Experiment Study on Sound Properties of Carbon Fiber Composite Material

Zhong Yan, Zhou Pu, Feng Haijun, and Zhang Yi

Shanghai Marine Equipment Research Institute, Shanghai, China
E-mail: zhongyan704@163.com

Abstract. In this paper, the sound absorption coefficient and transmission loss of carbon fiber composite material are tested by stand wave tube equipment, and the factors affecting the performance of the carbon fiber composite material are analyzed. The results show that the sandwich structure can effectively improve the sound absorption coefficient and transmission loss; increasing material thickness appropriately can also improve acoustic performance of the carbon fiber composite material. The carbon fiber composite material with reasonable structure design can be used as acoustic material in the field of vibration and noise reduction.

1. Introduction
Carbon fiber composite material is a kind of excellent mechanical material, with high strength, high modulus, low density, low temperature resistance, small linear expansion coefficient and a series of advantages, which is get increasingly attention and application in aerospace, building reinforcement, upgrade industries such as new energy vehicles[1]. As the application of carbon fiber composites expands to the field of vibration and noise reduction, new requirements are proposed for the acoustic performance of carbon fiber composites[2].

In this paper, acoustic properties of carbon fiber composite materials are tested by standing wave tube method and the affect factors are analyzed. The conclusion of the experiment can provide a scientific basis for the application of vibration damping noise reduction.

2. Experimental Study on Sound Absorption Performance

2.1 Test Method
The sound absorption coefficient is a physical parameter reflecting the sound absorption performance of sound absorbing materials. There are two methods for measuring the sound absorption performance of materials, reverberation chamber method and standing wave tube method[3]. Standing wave tube method can measure absorption coefficient and specific acoustic impedance of the normal incident
sound wave. The method has the following characteristics: small specimen area, easy installation and measurement, high measurement accuracy and low cost. The sound absorption coefficient measured by this method can also be used to compare the sound absorption performance of different materials and the same materials under different conditions[4-6]. Therefore, the standing wave tube method is adopted to test the sound absorption performance of the material in this paper.

2.2 Test Results and Analysis
The measurement of sound absorption coefficient is carried out on B&K4206 standard impedance tube. The internal diameter of impedance tube is 100mm and test frequency range is 64~1600Hz. The materials used in the test are shown in table 1, and the test results are shown.

| Material                        | Thickness /mm | Remark           |
|---------------------------------|---------------|------------------|
| Steel Plate                     | 11            | contrast-material|
| Carbon Fiber with E51 Resin     | 11            |                  |
| Carbon fiber with E51 Resin     | 22            |                  |
| Carbon Fiber with 3D Fabric Sandwich | 11   |                  |
| Carbon Fiber with Honeycomb Sandwich | 11   |                  |

Figure1. Comparison of Carbon fiber and Steel On Sound Absorption Coefficient
As shown as Figure 1, the absorption coefficient of carbon fiber and steel of same thickness is in the same order of magnitude, the absorption coefficient of carbon fiber is slightly lower than steel in low frequency range, slightly higher than the steel in high frequency. The overall sound absorption coefficients is below 0.1 .That is to say simple structure of carbon fiber composites has no obvious advantage in sound absorption performance. To improve the sound absorption performance of carbon fiber composites, the structural design and internal quality distribution should be optimized.

Figure2. Influence of Different Structures on Sound Absorption Coefficient
As shown as Figure 2, the sound absorption coefficient can be significantly increased by use the 3D fabric sandwich and honeycomb sandwich structure. The sound absorption coefficient of carbon fiber with 3D fabric sandwich above 600Hz is above 0.2, and the peak value reaches about 0.75, appearing around 1000Hz. This is because the 3D fabric sandwich changes the mass distribution characteristics, increases the flow resistance of the material, strengthens the reflection effect in the material internal, and improves the sound absorption performance of carbon fiber composite material.

![Figure 3](image)

**Figure 3.** Comparison of Different Thickness On Sound Absorption Coefficient

As shown as Figure 3, with the increase of thickness, the sound absorption coefficient in medium and high frequencies is greatly increased, and the sound absorption coefficient of low frequencies is also increased slightly. Because with the increase of the thickness, the propagation distance of the sound waves increases, more energy is consumed. So in the whole frequency range, especially in high frequencies, the sound absorption coefficient is increased significantly, the absorption property is improved. But when the material thickness increases to a certain extent, the change of sound absorption coefficient caused by thickness will be small.

3. Experimental Study on Acoustic Insulation Performance

3.1 Test Method

Sound insulation is the most commonly used physical quantity in the evaluation index of sound insulation performance. The sound insulation measurement methods have reverberation chamber method and four-microphone method\[7-8\]. The reverberation chamber method need special test environment and instruments, the test cycle is too long to meet the laboratory research. The four-microphone method is high-precision and convenient to test and study the performance of laboratory acoustic materials. Therefore, the four-microphone method is adopted in this paper. Figure 4 shows the measurement principle of four-microphone method. The signals produced by signal generator, are converted into sound waves through the speaker and enter the sound source tube. In the tube plane sound wave is generated. The plane waves are divided into two parts when meet test samples, one part is launched, forming plane sound waves; the other part pass through the samples, enter into the receiving tube and form reflected plane sound wave. Plane sound waves are also divided into two parts when meeting the end of sound absorption, one part is absorbed, the other part is reflected, and forming reflected plane sound waves. Two microphones are placed before and after the test sample to measure the sound pressure at the position.
3.2 Test Results and Analysis

Sound insulation measurement system is based on the absorption coefficient test device and increases transmission tube and sound absorption terminals. This make two microphones in the incident tube two microphone and two microphones in transmission tube measurements at the same time, it can separate two columns of wave in the incident tube and transmission tube, which have the opposite direction in the propagation. So the transmission loss is calculated conveniently. The test results are shown in Figure 5 and Figure 6.

![Diagram of Measurement System](image)

**Figure 4.** Schematic Diagram of Measurement System

**Figure 5.** Influence of Different Structures on Transmission Loss

As shown as Figure 5, 3D fabric sandwich and honeycomb sandwich structure can greatly improve the sound insulation performance of carbon fiber composite materials. The peak value of transmission loss appears at 31.5Hz, reaching over 40dB. This is because the sandwich structure divides the material into several closed cavities, which hinder sound waves propagation and heat exchange greatly. These cavity walls can also reflect sound waves effectively. Therefore the sandwich structure has good isolation effect, especially for lower frequencies. The sandwich structure can be adopted in the sound insulation engineering.
Figure 6. Comparison of Different Thickness on Transmission Loss
As shown as Figure 6, increasing the thickness can improve the sound insulation within a certain frequency range. This is because with the increase of thickness, the resistance to sound wave strengthens gradually. Sound waves lose more energy as they travel, the transmission energy decreases gradually, the transmission loss of the plate increases gradually. So in order to get better acoustic noise reduction, the thickness of carbon fiber composite materials can be appropriately increased.

4. Conclusion
In this paper, the sound absorption coefficient and insulation of carbon fiber composites are tested by standing wave tube method, and the influencing factors of material acoustics performance are analyzed. The following conclusions can be drawn:
(1) The carbon fiber sandwich structure can change the acoustics and dynamic characteristics of composite materials, increase the flow resistance of the material, strengthen the internal reflection effect of the sound waves in the material, and improve the sound absorption performance of materials.
(2) The sandwich structure has good sound insulation effect, especially for low frequency noise.
(3) Increasing of material thickness can improve the sound absorption coefficient in medium and high frequencies; it also can increase sound transmission loss on all frequencies.
(4) The carbon fiber composite materials designed with reasonable structure can be used as acoustic materials to reduce vibration and noise.

References
[1] Zhang Dingjin and Chen Hong, 2015 Advanced Materials Industry, 5, 31-35.
[2] Wang Guan, Ruan Zhuqing, 2015 Technical Acoustics, 34, 453-454.
[3] Maa Dahyou, 2002 Noise and Vibration Control Engineering, 427-431.
[4] Qu Bo and Zhu Beili, 2012 Noise and Vibration Control, 12, 44-46.
[5] MinQi, Peng Feng, YinYa, 2010 Acta Acoustic, 29, 321-330.
[6] MaYanhong, 2009 Journal of Beijing University of Aeronautics and Astronautics, 35, 653-656
[7] Yuelu Ren, 2013 Materials Letters, 91, 242-244.
[8] Thilagavathi T, 2010 Journal of Industrial Textiles, 39, 267-278.