AUTEX Research Journal, Vol. 3, No2, June 2003 © AUTEX

SOUND ABSORPTION PROPERTIES OF RECYCLED POLYESTER FIBROUS ASSEMBLY ABSORBERS

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Abstract

Sound absorption materials are generally classified into three types, porous, resonator, and panel. All of these three types are based on the theory of energy transforming from sound energy to thermal energy. In this paper, we examined the sound absorption coefficient of recycled polyester nonwovens for the purpose of substituting the conventionally used materials such as glasswool and rockwool. The use of recycled polyester nonwovens has many advantages compared to conventional sound absorbers, including reduced product cost, good handling, and environmental protection. The sound absorption coefficient of the recycled polyester nonwovens was determined by a two-microphone impedance measurement tube; the determination of the noise absorption coefficient is nothing more than the absorption energy rate of the material against the incidence energy. We have determined the relationship between the acoustic absorption values measured and the nonwoven parameters including fibre properties and web properties.

Keywords

nonwoven, sound absorption, porous, web, polyester

Introduction

Undesirable and potentially hazardous noises are a side-effect of a wide range of modern engineering and other processes. With the continuing development of new technologies, particularly the trend towards faster, more powerful machinery, the environmental impact of noise is a matter of increasing concern, and considerable efforts are being made to finding effective means of noise abatement [1-6]. The problem of noise generated within the closed space can be particularly acute, but several practical solutions do exist [7]. The use of textiles for noise reduction is based on two major advantages of these materials, namely low production costs and small specific gravity. Previous studies of noise absorption in nonwovens have shown that the noise absorption coefficients (NAC) of these media in the high frequency range (f>2000 Hz) are comparable to that of rockwool and glassfibre [8,9]. There are several studies on the NAC of nonwovens, but none so far has addressed the question of the extent to which the physical details of the pile surface influence this behavior [10].
This work is based on previous studies on the use of textiles as a noise control element which indicated the feasibility of applying textiles in noise abatement technology. To achieve this objective, we made several thermally bonded nonwovens and tested the possibility of enhancing the noise insulation coefficients of nonwoven webs used for noise reduction. Acoustic barriers made of

nonwoven structures may have several interesting applications, such as fillings inside walls separating neighboring apartments in wooden houses, as noise shelters in the transfer industry, and as acoustic enclosures to noise equipment in factories and workshops [11].

Experimental

Specimen preparation

We prepared several different types of thermally bonded nonwovens. These samples were produced at different fibre contents and fineness, but basically all the samples were made from recycled polyester fibres. We performed the carding process 3 times for better evenness and better orientation; we also developed a hot air bonding machine for low melting-point (LMP) polyester fibres, which was set to an air temperature of 130 ^{o}C, a feeding speed of 0.6 m/min and a 30-cm bonding area.
According to the fibre contents, three different types of polyester fibres were used. They have the same fibre lengths, but different diameters (1.25 den, 2 den, and 7 den, 38 mm) and We used low melting-point polyester fibre (6 den, 42 mm) for binding purposes. Table 1 shows the sample identifications for measuring sound absorption properties according to the difference of the fibre contents.
All nonwovens demoted by the fibre indicating number (FIN) have 40% low melting-point polyester contents; the portion of the fibre contents were increased with the FIN number from 0 to 60%. On the other hand, LMPs decreased low melting-point polyester fibre contents with an increasing LMP identification number from 70 to 40%.

Table 1. Manufacturing conditions of nonwovens depending on fibre contents in percent

<table>
<tr><th rowspan="2">Sample ID.</th><th rowspan="2">LMP polyester staple fibres (6 den, 42 mm), %</th><th colspan="3">Regular PET 38 mm staple fibres, %</th></tr>
<tr><th>1.25 den</th><th>2 den</th><th>7 den</th></tr>
<tr><td>FIN1</td><td>40</td><td>0</td><td>60</td><td rowspan="4">-</td></tr>
<tr><td>FIN2</td><td>40</td><td>20</td><td>40</td></tr>
<tr><td>FIN3</td><td>40</td><td>40</td><td>20</td></tr>
<tr><td>FIN4</td><td>40</td><td>60</td><td>0</td></tr>
<tr><td>LMP1</td><td>70</td><td colspan="2" rowspan="4">-</td><td>30</td></tr>
<tr><td>LMP2</td><td>60</td><td>40</td></tr>
<tr><td>LMP3</td><td>50</td><td>50</td></tr>
<tr><td>LMP4</td><td>40</td><td>60</td></tr>
</table>

We also prepared nonwoven samples for the investigation of the nonwovens' properties themselves, especially web properties. The nonwoven processing conditions for this purpose are given in Tables 2 and 3. Table 2 shows the manufacturing conditions for the effect of mid-web orientation angle on sound absorption properties, and Table 3 shows the contents of fibre and web formation for the effect of composite type structure on sound absorption properties.
We used 4 different type materials for panel resonance test, such as 0.03 mm PP film, 0.08 mm PP film, 0.03 mm aluminum foil and 0.58 mm spunbond nonwoven. We expected that panel structure could contribute to sound absorption because nonwovens have a micropore structure, although the panel could possibly be classified as a sound reflection material. The complex type nonwovens were tested in two different ways. COM1 to COM3 have a coated panel structure, and COM4 to COM6 have an inserted panel structure.

Table 2. Processing conditions of nonwovens depending on mid-web orientation angle in percent

Sample ID	LMP polyester staple fibres (6 den, 42 mm), %	Ultrafine fibre (0.05 den, 42 mm), %	Orientation angle, degree
LAY1	40	60	0
LAY2			35
LAY3			45
LAY4			90

Table 3. Processing conditions of nonwovens depending on panel vibration in percent

Structure	Sample ID.	LMP polyester staple fibres (6 den, 42 mm), %	Regular PET 42 mm staple fibres, %		Ultrafine fibres (0.05 den, 42 mm)	Layer type
			3 den	7 den		
Coating	COM1	30	50	20	-	PP film 0.03 mm
	COM2					PP film 0.08 mm
	COM3					Al foil 0.03 mm
Inserting	COM4	40	-	-	60	-
	COM5					SB nonwoven 0.58 mm
	COM6					PP film 0.08 mm

Sound absorption measurement

The equipment used in this experiment consisted of a two-microphone impedance measurement tube type 4206, dual channel signal analyzer type 2032, power amplifier type 2706 (all manufactured by Bruel and Kjaer), and a computer. The sample is fastened to the tube's left rigid wall, and a loudspeaker that can emit sound waves of well-defined frequencies is attached to its right rigid wall. The nodes and anti-nodes of the standing waves emitted by the loudspeaker and those reflected from the sample are detected by a small microphone that can slide along the axis of the tube. In other words, the analyzer generates a random signal which is then amplified. Then, the frequency weighting unit in the tube is applied to the sound source. Finally, the analyzer measures the response of the two microphones and calculates the frequency response function between the two microphone channels. From this frequency response function, all test sample data were calculated. The diameter of the tube d is smaller than the wavelength of the emitted sound wave (typically d=10 cm for f<1600 Hz and d=3 cm for f>1600 Hz), so the wave can be thought of as a plane wave propagating along the axis of the tube. The value of noise absorption coefficient (NAC) is given from 0 to 1, which means sound absorption is none in value 0, and sound absorption reaches the maximum in value 1. All sound absorption measurements were performed 5 times for each sample, and the frequency was set from 16 Hz to 5600 Hz.

Results and discussion

Nonwoven composed of different fibre contents

The content of fine fibre increased to FIN1, FIN2, FIN3 and FIN4; all the FINs contained 40% LMP, and the portion of the fine fibre increased from 0 to 60% against the coarse PET. The relationship between sound absorption and fine fibre contents is illustrated in Figure 1. The NAC of the sample is proportional to the increase in the fine fibre contents. The difference of NAC between FIN1 and FIN4 reached a maximum in f=750 Hz, and the variation between FIN1 and FIN4 reached almost 0.2. Increasing with the frequency, the difference of the NAC curves between samples decreased. In the case of high frequency (f>1500 Hz), NAC curves showed no clear tendency with fine fibre contents, but all the samples have an impressive sound absorption rate.

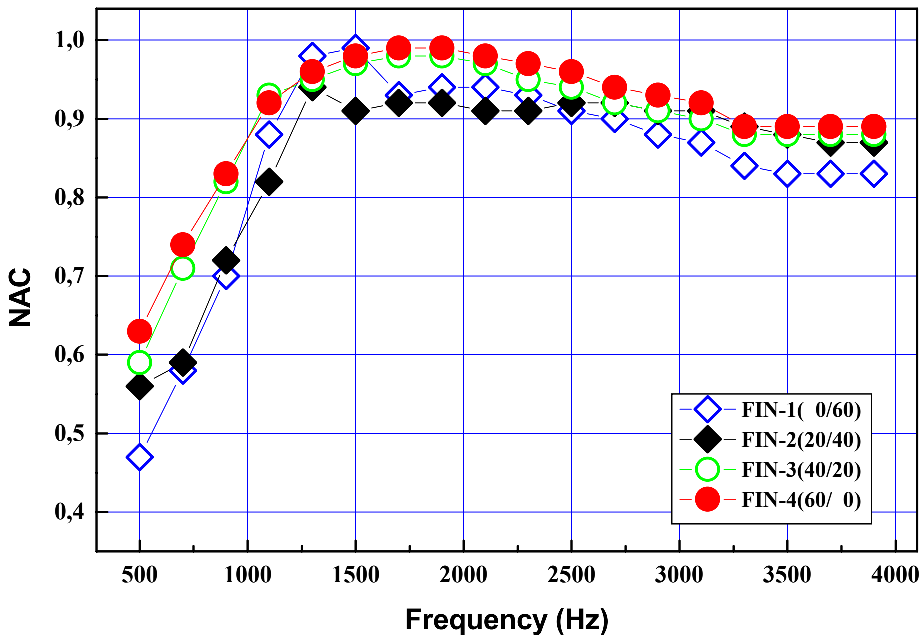

Figure 1. Effect of fine fibre contents on sound absorption properties

We also tested the effect of low melting-point polyester contents on sound absorption properties; low melting-point polyester was used for bonding and better strength. The schematic diagram of this test is given in Figure 2. Roughly, the increase of the low melting point polyester contents caused the NAC to decrease (visible especially within the range 2000-3500Hz) because of the decrease in the nonwoven thickness and the effect of the coincident effect. The melted low melting-point polyester fibre inside the nonwoven caused a decrease in nonwoven thickness and made the structure in the web shrink during the bonding process, which also resulted in the destruction of the micro-pore of the nonwoven structure. So the melted low melting-point polyester fibre can generate a micro-film structure in the inside of the absorber, which is supposed to make the coincident effect.

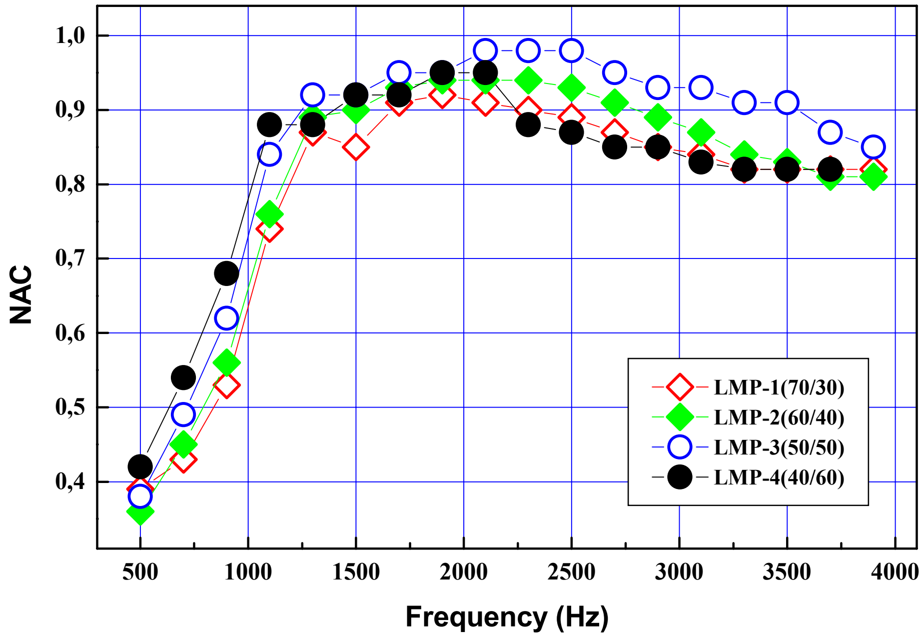

Figure 2. Effect of LMP on sound absorption properties

<u>**Nonwoven composed with multi-angle layered web and different thickness**</u>

Web orientation effects were analyzed through the nonwoven composed of the same fibre contents, but with different orientation angles (0°, 35°, 45° and 90°), manufactured and controlled during the carding process.

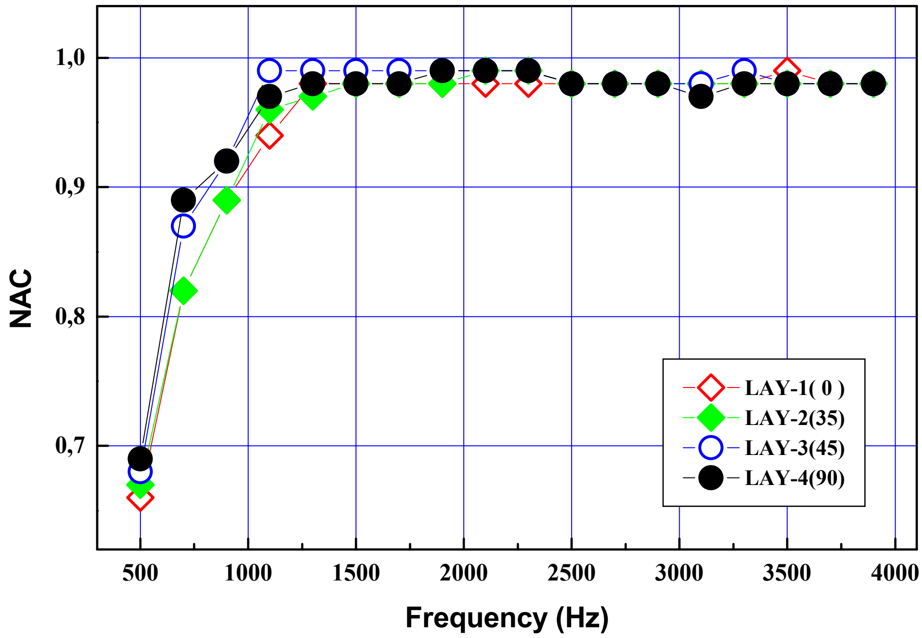

Figure 3. Effect of mid-web angle on sound absorption properties

The NAC of multi-angle layered web was shown in Figure 3. LAY-4 showed the highest NAC, which means the higher orientation angle variation gives smaller pore sizes. Not only the pore size but also air resistance is linked with web layering properties, although the difference in the NAC is marginal in the low and high frequencies, and even at middle frequency it did not show any great difference. So, the difference of NAC between samples was insignificant for the given specimen and frequency conditions (within a very broad range) in this experiment.

Resonance effect by panel vibration

6 different types of panel were used for panel vibration; we used thick and thin PP film, spunbond nonwoven and aluminum foil, which make vibrations on the surface or inside the sample by the sound pressure. The most obvious feature is a tremendous increase in the NAC in the low-frequency region without any exception. Figure 4 shows the increase of the NAC in the low- and middle-frequency region, but in the high-frequency region (f>1750 Hz), the coincidence effect causes a rapid drop in NAC of most of the samples (especially COM-2 ans COM-3); the decrease rate of the 0.03 mm PP film sample is lower than aluminum foil and 0.08 mm PP film. The coincidence effect moves to a low-frequency region when the material is thick, rigid and of low density.
In the case of inserting structure, it shows a clear increase of NAC at low frequency, and there is no decrease in NAC by a coincident effect in the high-frequency region.

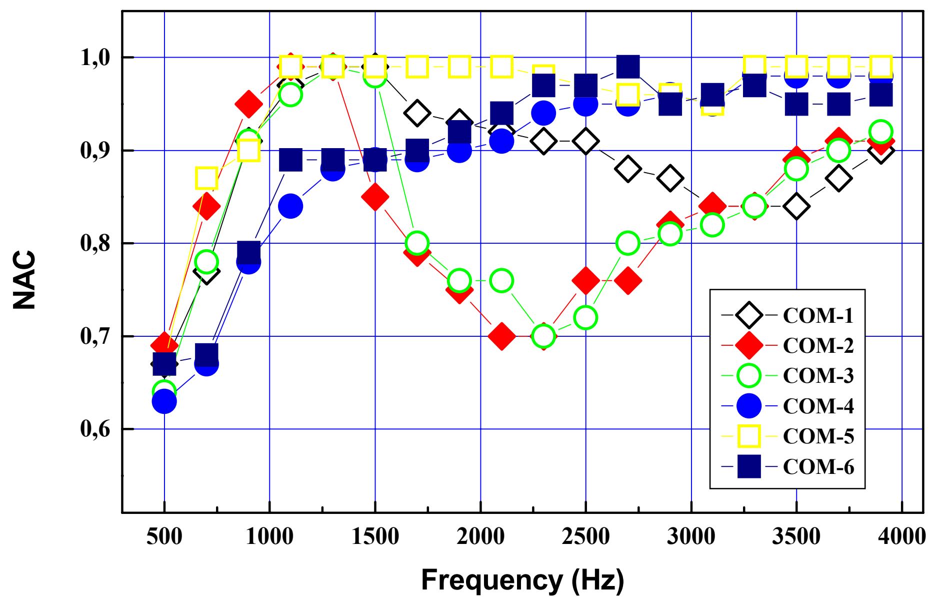

Figure 4. Effect of panel vibration on sound absorption properties

Conclusions

The effect of the fibre contents on the NAC usually depends on the content of the fine fibre. We think that nonwovens, which have more fine fibre, have more chance to contact the sound wave. This causes more resistance by means of friction of viscosity through the vibration of the air. The nonwovens' absorber which has an unoriented web in the middle layer has a higher NAC than nonwovens which have a totally oriented web structure, but the difference is marginal. The panel resonance effect has contributed to increase the NAC. In the case of coating structure, the panel promotes the NAC in low- and middle-frequency regions, but it has the reverse effect in the high-frequency region by the coincidence effect. Therefore, many considerations are required for the purpose of sound control; on the other hand, the inserted panel structure contributed to an increase in the NAC through all frequencies, because the reflected sound wave inside the nonwoven sound absorber can be absorbed again through the structure, so it could act as a double thickness.

Acknowledgements

The authors wish to thank SaeHan Co. and the Ministry of Commerce, industry and energy in South Korea for the financial support awarded to carry out this research, and also Yeungnam University in South Korea for allowing us to use an impedance tube for the sound absorption measurement test.

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