Paintability of Injection Molded $CaCO_3$ filled Recycled PET/Recycled PP Blend

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Abstract

Paintability of injection mold recycled PET/recycled PP blend filled with $CaCO_3$ was evaluated an adhesion strength by using surface and interfacial cutting analysis system (SAICAS). The blends of RPET, RPP and $CaCO_3$ were compounded by single screw extruder at various content of $CaCO_3$ and using compatibilizer for improve interfacial adhesion of recycled polymer blends. The blends were injection molded to square plate specimens then painted by using the Japanese lacquer for purpose studies. The SAICAS method can investigate surface adhesion of paint on injection molded specimens, which illustrates the profile of adhesion strength of painting on the blends at various content of $CaCO_3$. Specimens with higher $CaCO_3$ contents show better retention in paint adhesion. The results can indicate that $CaCO_3$ promoted paintability of the blends and exhibited the long term reliability of decorative painting on injection mold RPET/RPP blend products.

Keywords: Recycled polymer blend, $CaCO_3$, SAICAS, paintability, adhesion

1. Introduction

Calcium carbonate ($CaCO_3$) are used in compatibilized recycled polyethylene terephthalate (RPET) and recycled polypropylene (RPP) blend in order to achieve good balanced of rigidity and toughness [1]. An important consider for these materials applications, such as kitchenware decoration, furniture or automotive panels, is ability to be painted with typical painting system. Adhesion of paint on plastic, which has hydrophilicity and low surface energies results in poor wetting characteristics and poor adhesion strength [2-4]. Morphology, composition, crystallinity as well as processing conditions could be influenced on paint adhesion [5]. Preschilla et al [5] described that paint adhesion on compatibilized polyamide and polyphenylene ether blend was varied with molding conditions and surface morphology.

Adhesion test method can be investigated by various measuring techniques such as a knife with a pull-off adhesion tester, scrape tests or perform by tensile testing [2, 6]. A surface and interfacial cutting analysis system (SAICAS) evaluates the adhesion strengths of the coating samples, which are usually difficult to measure with a conventional adhesion tester. Fujino et al [6] studied on between adhesion promoter and thermoplastic polyolefin. They indicated that traditional peel strength measurement using tensile testing caused adhesion failure not only at the interface between substrate and adhesion promoter but also cohesive failure within adhesion promoter and substrate layers. It is interesting to note that SAICAS possible enables on reproducible measurement of the interface adhesive strength compared to traditional peel strength measurement [6-8].

The objective of this research is to study the effect of $CaCO_3$ content on paintability of $CaCO_3$ filled RPET/RPP blend by using SAICAS method.

2. Methodology

2.1 Materials

Both recycled polyethylene terephthalate (RPET) and recycled polypropylene (RPP) in the form of flake were provided by Yasuda Sangyo Co., Ltd. A finely ground commercial grade $CaCO_3$ (SOFTON 1200) with an average particle size of 1.8 μm was purchased from Bihoku Funka Kogyo, Ltd., Japan. A styrene-ethylene-butadiene-styrene base compound was used as compatibilizer, which purchased from JSR Corporation, Japan. The ratio of RPET/RPP blend was set at 95/5. The content of $CaCO_3$ was varied at 0, 3, 5, 7 and 10 wt%. The amount of the compatibilizer was fixed at 5 phr (part per hundred resins by weight).

2.2 Sample Preparation

The blends were prepared by single screw extruder (SRV-P70/62, Nihon Yuki Co., Ltd., Japan). RPET was dried by using a dehumidifying drier at 120 °C for 5 hours before compounding. The extruder barrel temperature was set at 260-285 °C and screw speed at 50 rpm. The blends were dried at 120 °C for 5 hours before prepared square plate specimens by injection molding machine (J110ELIII, JSW) at barrel temperature of 245-285 °C.

The Japanese lacquer was painted onto square plate injection molded specimens. The painted specimens were dried and baked in the oven at 120 °C for 1 hour and keep at room temperature before testing. The painted thickness was approximately 25 to 30 μm.

The painted specimens were immersed in hot water at 80 °C for 1 hour, dried with tissue paper, kept at room temperature for 10 minutes before SAICAS testing.

2.3 Characterization

Adhesion and peeling strength before and after immersion in hot water were measured by the Surface and Interfacial Cutting Analysis System (SAICAS, DN-20S, Daipla Winters). The blade width and angle were 1 mm and 20°-10°, respectively. The typical cutting profile was obtained by recording horizontal and cutting depth as a function of time. The peel strength (P) was characterized by dividing the measured horizontal force (F_H) by the blade width (w).

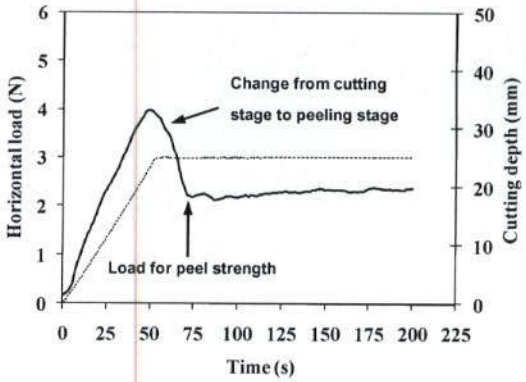
$$P = \frac{F_H}{w} \quad (1)$$

The degree of adhesion was defined as the ratio of the horizontal force in the peeling stage to the maximum horizontal force in the final part of the cutting stage [7].

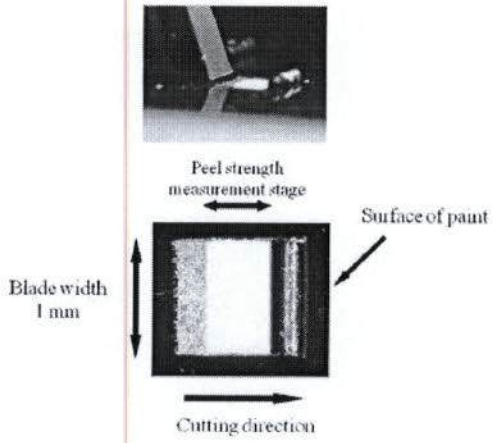
Thermal analysis was performed using differential scanning calorimeter (TA instruments, MDSC 2920). Specimens weighing about 5 mg were extracted from the center of specimens. The temperature range was studied from 30 to 300 °C under nitrogen atmosphere. The heating rate was set at 10 °C/min. The melting endotherm was recorded for analysis.

3. Results and Discussion

The SAICAS data revealed the typical cutting profile which provided horizontal and cutting depth as a function of time as shown in Fig. 1 (a). CCD microscope can be visualized of cutting and peeling between painted and the substrate as shown in Fig. 1 (b). The peeling starts at the interface of the painted and substrate when the horizontal load decreased as shown in Fig. 1, the cutting stage changes to the peeling stage. From the result, the peeling strength can calculate from the horizontal force which decreased after the cutting stage (load for peel strength in Fig. 1) divided by the blade width. Table 1 shows the peel strength and degree of adhesion of paint investigated by SAICAS. Peel strengths slightly increased when increasing $CaCO_3$ content which indicated that $CaCO_3$ promoted adhesion between paint and the substrate. The increment of degree of adhesion or degree of contact defined that strength near the interface was improved when incorporated with $CaCO_3$



(a)



(b)

Fig. 1. (a) Horizontal load and cutting depth profile and (b) Photograph from CCD camera (top) and optical microscope (bottom) of painted specimens with 0 wt% $CaCO_3$.

The effect of crystallinity of RPET phase on peel strength of paint on the blends shows in Fig. 2. The paint adhesion strength was found to have some correlation to the crystallinity of RPET in the blends. Fujino [6] reported that peel strength obtained from SAICAS kindly reflected to the

interfacial adhesive strength between paint and polymer substrate. From his studied, higher interfacial adhesive strength can be obtained from waterborne adhesion promoters with higher crystallinity.

Table 1 Peeling strength and degree of adhesion of painted specimens at 0-10 wt% $CaCO_3$.

$CaCO_3$ content (wt%)	Peel strength (kN/m)	Degree of adhesion	Crystallinity (%)
0	3.209	0.718	25.5
3	3.343	0.704	25.3
5	3.356	0.887	26.3
7	3.343	0.861	26.6
10	3.684	0.851	26.7

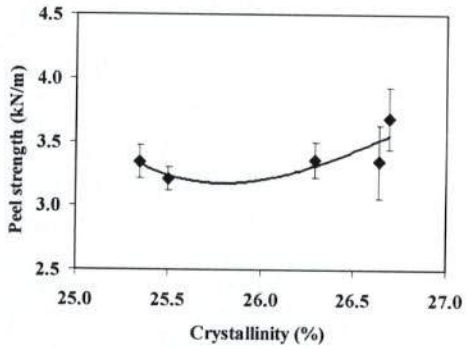


Fig. 2. Peel strength as function of crystallinity of painted injection molded specimens.

Fig. 3 reveals the effect of hot water immersion on peel strength of painted RPET/RPP blends at various contents of $CaCO_3$. Adhesion between paint and substrate was good even after immersion in hot water at 80 °C for 1 hour. It is concluded that the coated films retained 100% adhesion after immersion in hot water which exhibited reliability for using as kitchenware.

Fig. 4 shows optical micrographs of painted injection molded specimens with different layers. The SAICAS method revealed adhesive failure at the interface between the various layers of paint as well as between the paint and substrate. The interface failure between different layers of paint and interface between paint and substrate are presented in Fig. 5.

Fig. 5 presents a comparison between peel strength of paint on substrate by 1 and 2 layers. Different types of typical paint need to prepare 2 layers of painting. Weak boundary between the first and the second paint layers resulted in difficult to define this peel strength. However, the peel strength could be observed after cutting until interface between paint and substrate. The peel strength of 2 layers painting revealed higher than 1 layer. It was probably due to 2 interfaces from interface of paint layer and interface of paint and substrate. Furthermore, higher content of $CaCO_3$ trended to improve adhesion between paint and RPET/RPP substrate by exhibited higher in peel strength. It can be note that $CaCO_3$ on the surface of RPET/RPP blend substrate induced polar group and surface roughness which improved peel strength hence adhesion of paint on RPET/RPP blend was promoted.

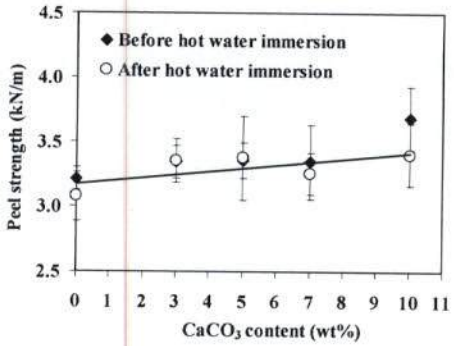


Fig. 3. Peel strength of painted specimens before and after immersion in hot water of 80 °C.

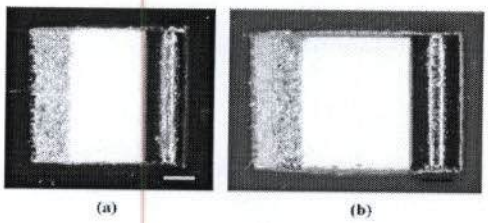


Fig. 4. Peel strength of painted specimens before and after immersion in hot water of 80 °C.

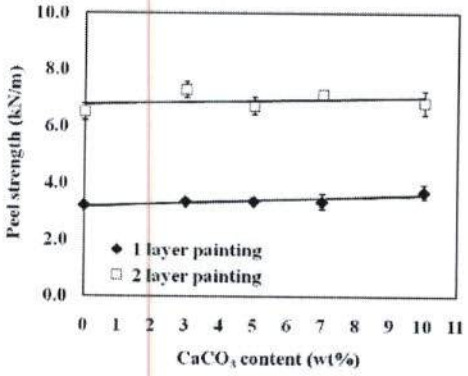


Fig. 5. Comparison of peel strength for specimens painted with 1 and 2 layers of lacquer.

4. Conclusions

A surface and interfacial cutting analysis system (SAICAS) provided typical cutting profile which exhibited peel or adhesion strength of painted RPET/RPP blend injection molded specimens. Peel strength slightly increased with the incorporation of $CaCO_3$. Better retention in peel strength after immersion in hot water was exhibited by specimens containing high $CaCO_3$ loadings. This research shows that $CaCO_3$ in the blends tends to improve and promote surface paintability of the RPET/RPP blends, which could be attributed to the enhanced crystallinity of the RPET phase.

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