1Pb-42

Proceedings of Symposium on Ultrasonic Electronics, Vol. 31 (2010) pp. 225-226
6-8 December, 2010

For practical use of thermoacoustic electric generation system －The effect of installation positions of resonance tube on electric generation efficiency－

熱音響発電システムの実用化に向けた研究 －共鳴管の設置位置が発電効率に与える影響－

Yuji kitadani[1‡], Shin-ichi Sakamoto[2], Kenji Shibata[1], Kentaro Kuroda[3] and Yoshiaki Watanabe[3] ([1]Facult. Eng., Doshisha Univ., [2]Depar. Elect. Sys. Eng., Univ. of Shiga Pref., [3] Facult. Life and Medi. Sci., Doshisha Univ.)
北谷 裕次[1‡], 坂本 眞一[2], 柴田 健次[1], 黒田 健太朗[3], 渡辺 好章[3] ([1]同志社大 工, [2]滋賀県立大 工, [3]同志社大 生命医科)

1. Introduction

Thermoacoustic systems[1-3] have attracted interest as next-generation systems. Thermoacoustic systems are driven by thermoacoustic phenomena[1,2]: mutual conversion between heat energy and sound energy.

Thermoacoustic electric generation system can be designed by connecting the loudspeaker with a loop-tube-type thermoacoustic system(loop tube). This thermoacoustic electric generation system can utilize solar and waste heat energy as an energy source. While such advantages are possessed, the sound field in the loop tube becomes difficult to control because this system generates sound waves through self-induced vibration. So this report was used that the resonance tube is added on the loop tube to realize stable generation of the sound. However, the electric generation efficiency changes according to the resonance tube installation position. Therefore, experimental investigations of electric generation efficiency were conducted by changing installation positions of the resonance tube.

2. Sound field in thermoacoustic system

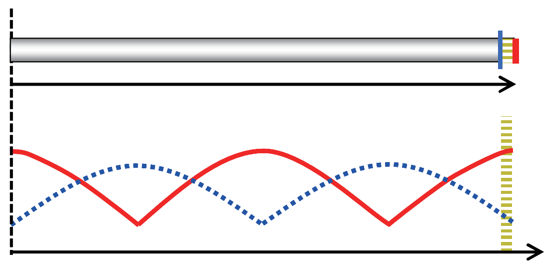

Fig. 1 Distribution of sound pressure and particle velocity in loop-tube.

Distribution of a sound pressure and a particle velocity in the loop tube are shown in Fig. 1. Figure 1 shows the one-wavelength mode resonance was generated in the loop tube. In this report, experimental investigations of electric generation efficiency were conducted by changing installation positions of the resonance tube from the node of the particle velocity to the antinode into nine positions in total.

3. Experimental system and method

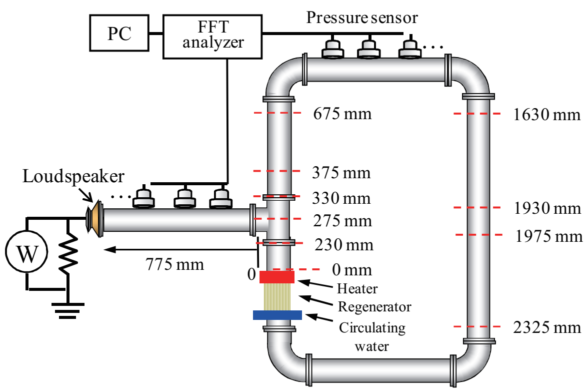

Fig. 2 Diagram of measurement system.

A block diagram of the measurement system is shown in Fig. 2. The total length of the loop tube was constructed 3300-mm-long system with stainless-steel tube of 42 mm inner diameter. We defined the position of the tops of the prime mover stack, heater as 0 mm. The tube center is the axis. Clockwise was defined as the positive direction. The installation position of the resonance tube has been changed from the heater into nine positions (230, 275, 330, 375, 675, 1630, 1930, 1975 or 2325 mm) in total. The total length of the resonance tube was constructed 775-mm-long system with stainless-steel tube of 42 mm inner diameter. The system was filled with air at 0.1 MPa pressure. The prime mover stack was a 50-mm-long honeycomb ceramic with a channel having a 0.45 mm radius. A spiral-type electrical heater inserted at the top of the stack served as the heat source. Heating power of 330 W was supplied for 400 s using a heater. Pressure sensors (PCB Inc.) were set on the system wall to measure the sound pressure in the loop tube

ssakamot@mail.doshisha.ac.jp

and the resonance tube. The intensity, the sound pressure, the particle velocity, and the phase difference between the sound pressure and the particle velocity were calculated using a two-sensor power method with pressure measurement results[4].

The full-range loudspeaker was located at the end of resonance tube. Impedance of the loudspeaker is 50 Ω when a resonant frequency of this measurement system is 100 Hz. Resistance was connected with the loudspeaker, and the electric power was measured using a wattmeter.

4. Results and discussion

Figure 3 shows the relation between insertion position of the resonance tube and electric power. In this figure, the total lengths of the loop tube are normalized. From Fig. 3, it was confirmed that the electricity generated has changed by changing the installation position of the resonance tube. It was confirmed that installation positions where the electricity generated is the largest becomes 0.084 and 0.584 from the heater. It is understood that these two insertion positions become 8.4 % from the antinode of the particle velocity. Moreover, it was confirmed that installation positions where the electricity generated is the least becomes 0.204 and 0.704 from the heater. It is understood that these two insertion positions become 20.4 % from the antinode of the particle velocity. Installation positions of the resonance tube compare the sound energy at 1930mm with 2325mm; installation positions of 8.4 % and 20.4 % from antinode of the particle velocity.

It was confirmed that the output sound energy at the prime mover was 10 W and 12.5 W. Distribution of the sound energy in the resonance tube is shown in Fig. 4. We defined the position of the connection as 0 mm. The tube center is the axis. The connection of the loudspeaker was defined as the positive direction. It was confirmed that the acoustic energy was 1.7 W in the connection with the loudspeaker when the resonance tube was connected with the position at 1930 mm. Therefore, the energy loss becomes 83 % until the sound energy reach the connection of the loudspeaker. Then electricity generated was 0.86 W. Therefore, the energy conversion efficiency of this system became 0.26 %. It was confirmed that the acoustic energy was 0.27 W in the connection with the loudspeaker when the resonance tube was connected with the position at 2325 mm. Therefore, the energy loss becomes 98 % until the sound energy reach the connection of the loudspeaker. Then electricity generated was 0.17 W. Therefore, the energy conversion efficiency of this system became 0.05 %. It was understood that installation position of the resonance tube with the energy loss become small until the sound energy reach the connection of the loudspeaker is important to improve electric generation efficiency.

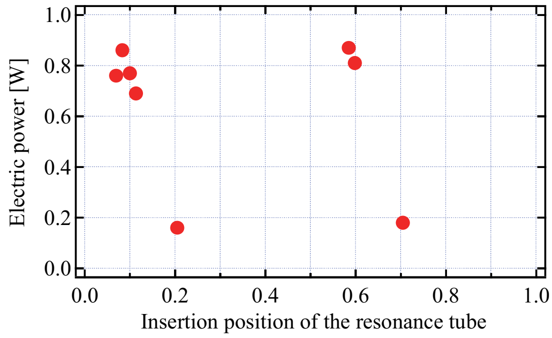

Fig. 3. Relation between insertion position of the resonance tube and electric power as a function of normalized distance from the heater.

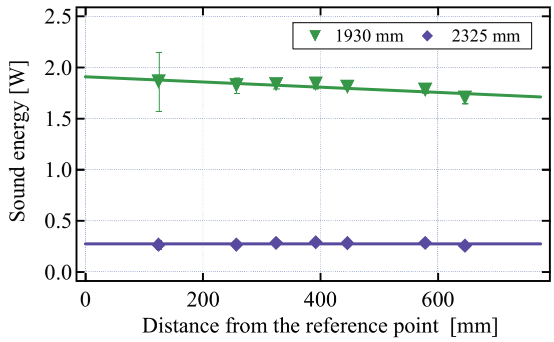

Fig. 4 Distribution of sound energy in resonance tube.

5. Conclusions

In this report, experimental investigations of electric generation efficiency were conducted by changing installation positions of the resonance tube. From the results, it was understood that the sound energy flows into the resonance tube by connecting the resonance tube where the resonant frequency similar to the loop tube from the antinode of the particle velocity to 8.4%. Moreover, it was understood that the electric generation efficiency improves.

Acknowledgment

This reseach was partially supported by Grant-in-Aid for Young Scientists (A), Kansai Research Foundation for technology promotion and Tateisi Science and Technology Foundation.

References

1. T. Yazaki *et al* , Appl. Phys. Lett., vol. 80, no. 1, pp. 157-159, Jan. 2002.
2. S. Sakamoto *et al* , Ultrasonics, vol. 42, pp.53-56, 2004.
3. S. Backhaus *et al* , Nature, vol. 399, pp.335-338, May, 1999.
4. T. Biwa *et al* , J. Acoust. Soc. Am. 124 (3), pp1584-1590(2008).