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# Effect of surface etching and ultrafine fibers on sound absorption characteristics

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## 1. INTRODUCTION

Sound absorbing materials are divided into several types according to the appearances and the characteristics. Basic mechanism of sound absorption in various sound absorbing materials is the conversion of sound energy into heat energy. Here, the important elements which govern by the conversion from sound into heat depend on the type of materials.[1~3]

Structural mechanism of sound absorption is classified roughly by three types, such as porous, resonance and panel types. Fibrous assemblies are generally included in porous type and the most important type for the noise control applications. In this case, it is necessary to use the thickness and air flow resistivity for the specification of materials.[4] Resonance and panel types are subsidiary used for sound absorption materials due to viscous loss at the perforated structure. The main factor for sound absorption caused by the resonance system which is composed of air mass in the perforation and air spring at the air space.[5]

The objective of this work was to examine the possibility for enhancing the noise absorption coefficients(NAC) of nonwoven by combining with sound reflecting materials, which have small NAC but relatively high reflection coefficients, and by using ultrafine fibers. Ultrafine fibers are used for the effect of fineness, etching and panel effects are investigated for the resonance type. The effect of ultrafine fiber and etching structure enhance viscosity and friction in internal and external, respectively, and panel resonance effect gives like Helmholtz resonator.[6~8]

## 2. THEORETICAL CONSIDERATION

### 2.1 Porous type

Nichols[9] express the porous type absorption mechanism, as formula (1).

$$\frac{R_1 d^2}{\rho^{1+x}} \approx constant \qquad (1)$$

Where, $R_1$ is the flow resistance, $d$ is the nonwoven thickness, $\rho$ is the nonwoven density, $x$ orientation constant(0.3~1.0).

### 2.2 Resonator type

Sound absorption coefficient has maximum value at the specific frequency. This is caused by the resonance of the system which is composed of the air mass in the perforation and the air spring at the air space. Resonant frequency $f_o$ is given by the formula (2).[10]

$$f_o = \frac{c}{2\pi}\sqrt{\frac{P}{L(t+0.8d)}} \quad (\mathrm{Hz}) \qquad (2)$$

Where, $c$ represents sound velocity, $P$ is the open area, $L$ is the thickness of air space, $t$ is plate thickness, $d$ is perforation diameter.

### 2.3 Panel type

The resonant frequency $f_o$ of a panel absorber is given by the formula (3).[11]

$$f_o = \frac{60}{\sqrt{mt}} \quad (\text{Hz}) \tag{3}$$

Where, $m$ is the mass per unit area, $t$ is depth of partitioned air space.

## 3. EXPERIMENTAL

We have investigated the effect of ultrafine fiber content on sound absorption, using regular PET(1.25den) and ultrafine fiber(0.3den). The fiber content of nonwoven is given in the Table I and the composition of the nonwoven for the effect of the surface etching is given in the Table II. All of them have contained 30% LMP(low melting polyester, 6den) fibers.

Table I. Sample identification for the contents of ultrafine fibers

(%)

| Sample ID. | Regular PET (1.25den) | Ultrafine fiber (0.3den) | Density (kg/m³) |
|---|---|---|---|
| U-1 | - | 70 | 24 |
| U-2 | 17.5 | 52.5 | 24 |
| U-3 | 35 | 35 | 22 |
| U-4 | 52.5 | 17.5 | 20 |
| U-5 | 70 | - | 20 |

Table II. Sample identification for the etching and resonance types

(%)

| Sample ID. | | Regular PET(recycled) | | Density (kg/m³) |
|---|---|---|---|---|
| | | 3den | 7den | |
| 1-C | WE/NE/NED | 50 | 20 | 36 |
| 2-C | WE/NE/NED | 30 | 40 | 36 |
| 1-R | WE/NE/NED | 50 | 20 | 36 |

Where, sample WE means 5mm×5mm(width× depth), NE is 2.5mm×5mm and NED is 2.5mm×10mm etching. The samples for resonance effect using film and foil are 1-C, 2-C, 1-R, 1-C(NE). They are set in impedance tube like Figure 1. The panels for the resonance test are PP film-A ( 0.001″ ), PP film-B ( 0.003″ ), aluminum foil ( 0.001″ ). The equipment for NAC measurement is a two-microphone impedance tube manufactured by Brüel & Kjær.

**Type (a)** Standard type

**Type (b)** Set panel on the front

**Type (c)** Set panel on the back

Figure 1 Schematic diagram of specimen setting for resonant effect.

## 4. RESULTS AND DISCUSSION

### 4.1 Content of ultrafine fibers

We used NAC and NRC(noise reduction coefficient) which are the expression of the sound absorption, especially NRC is the average of NAC at 250, 500, 1000, 2000Hz which frequently used as the objective method to estimate the sound absorption. The content of ultrafine fiber(0.3den) has decreased according to U-1, U-2, U-3, U-4, U-5, all of them have contained 30% LMP and they have 100, 70, 50, 30, 0% against the regular PET. The relationship between sound absorption and ultrafine fiber content is illustrated in Figure 2. NAC of the sample is proportional to the increase of the ultrafine fiber content.

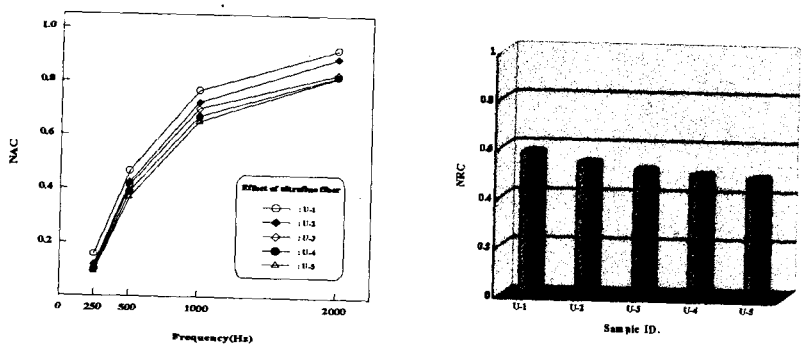


Figure 2 Effect of ultrafine fiber about NAC and NRC.

### 4.2 Surface etching

The effect of etching on 1-C sample is illustrated Figure 3. Tendency of the etching effect with NE types shows the highest NAC and NRC values, and then WE and NED. Etching on sample surface has enhanced the diffused reflection and contact area with sound energy. On the other hand, WE and NED samples have lower NAC and NRC against NE. In the case of WE and NED, they have wide etching surface of the Helmholtz resonator and decrease of the thickness, respectively. So, it is difficult to control sound absorption.

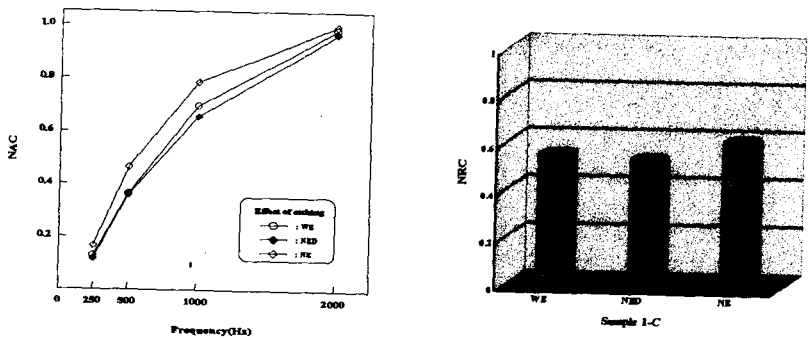


Figure 3 Effect of etching on 1-C about NAC and NRC.

### 4.3 Panel resonance

PP film and foil make resonance through the vibration, Figure 4 shows the increase of NAC in lower frequency region, but in high frequency region, coincidence effect makes rapidly drop on NAC, the decrease rate of sample PP film-A is the lower than foil and PP film-B. Coincidence effect move to low frequency region when the material is thick, rigid and low density.

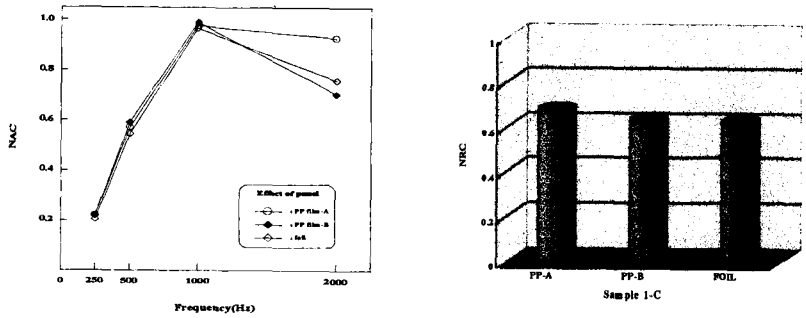


Figure 4 Effect of panel resonance on 1-C about NAC and NRC.

## 5. CONCLUSION

We have investigated three modes of sound absorption and determined the following results to improve NAC and NRC values with different material structures, such as ultrafine fiber, etching and panel resonance.

① The content of ultrafine fibers is directly proportional to NAC and NRC.

② Surface etching of nonwoven is effective to increase the NAC and NRC, and the rate of sound absorption depends on the width and depth.

③ Panel resonance effect has contributed to increase NAC in low frequency, but It has coincidence effect in high frequency and makes decrease in NAC.

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