Research on Processing Technology of Polyester Fabric Reinforced Polypropylene Thermoplastic Laminated Composites

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Abstract

Thermoplastic composites are eco-friendly to environment. In this study, PET/PP thermoplastic composite laminates were produced by interleaving polypropylene (PP) sheets with polyethylene terephthalate (PET) plain fabrics in the condition of varying thermocompression temperature, pressure and time. Afterwards, peel resistance, tensile and impact properties of PET/PP thermoplastic laminates were tested. And the tensile and impact performance of PET/PP laminates was respectively about 40 % and 320 % higher than PP laminates. It was shown that when thermal compressing under pressure of 40 Kg/cm2 at 230 ℃ for 0.5 minute, PET/PP thermoplastic laminates had optimum tensile and impact properties.

Introduction

There are three components composed of composites- one is matrix, another is reinforcement, and the other is interphase between matrix and reinforcement. And these components were composited to produce a type of multiphase material. By analyzing the composites structure, one continuous phase is the matrix, and the other phase is dispersing in the composite and surrounded by matrix phase which is known as the reinforcement. And fiber is usually a basic type of reinforcement for composites due to its size effect. Based on fracture mechanics, reinforced material doesn't have bigger size but should have defect as little as possible in order to approach to composites theoretical strength [1][2]. In the microcosmic level, the reinforcement phase and matrix phase which are made of composites are combined by physical and chemical effect to form the complex structure which is different from single reinforcement and matrix phase. Composited structure has significant influence on the whole composites properties varying with microstructures which is also be known as interphase- one of composite phases [1]. Excellent interphase makes stress effectively transferring from the reinforcement to the matrix, so it has a huge effect to mechanical properties. A great many of studies have been reported to pay attention to interphase issues. For example, Xiaojuan Si and other researchers used PP-g-AA to increase compatibility of PET/PP hybrid fibers, which improved dispersion significantly [3]. Maya Jacob John and other scholars used corn protein coupling agent to modify flax nonwoven, resulting in increases of interphase compatibility, tensile, flexural properties, and modulus of flax nonwoven/PP composites. The functional composite materials containing multiple fibers have been widely studied and successfully developed [5-7].

In this study, PP has lower melting point so that it was selected to be matrix. PET plain fabric was chosen as the reinforcement, and has higher melting point. To improve mechanical properties of PP and to take advantage of clamping force between warp and weft yarn, we used two kinds of thermoplastic materials which were recycled from environment to generate PET/PP laminates whose manufacturing process bring lower pollution and less waste. So in this research we discussed processing technology of PET/PP thermoplastic laminates.

Experimental

Materials and processing

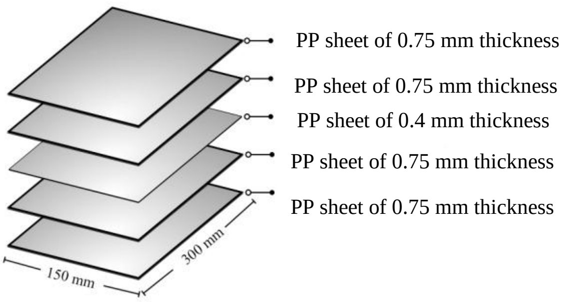
There were two procedures in the experiment, including PP laminates preparation and PET/PP composite laminates fabrication.

PP laminates

Firstly, oily release agent was coated on templates surface evenly. Secondly, two-layer PP sheets (Yongjia Chemistry Industry Co., Ltd) with thickness of 0.75 mm were laid on lower template, following by one-layer PP sheet with thickness of 0.40 mm. And then 0.75 mm thick two-layer PP sheets were laid under the upper template. PP laminates structure we prepared was shown in Fig.1. Finally PP laminates was placed at midplane of upper and lower templates in the distance of 3.0 mm,and put it on the hot press (Reid Electric, Taiwan) to make into laminates. Experimental parameters for hot-pressing were at the temperature of 230 ℃ unber pressure of 40, 60, and 80 Kg/cm^2 for 0.5 minute. After laminates was cooling to room temperature, the thickness of PP laminates was 3.0 mm.

PET/PP composite laminates

First of all, oily release agent was evenly coated on templates surface. And then, one-layer 1000D PET fabric was put on the one-layer PP sheet (0.8 mm thick × 300 mm long × 150 mm wide) whose tensile strength and elongation respectively in warp and filling direction was 164.34 M Pa, 24.90 % (warp) and 129.49 M Pa, 24.90 % (filling). Then one-layer PP sheet (1.2 mm thick× 300 mm long × 150 mm wide) was laid up following one-layer PET plain fabric. And then one-layer PP sheet 0.8 mm thick× 300 mm long × 150 mm wide was followed, and finally PET/PP laminates was produced as shown in Fig. 2. The PET/PP laminates was got by hot-pressing in templates distance of 3.0 mm using hot press(Reid Electric, Taiwan) at 230 ℃ under pressure of 40, 60, 80 Kg/cm^2 for 0.5 minute. Laminates was cooled to room temperature after hot- pressing, and 3.0 mm thick PET/PP laminates was produced.



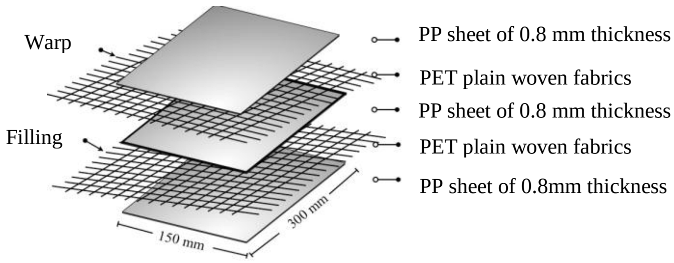


Fig. (1). PP laminate structure.

Fig.(2). PET/PP laminate structure.

Testing

In this study, PP laminates and PET/PP composite laminates were tested for tensile strength, impact properties, and peel resistance according to ASTM D 638, ASTM D 256, and ASTM D 1876, respectively.

Results and Discussion

The study presented peer resistance, tensile and impact properties of PET/PP thermoplastic laminates considering the hot-press temperature (230 ℃), pressure (40, 60, and 80 Kg/cm^2) and time(0.5 minutes) parameters for optimal manufacturing.

Impact properties of PET/PP thermoplastic composite laminates and PP laminates

Fig. 3(a) and (b) show impact strength decreasing with increase of hot-press pressure. The results have shown that impact strength of PET/PP laminates was about 320 % higher than that of PP laminates. From energy dissipation mechanisms, matrix-fiber fracture, fiber–matrix de-bonding and fiber pull-out take place during impact fracture. From Fig.3 (b), it is found that PP laminate is fit to fracture mechanism as described above. But the main failure mechanism in laminates was specimen fracture leading to lower energy dissipation and hence descending impact strength.

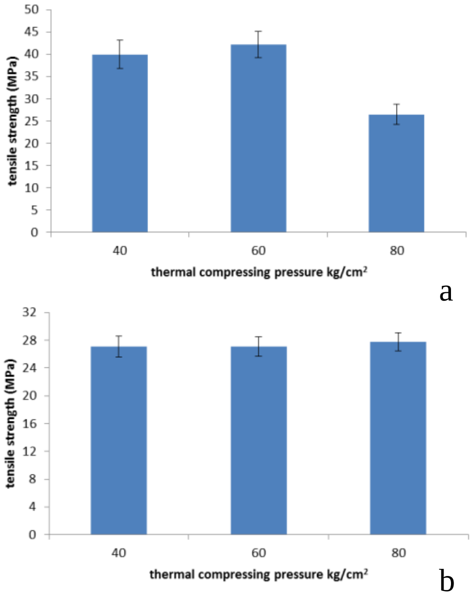


Fig.3 (a). The impact properties of PET/PP thermoplastic composite laminates thermally compressed at 230 ℃, under 40, 60, and 80 Kg/cm^2 pressure, for 0.5 minutes. (b). The impact properties of PP laminates thermally compressed at temperatureof 230 ℃, under pressure of 40, 60, and 80 Kg/cm^2, and periods of 0.5 minutes.

Tensile properties of PET/PP thermoplastic composite laminates and PP laminates

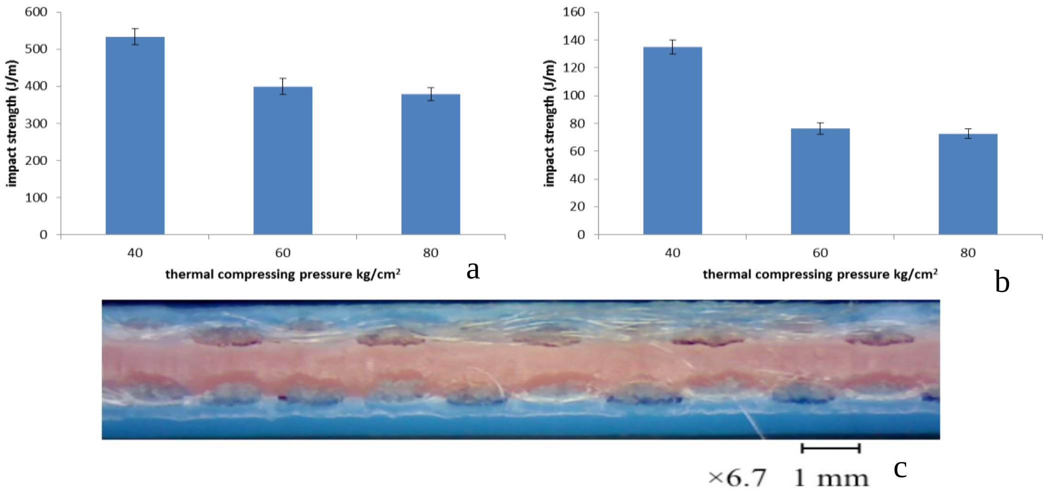


Fig.4 (a).The peel resistance of PET/PP thermoplastic composite laminates with thermal compressing temperature of 230 ℃, pressure of 40, 60, and 80 Kg/cm^2, and periods of 0.5 minutes. (b). The impact properties of PP laminates with at 230 ℃ thermal compressing temperature, pressure of 40, 60, and 80 Kg/cm^2 and periods of 0.5 minutes. (c). The cross-section of PET/PP thermoplastic composite laminates at 230 ℃ compressing temperature under60 Kg/cm^2 pressure, and 0.5 minutes periods.

From Fig.4(a) and (b) it is shown that the tensile strength of PET/PP and PP laminates were respectively 39.95 MPa and 27.1 MPa with thermal compressing at 230 ℃ under pressure of 40 Kg/cm^2 for 0.5 min. And the tensile strength of PET/PP was higher than that of PP laminates whose difference between two of them was up to 44 %. It was because fabrics effectively disperses tensile stress when specimens are sufferring tensile force. Therefore, PET fabrics addtion can improve the overall strength of composite laminates. With thermal compressing temperature at 230 ℃, pressure under 80 Kg/cm^2, and time for 0.5 min, PET/PP laminates have 26.47 MPa tensile strength, thus tensile properties decreased owing to reinforcement addition. Fig. 4(c) displays the cross-section of PET/PP laminates. It can be seen that many larger voids existed in laminates which may caused by interwoven of fabrics, making melting PP not impregnating fabrics effectively via physical adsorption. It is concluded that voids made the tensile properties decreasing and unstable.

Peel resistance of PET/PP thermoplastic composite laminates and PP laminates

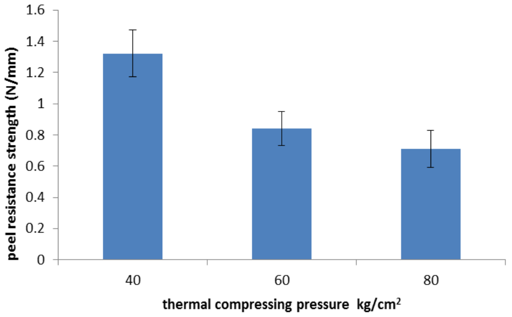


Fig. 5 The peel resistance of PET/PP laminates thermal compressing at 230 ℃ under pressure of 40, 60, 80 Kg/cm^2 for 0.5 minute.

Fig. 5 represents peel resistance decreasing with increase of hot-press pressure. That may be beacuse the time heat transferring to internal layers spends more than that of transferring to surface. Therefore, melting PP on surface was flowing to the plane direction in advance, and hard to thick direction in order to impregnat fabrics. In additional, the increase of the pressure on laminates made the situation more exacerbated. So it is concluded that higher pressure had negative effect on peel resistance of PET/PP laminates.

Conculsion

With thermal compressing temperature at 230 ℃, pressure of 40 Kg/cm^2 and time for 0.5 min, PET/PP thermoplastic composite laminates have optimum mechanical properties. Comparing with other common thermoplastic fibers, PET plain fabric has higher toughness and tensile properties; therefore, it can positively improve tensile and impact properties of PP laminates. From impact testing, it is shown that PET/PP thermoplastic composite laminates was about 320 % higher than PP laminates.

Acknowledgement

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