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The Prediction of Sound Absorbing Coefficient for Multi-Layer Non-Woven

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***Abstract*—**Automotive interior material consisting of several material layers has the sound-absorbing function. It is difficult to predict sound absorbing coefficient because of several material layers. So, many experimental tunings are required to achieve the target of sound absorption. Therefore, while the car interior materials are developed, so much time and money is spent. In this study, we present a method to predict the sound absorbing performance of the material with multi-layer using physical properties of each material. The properties are predicted by Foam-X software using the sound absorption coefficient data measured by impedance tube. Then, we will compare and analyze the predicted sound absorption coefficient with the data measured by scaled reverberation chamber and impedance tubes for a prototype. If the method is used instead of experimental tuning in the development of car interior material, the time and money can be saved, and then, the development effort can be reduced because it can be optimized by simulation.

***Keywords*—**Multi-layer nonwoven, sound absorption coefficient, scaled reverberation chamber, impedance tubes.

I. INTRODUCTION

NONWOVEN fabric is widely used as industrial fibers in automotive interior part. It has usually multi-layer with various materials. For easy recycling, it is studied to develop a single material too. But, it is not easy to meet the required performance by single material because automotive interior has many targets. Specially, it must have a sound-absorbing performance to reduce the noise. Because automotive interior is composed of multi-layer material, it is difficult to meet the required performance. So, we have many experimental tunings to meet the required performance for sound absorption in the development. It is disadvantageous in terms of cost and time aspects.

In this paper, we will present the method to predict the sound absorption coefficient for nonwoven material with multi-layer using physical properties for each nonwoven.

First of all, the sound absorption coefficient is measured by using acoustic impedance tube. And we calculate the physical properties of the material with it [1]-[3]. We predicted it using Foam-X software with inverse algorithm. We predict the sound absorption coefficient of multi-layer using commercial analysis tool. Also, we verify the sound absorption coefficient calculated by commercial analysis tool with a prototype. And we do correlation analysis of the calculated and measured values. For measuring the physical properties, expensive measuring equipment is needed. So, we predict it by using a software. Fig. 1 shows the process of the analysis and test.

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II. THE CALCULATION OF THE PROPERTY FOR ACOUSTIC MATERIAL

We measure the sound absorption coefficient with impedance tubes to predict the properties of nonwoven. The predicted properties are porosity, resistivity, tortuosity, viscous length, thermal length, and so on. It is calculated with the absorbed amount that is not reflected about the input sound in the tubes. The materials for the experiment are PET felt and mixed felt. Because the materials have high performance for sound absorption, those are widely used as automotive interior. The more experiments are conducted for prediction, the more it is accurate. First of all, the thickness of the materials for the experiment should be determined. It is 10 mm in thickness. The experiments for 1, 2, and 3-layer of the same material were conducted several times. Fig. 2 shows the result of the experiment for the sound absorbing coefficient. The physical properties are calculated with the measured sound absorbing coefficient. The used commercial software is Foam-X [2].

As shown in Fig. 3, the calculated properties are open porosity, resistivity, pore tortuosity, viscous length, thermal length, and so forth. For measuring the properties, expensive measurement system is required. But if it is calculated using the data of acoustic impedance, the cost and the time can be reduced.

III. THE CALCULATION OF THE SOUND ABSORBING COEFFICIENT FOR MULTI-LAYER

We predict the sound absorbing coefficient of compositing multi-layer using the commercial software NOVA as shown Fig. 4. The properties such as open porosity, resistivity, pore tortuosity, viscous length, thermal length and bulk density are required for the calculation [4], [5]. But, bulk density cannot be calculated using Foam-X. So, we measured it with Phi-X measurement system as shown Fig. 5. Table I shows the calculated and measured data for the prediction of the sound absorbing coefficient [6]. The data are the calculated value in the Foam-X software.

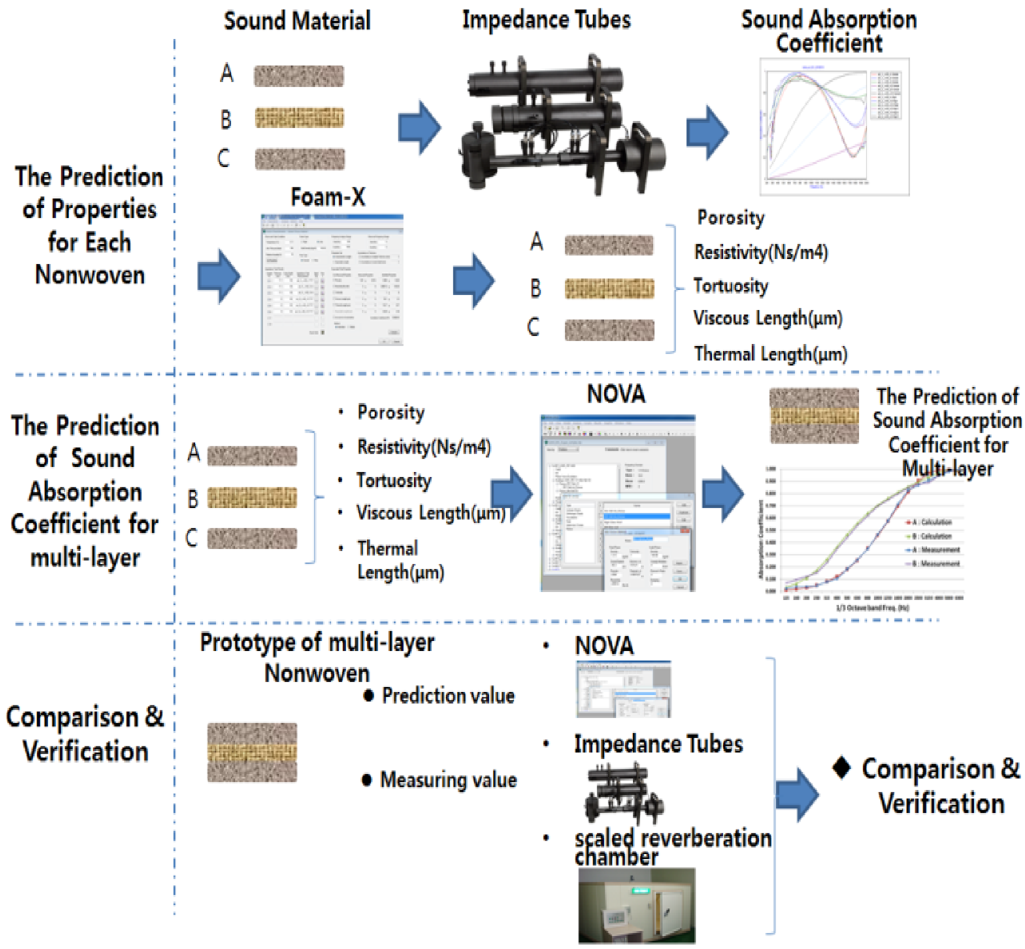


Fig. 1 The process for the prediction of sound absorption coefficient for automotive interior material with multi-layer

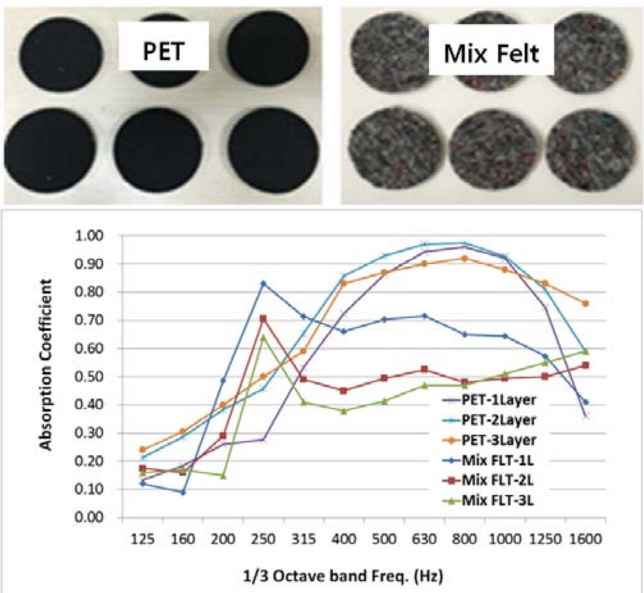
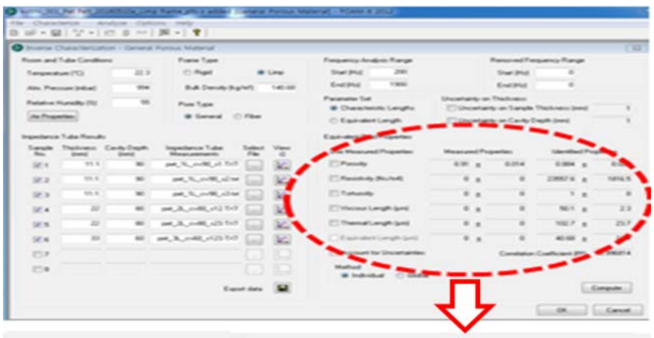


Fig. 2 The measured sound absorption coefficient by impedance tubes



Use Measured Properties	Measured Properties			Identified Properties		
Porosity	0.91	±	0.01	0.884	±	0.022
Resistivity(Ns/m4)	0	±		23557.6	±	1816.5
Tortuosity	0	±		1	±	0
Viscous Length(μm)	0	±		50.1	±	2.3
Thermal Length(μm)	0	±		102.7	±	23.7
Equivalent Length(μm)	0	±		40.68	±	2.34

Fig. 3 The prediction by Foam-X with the measured sound coefficient

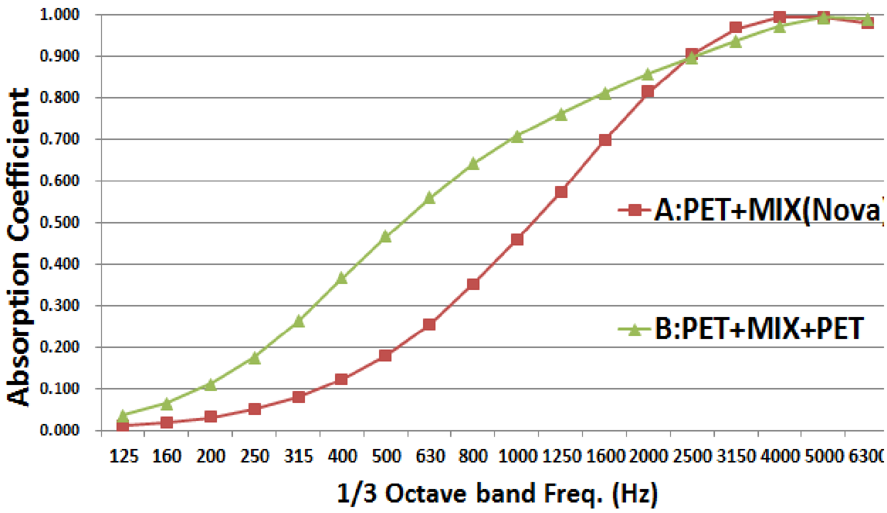


Fig. 4 The calculated sound absorbing coefficient

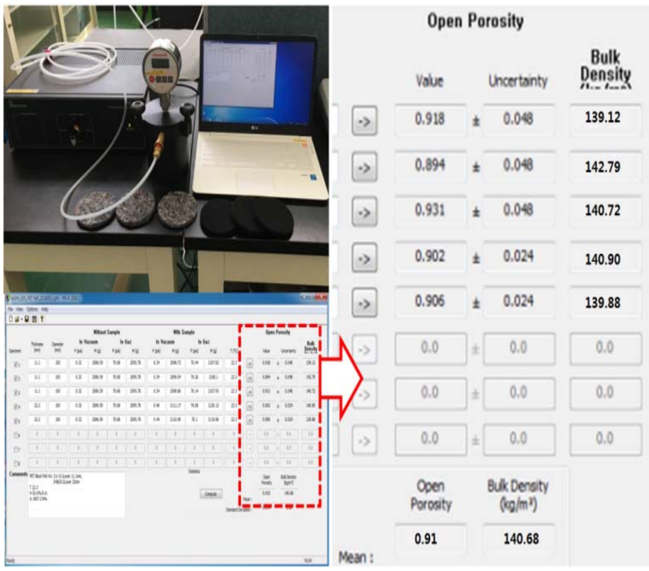


Fig. 5 The measurement of bulk density

TABLE I
MATERIAL PROPERTIES

material property	PET Felt	Mix Felt
open porosity	0.884	0.896
resistivity(Ns/m^4)	23557.6	138721.1
pore tortuosity	1	1
viscous length(μm)	50.1	70.2
thermal length(μm)	102.7	143.1
bulk density (kg/m^3)	140.68	135.21

Fig. 6 shows the test samples for scaled reverberation chamber and impedance tubes. The compositing multi-layer is 2-layer and 3-layer. The composition for 2-layer is PET felt and mixed felt. And the three layers are PET felt, mix felt, and PET felt. For the comparison and verification, we fabricated the prototypes for 2-layer and 3-layer. These are for the impedance tubes and the scaled reverberation chamber. We compared the data for two cases.

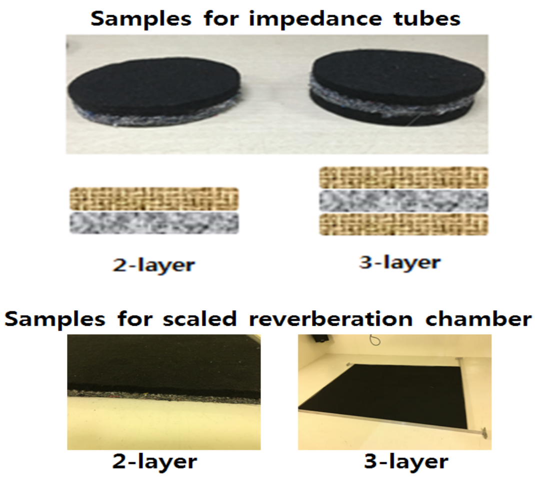


Fig. 6 The test sample with multi-layer

Fig. 7 shows the curves of the sound absorbing coefficient calculated by using NOVA and conducted by using impedance tubes. As shown in Fig. 7, the curves are similar because the error is in 10%. It shows that the sound absorbing coefficient for multi-layer with the calculated properties can be predicted. So, we can use the method for the sound absorption design of automotive interior with multi-layer for impedance tube. Fig. 8 shows the curves of the sound absorption coefficient calculated by using NOVA and conducted with the scaled reverberation chamber. As shown in Fig. 8, there is some error in the curves. For the impedance tubes, the direction of sound progress is perpendicular to the side of nonwoven. It is different from the scaled reverberation chamber. So, we need to identify it. Additionally, we will find correlation coefficient in the future.

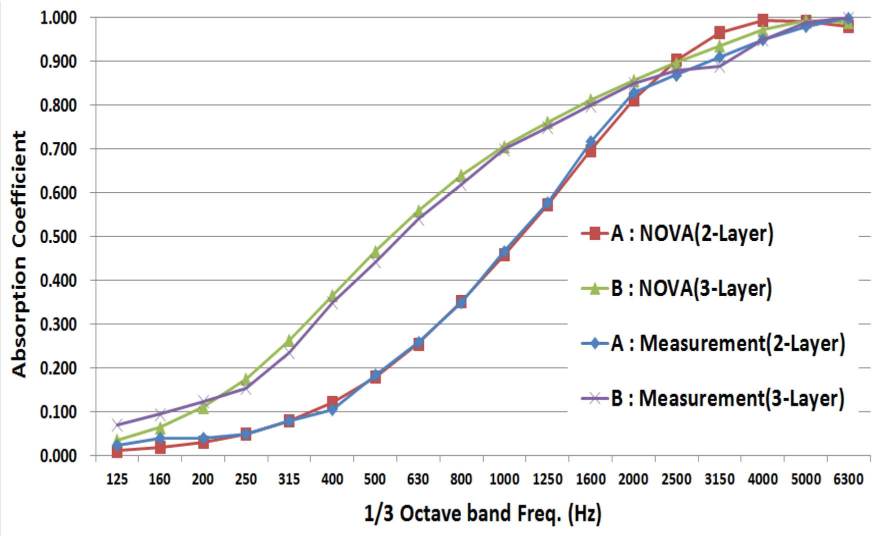


Fig. 7 The comparison of the calculated and measured data with impedance tubes

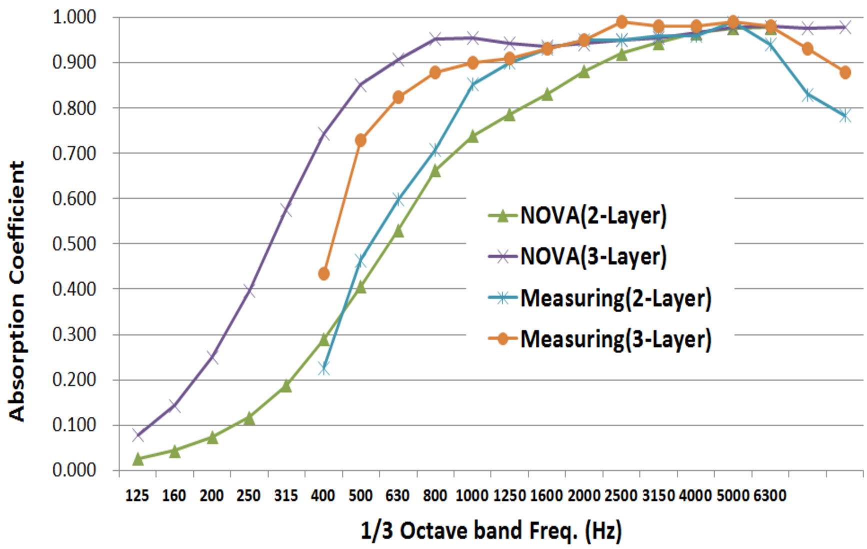


Fig. 8 The comparison of the calculated and measured data with scaled reverberation chamber

IV. Conclusion

We measured the sound absorption coefficient for several materials using impedance tube. With the data, we calculated the physical properties by using commercial software Foam-X. And using the data, we predicted the sound absorption coefficient for materials with multi-layer. And then it was compared with the measured value with the prototypes for the impedance tubes and the scaled reverberation chamber. The sound absorption coefficient curves predicted by software and measured by impedance tubes are nearly the same. But, for scaled reverberation chamber, it has some difference. We will investigate the reason and find the correlation coefficient for it in the future.

In this paper, it was verified that this method can be used for sound absorption design for automotive interior with multi-layer for impedance tubes. It is not easy to meet the target for the sound absorption since the material consists of multi-layer. While the automotive interior with multi-layer is developed, the tuning test is conducted so many times in practice. If sound absorption is predicted, it can be developed without many tuning tests. So, it can save money and time.

Acknowledgment

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