Manufacturing Technique of Sound-Absorbent PET/ TPU Composites

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Abstract

Five testing matrixes were prepared to test with sound absorption, tensile strength, and thermal conductivity respectively. The low-melting-point (low-Tm) polyester (PET) fibers were blended with weight ratios (10 wt%, 20 wt%, 30 wt%, 40 wt% and 50 wt %) with PET staples, forming the PET nonwoven fabrics. The thermoplastic polyurethane (TPU) was thermal bounded with the nonwoven fabrics with different lamination number to examine the sound absorption rate, creating the PET/ TPU composites. Afterward, four sets of samples – PET nonwoven fabrics and PET/ TPU composites with TPU films laminated on the front, in the middle, and on the rear of the composites, were compared. PET/ TPU composite with TPU film laminated in the middle exhibited the optimum sound absorption; moreover, 30 wt% was proved to be the optimum parameter of the low-Tm PET fibers for the PET/ TPU composites.

Introduction

The porous sound-absorptive composites made of nonwoven fabric is excellent to absorb intermediate- and high-frequency sounds, but acts poorly on a 500 Hz frequency. Most of them are coated with impermeable films to absorb low-frequency sound and some certain high-frequency ones. This experiment aimed to retain the impermeable film's advantage by improving its sound absorption ability on high frequencies [1-3].

Industrial-grade functional textiles are the one of the major productive goals for textile industry in the application fields [4-13]. In this study, TPU films were placed in different locations to detect its sound absorption effects for low-mediate frequent sounds. The material applied here was non-toxic and environmental-friendly PET/TPU.

Experimental

Two types of PET were used. A PET staples (fineness: 13.36 denier; length: 66.3 mm; elongation: 61 %) were mixed with low-Tm PET fibers (fineness: 4.0 denier; length: 51 mm; melting point:110 ℃; weight ratio: 10 wt%, 20 wt%, 30 wt%, 40 wt% , 50 wt%), forming the PET nonwoven fabrics. Afterward, the PET nonwoven fabrics were measured with sound absorption, tensile strength, and thermal conductivity, which determined the optimum parameters. The Two-microphones Impedance Tube was used to examine the nonwoven fabrics' sound absorption for sounds ranging from 125 Hz to 4000 Hz. Tensile strength was tested in machine direction (MD) and cross machine direction (CD), according to ASTM D5035-06. The measurement of thermal-conductive coefficient was based on ASTM C177 (Guarded-hot-plate); meanwhile, thermal conductivity's plate temperature was based on the standard of ASTM C1058. The three experiment mains to find out the best low melting point PET proportion matrix. Subsequently, the nonwoven fabrics (density: 200 g/m^2; thickness: 30 mm) were laminated with TPU films (thickness: 0.5 m; density: 1.22 g/cm^3; melting point: 120 ℃), and then thermal-bonded at 190 ℃ for 20 minutes. Finally, PET/ TPU composites were measured with sound absorption by Two-microphones Impedance Tube (ASTME1050-90), obtaining the sound absorption curve diagrams and sound-absorption coefficient. The parameter of each composite was observed for sound-absorption coefficients based on the three TPU films lamination positions – the front, the middle, and the rear of the composites.

Results and Discussion

Tensile Strength Test of the PET nonwoven fabrics

Figure 1 reveals that the tensile strength of the PET nonwoven fabrics increase with the weight ratio of the low-Tm PET; however, the tensile strength in MD is much lower than that in CD. Low-Tm PET acted as an adhesive medium, enhancing the tensile strength. When within its saturation point of 40 wt%, the greater weight ratio of low-Tm PET, the better adhesion low-Tm PET provided. Moreover, PET has better tensile strength than that of low-Tm PET; therefore, the fabrics' tensile strength stopped increasing when low-Tm added beyond the saturation point.

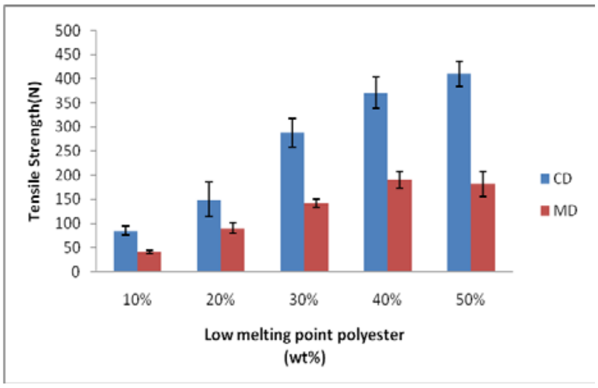

Figure 1 Tensile strength of PET nonwoven fabrics with different weight ratios of low-Tm PET.

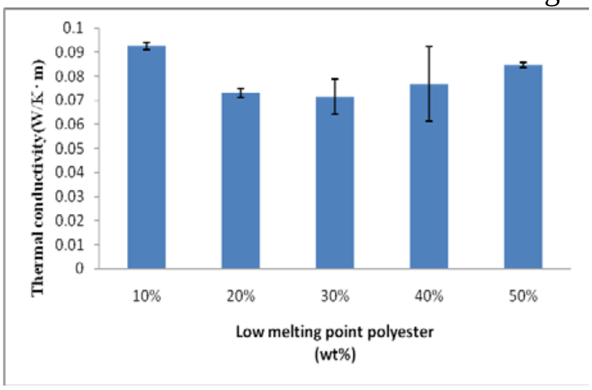

Figure 2 Thermal conductivity of PET nonwoven fabrics with different weight ratios of low-Tm PET.

Thermal conductivity of the PET nonwoven fabrics

Heat is conducted via radiation, transfer and convection. Among them, air flow is of vital importance to heat transmission and convection. Figure 2 reports that the optimum heat obstruction effect was found in 30 wt% because the porous structure of nonwoven fabric obstructed heat transmission. The low-Tm PET was too little (10 and 20 wt%) to form a three-dimensional heat-obstruction web. The holes were too few and too big, enabling the heated air flow faster, so the thermal conductivity rate was better. Further, thermal conductivity increased dramatically when low-Tm exceeded 30 wt%. The main material of low-Tm PET was spiral of hollow fibers, allowing air stagnating within and thus the stagnant air was not able to transfer heat. The thermal conductivity of Spiral of Hollow fibers is bad. The more the low melting point PET was added, the less the Spiral of Hollow fiber was left; thus, the matrix's thermal conductivity was advanced.

The influence of weight ratio of low-Tm PET on the sound absorption of PET nonwoven fabrics

Exterior holes, inner structure, flow resistance and thickness that a material possesses contribute to its sound absorption ability, and these characteristics mainly transfer the energy of sound waves into heat. The 30-mm-thick nonwoven fabric used here was of three-dimensional porous structure. Figure 3 shows the less the weight ratio of low-Tm PET, the lower the sound absorption of the PET nonwoven fabrics. Insufficient low melting point PET leads to poor adhesiveness; therefore, the matrix fails to form a functional three-dimensional structure to resist sound waves. Though weight ratio over 30 wt% benefitted the sound absorption ability of PET nonwoven fabrics, the difference between 30 to 50 wt% was minor. The low-Tm PET is the main adhesive medium; when it increased from 30 to 50 wt%, the fewer porous structures were formed to transfer sound into heat. The sound absorption rate was lessened accordingly.

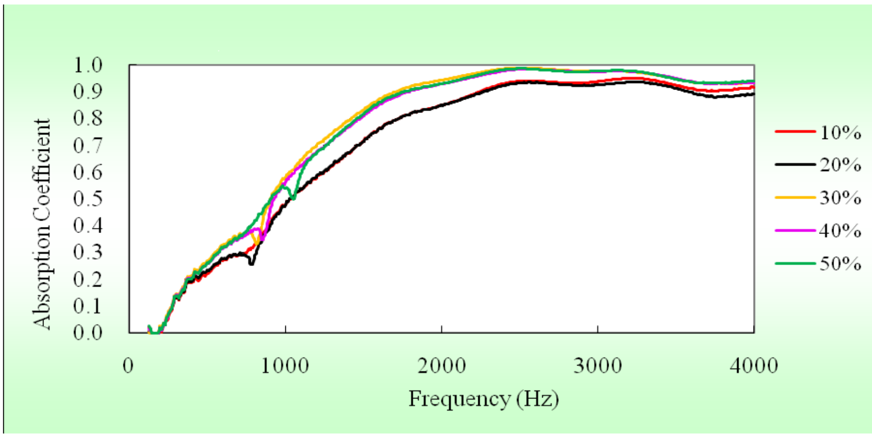

Figure 3 Sound absorption rates of PET nonwoven fabrics with different weight ratios of low-Tm PET.

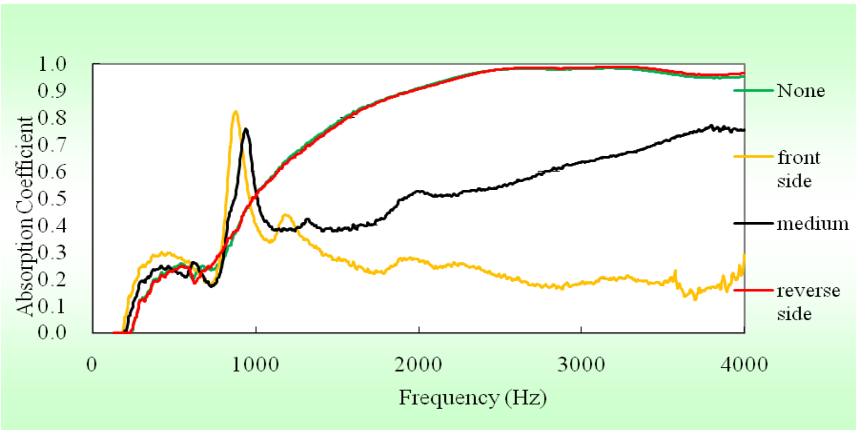

Figure 4 Sound absorption rates of PET/TPU composites with TPU films located in different positions.

The influence of the location of TPU film on the sound absorption of PET/ TPU composites

Fewer holes on the composite surface advanced the sound absorption rates on low frequencies, but also lessened the sound absorption on high frequencies. The location of TPU films had an effect on sound absorption, too. With a TPU film laminated and thermal-bonded on the front, the composites demonstrate a maximum resonance peak on low and medium frequencies, but the peak descends slowly on higher frequency (as Figure 4). TPU films were impermeable and when on low frequencies, the whole composite structure could be deemed as a single movement, decreasing the incident sound energy by the mechanism of vibration and noise reduction so the composites would generate a resonance absorption peak. The sound absorption mechanism on high frequencies was when sound waves entered the structure, the air molecule speed increased a relative velocity with the materials‘ interior , resulting in viscous flow loss. Because TPU films had no pores on the surface, high-frequent sounds were not able to enter the composites and most energy was reflected by the surface, decreasing the sound absorption ability of the composite largely on high frequencies. Subsequently, if the TPU films were laminated and thermal-bonded on the rear of the composites, the film itself had no materials behind it, and thus losing the ability of vibration and noise reduction, so the composite demonstrated the same sound absorption as that of PET nonwoven fabrics. Finally, with the TPU films laminated and thermal-bonded in the middle of the composites, the first half porous materials of the composite lost partial energy on high frequencies, after which the TPU film in the middle processed vibration and noise reduction and thus generating a formant on low frquencies. Therefore, the PET/ TPU composites also had a better sound absorption ability on high frequencies.

Conclusion

The PET/TPU composites developed in this research were made with PET nonwoven fabrics attached with TPU films. The tensile strength of the PET nonwoven fabrics in CD is higher than that in MD. In addition, the tensile strength of PET nonwoven fabrics increased when the low-Tm PET fibers were added to make the PET nonwoven fabrics. Low-Tm PET fibers acted as an adhesive medium to enhance the tensile strength of the nonwoven. Low-Tm PET with different weight ratios and PET staples comprised the fabrics with optimum parameters: weight ratio of low-Tm was 30 wt%; tensile strength in CD was 287.7 N; tensile strength in MD was 142.3 N; thermal conductivity was 0.071538 W/K‧m; and the NRC sound absorption coefficient was 0.468. Finally, the optimum sound coefficient of the resulting PET/ TPU composites occurred when the TPU films were laminated in middle of the composites.

Acknowledge

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