Investigation on the structure and mechanical properties of acoustic-absorbing composite laminates

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Abstract. This study designed a novel porous acoustic-absorbing composite laminates structure with reinforced mechanical properties. Three-dimensional crimped hollow polyester (3D CHPET) fiber and high resilience polyester (HRPET) fibers with various blending ratio were fabricated into porous base fabric. Kevlar woven plain fabric was embedded between HRPET/CHPET porous base fabrics to reinforce strength, which were combined through needle punching and thermal bonding process. Air permeability and tear strength of the acoustic-absorbing composite laminates were tested to evaluate the mechanical properties of the acoustic-absorbing composite laminates. The results showed that the acoustic-absorbing composite laminates exhibited a little higher air permeability after being thermal-treated. Tear strength of the thermal-treated composite laminates was also better than that without thermal treating.

1. Introduction

Acoustic-absorbing materials are vitally important component of building, packaging, automobile materials to prevent from impact by acoustic wave [1]. Acoustic energy can be absorbed by porous structure because the acoustic wave will be reflected several times by the network so that the acoustic energy transforms to mechanical energy [2, 3]. In terms of protective materials, the acoustic-absorbing component should meet some requirements: acoustic-absorbing structure to dissipate wave energy [4, 5]; open structure in the face sheet to allow the wave entering [6]; high mechanical properties to prevent from damage. The mechanical properties determined the durability of the materials.

In this paper, a novel porous acoustic-absorbing composite laminates structure with reinforced mechanical properties will be designed. In order to produce high strength face sheet with open structure, three-dimensional crimped hollow polyester (3D CHPET) fiber and high resilience polyester (HRPET) fibers with various blending ratio were fabricated into porous base fabric. Kevlar woven plain fabric was embedded between HRPET/CHPET porous base fabrics to reinforce strength, which were combined through needle punching and thermal bonding process. Air permeability and tear strength of the acoustic-absorbing composite laminates were tested to evaluate the mechanical properties of the acoustic-absorbing composite laminates.

2. Experimental

2.1. Materials

The HRPET fiber was purchased from Far Eastern Textile Company, Taiwan. HRPET was composed of outer and inner components, which has low-melting and high-melting points of 170 °C and 265 °C,
respectively. The two components ensure the fiber the ability to melt the sheath with the core keep steady when thermal treating at the temperature between the two melting points. 3D CHPET exhibiting curl appearance, which allowed the materials had fluffy property, was also supplied by Far Eastern. The CHPET fiber has a normal melting point of 265 °C.

2.2. Composite laminates fabrication

2.2.1. Porous base fabric. The base fabric of acoustic-absorbing composite laminates was manufactured by CHPET and HRPET fibers with various blending ratio. Samples had porous structure because of a large amount of voids existing. With the increase of CHPET weight ratio ranging from 30% to 70%, the porous base fabric was designed with HRPET/CHPET weight ratio of 3:7, 4:6, 5:5, 6:4, and 7:3. The CHPET fiber and HRPET fiber with a certain weight ratio were input into the nonwoven machine. After mixing, fibers were carded and laid as a fiber network. Needle punching of 100 punches/min help to produce fiber struts and reinforce the fiber network in thickness direction. Porous base fabric All the samples had an areal density of 150 g/m².

2.2.2. Composite laminates. Kevlar fiber had excellent mechanical properties and was widely applied as reinforcement in composites. Kevlar fiber performed high tensile strength, shear strength and punching resistance. A Kevlar plain woven sheet with 3000 filaments/yarn was inserted between two overlapped porous base fabrics and bonded by needle punching and thermal bonding. Thermal treatment took place at a temperature of 180 °C and needle punching has same setting as in porous base fabric fabrication.

2.3. Mechanical Testing

2.3.1. Air permeability. Air permeability test was carried out according to the standard of ASTM D737. Samples were cut into 10 × 10 cm² and was placed on the test head of the apparatus. The air permeability was calculated in cm³/cm²/s. Five specimens were tested for each sample.

2.3.2. Tear strength. Tear strength test was conducted by Instron 5566 testing machine according to ASTM D5587. Specimen was prepared into 75× 150 mm² with a 15 mm slot in the middle of the long side. Five specimens were tested for each sample.

3. Results and discussion

3.1. Air permeability of acoustic-absorbing composite laminates
Air permeability is related to the fiber fineness, areal density, and finishing process. Figure 1 illustrates that the air permeability of the acoustic-absorbing composite laminates with and without thermal treatment. Figure 1(a) shows that the non-treated air permeability decreased with the HRPET ratio increasing because the HRPET fiber was smooth and fine while the CHPET fiber had crimped structure which increase the resistance to permeation. After thermal treatment, the outer layer of HRPET melt and the void in the fabric was increased. Therefore, the air permeability in Figure 1(b) was a little higher than that in (a), especially the samples with high HRPET ratio. The air permeability of all the samples were higher than 200cm³/cm²/s, which means that the HRPET/CHPET porous base fabric had large amount of voids. It allows more acoustic wave entering the acoustic absorbing materials and the network improving wave reflection to dissipate the acoustic energy.
3.2. Tear strength of acoustic-absorbing composite laminates

Tear strength was measured in both cross-machine direction and machine direction of the HRPET/CHPET porous base fabric. Figure 2 illustrates the tear strength of non-treated samples and it is found that the CD is a little higher than MD when HRPET fiber occupies 30% and 40%, which is because the degree of orientation of CD is higher than that of MD and fiber fracture can absorb more tear energy. With the increase in CHPET, more crimps enhanced the friction between fibers and the value of MD is improved. Except CD of 3H/7C, tear strength is no more than 100N, which demonstrates the tear strength of non-treated samples. Tear strength is always decreased with the weight ratio of HRPET increasing.

Figure 3 shows the tear strength of the laminates after being thermal treated. It is apparent that the tear strengths of CD are higher than that of MD at various fiber ratio. The tear strength of CD and MD samples has a slight decrease with the HRPET ratio increasing. The peak value appears at 4H/6C. As thermal bonding improve the bonding strength between fibers, the fabric has to fracture instead of friction to resist the tear force. Furthermore, thermal treatment significant influenced the strength that the CD is about 30% higher than MD, which is more obvious than non-treated samples.
4. Conclusions
In this study, a novel porous acoustic-absorbing composite laminates structure with reinforced mechanical properties was successfully fabricated. CHPET fiber and HRPET fibers with various blending ratio were fabricated into porous base fabric. Kevlar woven plain fabric was embedded between HRPET/CHPET porous base fabrics to reinforce strength, which were combined through needle punching and thermal bonding process. The results showed that the acoustic-absorbing composite laminates exhibited a little higher air permeability after being thermal-treated. Tear strength of the thermal-treated composite laminates was also better than that without thermal treating. The tear strength performed a decreasing tendency with the HEPET ratio decreased because the fibers were restricted and fractured in sequence.

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