Acoustic performance of sonic crystal made from a half of PVC pipe

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Abstract. As an alternative ingredient that is safe for health, the sonic crystal (SC) is expected to provide acoustic performance like other acoustic materials. Generally, SC is designed with certain forms and formations. This paper discusses the performance of SC made from a half the PVC pipe with diameter of pipe is 3.8 cm, 5.1 cm and 6.8 cm, with the direct angle of sound 90°. The parameters that measurement is the resonance frequency. Based on the measurement result, the resonance frequency value is 40 Hz, for a diameter 3.8 cm then 63 Hz for diameter 5.1 cm and 6.8 cm. Beside as a resonator, the sonic crystal was design able to absorb the sound.

1. Introduction
The development of technology and materials, also impact on the development of quality of life and community needs. The demands of acoustic material that can provide an acoustic level of comfort and no harm to health become one of the things that are currently developing. The One of acoustic material that capable of providing the ability to control the sound frequency through sound resonance. One piece of acoustic material capable of reducing sound but safe is sonic crystal. The picture 1 shows an illustration of the base of a Helmholtz resonator.

![Figure 1. Basic of the Helmholtz resonator](image)

Based on figure 1, the value of resonant frequency is determined by the radius of the hole (A), the length of the hole’s neck (l) and the volume (V) of a resonator. The resonant frequency value can be calculated through the resonator Helmholtz equation (1),

$$f_0 = \frac{c}{2\pi \sqrt{\frac{A}{lV}}}$$

Where $f_0$ is a fundamentals frequency, $c$ is velocity of sound, $A$ is surface of opening area, $l$ is the neck length and $V$ is volume of cavity.
In its development, the resonator can be formed from several Helmholtz resonators arranged with a certain formation that's called sonic crystal. Figure 2 shows the arrangement pattern of the sonic crystal.

![Figure 2. Model of sonic crystal (a). Model of sonic crystal, (b), cross section of Sonic crystals]

Based on figure 2, the fundamental frequency calculation of sonic crystal can also be calculated by using the equation (2)

$$f_n = \frac{c}{2\pi} \frac{R_h}{R_i^n \sqrt{\delta l}}$$  \hspace{1cm} (2)

where $c$ is the velocity of sound in air, $R_h$ is the radius of the hole, $R_i^n$ is the internal radius of a resonator, and $L$ is the length of the resonator. Whereas $\delta l = l + 0,48 \sqrt{\frac{\pi R_h^2}{\delta l}}$ where $l$ is the length of the pipe [1].

This paper discusses the resonance capability of the SC design made of ½ PVC pipe with 3 variations of pipe radius. The variation of pipe radius is 1.5", 2" and 2.5 ". The purpose is to know the effect of resonator size on resonator performance (resonance frequency).

In part II is explained about the process of measuring the resonant frequency. Section III describes the results of calculations and analysis of the results of measurement values. Finally in section IV contains the conclusions of the study.

2. Experimental Methods

In this paper, the tested sonic crystal is made from the half of the pipe with variations diameters are 3.8 cm, 5.1 cm and 6.8 cm. Figure 3 shown the sonic crystal that design ot this research.

![Figure 3. The sonic crystal are made]

Measurements of resonance frequency using comparison the SPL values when the space conditions are empty and when the resonator material is placed. Measurements were performed in the semi-anechoic room Department of Physics ITS. Figure 4 shows the measurement scheme [1].
Figure 4. Schema for measurement of respon frequency sonic crystal

Based on figure 4, the sound produced by the speakers will be received by the microphone. The signal that received by the microphone is then analysed using the sound analyser YMEC v5.1 to obtain the SPL parameters before and after the sonic crystal at the room.

3. Results and discussion

3.1. Results
As a mention at part 1, the capability of acoustics material sonic crystal to control the sound can be obtained through the design and form of Sonic Crystal. Base on equation 2, the resonance frequency of sonic crystal can also be predicted. Table 1 shows the specs of the designed sonic crystal.

| L (m) | Ri (m) | l (m) | Rh (m) | frequency (Hz) |
|-------|--------|-------|--------|----------------|
| 0.6   | 0.038  | 0.002 | 0.0015 | 62             |
| 0.6   | 0.051  | 0.002 | 0.0015 | 46             |
| 0.6   | 0.064  | 0.002 | 0.0015 | 37             |

Based on table 1, the resonant frequency value is strongly influenced by the Ri value. This means that the resonant frequency value depends on the volume of the cavity (equation 1). To determine the ability of sound resonance, the sonic crystal that designed be measured to get the response to the sound. Based on the measurements, the response of the designed sonic crystal looks like in Fig. 5.

Figure 5. Frequency Response of Sonic Crystal
Based on Lagarrigue [1], 2013, the value of resonant frequency can be shown by changing the amplitude value when the room is empty and contains the resonator. Based on the fig. 5, the resonance frequency is 40 Hz for the 3.8 cm diameter sonic crystal, then 63 Hz for the 5.1 cm and 6.4 cm diameters.

3.2. Discussion
The ability to control the sound on sonic crystal will be dependent on the size of the hole on each resonator as shown by Table 1. In addition, the arrangement of pattern sonic crystals will also affect the controlled frequency range. Based on fig. 5, the crystal sonic resonance frequency value is indicated by the difference of the sound response pattern between the spaces being empty and when there is a resonator. In general, base on fig 5, the designed crystal sonic has a tendency to absorb sound almost in all frequency. This is shown by the trend response of sonic crystals that are made to reduce sound almost in all frequencies, especially at high frequencies. From fig. 5 also shows that the performance of sonic crystal at high frequencies will be reflected the sound so that the intensity of the sound received by the microphone becomes smaller. Based on fig. 5 also seen that the smaller the diameter of pipe, then the ability to reduce the sound becomes larger. While reduction at high frequencies is multiples of the frequency of resonance. For example band gap for diameter pipe of 1.5" is 5000 Hz. for diameter pipe is 2.0 " at 3100 Hz, and for 2.5" at 2500 Hz.

4. Conclusions
In theory, the resonant frequency value will be higher if the resonator has a smaller of open area. Base on measurement, the performance of sonic crystals was made can be the resonance of the sound at frequency 40 Hz for diameter 3.8 cm and 63 Hz for diameters of 5.1 cm and 6.8 cm. In addition to being a resonator, the crystal sonic made can be a good sound absorber.

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6. References
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