Perforated Flexible Membrane Insertion Influence on The Sound Absorption Performance of Cavity Backed Micro Perforated Panel

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Abstract

Sound absorption performance of cavity backed perforated panel on respect to the influence of flexible perforated membrane insertion was investigated by using a laboratory experiment. A layer of perforated flexible membrane was fitted inside the cavity backed MPP and the sound absorption coefficient was measured using transfer function based impedance tube technique. Since the inserted perforated membrane oscillated while the sound waves propagated through its perforations, it increased values of oscillating masses inside orifices which was then increased energy loss due to viscous damping associated to the span of amplitudes of the membrane resonance modes. The insertion gave possibility to get a cavity backed MPP design with the higher sound absorption coefficient in a wider low and mid frequency range compared to its of surface modification technique by means variation of the MPP porosity.

Keywords: flexible perforated membrane, cavity backed MPP, sound absorption

1. Introduction

Micro Perforated panel (MPP) have been used and developed for long time, especially for dealing with severe circumstance to reduce noise without porous or fibrous materials. The analytical based analysis about this kind of sound absorber was initially contributed by Maa and followed by many other researchers such as Jung et al, Atalla et al and Jaouen and Becot.[1-6] The other work was conducted by Sakagami et al investigates the acoustical effect of thickness, the use of elastic support, and attaching honeycomb structure to MPP since those three treatments are important in practical room applications.[7] Similar work also conducted by Hannink by using the concept of tube resonators.[8] Even though combination of honeycomb structure and air layer between MPP and the back wall are electrically equivalent to additional impedance in the lumped model, but they find that this treatment does not affect normal absorption.

The use of perforated surface is also found in Wu et al where they report that the diffuser has enhanced absorption when it uses perforated plate in some wells. A perforated plate not only extends the absorption to lower band but also maintaining good performance at mid frequency range. This behavior hence the diffuser become considerably better wide absorber.[9] In this case the diffuser wells work in a same manner with the cavity backed MPP.

Two successive similar investigation by Wang et al and Wang and Huang gives another better understanding on the properties of cavity backed MPP. Based on experimental proves Wang et al found that the shape of the back cavity can significantly alter absorption mechanism and changes the overall performance of the cavity backed MPP. Wang and

Huang then continue this work with the use of parallel arrangement or array of three cavities with different depth covered by a MPP. This research shows that the array requires lower acoustics resistance for the good absorption performance and its frequency response shifted due to inter resonator interaction.[10,11] Another work provided by Miasa and Okuma with multileaf microperforated panel both theoretical and experimental study. They found that arrangement of multi layer microperforated panel with different porosity can increase absorption in low and medium frequency range.[12]

Those mentioned prior works above entirely cover issue for MPP performance enhancement through two different strategies. The first is a surface treatment by means of changes on porosity and resistivity and the second one is cavity variations. No other method has been published yet proposing a different approach.

The following analysis in this paper dealing with the utilization of perforated flexible membrane insertion for increasing sound absorption performance of the traditional cavity backed MPP through a laboratory experiment investigation.

2. Flexible Perforated Membrane Insertion

Maa was proposed formula for calculating the absorption coefficient and relative impedance r+jωm of the MPP absorber at normal incident respectively given by 3,

$$\alpha = \frac{4r}{(1+r)^2 + \left[\omega m - \cot\left(\frac{\omega D}{c}\right)\right]^2} \tag{1}$$

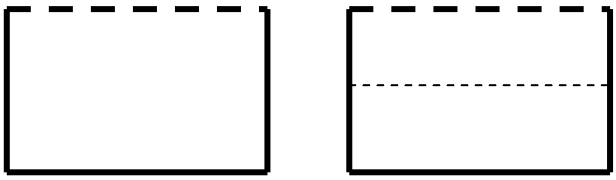
and

$$r = \frac{32\eta}{\sigma\rho c}\frac{1}{a^2}\left[\left(1+\frac{k^2}{32}\right)^{1/2} + \frac{\sqrt{2}}{32}\frac{ka}{t}\right] \tag{2}$$

where relative impedance is ratio of specific acoustic impedance per unit area divided by the characteristic impedance ρc in air. ρ being density and c is the velocity of sound in the air while t, a, σ and D are the panel thickness, orifice diameter, panel porosity and the cavity depth respectively. $k=10d\sqrt{f}$. η is coefficient of viscosity in air and f is frequency.

When dealing with such cavity backed MPP one can understand that sound absorption mechanism is due to cavity depth which is associated with its reactance to contribute for absorbing low frequency noise and perforation ratio for viscous damping in the high frequency band.

The idea of flexible perforated membrane insertion as depicted in Fig. 1. By using flexible membrane fitted inside the cavity, it would oscillate according disturbance caused by incident sound waves passing through the front MPP. To be assumed that the oscillating perforated membrane increase values of ascillating masses in the orifice and increase sound absorption in the high frequency range accordingly. In addition, according to its elasticity, fitting flexible perforated membrane inside the cavity can control the reactance of cavity to get the better sound absorption in the low and mid frequency range.



(a) (b)

Fig. 1. A classic cavity backed MPP (a) and its proposed modification with perforated flexible membrane insertion (b).

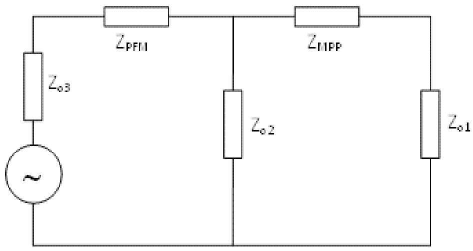


Fig. 2. Electro-acoustic analogy of the proposed cavity backed MPP with insertion

From this assumption and configuration one can drive similar but more simple electro acoustic model after Miasa and Okuma for the proposing cavity backed MPP as depicted in Figure (2). Zo1 being the impedance of open air in the front of MPP which is equal to the impedance of air inside the cavity in the front and the rear of the perforated flexible membrane that is

Z_o1=ρ_o c. ZMPP and ZPFM are impedance of the MPP and perforated flexible membrane respectively. Both consists of its real and imaginary part. Incident plane sound wave to be assumed propagates normally upon both MPP and flexible membrane.

3. Devices and Experimental Procedures

The experimental set up is based on ASTM E1050-98 as schematized and is shown in Fig. 3, which is a standard method for measuring sound absorption and reflection coefficient based on transfer function analysis. The experiment has been conducted by using Bruel&Kjaer (B&K) impedance tube 4206 connected to B&K Pulse Analyzer. The large tube with 100 mm diameter was utilized since the analysis to be focused in low and mid frequency range up to 1.6 kHz. The whole data acquisition and processing are controlled by computer with a dedicated B&K material testing software.

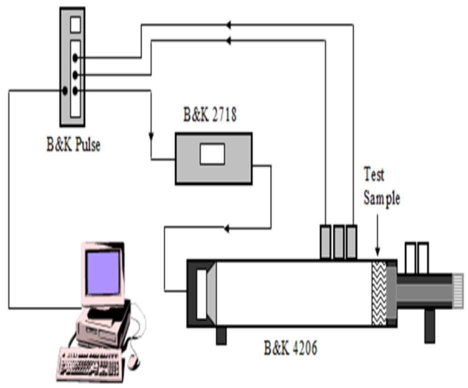


Fig. 3. Schematic set-up of the experiment. The device consists of Bruel&Kjaer Pulse, power amplifier, impedance tube, test sample and a pair of microphones. The entire process controlled by computer equipped with dedicated Bruel&Kjaer software for material testing.

The B&K impedance tube is equipped with an internal fixed loudspeaker at the one end and two microphones in a certain fixed position from the test sample surface which is placed in the opposite position to the loudspeaker. As the internal function generator of B&K Pulse being activated, random noise generated from the loudspeaker and propagates inside the tube as a plane waves. Since the far end of the tube are closed tightly there are no portion of incident waves were transmitted and the transfer function calculated based on the captured signal from the two microphones. The microphones capturing both upstream and downstream signals to be decomposed for separating incident and reflected waves component. Such procedures are included in the B&K dedicated material testing software.

According Fig. 3 the transfer function between two microphones are given by following equation,[13]

$$H_{12} = \frac{P_2}{P_1} = \frac{e^{jkh} + Re^{-jkh}}{e^{jk(h+s)} + e^{-jk(h+s)}} \quad (4)$$

P1 and P2 are sound pressure level captured by microphone number one and number two respectively while h and s are the distance of microphones from sample surface. Measured reflection coefficient (R) and absorption coefficient (α) are given by,

$$R = \frac{H_{12} - e^{jks}}{e^{jks} - H_{12}} e^{j2k(h+s)} \quad (5)$$

and

$$\alpha = 1 - |R|^2 \quad (6)$$

According Figure (2) the sound absorption assumed accumulatively caused by two different mechanism. That is resonance and viscous damping. Prosity of the MPP and flexible membrane contribute for absorption in high frequency range while the cavity and elasticity of the flexible membrane canges the reactance which is brings better sound absorption in the low and mid frequency range. When the membrance oscillate and resonance, energy loss occur due to viscous damping of the oscillating masses of the membrane orifices. So the transmission loss of the flexible membrane must take into account on the calculation of sound absorption coefficient. According this the sound absorption coefficient of cavity backed MPP with flexible membrane insertion, α_T, is given by,

$$\alpha_T = \alpha_1 - TL_{PFM} = 1 - |R|^2 \quad (7)$$

where α_1 and TLPFM are sound absorption cavity backed MPP without insertion and the transmission loss of perforated flexible membrane respectively.

4. Results and Discussion

For comparison purposes, Figure (4) shows sound absorption coefficient of cavity backed perforated panel while Figure (5) shows the performance of proposing approach. The traditional cavity backed MPP has the best sound absorption performance of 0.2 for frequency below 400 hz.

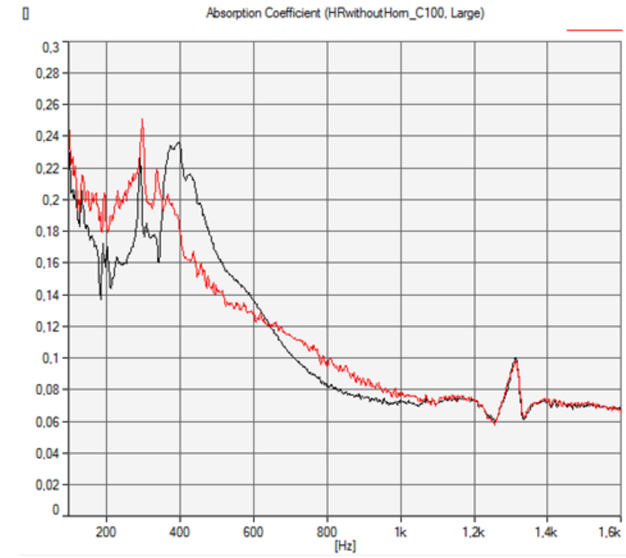


Fig. 4. Sound absorption of two similar cavity backed perforated panel.

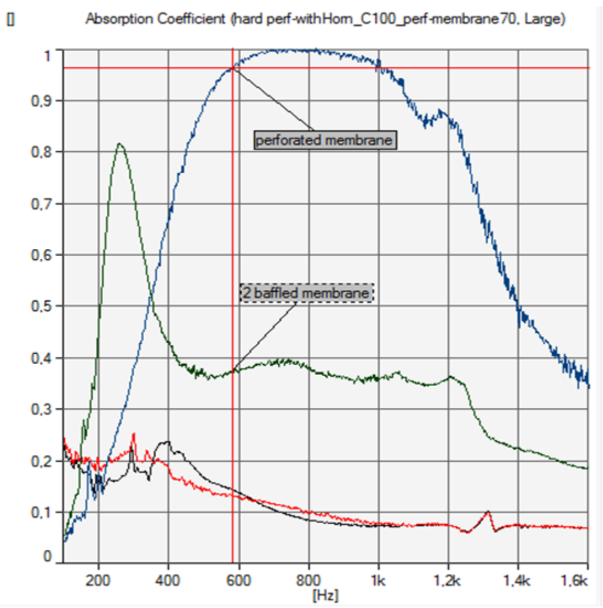


Fig. 5. Sound absorption improvement of proposed structure

An improvement achieved when a baffled double layered membrane attached inside the cavity. A moderate and high sound absorption coeffecient occured at mid and low frequency range respctively. This sound absorption increament due to the change of cavity reactance. The new structure has three independent segment splitted by the two membrane layer that worked like additional spring that oscillate at almost similar low frequency as occured at cavity without insertion.

The different sound absorption response happened when the perforated flexible membrane attached. The losses at high frequency range is icreased significantly due to membrane resonance modes. It elongated the air mass oscillating region of the oscillating masses in the orifices of inserted flexible membrane.

It giving another advantage the membrane response is similar a coupled cavity backed MPP that change cavity reactance in a unique way. In this case the resonance frequency not shipted to lower frequency band significantly as happened with the baffled membrane. The flexibility and perforation of perforated membrane giving a wide commulative resonance frequency span to form a wider sound absorption range that would not accured when using a hard or thick insertion layer.

It is clear here that proposing structure has two major advantages compare to existing traditional single cavity backed MPP. First, as explained above the membrane oscillation modes move the orifices to give a more effective viscous damping mechanism and increase loss at high frequency range. This also provides solution for the problem that not yet solve by Hannink since it is proven that proposing structure affect normal absorption signifcantly which is could not be done by using existing combination of honeycomb structure and air layer between the MPP and its back wall.

Secondly, it is very common in quadratic residue diffuser (QRD) optimization purposes to do surface modification by using MPP and extended well depth to controll the low frequency noise[14]. This means proposed cavity backed MPP with inserted flexible membrane found a great success on improving the sound absorption in a wider frequency range. It would brings a better performance on controlling the low to mid frequency noise without any significant influence on the QRD scattering pattern.

5. Conclusion

The proposing felixible perforated membrane isertion gives major advantages compared to previous surface modification techniques such as cavity backed MPP and is extended well depth as implemented by many previous researchers. It is more effective for controlling a wide frequency band compared to the existing single cavity backed MPP. The proposed structure also has a unique feature for applied in improvement QRD performance.

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