Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 146 (2016) 120 – 127

Procedia Engineering

www.elsevier.com/locate/procedia

8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015

Investigation on impedance chip muffler performance

Xiaohua Sun[a],Fei Wang[a,*]

[a]*School of Environment and Architecture, University of Shanghai for Science and Technology, 516Jungong Road, Shanghai20093, China*

Abstract

Nowadays it is quite significant to control the noise generated from the fan, air conditioning and air flow, as well as to reduce the noise pressure level. The chip mufflers have been widely used for its advantages of large air volume and high amount of noise elimination. The method adopted in our study is comparison. Before determining the muffler insertion loss, we should do the controlled experiment without the muffler, then we use the muffler to replace the duct for the experiment. So we can obtain the insertion loss by measuring the noise level in the two different conditions. Attention should be paid to the noise conditions and the main duct speed which should remain the same in the whole experiment process. By measuring, calculating and analyzing the insertion loss of the chip mufflers with different silencing cotton density under different main duct speed, verifying that the muffler have a very good silencing effectiveness for the high and intermediate frequency noise, reaching the quadratic relationship between noise elimination and silencing cotton density which is beneficial to optimize the chip muffler performance in the future.

Peer-review under responsibility of the organizing committee of CCHVAC 2015

Keywords: *Noise; Chip muffler; Insertion loss; Silencing cotton density*

1. Introduction

Impedance chip muffler [1] is a kind of absorptive muffler, using the arrangement of the sound-absorbing material on the inner wall of the duct or the sound-absorbing effect of the sound-absorbing structure to make the noise reduce rapidly with distance along the duct so as to achieve the aim of noise elimination. Impedance muffler's effective frequency band is wide and it has a good silencing effectiveness for the high and intermediate frequency noise, but its service life is short in the high temperature erosion gas and its silencing effectiveness of the low frequency noise is poor, the actual noise elimination is related with the frequency. We can draw the relationship among the quantity of

* Corresponding author. Tel.: 18621805866.
E-mail address: 18621805866@163.com

Peer-review under responsibility of the organizing committee of CCHVAC 2015
doi:10.1016/j.proeng.2016.06.361

muffler noise elimination, frequency and silencing cotton density through the study of the impedance chip muffler's insertion loss, which provides certain theoretical guidance and reference for the further study.

Nomenclature

D	the insertion loss of each frequency band [dB]
ΔL_P	insertion loss (same as the amount of noise elimination) [dB]
ρ	density of the silencing cotton [kg/m^3]
α	the modified value of different main wind speed
β	the modified value of different silencing cotton density

2. The muffler's acoustic performance

The noise elimination of the muffler is an important index of its acoustic performance. Our research adopts the insertion loss [2, 3] as the acoustic performance of muffler evaluation index. Insertion loss is calculated according to the results of the test of monitoring system, actually we measure the noise pressure level before and after the measuring system which connected muffler, the difference of them is insertion loss which directly reflect the muffler's noise elimination effect. We use direct method to measure the insertion loss, as we keep the reference and the noise position as the same, the equivalence of the test results are good.

3. Methods

3.1. The design principle and installation drawing of muffler test bench

According to the laboratory conditions, we set different wind speed, and we control the air volume entered the system by different nozzle combinations. The fan rotation speed controlled by frequency converter so as to achieve the required air volume. In the drawing, noise goes through the straight duct, muffler is connected in the straight duct with two microphones (GRAS Type 40AE) connecting before and after the chip muffler. The collected signals will go into the modal analysis device through microphones, the modal analytical device used as a voice signal acquisition device connected to the computer, then analyze the signals through the software (DEWEsoft) on the computer to output the spectrum. The system structure [4] is as follows:

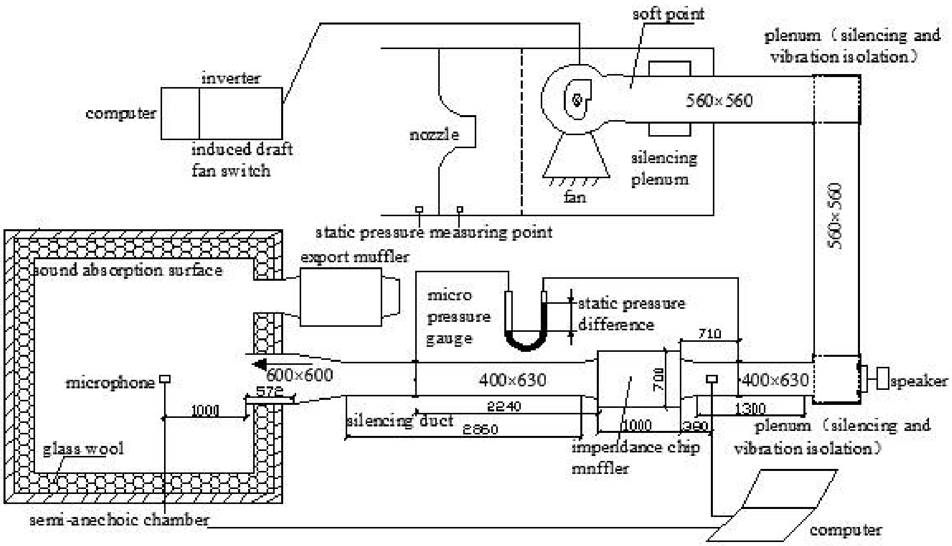

Fig. 1. Test bench of muffler measurement.

3.2. Design conditions of the muffler

The muffler simulation test bench is composed of noise resources, main duct, muffler, test instrument and so on. According to the type and structure of the selected muffler, we choose 100 mm (standard) thick glass wool as anechoic materials in experiment, its geometry is 1000×700×100 mm. The densities of the glass wool are 24 kg/m^3, 32kg/m^3, 40kg/m^3 and 48kg/m^3. The profile of the muffler is:

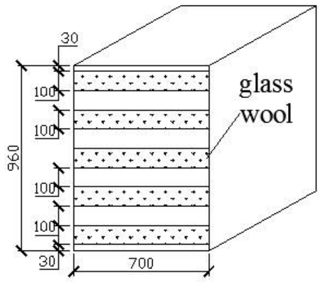

Fig. 2. The profile of muffler.

- First point: Measuring point position of the muffler's static pressure difference [5]:
  a. The distance between upstream pressure test point and muffler is: $l_1 > 0.5d = 50$ mm, in this study
  $l_1 > 0.5d = 50$ mm;
  b. The distance between downstream pressure test point and muffler is: $l_2 > 6d = 600$ mm, in this study $l_2 = 2050$ mm.
  Where: d is acoustic slice thickness, d = 100 mm, the muffler pressure difference on both sides are measured by pitot tube and static tube with micro pressure gauge.
- Second point: The given wind speed and its corresponding air volume [6] is shown in table 1.

Table 1. The air volume of muffler performance experiment.

Section area (m^2)	0.252					
Wind speed (m/s)	10	8	6	4	2	0
Air volume (m^3/h)	9072	7258	5443	3629	1814	0

4. Determination of the muffler insertion loss

We adopt the semi-anechoic chamber in this experiment, and two points before and after the muffler are selected. Do controlled experiment before installing the muffler, then use the muffler to replace the duct. The noise conditions and the main air speed should be kept the same as the controlled experiment. Measuring the corresponding noise pressure level of each frequency band, we obtain the insertion loss of each frequency band through the difference between the two noise pressure level. The introductions of the semi-anechoic chamber are as follows:

- First point: If we adopt the semi-anechoic chamber as the reception room, the noise power level radiated into the reception room through the nozzle should be measured according to GB 6882.
- Second point: Do the controlled and corresponding low noise air flow experiment, measure the measuring points' noise pressure level of acoustic sources, noise pressure level of standard acoustic sources at the end and noise pressure level of background noise, noise pressure level of background noise at the end. Then conclude noise pressure level of standard acoustic sources L_{p1} at the end of each frequency band under the controlled and its corresponding modified value K_1。
- Last point: Use the muffler to replace the duct for the experiment and do the corresponding low noise air flow experiment, noise source experiment. Measure noise pressure level of background noise, noise pressure level of background noise at the end and noise pressure level of acoustic sources, noise pressure level of acoustic sources at the end of each measuring point. Then calculate averaged noise pressure level of acoustic sources L_{p2} at the end of each frequency band and its corresponding modified value K_2.

Table 2. The modified value of background noise pressure level K [7] .

Difference between measured and background (dB)	3	4~5	6~9	10 or above
The modified value K (dB)	3	2	1	0

We can record the differences that below 3 dB, but just for reference.

The insertion loss of each frequency band is determined by the following equation [7]:

$$D = L_{p1} + L_{p2} + K_2 - K_1 \quad (1)$$

5. Results and analysis

5.1. Analyze the insertion loss of various silencing cotton density

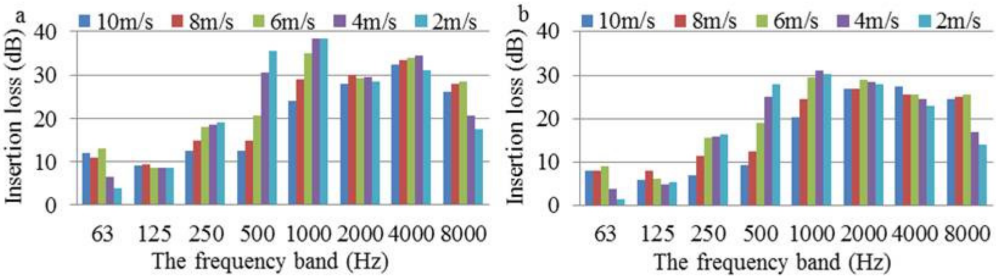

Fig. 3. The insertion loss under the silencing cotton density of 48kg/m^3 (a) and 40kg/m^3 (b).

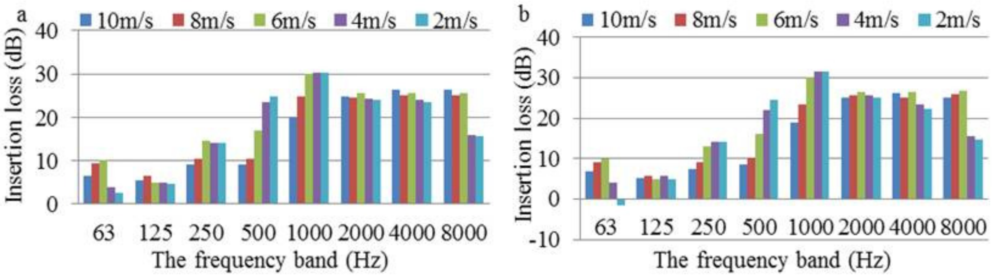

Fig. 4. The insertion loss under the silencing cotton density of 32kg/m^3 (a) and 24kg/m^3 (b).

5.2. Analyze the insertion loss of various main wind speed

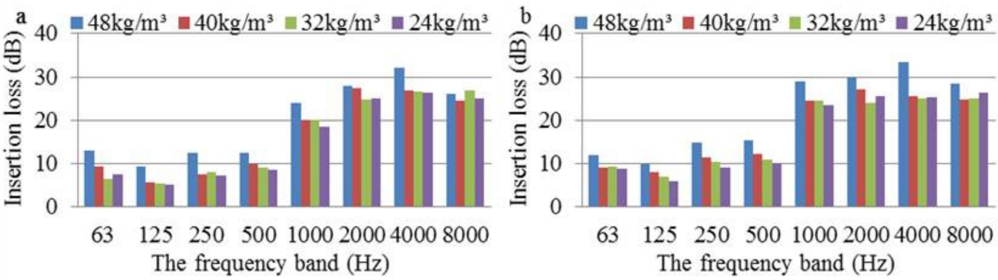

Fig. 5. The insertion loss under the main wind speed of 10 m/s (a) and 8 m/s (b).

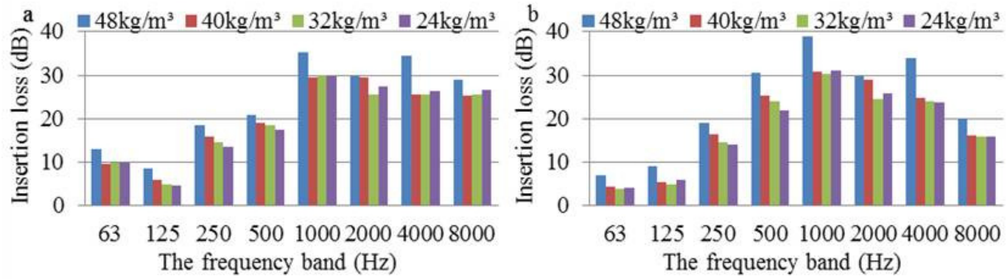

Fig. 6. The insertion loss under the main wind speed of 6 m/s (a) and 4 m/s (b).

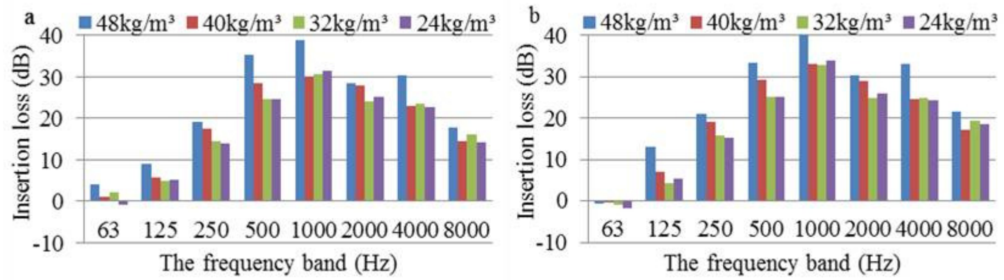

Fig. 7. The insertion loss under the main wind speed of 2 m/s (a) and 0 m/s (b).

5.3. Explore the model of impedance chip muffler

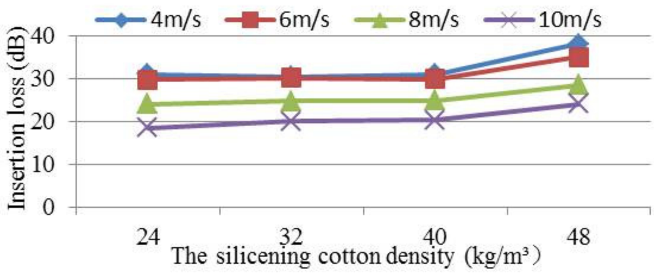

Fig. 8. The mufflers' insertion loss under the frequency of 1000Hz

Due to the amount of the impedance chip muffler noise elimination is connected with silencing cotton density and wind speed, so when design, we should control the air speed and cotton density reasonably to improve the amount of noise elimination and reduce the resistance loss. It is clearly seen from the above bar chart that the muffler's silencing effectiveness achieves its best when the frequency band is about 1000Hz. As the main duct speed of the ventilation and air conditioning system is about 6~8m/s, so we draw the line chart with different silencing cotton density under the same frequency band of 1000Hz when we choose the main duct speed as 4m/s, 6m/s, 8m/s and 10m/s, which are shown in figure 8.

We can conclude the function relation among insertion loss, silencing cotton density and wind speed from figure 8 and experimental data when the frequency band is about 1000Hz, which is:

$$\Delta L_P = 0.003\rho^2 + 21.888 + \alpha + \beta \quad (2)$$

Table 3. The modified value of different main duct speed α.

Different wind speed (m/s)	4	6	8	10
Modified value α	7.6	5.7	0	-4.7

Table 4. The modified value of different silencing cotton density β.

Name	24kg/m³	32 kg/m³	40 kg/m³	48 kg/m³
4m/s	0.3	-2.0	-3.1	2.2
6m/s	0.4	-0.6	-3.1	0.7
8m/s	-0.2	-0.4	-2.1	0.0
10m/s	-0.3	-0.2	-1.7	-0.6

Notice: the above equation and modified value are only applied to the impedance chip muffler under this experimental conditions which are only for reference.

Table 5. Insertion loss difference between measured and fitted values.

Name	24kg/m³	32 kg/m³	40 kg/m³	48 kg/m³
4m/s	-0.016	0.04	0.012	0
6m/s	-0.016	0.04	0.012	0
8m/s	-0.016	0.04	0.012	0
10m/s	-0.016	0.04	0.012	0

From table 5, we can see clearly that the equation’s fitting is perfect, insertion loss difference between the measured value and the fitted value is quite small. Thus higher credibility can be given to the equation.

6. Conclusions

The muffler noise elimination effectiveness varies with the main duct wind speed and the anechoic material, but in total, the muffler has a very good silencing effectiveness for the high and intermediate frequency noise (500~8000Hz). It is fully proved from the experimental results that the impedance chip muffler does good with the high and intermediate frequency noise, but poor when the noise frequency is low.

When the anechoic material is kept as the same, the muffler’s noise elimination effectiveness varies with the wind speed and achieves its best when the frequency band is about 1000Hz, also the muffler do good with large wind speed when the frequency band is about 63Hz. And the noise elimination effectiveness increases gradually along with the increase of the silencing cotton density.

When the main duct wind speed is kept as the same, the muffler’s noise elimination effectiveness varies with the anechoic material and attains its best when the frequency band is about 1000Hz, the greater the silencing cotton density, the greater the insertion loss. And the noise elimination effectiveness decreases gradually along with the increase of the duct wind speed.

We can see the quadratic relationship between noise elimination and silencing cotton density from the above equation which is beneficial to optimize the chip muffler performance, and also has a great significance for people to design the impedance chip muffler in the future.

Acknowledgements

The name of the project is solar energy distributed generation front-end integration technology and demonstration project, its number is CXY-2013-49 of shanghai.

References

[1] Baoluo Shen, Design of the dissipative silencer with absorbent plates and its application to environmental noise control, Applied Acoustics, 15(1996)18-22.
[2] Laiyu Lin, Kai Sun, Q. Xiao, Test and experiment of a micropunched plate muffler, Heating Ventilating & Air Conditioning, 39(2009)15-19.

[3] Jia Wei, S. Lu, B. Wang, Y. Shen, Discussion finite element on insertion loss of reactive muffler, Machinery Design & Manufacture, 9(2011)35-37.
[4] Architectural institute of physics of China Academy of Building Research, The architectural acoustics design manual, Beijing: China building industry Press,1987.
[5] Institute of acoustics, Chinese academy of sciences, GB/T 25516-2010 Acoustics—Laboratory measurement procedures for ducted silencers and air—Terminal units loss, flow noise and pressure loss,Beijing: China Standards Press,2010.
[6] Guangcai Gong, ect. The fulid distribution network, mechanical design press,2005.
[7] State bureau of technical supervision,GB/T 4760-1955Acoustics—Measurement procedure for silencers, Beijing: China Standards Press,1995.
[8] Laiyu Lin, J. Kang , Kai Sun, Development and testing of micro slit panel mufflers, Heating Ventilating & Air Conditioning, 4(2011) 134-137.