Cavity Sound Pressure Enhancement of the Second Generation Power Generating Helmholtz Resonator with X-shaped Cavity Junction

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Abstract

Cavity sound pressure level is a very important measure when dealing with the design of resonator based power generating sound absorbers and sound diffusers. This paper presents results from experimental study of the performance of the second generation iARG-X2 power generating Helmholtz resonator. The use of specific X-shaped extention for the cavity junction could encrease the sound pressure inside the cavity up to 16 dB above of the similar resonator without extention. The experiment was conducted with various types sound source, i.e. single tone, dual sine, and random noise that all resulting similar cavity sound pressure increment pattern. It brings new possibility for the development of power generating sound absorber and sound diffuser which is very usefull in green modern life style both for indoor and outdoor noise control applications.

Keywords: cavity sound pressure, x-shaped junction, Helmholtz resonator

1. Introduction

Currently advances on smart and functional material innovations meet the needs for possibility to create sound and vibration driven power generator in smaller and compact size. Since then sound and vibration based energy harvesting system now facing very promising development not only because of the healthy and green leaving reason but due to its business prospectives either.

Some successive development achieved on nanogenator and piezoelectronic nano wire research has introduce the idea of nanopiezotronic for harvesting energy by using nano scale piezoelectric materials.[1-6] It gives new possibility for improving performance of some acoustics resonator based energy harvesting system.[7]

Sound and vibration based energy harvesting system has been widely investigated and developed by many researchers in various way. The use of piezoelectric and its combination with electromagnetic transducer was the most common to convert vibration energy into electricity.[8-11] In other side, the sound driven energy harvesting are very rare and limited yet.

To do the sound driven energy harvesting by using acoustic resonator, researchers utilized the sound wave pressure fluctuation inside the cavity to deflect piezoelectric layer.[12-15] So to increase sound pressure level inside resonator cavity indeed one of very challenging work in the development of sound driven energy harvesting technology.

This paper presenting result from laboratory investigation on the use of x-shaped cavity junction for increasing the pressure of the sound wave inside Helmholtz resonator cavity.

2. The X-shaped Cavity Junction Resonator

Enhancement of acoustic energy harvesting has been done i.e. by Carrara et by using elliptical acoustic mirror configuration. Acoustic harvester was formed along a semi elliptical path on the surface of a plate.[16] Different technique was implemented in power generating sound absorber design by placing specific shaped extended neck on certain posisition inside of resonator cavity.[17]

The x-shaped cavity junction reported in this paper was developed for improving the previous design in Ref (17). It consist of two horn-shaped necks attached to the coupled cavities as depicted in Figure (1).

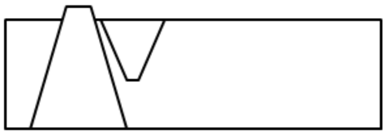

Fig. 1. Basic design of the x-shaped cavity which is work as inter-cavity junction between cavities of Helmholtz resonator.

The two horn-shaped extended neck was placed in opposite direction each other to form x-shaped configuration inside the inter-cavity junction.

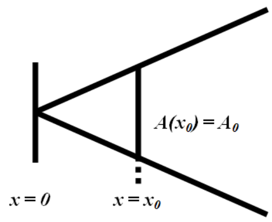

Fig. 2. Mathematical model of the extended neck.

A mathematical model after Kulik[18] was used for derive equation for the wave propagation along the junction as depicted in Figure (2). The upstream and downstream component of the sound wave is given by,

$$g(x) = p(x)\, x = g_{\rightarrow} e^{-ikx} + g_{\leftarrow} e^{+ikx} \qquad (1)$$

According Figure (2), for junction diameter $x \gg \lambda/_{2\pi}$ the impedance is

$$Z(x) = \frac{p_{\rightarrow(x)}}{v_{\rightarrow(x)}} = \rho c[(j2\pi x/\lambda)/((j2\pi x/\lambda) + 1)] \qquad (2)$$

3. Method

The laboratory investigation was conducted by using two similar horn shaped junction with the mouth tip and horn diameter 0.5 cm and 4.5 cm respectively.

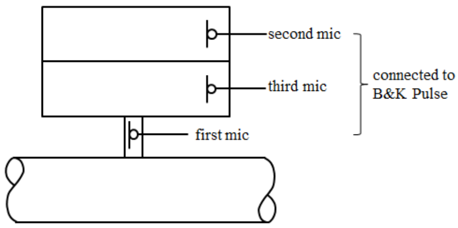

Fig. 3. Experiment configuration using three microphones. The tested Helmholtz resonator attached as a side branch of B&K 4206 impedance tube.

Tested Helmholtz resonator was attached as side branch of B&K 4206 impedance tube. All experiments controlled by using B&K LAN-XI Data Acquisition System in three different sound waves types single tone, dual sine and random noise. Three pieces B&K 4189 quarter inch microphones used for capturing the each type of sound waves in three different point as ilustrated in Figure (3).

First microphone attached to the Helmholtz resonator neck, while the second and third microphone placed in the second cavity and the inter-cavity junction respectively. All microphones connected to the FFT modul of the B&K Pulse. The all captured signals then to be analyzed using FFT analyzer to get its FFT spectrum.

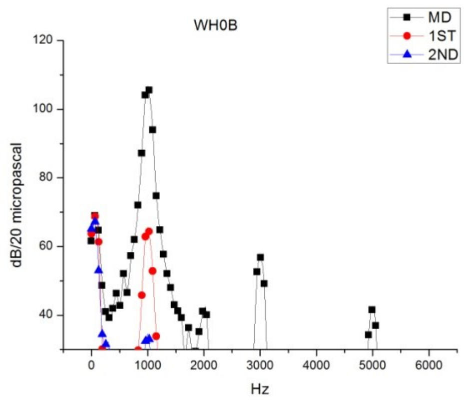

Fig. 4. Measured sound pressure level on the experimen without x-shaped cavity junction.

4. Result and Discussion

FFT spectrum resulted from experiment on two cavity Helmholtz resonator without and with x-shaped cavity junction depicted in Figure (4) and Figure (5) respictevely. Sound pressure from the main duct in the resonator neck is 105 dB/20μPa, while measured sound pressure level by the second and third microphone are 64dB/20μPa and 33dB/20μPa.

A very significant amplification occured on third microphone when the x-shaped cavity junction attached as shown in Figure (5). Measured sound prsessure level by second and third microphones are 62,6dB/20μPa and 49,7dB/20μPa.

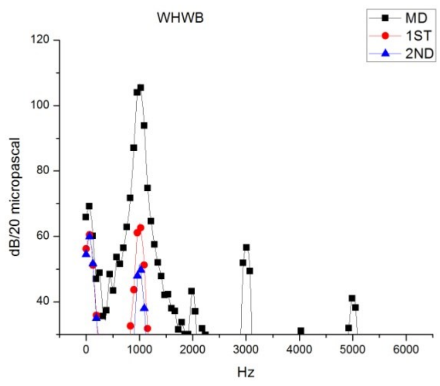

Fig. 5. Measured sound pressure level when the x-shaped cavity junction attached.

Figure (5) shows increament of 16,6 dB/20μPa on the third microphone when the proposed x-shaped cavity junction attached inside the Helmholtz resonator. Increament of 16,6 dB is much higher compared to the 3 dB increament reached on the previous work as reported in Ref (17). Similar sound pressure increament phenomena also occur on the experiment using dual sine sound wave 4kHz and 6 kHz as shown in Figure (6).

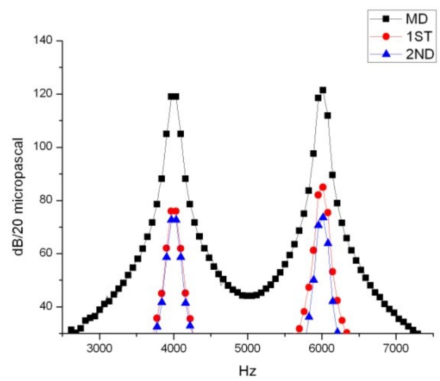

Fig. 6. Result from experiment using dual sine 4 kHz and 6 kHz sound source.

The inner cavity sound pressure level increament as the x-shaped cavity junction attached to the helmholtz resonator is related to the change of junction impedance. As the junction diameter decrease, the particle velocity decreased but the sound pressure increased exponentially and reach its maximum when flow along short straight thin tube on the reverse horn-shaped tip.

Accordingly, the small decreament of sound pressure level from 64dB/20μPa as shown on Figure (4) to 62,6dB/20μPa on Figure (5) due to quasi expansion junction on the boundary between first horn to the second horn of the x-shaped cavity junction.

When the sound wave reach the interface of second cavity of the Helmholtz resonator with the top side of the x-cavity junction, the particle velocity and sound presssure changes due to boundary condition. It caused sound pressure level decrease. As the sound wave flows through the second reverse horn the second step of sound pressure level increament occured as shown in Figure (5) and Figure (6).

It shown that proposed x-shaped cavity junction reported in this paper has significant advantages not only on increasing of the Helmholtz resonator inner cavity sound pressure level but on the possibility for focusing the sound wave to arbitrary focal point inside the cavity either.

The higher inner cavity sound pressure level is very important in sound driven energy harvesting system since the higher pressure required for driving higher stress to the piezoelectric layer to get higher electricity output.

The ability of x-shaped cavity junction on focusing the sound wave to arbitrary position brings advantage for increasing driving force to a focal point on the piezoelectric layer which is not yet reported by previous researchers. It also providing felexibility on custom designing Helmholtz resonator based sound driven energy harvesting energy.

5. Conclusion

The proposed x-shaped cavity junction reported in this paper has two significant advantages on the ability for icreasing the inner cavity sound pressure level and the possibility for focusing sound waves to arbitrary focal position inside the resonator cavity. It brings possibility for creating custom designing improved Helmholtz resonator based sound driven energy harvesting system.

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