3Pb3-1

Research on acoustic energy harvesting method based on coupled Helmholtz resonators

Lin Sun, Jie Gao, Xiaofeng Zhang‡
(College of Physics and Information Technology, Shaanxi Normal Univ. Xi 'an 710062, China)

1. Introduction

Noise is very common environmental pollution and high decibel noise have a great impact on people's lives. If the noise can be collected and converted into electric energy, it will not only effectively reduce the noise pollution to the environment, but also provide power for electrical devices, such as the street lamps， low power equipment and so on(1). Some acoustic energy harvesting devices have been presented to collect the noise into electrical power(2-4). However, most of them may produce electromagnetic pollution in this process and then cause harm to human body. In order to overcome the shortcomings of the existing acoustic energy harvesting technologies, a coupled Helmholtz resonator (HR) acoustic energy harvesting device is proposed in this paper, which can not only effectively collect the noise in the environment, but also efficiently convert the acoustic energy into electrical energy. The structure of resonant cavity is optimal to improve the energy conversion efficiency.

2. Structure of coupled Helmholtz resonator (HR)

The structure of the coupled HR with an inclined bottom is shown in **Fig.1**.

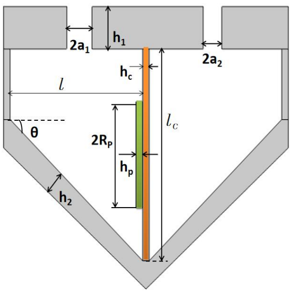

Fig. 1 Schematic diagram of a coupled HR with an inclined bottom

The sidewall between the two cavities of coupling HR is constructed by a piezoelectric composite sheet (PCS), which is made of a planar copper sheet and a piezoelectric ceramics sheet (PZT-5H). The specific parameters of HR are given as follows: the neck diameters of two cavities of coupling HR a_1=4.8mm, a_2=5.1mm. The wall thickness h_1=6mm, h_2=4mm. The thickness of the planar copper sheet h_c=0.1mm and its height is l_c. The thickness of planar piezoelectric ceramic is h_p and its radius is R_p. The width of the cavity l=35mm and the angle between the inclined bottom of the cavity and the horizontal line is θ. PCS between two adjacent cavities will produce bending deformation under the alternating action of the push-pull force caused by the opposite phase then(5). Further, the reflection of the tilted bottom to the normal incident sound wave strengthens the sound pressure on both sides of PCS. The reflection effect can obviously improve the acoustic-electric conversion efficiency of PCS.

3. Finite element simulation of coupled Helmholtz resonator (HR)

In order to verify the push-pull effect on PCS in coupled HR with tilted bottom, the working mechanism of the coupled HR is studied through the corresponding 3D numerical simulation model using the acoustic-structural interaction module in commercial software COMSOL Multiphysics. The plane wave with acoustic pressure of 1Pa is normal incident from the top of the HR, the acoustic field distribution inside the HR at 505 Hz is calculated, and the result is shown in **Fig.2**. We can find that the phases in the adjacent cavities is nearly opposite, which makes the PCS receive a push-pull force from the two adjacent cavities at the same time. So, the PCS can be excited to produce the higher output voltage than single HR.

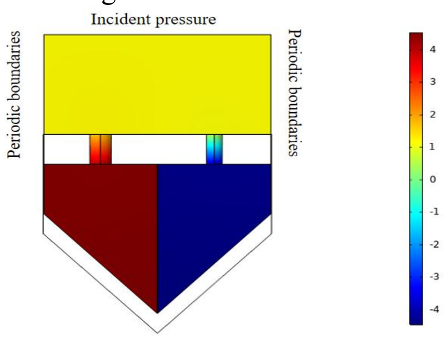

Fig. 2 The acoustic field distribution in the longitudinal section of the cycle unit at 505 Hz.

3.1 The effect of θ on output voltage

In order to further optimize the structure of coupled HR, we simulate the output voltage of the coupled HR with the bottom dip angle varying 0°~60°. The step of the inclination angle is 10° and

Email address: xiaofengzhang71@snnu.edu.cn

the incident sound pressure is 1Pa. The curves of the output voltage versus frequency are shown in **Fig.3**. It can be seen that the amplitude of output voltage has an optimal value with the increase of the bottom inclination angle. The output voltage value at θ=10° is about 2.17 times that of the case when θ=0°. The inclined bottom can obviously improve the acoustic-electric conversion efficiency of coupled HR cavities.

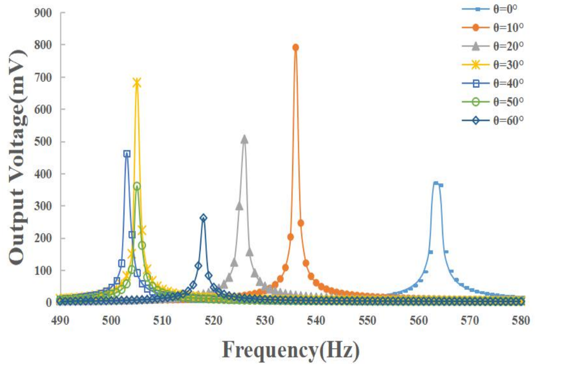

Fig. 3 Output voltage versus frequency at different inclination angle θ. with an incident SPL=94 dB of the coupled HR with h_p=0.1mm, R_p=16mm

3.2 The effect of the thickness of planar piezoelectric ceramic on output voltage

Under the same simulation conditions, we study the effect of the thickness of the PCS on output voltage. The thickness of planar piezoelectric ceramic varies from 0.1mm to 0.5mm with the step 0.1mm. The curves of the amplitude of output voltage versus frequency at different PCS thickness are shown in **Fig.4**. It can be seen that the amplitude of output voltage decreases with the increase of the thickness of planar piezoelectric ceramic. The thinner the PCS is, the higher voltage can be obtained.

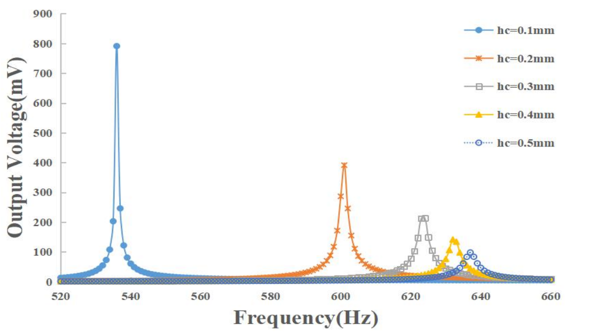

Fig. 4 Output voltage versus frequency with different thickness of piezoelectric disk hp when incident SPL=94 dB of coupled HR with θ=10°and R_p=16mm.

3.3 The effect of the radius of planar piezoelectric ceramic on output voltage

Then, we study the effect of the radius of planar piezoelectric ceramic on output voltage.The results are shown in **Fig.5**. It can be seen that the amplitude of output voltage has an optimal value with the increase of the radius of planar piezoelectric ceramic. The maximum 1.1V can be obtained when R_p=15mm. So, we can design the coupled HR with the optimal parameters to obtain the high output voltage.

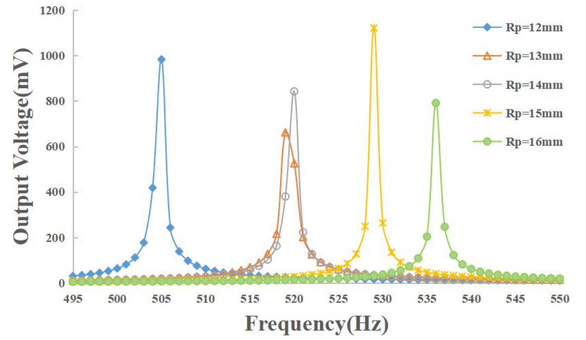

Fig. 5 Output voltage versus frequency at different radius of piezoelectric disk R_p with the incident SPL=94 dB of coupled HR with θ=10° and h_p=0.1mm.

4. Conclusions

In this study, we demonstrate the acoustic energy harvesting mechanism of a coupled Helmholtz resonator with inclined bottom. The double cavity coupling model is established using finite element method.and the effect of the parameters of the HR and PCS on output voltage are analyzed. The simulation results show that there is an optimal value for the bottom inclination angle and the radius of the piezoelectric plate. We can obtain the high output voltage by adjusting the parameters of the coupled HR cavities and the size of the PCS.

Acknowledgment

This work was supported by the National Natural Science Foundation of China (Grant Nos. 11674208 and 11874252).

References

1. Liu, Guorong, Li,et al. Recent developments of film bulk acoustic resonators[J]. Functional Materials Letters, 2016.
2. Selamet A , Lee I . Helmholtz resonator with extended neck[J]. Journal of the Acoustical Society of America, 2003, 113(4):1975.
3. Sun K H , Kim J E , Kim J , et al. Sound energy harvesting using a doubly coiled-up acoustic metamaterial cavity[J]. Smart Materials & Structures, 2017.
4. Lee HY, Choi B. A multilayer PVDF composite cantilever in the Helmholtz resonator for energy harvesting from sound pressure[J]. Smart Materials & Structures, 2013, 22(11):115025.
5. Liu G S, Peng Y Y, Liu M H, et al. Broadband Acoustic energy and metasurface with coupled Helmholtz resonators[J]. Applied Physics Letters, 2018, 113(15):153503.1-153503.5.