An experimental investigation of sound absorbing plate in SVU

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ABSTRACT

A new model of square SVU (Soundproofing ventilation unit) having an inlet and an outlet which is located on the crossed right angle face is proposed in this work. The outlet position was improved by placing it on the larger face of the SVU in order to increases the ventilation effect. In addition, the outlet is located in the center of the SVU to avoid the resonance of plane wave sound pressure. The sound propagating through SVU is a combination of a plane wave and the higher order mode wave. To maximize the soundproof capability it is necessary to reduce sound pressure levels or prevent the generation of those waves in any technique. In present work, the introduction of sound absorbing plate inside the SVU is considered. A series of experimental based on the Insertion Loss measurement method were performed to verify the actual sound attenuation characteristics of SVU.

Keywords: sound absorbing, sound attenuation, sound propagation

1. INTRODUCTION

The authors are presenting a concept of manufacturing windows called SPCW (Sound Proofing Casement Windows) which are capable of ventilating, regulating sunlight and reducing traffic noise inside the homes of developing countries in tropical climate zones [1]. The SPCW combines two basic components : the ventilation soundproofing unit and the lighting unit. The lighting unit can be constructed using one glass layer mounted between two soundproofing ventilation units (SVU).

The SVU can consist of a square, rectangular cuboid or more complicated shapes depending on decorative considerations. Needless to say, the unit requires a simple internal structure and large input and output to maximize ventilation as well as preventing outside noise from entering the home. Actually, an input and output can be located in various positions on the SVU according to the design of window.

A previous study [1] discussed a rectangular SVU having an inlet and an outlet located on the opposite face. However, this enables only a small outlet are to be constructed, which causes ventilation features to suffer. To improve this problem, a square SUV having an inlet and an outlet which is located on the crossed right angle face is proposed in this work. In order to further increase the sound proofing capability, the installation of SAP (sound absorbing plate) inside the SVU is required. Specifically, sound propagation inside the SVU has a plane-wave and higher-order mode[3-5] components. Experimentally, The resonance of those waves is contingent on the impedance of SAP and the shape of SVU. This paper focuses on the

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measurement of the above square SVU with various kind and located position of SAP to maximize the soundproof ability.

2. THEORY

The SVU which has a dimension of $a \times a \times d$ is shown in Fig. 1. Dimension of an input and output are $(a_{i2} - a_{i1}) \times (b_{i2} - b_{i1})$ and $(a_{02} - a_{01}) \times (d_{02} - d_{01})$, they located on the face which has a section area of $S_{ab} = a \times a$ and $S_{ad} = a \times d$, respectively.

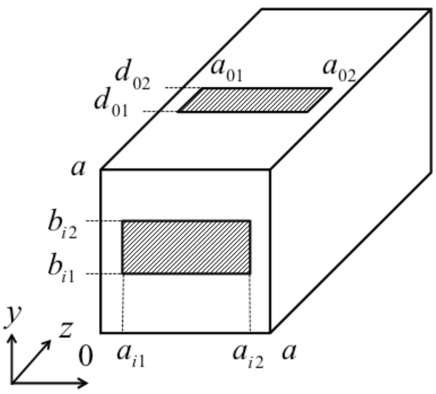

Figure 1 – Square soundproofing ventilation unit

When SAP is not attached inside the SVU, sound pressure on the output becomes [1]

$$\overline{P}_0 = j4Z_0U_i\left[\frac{-\tilde{\Theta}_{0,0}}{\sin(kd/2)} + \frac{1}{k}\sum\frac{I_{m,n}\tilde{\Theta}_{m,n}}{S_{ab}S_i}\frac{\cos(n\pi)}{\mu_{m,n}\sinh(\mu_{m,n}d/2)}\right] \tag{1}$$

where

$$\mu_{m,n} = \sqrt{(m\pi/a)^2 + (n\pi/a)^2 - k^2} \tag{2}$$

$$\tilde{\Theta}_{0,0} = \frac{2\Delta a\sin(k\Delta d)}{kS_{ab}} \tag{3}$$

$$\tilde{\Theta}_{m,n} = \frac{2a}{m\pi}\cos\left(\frac{m\pi}{2}\right)\sin\left(\frac{n\pi d}{a}\right)\sinh(\mu_{m,n}\Delta d) \tag{4}$$

where k is wave number, c is sound velocity, other symbols are defined in [1]. The first term in bracket of Eq. (1) represents the sound pressure of plane wave and the second one is the sound pressure of the higher-mode waves, respectively. The output sound pressure increases when its denominators are zero. Namely, at the following resonance frequency of

$$\sin(kd/2) = 0 \qquad \therefore \qquad f = \eta\frac{c}{d} \quad (\eta = 1, 2, 3....) \tag{5}$$

$$\mu_{m,n}\sinh(\mu_{m,n}d) = 0 \qquad \therefore \quad f_{m,n} = \frac{c}{2}\sqrt{\frac{m^2+n^2}{a^2} + \left(\frac{\eta}{d}\right)^2} \quad (\eta = 0, 1, 2, ...) \tag{6}$$

3. EXPERIMENTS

A block diagram of the experimental apparatus [3] is shown in Fig. 2. Two microphones were located at input and output of SVU to measure the sound pressure P_A and P_B. The dimensions of the SVU considered in this work are a=14cm, and d=56cm. The SAP had a thickness of 3.2cm. It was drilled with some holes so that the porosity, the ratio of the total holes areas to the SAP surface area, are 10%, 20%, 30%,. Structure and the shape of SAP are shown in Fig. 3. They were located at h=14cm, 38cm, 43cm, 56cm from the input of SVU, respectively.

The parameter C_w which related to Insertion-Loss is defined from the measurement as follows [3] :

$$20\log_{10}\left|C_w\right| = 20\log_{10}\left|P_A / P_B\right| - 20\log_{10}\left|Z_0 \sin\left(kL_0\right)\right| \tag{7}$$

where P_A and P_B are the sound pressures of Microphone-1 and Microphone-2, respectively. Notes that, Eq. (7) corresponds to our theoretical Eq. (1).

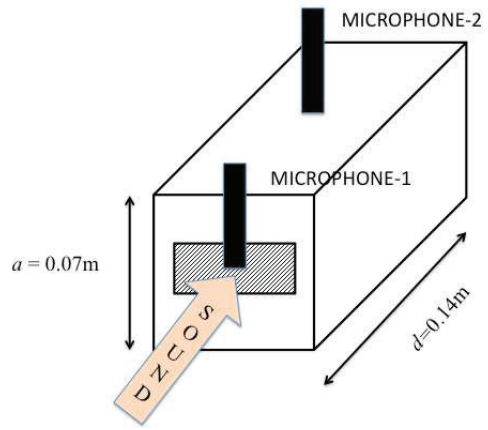

Figure 2 – Measurement apparatus

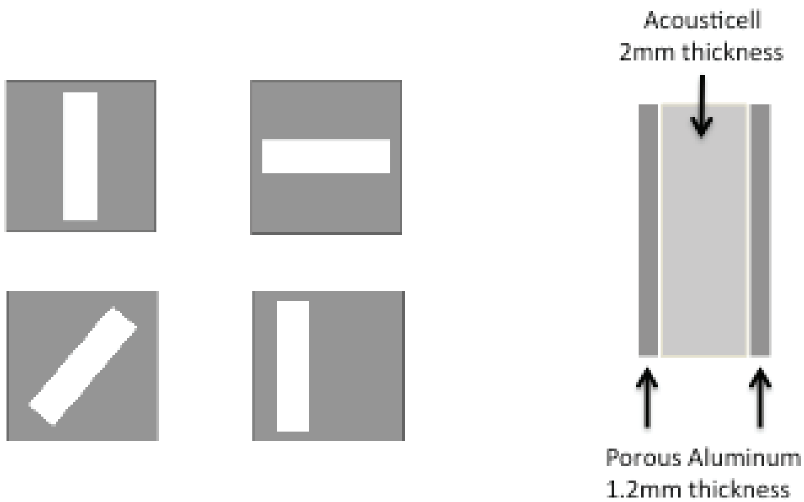

Figure 3 –The sound absorbing plate

4. RESULTS

Figure 4 shows the Cw that related to Insertion-loss of SVU when SAP is located at h=56cm. The plane wave (marked by X symbol) and the higher-order mode waves have many resonance frequencies occurred corresponding to the increasing value of η in Eq. (3) and Eq. (4). In the presence of SAP, the fundamental resonance frequency is found to be shifted to the lower frequency range and the value of Cw is higher in comparison with those of SVU. More soundproof effect is obtained when increase the SAP thickness as shown in Fig. 5. Figure 6 and Fig. 7 show the case when SAP is located at the position before and after the output. It can be seen that those fundamental resonance frequency is similar and the level of Cw is considered that there is no significant difference. Notes that, the SAP used in our experiment has a shape as shown in the upper, left side of Fig. 3.

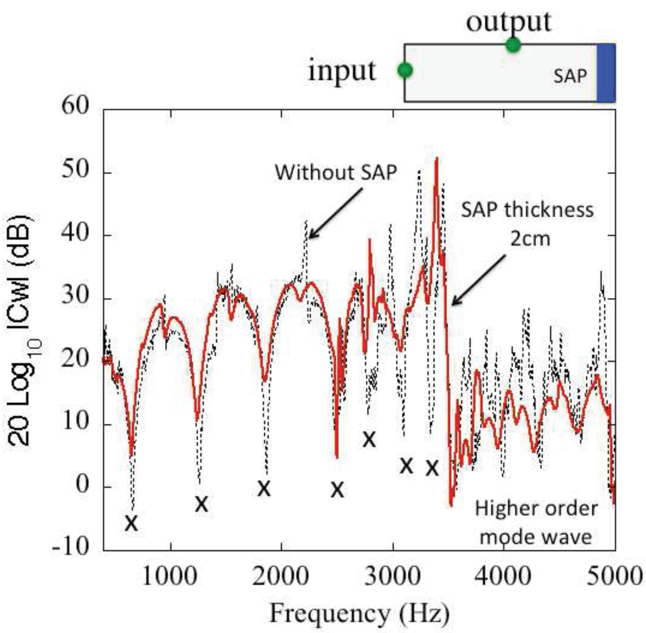

Figure 4 –When SAP is located at one end of SVU

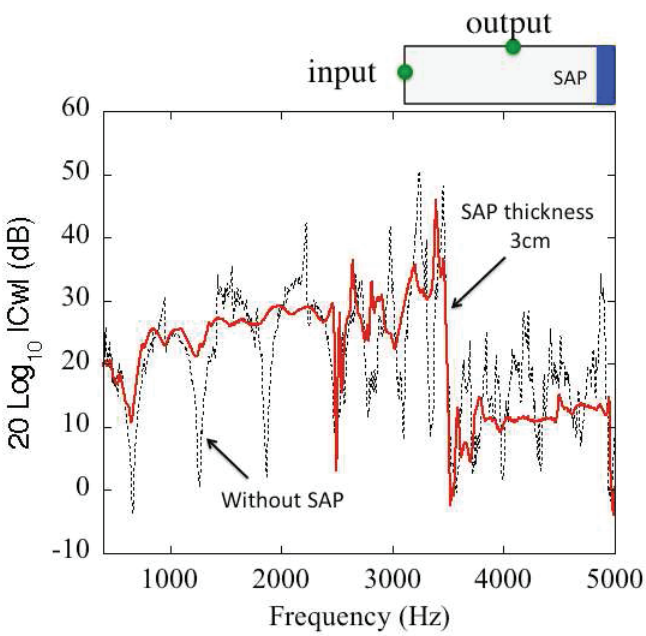

Figure 5 –When changing a SAP thickness

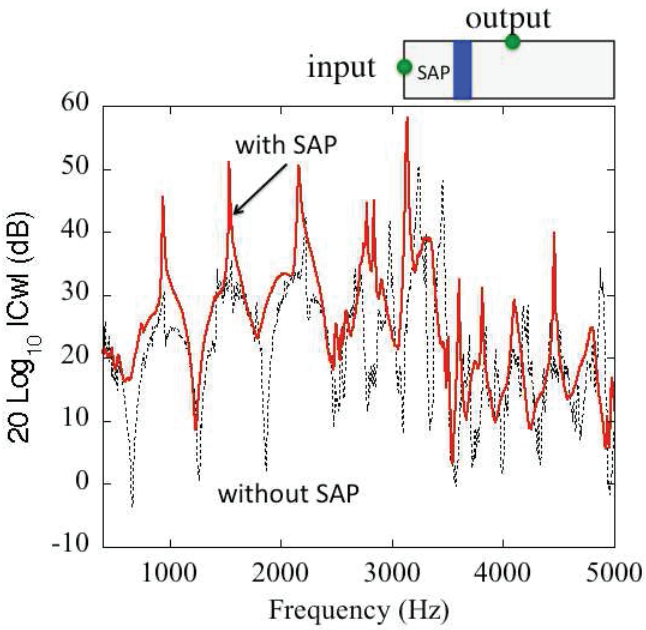

Figure 6 –When SAP is located before the output

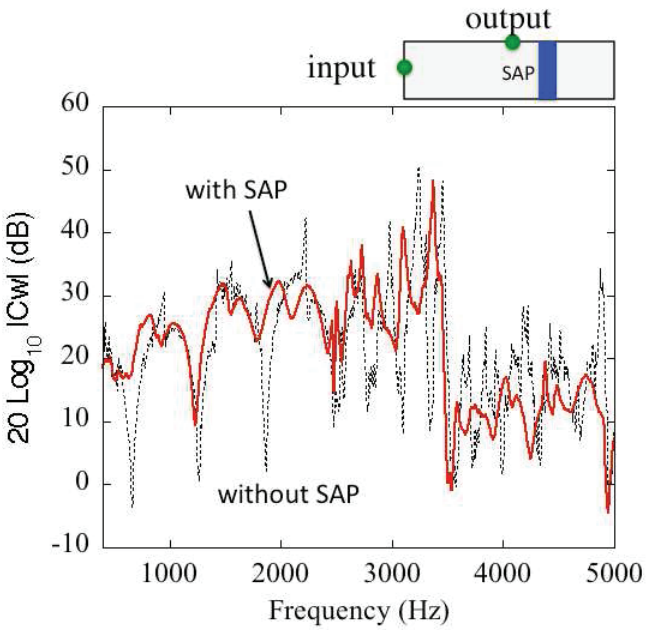

Figure 7 –When SAP is located after the output

5. CONCLUSIONS

The characteristics of sound propagation in square soundproofing ventilation unit having an inlet and an outlet which is located on the crossed right angle face have been analysed. The sound propagating is a combination of a plane wave and the higher order mode wave. To maximize the soundproof capability it is necessary to reduce sound pressure levels of a plane wave and the higher order mode wave. In present work, the introduction of sound absorbing plate inside the SVU is considered. A series of experimental were performed to verify the actual sound characteristics of SVU in case of with and without a sound absorbing plate. Based on the obtained results, the theoretical calculation will be performed and present in the next paper.

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