO₃. These results evidenced the influence of CaCO₃ particles in flexural strength of PET/PP.

3.3 Microstructure

SEM micrographs of the PET/PP blends with/without CaCO₃ are presented in Fig. 9. Figs. 9b-9d illustrate the morphology of the surface of the PET/PP/CaCO₃ blends at 2, 4 and 6 wt% filler loadings. The sample S1 can see the pictures of the

spherulites of PP in PET. The PET/PP pairs tend to separate into two liquid phases. PP is presumed to be the dispersed phase due to its high viscosity and elasticity. The size of PP spherulites is coarse and could be easily distinguished. However, the electron micrographs of Figs. 9b and 9c show that the PET/PP/CaCO₃ blends promote a much finer morphology. When adding CaCO₃, PP spherulites are finer, except at loadings of 6% CaCO₃. A reduction in PP dispersed phase sizes was evident with the incorporation of CaCO₃ [4].

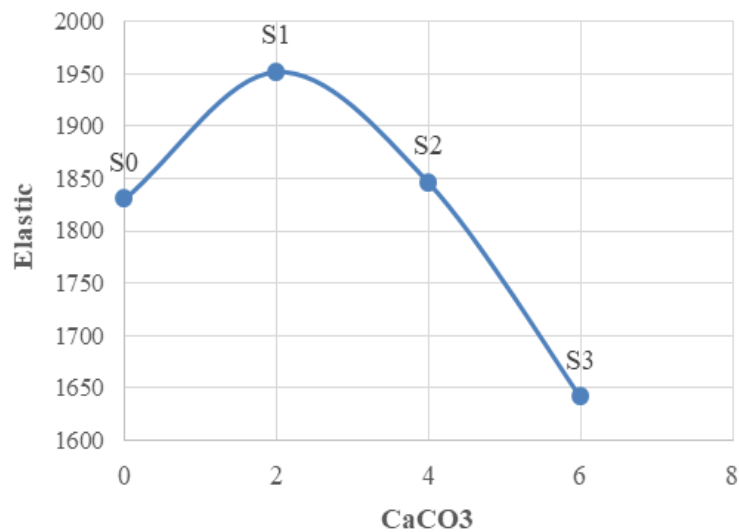
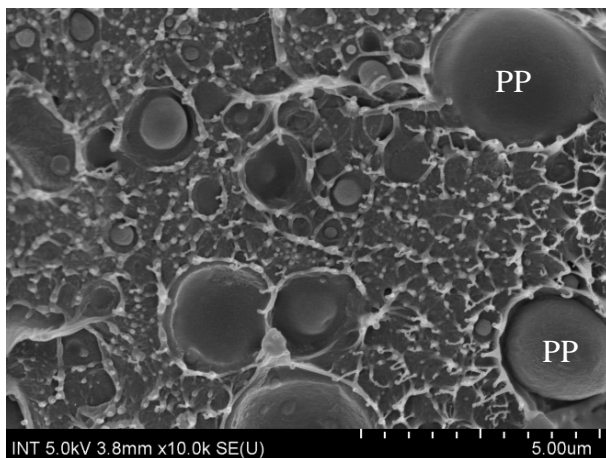
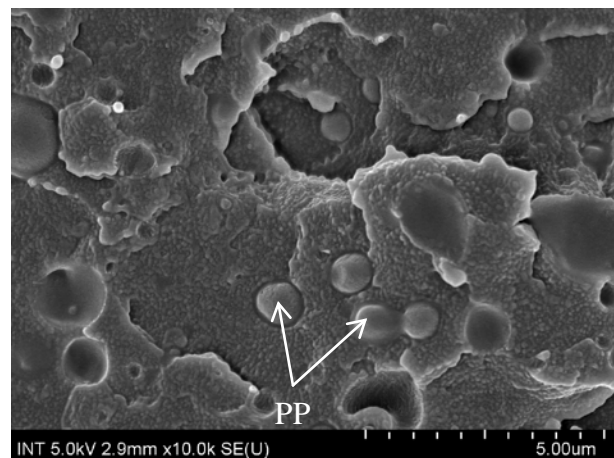


Fig. 8 Effects on elasticity in different composition of CaCO₃ filler.



(a) S1 sample (0 wt% CaCO₃)



(b) S2 sample (2 wt% CaCO₃)

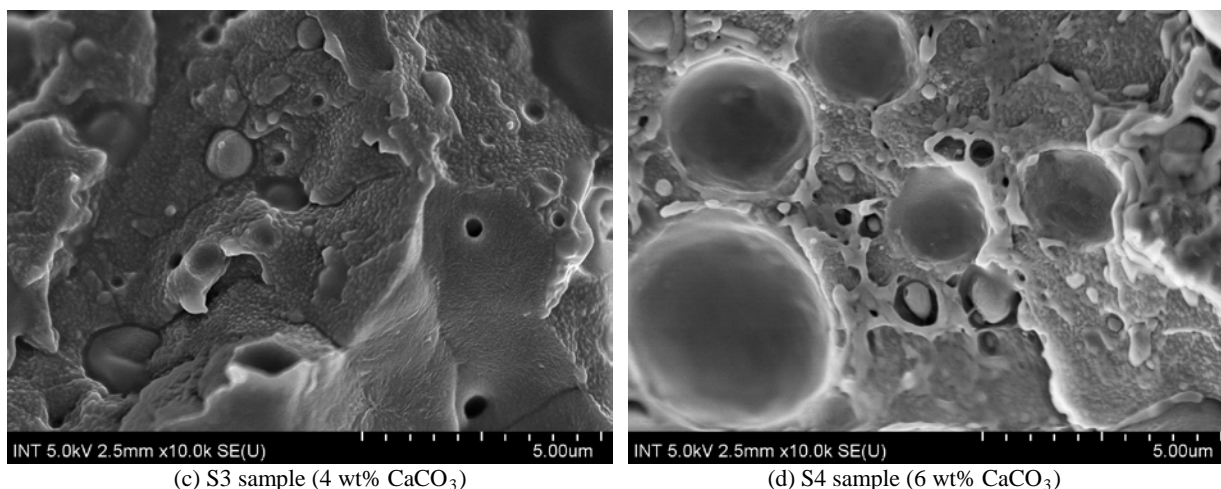


Fig. 9 SEM micrographs for the PET/PP blend with different weight percent of CaCO₃.

4. Conclusions

Flexural mechanical properties seem to be affected by the dispersion of the CaCO₃ particles; great increases in elastic modulus were obtained with the addition of small content of CaCO₃ particles.

The addition of CaCO₃ is found to improve the flexural strength of the blends at loadings of 2% and 4% CaCO₃ with flexural strength 57.19 MPa and 66.05 MPa, respectively.

As a conclusion CaCO₃ can improve the mechanical properties of PET/PP if it is present only in a small amount.

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