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Acoustic design of the air transparent soundproofing wall

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Abstract

If air can pass through a noise reducing wall, there are many benefits. Enclosures can reduce heat loads and noise barriers can decrease wind loads. The air transparent soundproofing wall is suggested using plenum chamber arrays. The sound transmission loss can be influenced by several geometric parameters. Among them, there are two key parameters to characterize the acoustic performance. The one is the higher order mode cut-on frequency inside a chamber. The other is the spring-mass-spring resonance frequency. To optimize sound insulation of plenum chamber arrays, two above frequencies need to be designed. The sound transmission loss of the air transparent soundproofing wall was designed and tested. To apply industrial fields as noise barriers or enclosures, the single number rating, Rw, is selected as a performance indicator. The measured transmission loss shows Rw-30 dB (the single number rating). Even this wall is thicker than industrial insulation materials, this wall can allow the natural ventilation and reduce the wind load. If target frequency of the noise reducing measure is fixed, the soundproofing wall can be used in many applications.

Keywords: noise barriers, enclosure, transmission loss, resonator, ventilation

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1 Introduction

Acoustic enclosure and sound barrier are most frequently used measures to reduce noise radiated by machines, equipments and vehicles. In both measures, additional functions are usually needed. In case of enclosures the ventilation is required to reduce heat load. Barriers need to decrease wind load because of construction costs. Additional functions can be fulfilled by adding holes through a wall. However leakage can cause a decrease of sound insulation performance. In this paper, plenum chamber arrays are suggested to obtain high acoustic performance with holes.

The acoustic performance of a plenum chamber was already researched using 4-pole parameters [1~3]. The sound insulation of plenum chamber arrays can be characterized by two critical frequencies among several parameters like inlet/outlet area, locations of inlet/outlet, chamber section area, chamber length, and so on. The one is the higher order mode cut-on frequency inside a chamber. Due to the higher order mode propagation inside a chamber, the transmission loss goes to zero at the higher mode cut-on frequency. The other is the spring-mass-spring resonance frequency. A plenum chamber can be considered as a mass having two springs. It acts like a mass connected to two springs.

To optimize sound insulation of plenum chamber arrays, two above frequencies can be designed. In general the acoustic performance of the noise barrier can be evaluated using single number rating like Rw [4], STC (Sound Transmission Class) [5]. To obtain high Rw or STC, the wall has high sound transmission loss within audible ranges. In this paper, the air transparent soundproofing wall is designed to obtain high Rw using plenum chamber arrays.

2 Acoustic performance of plenum chamber arrays

The transmission loss of a plenum chamber can be predicted by 4-pole parameters or FE analysis. If the only plane wave propagates in the chamber, the attenuation goes to zero at harmonics of the half-wavelength frequency due to a length of the chamber. However, transmission loss has troughs at a higher-order mode cut-on frequency because higher order modes propagate in a chamber.

In conventional applications, a plenum chamber is used as a attenuating device in duct systems. In this case, inlet and outlet pipes connected to the plenum chamber directly. There is no area changes. But plenum chambers are used as noise reducing walls, the inlet and outlet area of a plenum chamber faces to open area. In this case, each plenum chamber acts like a mass connected to two springs in opposite directions. This resonance is similar with the spring-mass resonance of the Helmholtz resonator.

3 Optimum design

If plenum chamber arrays are applied to industrial fields, the acoustic performance within audible ranges has reasonable values. In this paper, the single number rating (Rw) of transmission loss is used as the indicator of acoustic performance. Rw is the value of the reference curve at 500 Hz when the reference curve is shifted as high as possible under following conditions: the sum of deficiencies (that is, unfavorable deviation below the reference curve) within 100 Hz to 3150 Hz should be greater than 32.0 dB [4].

To increase sound insulation, the spring-mass-spring resonance frequency need to be low as possible and the higher-order cut-on frequency need to be high as possible. However there is a constraint because both frequencies are related by chamber dimensions. To optimize the acoustic performance in this paper, the resonance frequency set to 125 Hz and first circular (0,1) mode cut-on frequency is designed as 4187 Hz. The geometry of this chamber is shown in Fig. 1. To decrease resonance frequency, extended inlet and outlet are adopted. The perforation ratio is designed to be almost 1 % because if it increases, the resonance frequency increases.

$$f_r = \frac{c}{2\pi}\sqrt{2 * \frac{S}{l\,V}} \approx 125\ \mathrm{Hz} \tag{1}$$

$$f_{cut-on} = \frac{3.83}{\pi D}\mathrm{c} \approx 4187\ \mathrm{Hz} \tag{2}$$

where c is speed of sound, S means area of neck, l is equivalent length of neck, V is volume of chamber and D is a diameter of a chamber.

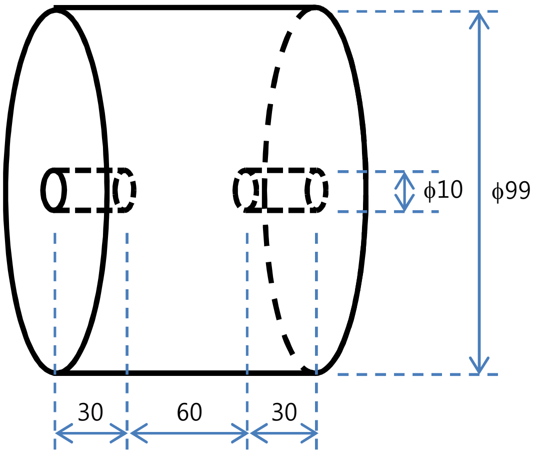

Figure 1: Optimum design for plenum chamber arrays [unit: mm]

4 Measurements

The air-transparent soundproofing wall is made by 90 plenum chambers. The sound transmission loss was measured using scaled reverberation chambers. The measurement was done in accordance with the test standards: ISO 10140:2010. The test facility consists of two adjacent chambers with a test opening between them is which the test specimen is inserted. Sizes of specimen are 1.2 m (width) and 1.0 m (height), volume of source and receiving room are 2.808 m^3 and 3.252 m^3 [6~7]. The shape of chambers is designed to be irregular in order to avoid the occurrence of standing waves. Two speakers (JBL, CONTROL 1X) were used to generate random noise in a source room. A half-inch microphone (GRAS) was used to measure sound pressure levels at six positions in each chamber. The volume of a chamber limits the lowest test frequency band due to the lack of mode count. The receiving room has about 8 modes in 315 Hz of 1/3 octave band. As a rule of thumb, it is expected that the frequency band above 315 Hz hive reasonable data.

Figure 2 shows test specimen consists of 90 plenum chambers. The measured sound transmission loss is shown in Fig. 3. The single number rating, Rw is 30 dB. As we expected, transmission loss has low values below 125 Hz and above 4000 Hz. The dip at 1600 Hz band can be explained the half-wavelength resonance due to the chamber length (0.12m). Measured values under 315 Hz band may contain errors because it is obtained in non diffuse fields as explained in above paragraph.

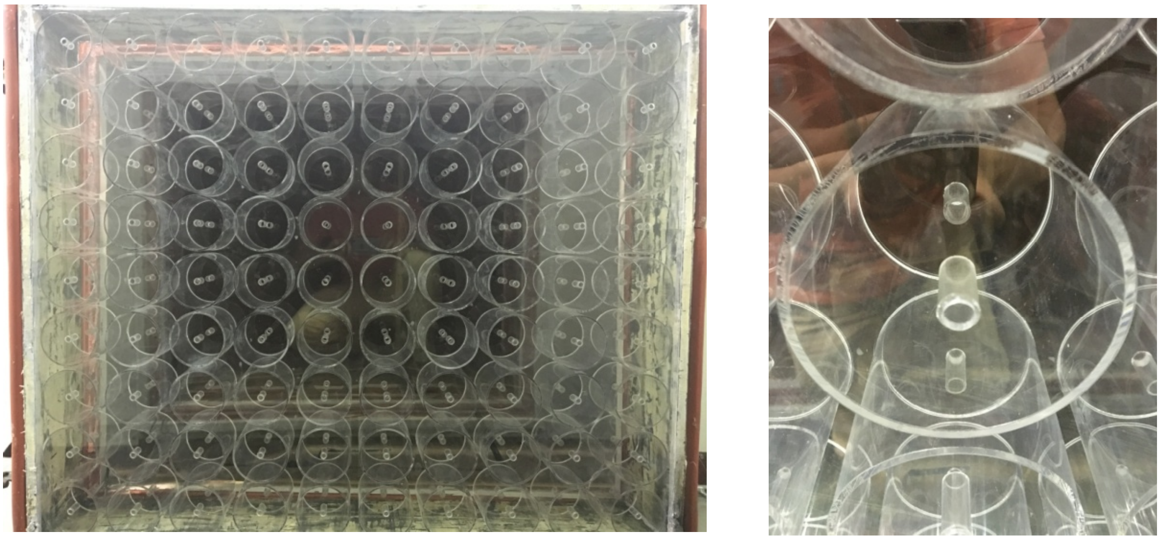

Figure 2: Photo of test specimen

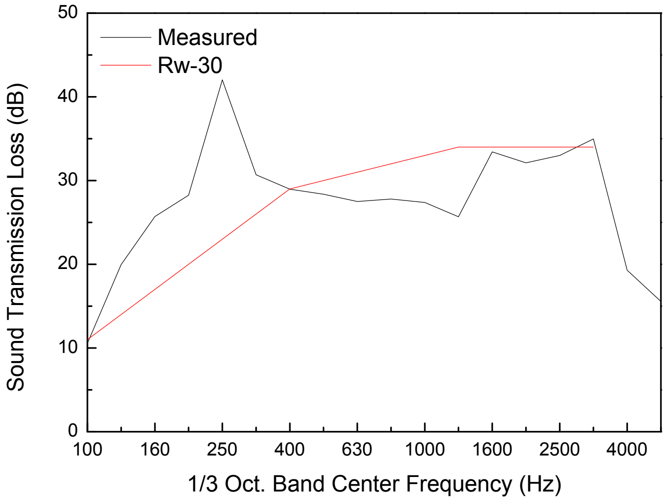

Figure 3: Measured sound transmission loss

5 Conclusions

The sound insulation of the air transparent soundproofing wall was designed and tested. To apply industrial fields as noise barriers or enclosures, the single number rating, Rw, is selected as a performance indicator. To increase acoustic performance, two critical frequency need to be optimized. The spring-mass-spring resonance frequency is designed to be 125 Hz and the first circular mode (0,1) cut-on frequency is designed to be larger than 3150 Hz. The measured transmission loss shows two critical frequencies and the single number rating has Rw-30 dB. Even this wall is thicker than industrial insulation materials, this wall can allow the natural ventilation and reduce the wind load. If target frequency of the noise reducing measure is fixed, the soundproofing wall can be used in many applications.

Acknowledgments

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References

[1] J.-G. Ih and B.-H. Lee. Analysis of higher-order mode effects in the circular expansion chamber. Journal of the Acoustical Society of America. 1985; 77: 1377-1388.

[2] J.-G. Ih and B.-H. Lee. Theoretical prediction of the transmission loss of circular reversing chamber mufflers. Journal of Sound and Vibration. 1987; 112: 261-272.

[3] J.-G. Ih. The Reactive Attenuation of rectangular plenum chambers. Journal of Sound and Vibration. 1992; 157: 93~122.

[4] ISO 717-1:2013. Acoustics -- Rating of sound insulation in buildings and of building elements -- Part 1: Airborne sound insulation

[5] ASTM E 413-10. Classification for rating sound insulation

[6] H.-J. Kang, B.-K. Kim, J.-S. Kim and J.-S. Lee. Characteristics of sound insulation in the scaled chambers. Proc INTER-NOISE 2004; 22-25 August 2004; Prague, Czech Republic 2004

[7] S.-H. Lee and S.-H Kim. A study on sound insulation using rectangular plenum chamber arrays . Proc INTER-NOISE 2014; 16-19 November 2014; Melbourne, Australia 2004