Processing Technique of Fiber-Based Composite Sound Absorbent/Thermal-Insulating Board

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Abstract.

The rapid advances in technology have driven people for seeking ways to improve the quality of their living environment. While excessive noise is more likely to affect people physically and psychologically such as tiredness, dulling of the senses, lack of concentration, and reduction in work efficiency, etc, therefore, noise suppression has become an important research issue. In this research, 7 D polyester staple fiber and 4 D low melting point fiber have been used to fabricate the polyethylene terephthalate (PET) fabric through the process of opening, blending, carding lining, lapping, and needle-punching. Meanwhile, the contents of low-melting point polyester fiber are varied as 10 wt%, 20 wt%, 30 wt%, 40 wt% and 50 wt% in PET fabric. The physical properties of PET fabrics are then evaluated after hot pressing process. Experimental results show that 50 wt% low-melting point polyester fiber is the best choice for PET fabric. Further, the techniques of lamination and multiple needle-punching are employed to make the PET/PP composite sound-absorbing board. A layer of polypropylene (PP) nonwoven selvages is placed between two layers of PET fabrics in the process of lamination. The PET/PP fibers casted into a mold are then put into a hot-air circulation oven around 170 ℃ for 10 minutes. Afterwards, the evaluation of PET/PP composite sound-absorbing board on sound absorption, flame resistance, thermal insulation, and relative mechanical properties is properly conducted.

Introduction

Noise, longitudinal sound waves, usually transmits through the air. While traveling through the sound-absorbing materials such as foam or fiber, the branched structures of sound-absorbing materials increase the resistance of air vibration and the friction between the air molecules and internal wall of hole. This contributes to sound absorption by transforming sound energy into heat dissipation [1].The most common sound absorbing materials used are porous. The abundant interconnected pores extending to the outer surface of sound-absorbing materials can allow air to enter freely [2]. Thermal insulating materials which retard heat transmission can be classified into porous materials and heat-reflecting materials [3]. For porous materials like foam and fiber, the low thermal conductivity coefficient that the air or inactive gas inside pores possesses leads to effective thermal insulation. On the other hand, the high reflection coefficient of heat-reflecting materials such as gold and silver can effectively reflect heat to achieve thermal insulation. Recently, the fiber-based thermal insulating and sound-absorbing products have been broadly explored and developed [4-5]. The purpose of this study is to fabricate the porous sound absorption composite board by using polyester fiber, PP selvages and low-melting point polyester. Owing to the significant features of thermal insulation and sound absorption, the board is expected to be broadly adopted as building materials.

Experiment

7 D polyester staple fiber (length: 64 mm, manufactured by Far Eastern New Century Corporation, Taiwan) and 4 D low melting point fiber (length: 51 mm, manufactured by Huvis Corporation, Korea) have been used to fabricate the PET fabric by opening, blending, carding lining, lapping, and needle-punching. In the meantime, the contents of low-melting point polyester fiber are varied as 10 wt%, 20 wt%, 30 wt%, 40 wt% and 50 wt% in PET fabrics. The PET fabric with 50 wt% low-melting point polyester fiber is then chosen as the base fabric for fabricating the PET/PP composite sound-absorbing board. As an additional layer of PET fabric or PP selvage is added, the fiber-to-fiber cohesion between layers is reinforced by the multiple needle-punching technique during the process of lamination. The aforementioned procedure is repeated until the number of layers of PET fabrics reaching 10. At the end, the physical properties of sound absorption, ultimate tensile strength and thermal conductivity coefficient of the test samples are properly evaluated in accordance with ASTM E1050- 08, ASTM D5035-06, ASTM C177 and ASTM D2863 respectively.

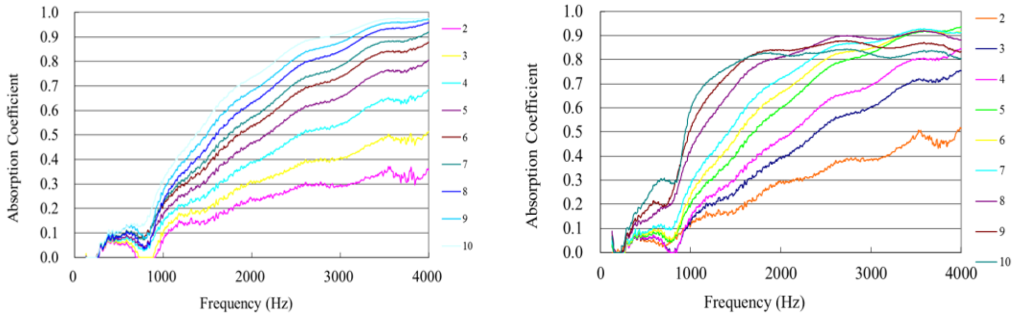
Results and Discussions

The influence of number of laminated layers of PET/PP composite sound-absorbing board on sound absorption coefficients

The sound absorption coefficients of PET composite sound-absorbing board are illustrated in Figures 1, respectively. As shown in Figure 1(b), the PET/PP/PET formation of PET/PP composite sound-absorbing board increases sound absorption in medium-frequency range. However, as layers of the high-density PP selvage increase, the air-flow obstruction that the PET/PP composite sound-absorbing board causes can decrease the sound absorption in high-frequency range. When the composite layers increase to 10, the average value of sound absorption coefficient for PET/PP composite sound-absorbing board can reach 0.667. Also, the sound absorption in medium-frequency range is obviously enhanced.

The influence of number of laminated layers of PET/PP composite sound-absorbing board on ultimate tensile strength

Figure 2(a) illustrates the ultimate tensile strength (tensile strength at break) of PET composite sound-absorbing board, and Figure 2(b) shows the ultimate tensile strength of PET/PP composite sound-absorbing board. From Figures 2(a) and 2(b), as the number of laminated layers increases, the ultimate tensile strength of PET fabrics and PET/PP composite sound-absorbing board also increases in both cross machine direction (CD) and machine direction (MD). As an additional layer of PET fabric or PP selvage is added, the fiber-to-fiber cohesion between layers is reinforced by the needle-punching technique. Therefore, the more the layers are added, the better the fiber-to-fiber cohesion is. This contributes to increase the ultimate tensile strength of composite sound-absorbing board. When the composite layers increase to 10, the ultimate tensile strength of PET fabrics and PET/PP composite sound-absorbing board in CD are measured as 7.502 MPa and 6.579 MPa respectively. As shown in Figures 2(a) and 2(b), it is evident that the ultimate tensile strength of PET/PP composite sound absorption board is less than that of PET fabrics. The experimental results indicate that a single layer of PET fabric has greater ultimate tensile strength as compared to a single layer of PP selvage. Thus, while conducting the tensile strength test, the PP selvage layers of PET/PP composite sound absorption board are subject to break first and separate from the layers of PET fabrics causing the reduction of the tensile strength.



(a) (b)

Figure 1. Test results of sound absorption coefficients of PET composite sound-absorbing board toward incident sound in the frequency range of 125 Hz to 4000 Hz. (a)Without PP selvage (b) With PP selvage

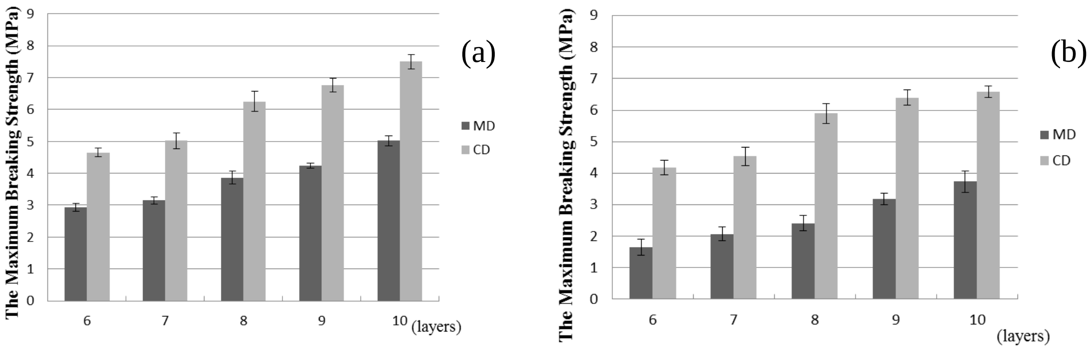


Figure 2. The ultimate tensile strength of PET composite sound absorption board in both CD and MD. (a)Without PP selvage (b)With PP selvage

The influence of number of laminated layers of PET/PP composite sound-absorbing board on thermal conductivity coefficients

The thermal conductivity coefficients of PET/PP composite sound-absorbing board are listed in Table 1. According to Table 1, the variation in number of laminated layers of PET/PP composite sound-absorption board shows little influence on thermal conductivity. Notice that the fiber structure formation of porous materials used in this study is irregular. Also, it is noteworthy that the static air provides excellent thermal insulation. Therefore, the irregular fiber structure formation and the air contained within the gaps provide porous materials an effective mechanism to facilitate the thermal insulation.

Table 1. Thermal conductivity coefficients of PET/PP composite sound-absorbing board.

	7 layers	8 layers	9 layers	10 layers

(W/m・K)	0.0365	0.0565	0.0355	0.0484

The Limiting Oxygen Index (LOI) test of composite sound-absorption board

As shown in Table 2, the LOI value increases along with the thickness of PET/PP composite sound-absorption board. Under the same thickness, the fiber structure of PET/PP composite sound-absorption board becomes denser and tighter with the increasing number of laminated layers. Accordingly, the amount of air contained within the gaps of fiber structure becomes less dense. Therefore, the LOT value of PET/PP composite sound-absorption board increases along with the increasing number of laminated layers since the flame is unlikely to react with combustion-supporting gas. The measured LOI value reaches its optimal value at 17 when the composite layers increase to 10.

Table 2. The LOI value of PET/PP composite sound-absorption board.

	7 layers	8 layers	9 layers	10 layers
LOI	16	16	17	17

Conclusions

In this research, the processing technique of fiber-based sound-absorbent and thermal-insulating compound board has been adequately developed. The experimental results show that the PET/PP composite sound-absorption board has less ultimate tensile strength as compared to that of PET fabrics. Also, as the number of laminated layers reaches at 10, the optimal ultimate tensile strength of PET fabrics and PET/PP composite sound-absorption board are 7.502 MPa and 6.579 MPa, respectively. The low LOI value (measured at 17) indicates that the composite sound-absorption board has poor flame-retardant performance. To improve flame-retardant performance, it is necessary to further investigate the effect of adding flame retardant agents in the composite sound-absorption board. The thickness of PET fabrics increases along with the increasing number of laminated layers of PET/PP composite sound-absorption board. This enhances the sound absorption performance over the full frequency range, especially at high level with the sound absorption coefficient 0.975. As seen from the results, the average sound-absorption coefficient of PET/PP composite sound-absorption board is about 0.677 when the number of laminated layers reaches 10. Finally, the measured thermal conductivity coefficient of PET/PP composite sound-absorption board is between 0.03-0.06 W/K・m. With the excellent performance of thermal insulation and sound absorption, it is concluded that the composite sound-absorption board in this study is a suitable building material.

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