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The sound absorption properties of the recycled PET nonwovens

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1. INTRODUCTION

The sound absorption materials are generally classified by three types, such as porous, resonator, panel.[1~5] All of these types are based on theory of energy transform from sound energy to thermal energy. At first, the sound energy transform from the porous type uses to friction and viscose resistance. Secondly, resonator type uses to resonance frequency, absorption coefficient reach the highest. It can be calculated the equation (1).

$$f_0 = \frac{c}{2\pi}\sqrt{\frac{k}{(t+0.8d)L}} \quad (1)$$

Where f_0 is resonance frequency, c is sound velocity, t is thickness of the slit, d is hole diameter, L is thickness of the air layer, k is the portion of the hole on the slit and p is the pitch(Length between the hole). Finally, panel type which uses the vibration reduces sound energy through the inner friction, the natural frequency of the panel. It can be expressed like equation (2).[6]

$$f_0 \fallingdotseq \frac{600}{\sqrt{mh}}(\mathrm{Hz}) \quad (2)$$

Where m is surface density of panel and h is thickness of behind air layer. Among these types, the fibrous assemblies for sound absorption is considered to be the porous type. Although we generally use rockwool or glassmat for the soundproof purpose, their materials sometimes make the harmful cancer to human body and the difficult handle in building noise barriers.

In this paper, we have examined the sound absorption of recycled PET nonwovens as the substitution to the conventionally used sound absorption materials. The use of PET nonwovens gives many additional advantages such as reducd product cost, fairly good handling, and environmental protection. In this study, the noise absorption coefficient(NAC) of the PET nonwovens was determined by a two-microphone impedance measurement tube. The determination of the NAC is literally absorption energy rate of the material against the incidence energy. For the purpose of relative comparison, we have used the noise reduction coefficient(NRC) value which is defined as the average of the specified frequencies at 250, 500, 1000, 2000Hz. We have determined the relationship between the measured acoustic absorption parameters and the nonwoven parameters such as fiber content and denier, density, structure. They showed interesting results to the condition, furthermore the results encourged us to use of such materials for the noise barriers.

2. EXPERIMENTAL

2.1 Specimen preparation

We have prepared 8 different types of nonwovens for the study, the sample was produced by different fiber content and fineness, but basically all of them are made from polyester terephthalated(PET) fibers. The values of fiber contents used in this test are given in the Table Ⅰ. In the table, we used symbols for the tested sample such as L(low melting PET), F(4 den), C(8 den), R(random), O(oriented), and the number of the symbol means the rate of the used fiber content. Namely, L3OF5RC2O consists of 30% oriented structure with low melting PET, 50% unoriented structure 4 den PET and 20% oriented 8 den PET.

Table I The sample characteristics for sound absorption materials (%)

No.	Sample ID.	LMP content (6 den)	Regular using material (recycled)		Density (kg/m^3)
			4 den	8 den	
1	L3OC7O	30	-	70	36
2	L3OF2OC5O-1	30	20	50	30
3	L3OF2OC5O-2	30	20	50	32
4	L3OF2OC5O-3	30	20	50	36
5	L3OF3OC4O	30	30	40	36
6	L3OF3RC4O	30	30	40	36
7	L3OF5OC2O	30	50	20	36
8	L3OF5RC2O	30	50	20	36

We have prepared 100㎜∅ samples for the low-frequency and 30㎜∅ samples for the high-frequency. Respectively The test carried out 5 times for each sample and they averaged for data.

2.2 Impedance tube device and technique

In the test method using two-microphone impedance measurement tube, plane waves are generated

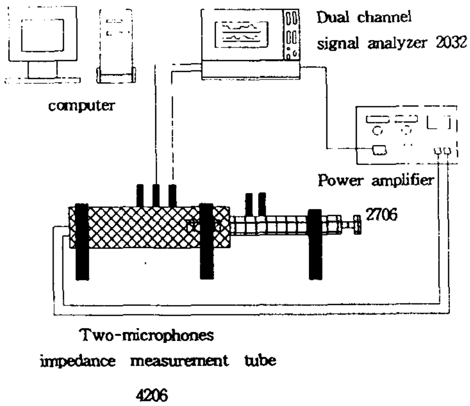

Figure 1. Set-up for noise absorption coefficient.

in a tube by a random noise source, and the decomposion of the standing wave is achieved with the measurement of acoustic pressures at two fixed locations close to the sample using wall-mounted microphones. The test machine for this work is a two-microphone impedance measurement tube manufactured by Brüel & Kjær. Illustration in Figure 1 is the set-up of the test machines for normal sound absorption coefficient.

The analyzer generates a random signal which is then amplified by Power Amplifier Type 2706. Frequency weighting unit in the tube, and then applied to the sound source. The analyzer then has measured the response of the two microphones and calculated the frequency response function between the two microphone channels. From this frequency response function, all test sample data were calculated.[7~8)]

3. RESULTS AND DISCUSSION

We have investigated the effect of fiber parameters on the NAC of the PET nonwovens in the audible frequency range($125<f<4000$Hz). The normal incidence NAC of the specimen designated by α, is defined by $\alpha = (I_0 - I_1) / I_0$, where I_0 and I_1 are the energy flux of the incident and reflected waves. We used the NRC to determine absorption coefficient of specimen. The NRC is defined as the arithmetic average of the NAC over the frequencies 250, 500, 1000 and 2000Hz.

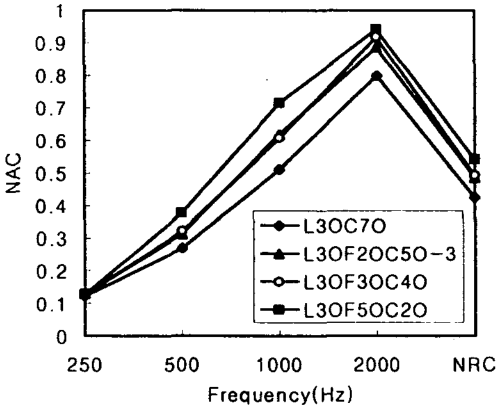

Figure 2. NAC per specified frequency and NRC following the fiber content.

In the Figure 2, the effect of the fiber content is displayed. Sample number 1, 4, 5, 7 got some structure and density but they only have a difference with fiber content. The results show the more nonwovens have finer fiber(i.e. more have 4 den), they have the higher absorption.

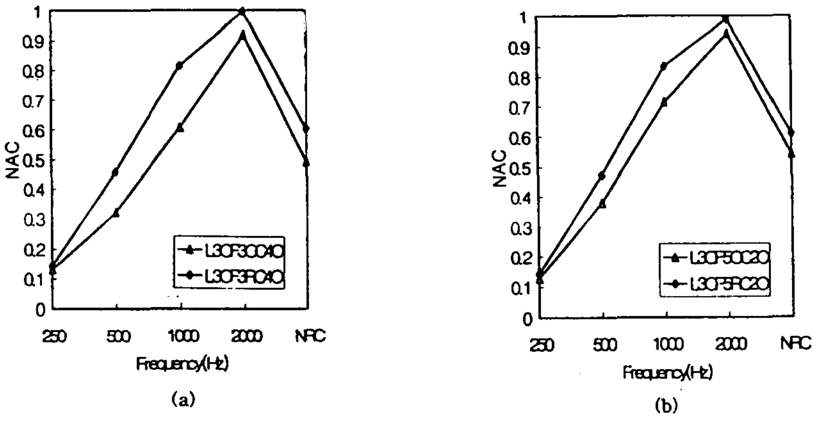

Figure 3. NAC per specified frequency and NRC following the orientation.

Two couples of sample are chosen for investigation the effect of orientation(Sample number 5,6 and 7,8). Two pairs have same fiber content and density with themselves. The only different factor in the pairs is fiber orientation in web structure. Results from the orientation effect are shown in Figure 3. Big difference among the samples is in the middle frequency(f=500-1000Hz), but relatively small difference among the samples in the low and high frequency.

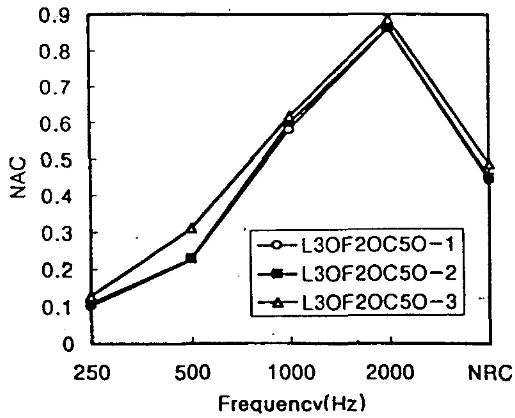

Figure 4. NAC per specified frequency and NRC following the density.

The effect of the nonwoven density is given in Figure 4. with different Samples. They have same structure and fiber content but NAC value increased with increasing density. Big difference among the samples is in the f=500Hz but relatively small difference among the samples in the low and high frequency. According to the result, NRC order of the test samples is matched with the order of weight. i. e. the NAC of the samples depends on the nonwoven density. The Table II indicates the NAC value for specified frequency and NRC values.

Table II The NAC and NRC results of applied samples

No.	Sample ID.	NAC for specified frequency				NRC
		250Hz	500Hz	1000Hz	2000Hz	
1	L3OC7O	0.124	0.269	0.512	0.800	0.426
2	L3OF2OC5O-1	0.102	0.230	0.582	0.862	0.444
3	L3OF2OC5O-2	0.109	0.229	0.600	0.864	0.451
4	L3OF2OC5O-3	0.129	0.312	0.619	0.887	0.487
5	L3OF3OC4O	0.129	0.321	0.608	0.918	0.494
6	L3OF3RC4O	0.142	0.458	0.815	0.997	0.603
7	L3OF5OC2O	0.129	0.378	0.715	0.943	0.542
8	L3OF5RC2O	0.144	0.471	0.834	0.990	0.610

4. CONCULSIONS

We got the definition for the effect of fiber content, structure and nonwoven density.

① The effect of the fiber content on the NAC usually depends on the content of the finer fiber. We think that nonwovnes, which got more finer fiber, have more chance to contact with sound wave, it causes more resistance like friction or viscose through the vibration of the air.

② The PET nonwovens unoriented web in the middle layer have definitely higher NAC than nonwovens which have totally oriented web structure. The effect on NAC is very clear from all frequency range. The reason is that the penetrated sound through the oriented web is effectively dispersed in the random web than oriented web, so they lost a lot of sound energy in the random structure.

③ The effect of nonwoven density can be thought on the same idea like the effect of fiber content. It is based on energy transform from vibration energy to thermal energy. It means that the high density material have more contact area than low density material through the porosity.

Through the conclusions, the most obvious featuere is NAC increasing with frequency, from the results we confirmed that density and structure are certainly influence on the NAC.

We can think that nonwovens have high density and finer fiber which cause flow resistance(friction resistance) such as thick absorption material. Moreover, if they have unoriented web in the middle layer, the effect of NAC can be greatly improved. The influnce on the NAC from nonwoven parameters hard to think separately from each other. Through the work we found that the NAC of the PET nonwoven can be improved through the investigation of the optimal fiber content, web structure and nonwoven density.

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