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# Effect of Glass Fiber Length and Content on Mechanical Properties of Polybutylene Terephthalate

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## Abstract

The effect of glass fiber (GF) length and content were studied on mechanical properties of polybutylene terephthalate (PBT). The glass fiber was found to be highly compatible with PBT. The PBT/6 mm GF 30% composite possessed the highest flexural modulus (FM) and flexural strength (FS). The FM and FS were increased with the increasing of GF content. The longer glass fiber resulted in the higher value of FM and FS but hardly affected on the deflection and unnotched izod impact strength of the composites. The impact strength of composites was drastically decreased with the addition of glass fiber as compared with neat PBT.

**Keywords:** PBT; Glass fiber; Flexural properties; Impact strength

## Introduction

The idea of making thin plastics board to replace wood and cement wall for construction materials of temporary home during flood was the inspiration to initiate this study. PBT is a good candidate for the mentioned purposes. PBT is thermoplastic engineering polymer which has various good properties such as high strength and rigidity, low moisture absorption, water and chemical resistance, high thermal stability, hardness, abrasion, short-cycle time of molding and good surface appearance. PBT could be self-ignited when heating up to more than 150°C (or 200°C with glass-fiber reinforcement) [1-3]. PBT is suitable materials for making plastic board to be used as wall panel. But in this field, even if PBT has high stiffness to a certain extent, this property could be improved, and one way to do this is the addition of glass fiber to reinforce PBT [4]. The effect of glass fiber length and content had been reported in some polymers such as polypropylene [5]. However, no publication has yet mentioned on the study of the influences of glass fiber length and content on PBT. The objective of this work is to investigate the glass fiber length and content on properties of PBT/glass fiber composites.

## Experimental

### *Materials*

PBT (Pocan B 1,600) was purchased from Sy Smile Co., Ltd. (Bangkok, Thailand). Glass fiber (EC 979) was purchased from Polyline Co., Ltd. (Bangkok, Thailand). **Compounding and moulding:** PBT were dried in oven for 8 hrs at 100°C and then wetted by methanol for the PBT/glass fiber adhesion. Such PBT would be compounded with fiberglass of 3 mm and 6 mm in length by twin screw extruder under temperature of 250-275°C in different zones at screw speed of 100 rpm. The extrudate was pelletized and then injection-molded into standard tensile test specimens and flexural bars using a Battenfeld BA 250 injection molding machine with the barrel temperature profiles of 250, 260, 285 and 280°C. The injection pressure used was 68 bars.

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*Characterizations*

Fourier transform infrared spectroscopy (FT-IR) spectra of PBT, PBT/glass fiber composites, and glass fiber were recorded with Fourier transform infrared spectrometer in the wavelength range of 4,000-400 $cm^{-1}$. Morphology of the PBT/glass fiber composites were investigated using a scanning electron microscope (SEM) at 50 and 500 magnifications. The flexural modulus, flexural strength, and deflection of PBT and PBT/glass fiber composites were determined .by using LLOYD LR 50K Universal Testing Machine according to ASTM D790. The unnotched izod impactstrength of PBT and PBT/glass fiber composites were determined by using impact tester with the 4 J pendulum according to ASTM D256.

## Results and discussion

The FTIR spectra on neat PBT, silane treated glass fiber, and PBT/glass fiber composite in a wave number range of 4,000–400 $cm^{-1}$ were shown in Figure 1. FTIR spectra shows the peak of PBT at the wave number about 1,730 $cm^{-1}$ due to C=O stretching, 1,240 $cm^{-1}$ from the ester, 1,100 $cm^{-1}$ and 730 $cm^{-1}$ from aromatic C-H. The peak around 1,730 $cm^{-1}$ appeared in the spectra of silane on both glass fiber and neat PBT. This result indicated that C=O functionality existed and acted as coupling agent between PBT and glass fiber. In other words, glass fiber is highly compatible with PBT.

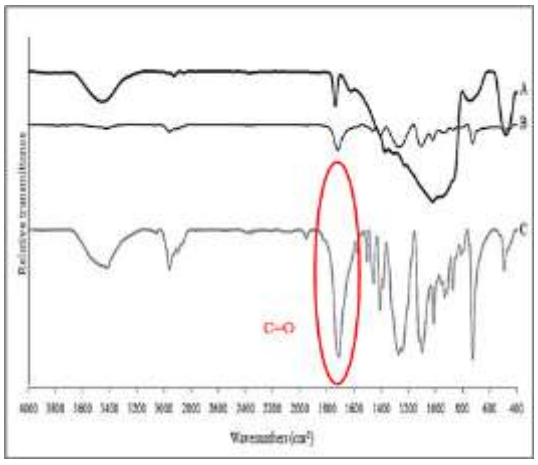



**Figure 1.** FTIR spectra: (A) Silane on GF, (B) PBT, and (C) PBT/GF Composite.

Figure 2 shows the SEM micrograph of fracture surface of PBT/glass fiber composites. It could depict the compatibility between PBT and glass fiber in the composite. As seen in Figure 2, PBT stood out on the surface of glass fiber in form of the fracture lines. This result indicated the interaction between PBT and glass fiber which supported the compatibility between PBT and glass fiber in the composites with the compliance of the results from FTIR.

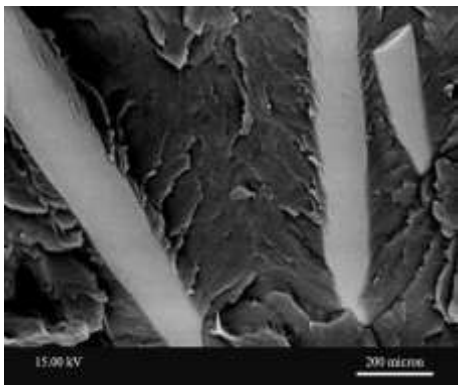



**Figure 2.** SEM micrographs of the fracture surface of PBT/glass fiber composites (mag. 500 x).

Figure 3(a) shows the effect of length and content of glass fiber on flexural modulus of PBT and PBT/glass fiber composites. The flexural modulus of PBT/glass fiber composites was moderately increased with the increment loading of glass fiber compared with neat PBT. The increase in modulus is governed by the nature of stiff glass fiber compared to the matrix and thus enhanced the stiffness of polymer. The result complied with the study of K. Friedrich et al., who had investigated the adding of higher stiff material into the lower stiffness matrix. It was found that the high stiffness material that dispersed in the matrix provided good reinforcement for the matrix and overall stiffness of the material [6]. These composites showed the flexural strength in a similar trend (as seen in Figure 3(b) as well as the flexural modulus. The enhancement in flexural strength was observed in all PBT/glass fiber composites. These might be caused by high dispersion and high interfacial adhesion between the glass fiber and the PBT matrix (as seen in Figure 2 and 4). The modulus and flexural strength were greatly improved when 30 wt% glass fibers were incorporated into PBT. Hence, it could be seen that the addition of glass fiber to PBT was an efficient mean to enhance the flexural properties of PBT.

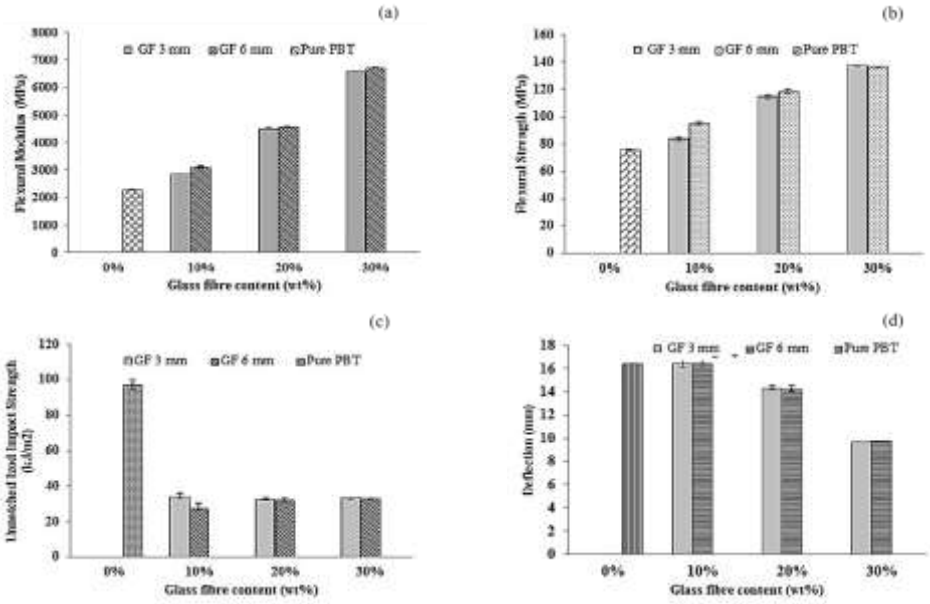
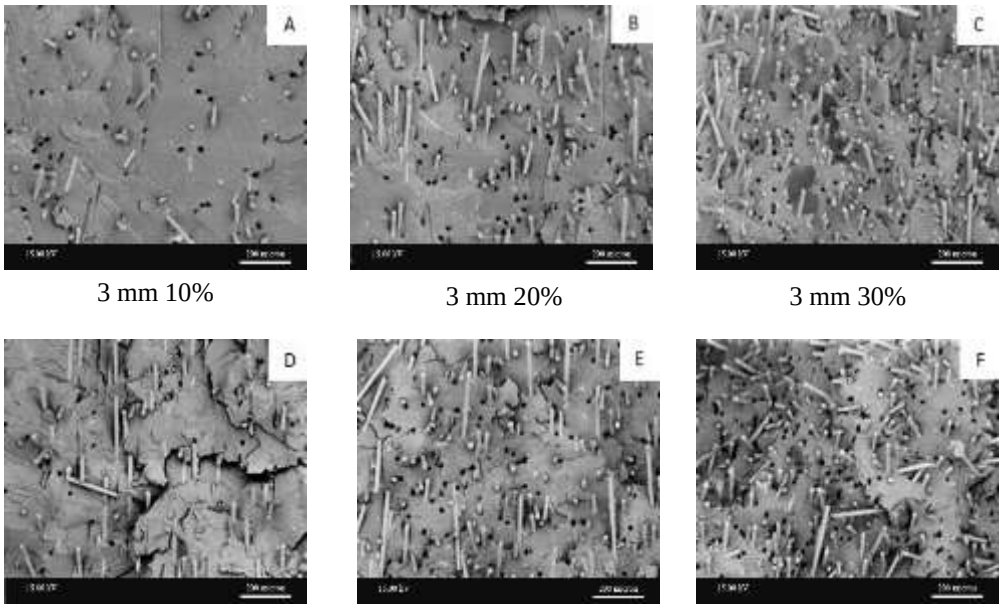



**Figure 3.** (a) flexural modulus (b) flexural strength (c) deflection and (d) impact strength of PBT and PBT/glass fiber composites.

From Figure 3(a-b), from the aspect of same glass fiber content, flexural modulus and flexural strength of the composites with 6 mm long fiber were higher than the composites with glass fibers 3 mm in length. As seen in Figure 4, at the same amount of glass fiber, the specimens that were compounded with 6 mm glass fibers showed more dispersion of glass fibers on the matrix than the specimens with the one of 3 mm glass fibers. The longer glass fibers of 6 mm in length were highly possible chopped down into shorter fibers of various sizes by screw during compounding. Hence, the aspect ratio of 6 mm glass fibers was higher than the one of 3 mm glass fibers. Higher aspect ratio means higher contact surface area, and then more loading could be transferred from PBT matrix to fibers. Therefore, the considerable enhancement in the flexural modulus and flexural strength of composites could very well be related to aspect ratio of glass fibers.




3 mm 10% 3 mm 20% 3 mm 30%

6 mm 10% 6 mm 20% 6 mm 30%

**Figure 4.** SEM micrographs of the fracture surface of PBT/glass fiber composites (mag. 50 x).

Figure 3(c) showed the effect of glass fiber on deflection for these composites. Prior to the addition of glass fiber, PBT is very ductile. With the addition of only 10 wt% glass fiber, the deflection of composites did not change in relation to the neat PBT. Once 20 wt% glass fibers was added, the deflection of composites dropped dramatically at approximately of 12% and even more reduction for the deflection of about 28% at the glass fiber contents of 30% by weight. As mentioned earlier, the addition of glass fiber in plastic matrix could enhance the stiffness with the reduction of toughness because of the polymer mobility restriction by the rigid glass fiber. In other words, PBT chains would typically slip pass each other but more difficulty in mobility in the glass fiber presence. The lengths of glass fiber slightly affect the deflection of composites

Figure 3(d) showed the effect of length and content of glass fibers on impact strength of PBT and PBT/glass fiber composites. PBT is typically tough material. With the addition of 10, 20, and 30 wt% glass fiber, the impact strength of composites sharply dropped compared to neat PBT. The addition of glass fiber to PBT matrix dramatically reduced the energy absorbed by the specimen compared to neat PBT. It could be presumed that glass fiber restricted the transfer of energy and mobility of polymeric chains, and thereby stored energy and stress at the position which caused fracture and fracture propagation. This indicated the reduced capacities of energy absorption during fracture propagation.

## Conclusion

When the glass fiber content was increased, the flexural modulus and flexural strength of PBT composites would be raised. In contrast, the deflection would be reduced under higher glass fiber loading. However, there was no relationship between glass fiber content and impact strength of composites. As per fiber length, both flexural modulus and flexural strength had been raised once the fiber length was increased accordingly. While the glass fiber length demonstrated little to no effect on the deflection. The glass fiber length only had influence on impact strength at 10% loading. Therefore, PBT/6 mm GF 30% composites demonstrated the highest flexural strength and flexural modulus.

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