On the role of hanging baffle performance enhancement by using slotted Helmholtz resonator array

R. Hanina, I. Yahya*, Harjana
The Iwany Acoustics Research Group (iARG), Physics Department,
Universitas Sebelas Maret, Jl. Ir. Sutami 36A Kentingan, Surakarta

*E-mail:iyahya@mipa.uns.ac.id

Abstract. This paper emphasizes on the experimental investigation performance of hanging baffle with slotted Helmholtz resonator array inclusion. Laboratory test procedure refers to ATMS E-1050 was conducted for measuring the sound absorption coefficient of the Helmholtz resonator, while interrupted noise reverberation time measurement refers to ISO 3382-2 has been done for room acoustic performance test of the proposed design hanging baffle. The result shows that broadband absorption occurs when the Helmholtz resonator inserted to the hanging baffle. Sound energy dissipation increase both in resonance and viscous damping mechanism. It reduces the reverberation time significantly in all frequencies. The proposed design slotted resonator inclusion has brought opportunity for tuning the response and performance of the hanging baffle.

1. Introduction
The needs for high quality and acoustically comfortable in a room are increasing rapidly time to time. It leads to the quest for new approach and innovation to give a better listening and speech experience. One of the most common measures to describe of room acoustics performance is reverberation time [1,2]. Various techniques have been implemented by researchers to get a better room acoustic performance such as variations of wall absorption [3,4], different type resonators [5] and baffles [6,7]. This paper emphasizes on the experimental examination of the performance of hanging baffles with an inclusion of an array of Helmholtz resonators in particular sound diffuser like configuration. The proposing approach has two significant advantages, first for controlling the low frequency modes of the room by using Helmholtz resonators, and the second to stimulate scattering effect caused by its sound diffuser like configuration. These two different noise control mechanism to be expected occurs accumulatively for increasing the energy decay rate inside the room and resulting significant correction to reverberation time. The other advantages of proposed hanging baffle are it could be configured freely to get optimum multiple reflections and also two-sided surface absorption effect which cannot conduct by using wall mounted sound absorber and or diffuser.

2. Methods
The diagram of proposed baffle depicted in Figure 1. It made from commercial sponge with dimension (l x w x h) are 100cm, 12cm, and 50cm respectively. Each baffle has seven unit of quarter wavelength resonator with internal diameter 8 cm to be slotted with Helmholtz resonators. Each resonator inserted in various depth from baffle surface to form sound diffuser like structure.

The sound absorption coefficient of the Helmholtz resonator was measured using impedance tube after ASTM E-1050. The experiment conducted by using B&K 4206 impedance tube and the whole data analyzed by dedicated B&K material testing software. There are two types of resonators with different
cavity length, \( h \), in three different value of \( d_2 \) was measured. The detail of parameters for the test presented in Table 1.

![Diagram](image)

**Figure 1.** (a). side view of the baffle with seven half wavelength resonators where six of it slotted with Helmholtz resonator fitted inside it. (b). the bottom view, (c). Details of the resonator. \( HR \) and \( BC \) is the Helmholtz resonator and back cavity respectively, \( h \) is the HR length, \( d_1 \) is sound diffuser like well depth while \( d_2 \) is slit like cavity depth.

**Table 1.** Parameters for impedance tube test

| No | \( h \) (cm) | \( d_1 \) (cm) | \( d_2 \) (cm) |
|----|-------------|----------------|---------------|
|    | (i)        | (ii)           | (iii)         |
| 1  | 8          | 0              | Fixed: 4      |
| 2  | 16         | 0              | 4             |
|    |            | 8              | 12            |

A room performance test conducted following the Helmholtz resonator laboratory test. To this purpose, there is six unit of hanging baffle installed inside the room. Reverberation time measurement refers to ISO 3382-2 test procedure was conducted by using B&K Omni-power 4292 for generating the interrupted noise and B&K 2270 handheld analyzer for measuring and analysis the data in one-third octave band. The whole experiment conducted in a fixed value of \( d_2 \) for 8 cm and various \( d_1 \) ranging from 5 cm to 15 cm with 5 cm increment from the edge to center well of the baffle. The center well has no inclusion to keep it work as a quarter wavelength resonator.

3. Results and discussions

The sound absorption coefficient of the two Helmholtz resonator with \( h \) value of 8 cm and 16 cm presented in Figure 2. Helmholtz resonator with a longer tube is increasing performance in the low frequency from 150 Hz to 300 Hz. The similar increment also occurred at the frequency range above of 1.4 kHz. These increments are related to the coupling effect of the slotted Helmholtz resonator (HR) with the back cavity (BC) to form a two degree of freedom Helmholtz resonator. When the volume of the first cavity increased, it changes the reactance of the resonator and shifting the resonator performance to the lower frequency band. As a result, an increment at higher frequency band above 1.4 kHz occurred accordingly.

Interesting phenomena occurred with the test for different \( d_2 \) values as presented in Figure 3. As the value of \( d_2 \) increased, the sound absorption coefficient for frequency range above 800 Hz increased as well. Contrary it reduces the sound absorption for frequency below 800 Hz. The thin tubular shaped empty well area between the slotted cavity and the wall of the quarter wavelength resonator increase sound wave energy dissipation in two different way. First, quarter wavelength resonance effect of the resonator with the depth of \( d_2 \). Secondly, this thin area also increases viscous damping according to the
porous wall of quarter wavelength resonator. Both improves sound absorption performance at high frequency range. In the same time as the $d_2$ increased, it slightly reduces the volume of the back cavity of the coupled Helmholtz resonator which takes into account to the changes sound absorption performance in the range between the first and second resonant frequency of the coupled Helmholtz resonator. It gives a possibility for tuning the performance of the proposed slotted resonator design. The combination of coupled or slotted Helmholtz resonators with various $d_2$ would give an excellent opportunity to get broadband absorption performance in the real room acoustic applications.

![Graph](image1.png)

**Figure 2.** The influence of tube length on the sound absorption coefficient of the slotted Helmholtz resonator.

![Graph](image2.png)

**Figure 3.** The influence of $d_2$ depth on the performance of the slotted Helmholtz resonator.

The results of reverberation time measurement presented in Figure 4 and Figure 5 which is the performance of the baffle without and with slotted Helmholtz resonator respectively. As shown in Figure 4, the $T_{20}$ and $T_{30}$ for the whole frequencies are reduced significantly after treatment with the proposed baffle even though without slotted Helmholtz resonator inclusion. The discrepancies values between before and after treatment occurred as the array of seven quarter wavelength resonator on each baffle increase sound waves energy dissipation both in resonance and viscous damping mechanism. For example, $T_{20}$ decreased to 1.74 seconds from 2.72 seconds before treatment, while $T_{30}$ become 1.94 second which is much lower compared to 3.09 second before treatment both for frequency 100 Hz.
Figure 4. The performance of the proposed baffle without slotted Helmholtz resonator.

Figure 5. Reverberation time performance of the baffle with slotted Helmholtz resonator inclusion.
When the proposed slotted Helmholtz resonator fitted into the hanging baffle, its performance increased as presented in Figure 5. Both $T_{20}$ and $T_{30}$ values decreased for all frequencies. $T_{20}$ dropped to 1.72 seconds while $T_{30}$ reduced to 1.25 second for 100 Hz. As mentioned above that when the Helmholtz resonator fitted into the baffle, the coupled structure gives a better, and wider sound absorption performance especially in the low frequency band since both of its resonant frequencies are less than the quarter wavelength resonator. Also, the sound diffuser like the configuration of the slotted Helmholtz resonator also plays an important role to produce the scattering effect for controlling the low-frequency noise.

It concludes that inclusion of slotted Helmholtz resonator into hanging baffle giving a significant improvement to the acoustic quality of a room. Also, the proposed design also has brought opportunity for tuning the hanging baffle response with varying front quarter wavelength resonator depth.

4. References

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