Processing Technique and Sound Absorption Property of Three-Dimensional Recycled Polypropylene Nonwoven Composites

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Abstract

Noise pollution has become a kind of serious environmental pollution problems. It not only makes people feel fatigue but also affects their concentration and work efficiency. People's health and work efficiency could be promoted by improving and reducing the noise pollution problem. In this research, the recycled polyester (PET) fibers, polypropylene (PP) fiber and flame-retardant-hollow-crimp 7D PET fiber with a ratio of 2:1:7, 2:2:6, 2:3:5, 2:4:4, and 2:5:3 were fabricated and then needle-punched, creating the PET/PP/PET fabric. Next, a layer of recycled PP selvage and a layer of fabric were laminated in turn on the base fabric before needle-punching with a certain punching-depth, which was repeated until the 10-layer PET/PP/PET nonwoven composite was completed. Finally, the resulting PET/PP/PET nonwoven composite was measured with its physical properties and sound absorption ability.

Introduction

Nonwoven is different from the traditional woven cloth. With the help of advancing technology, novel nonwoven fabrics have been developed and applied based on diverse requirements and innovative functions. New functional nonwoven composite has been progressing constantly, contributing to clothes, daily accessories, industrial appliance , computer, as well as filtration, heat preservation, and thermal insulation required by aeronautical industry [1,2].Nonwoven fabrics are composed of fiber net which is held jointly by fibers' interactive attraction or by chemical adhesive[3].

Selvages from the trimming nonwoven in the producing process have been treated as waste, called as nonwoven selvages. The common ways to dispose selvage waste are to burn or bury them, which cause serious resource waste and environmental pollution. To reuse the waste effectively, the recycled PET selvages was one material we used in this study[4].Among all pollutions, noise pollution is the one we encounter the most commonly. Different individuals put up with different levels of noise pollution, and is particularly alert to noise ranging 1 kHz-3kHz. Meanwhile, 1 kHz-3kHz wears people down with fatigue, distracting people from working efficiency and concentration[5,6]. Due to the shelter effect by noise, people become less sensitive to some dangerous signals, therefore ending up in accidents [7].The research employed the porous character in fibers for sound-absorbing effect, attained by energy variance in sound transmission to sound-absorbent materials. Sound is a kind of energy, which does not disappear suddenly based on the law of conservation of energy; however, it may transform into different states, assimilating the attrition. Thus, different fiber weight ratios, multiple needle-punching and the addition of nonwoven selvages were applied in this study, creating the three-dimensional recycled PP nonwoven fabrics with different levels of sound absorption [4].

Experiment

Recycled 6D PET fibers (length: 64 mm) were provided by True Young Co., Ltd; 6D PP fibers (length: 50mm) were supplied by Taiwan polypropylene Co., Ltd; and flame-retardant hollow crimp 7D PET fibers (length: 64mm) were offered by Far Eastern New Century. The fabric was fabricated using the three materials with a ratio of 2:1:7, 2:2:6, 2:3:5, 2:4:4, and 2:5:3, and subsequently blending, carding lining, lapping, needle-punching and thermo-bonding were conducted. The resulting fabric was then measured with the tensile strength and strain using the universal strength testing machine, determining the optimum parameter for PP fibers was 10 wt%, i.e., optimum ratio of three material was 2:1:7.Two different samples (i.e., compound board and nonwoven composite) were prepared as follows. Firstly, the fabric pieces were laminated and then joined by needle-punching with the lamination of each layer, forming a 10-layer compound board. The compound board with a constant thickness of 1cm was then placed in the hot baking oven at 160 °C for ten minutes. Secondly, a layer of recycled PP selvage (Kang Na Hsiung Enterprise Co. Ltd) and a layer of fabric were laminated in turn on the base fabric before needle-punching, which was repeated until the 10-layer recycled PET/PP/PET nonwoven composite was completed. Each piece of the nonwoven composite comprised a structure, with ten layers of fabric enclosing nine layers of selvage; additionally, the nonwoven composite was made up of 100 g/m^2 PP selvage. Samples were evaluated with maximum breaking strength, sound absorption property and air permeability in accordance with ASTM D5035-06, ASTM E1050-08, and ASTM D737-04.2008 severally.

Results and Discussion

Tenacity of the fabric by tensile strength testing

According to Figure 1, the optimum tenacity decreases as the polypropylene fibers melt. The strength of the single PET fiber is better than the PP fiber, hence possessing a relatively better fiber cohesion. Therefore, the optimum breaking strength of 9.58 KPa occurred when the fabric was plotted with 10 wt% PP fibers and 70 wt% PET fibers.

Sound absorption property of the compound board and nonwoven composite

There were two different samples compared in this measurement, and both of them were made up of PET/PP/PET fabric pieces. The compound board was made of fabric pieces without PP selvage (Figure 2(a)) and the nonwoven composite was composed of fabric pieces with PP selvage (Figure 2(a)). Figure 2 reveals that compound board exhibits a worse sound absorption in low frequency than in high frequency. It was because that the wavelength in low frequency was longer, which was ascribed to a lower sound absorption coefficient. When the compound board was laminated with ten layers of fabric pieces, the 10-layer compound board displayed a coefficient of 1.0. Additionally, the 7-layer nonwoven composite with 6-layer of selvage (Figure 2(a)) also had a relatively higher sound absorption than 7-layer of compound board without selvages (Figure 2(a)).

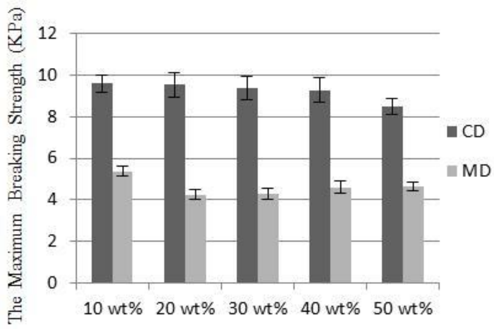

Figure 1. Maximum breaking strength of the fabric pieces with different content of PP fibers in the

cross machine direction (CD) and machine direction (MD).

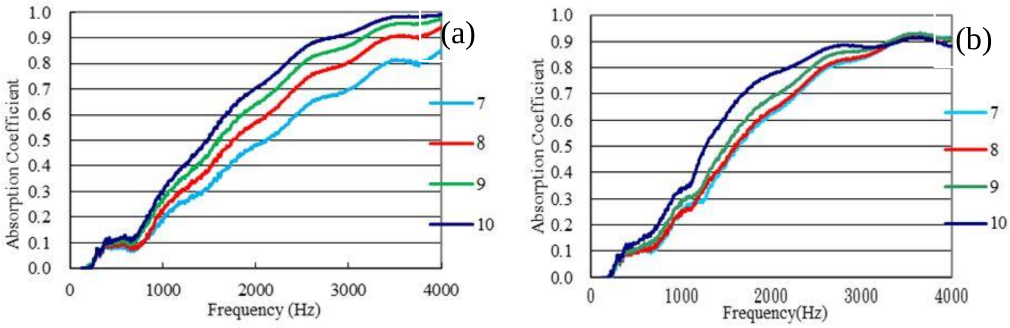

Figure 2. Sound absorption coefficient of the PET/PP/PET compound board in the frequency range of 125Hz to 4000 Hz. The number of the laminated fabric pieces is 7, 8, 9 and 10 layers. (a) without PP selvage (b) with PP selvage

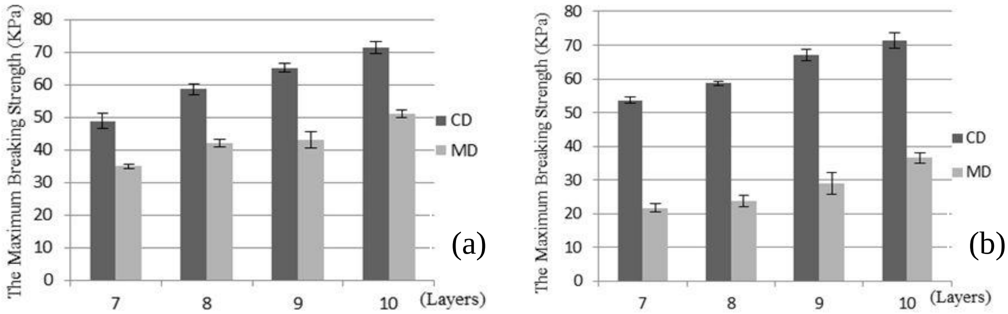

Figure 3. Maximum breaking strength of the PET/PP/PET nonwoven composite in the cross machine direction (CD) and machine direction (MD).The number of the laminated fabric pieces is 7, 8, 9 and 10 layers. (a) without PP selvage (b) with PP selvage

Tenacity of compound board without PP selvage and nonwoven composite with PP selvages

Two samples of compound board and nonwoven composite were compared in tensile strength testing in cross machine direction (CD) (Figure 3). The later exhibited a better tenacity than the former, because the later was laminated with selvages. Nonwoven composite and PP selvages were thermal-bonded, contributing to fiber connection, and further reinforcing the lamination. With an increase in lamination layers, the nonwoven composite also exhibited a better tenacity, reaching n average tenacity of 62.7 KPa.

Air permeability of the compound board without PP selvage and the nonwoven composite with PP selvage

The sound absorption of most sound-absorbent materials depends on the surface porosity, which was measured in this study and defined by the difficulty the air wave going through the interior of the material by the vibration of air medium. Table 1 summarizes that 7-layer compound board exhibits a higher air permeability than 7-layer nonwoven composite. It was because compound board had lower density; when its lamination thickness increased, its density increased, resulting in lower air permeability. Similarly, nonwoven composite was with PP selvage, when it was laminated with more layers, its density was heightened and the fiber pores became smaller, prohibiting air from penetrating. Hence, the higher the lamination number, the lower the air permeability.

Table 1.Air permeability of the compound board (without PP selvages) and nonwoven composite (with PP selvages).

air permeability [$cm^3/(cm^2/s)$]	7-layer	8-layer	9-layer	10-layer
with PP selvages	34.5±0.6	26.7±0.5	24.1±0.5	-

without PP selvages	17.4±0.4	14.6±0.2	10.1±0.5	-

"-"Couldn't Test。

Conclusions

Based on the results, the tenacity of the PET/PP/PET fabric decreased with an increase in PP fibers. When the PP fiber content is lower, the fabric had a tenacity of 9.32KPa in CD and 4.74KPa in MD. Meanwhile, from tensile strength testing, the optimum tenacity of compound board was better than that of nonwoven composite, and its average tenacity was 42.9KPa in MD and 61.2 KPa in CD. Both samples displayed lower air permeability with an increase in their lamination number. The sound absorption of both samples went up with the increase in sound wave frequency, and the sound absorption curve became flat when the frequency reached a curtain frequency. In addition, the increase of thickness and basis weight of the samples contributed to sound absorption in a medium/low frequency. In short, 10-layer nonwoven composite with 9-layer of PP selvages had the optimum sound absorption, the mean was 0.638. Thus, we concluded that PET/PP/PET nonwoven composite laminated with PP selvage attained to an optimum sound absorption; the addition of the selvage proved to be valuable for recycling and reuse as well as for cost reduction. For sound absorption in high frequency and for a better mechanical property, pure PET/PP/PET compound board without PP selvage was a good decision; for a medium/ low frequency, PET/PP/PET nonwoven composite with PP selvage was an ideal selection. Different designs of the compound board and nonwoven composite were suggested to be fostered in accordance with the function requirements of the resulting products.

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