3Pa4-6

Fundamental Study on Stack Characteristics in Standing Wave Sound Field in a Thermoacoustic Heat Pump

Shin-ichi Sakamoto[1†], Toshiki Nakazawa[2], Teruya Shichiri[2], Satoru Ono[3], Tsuyoshi Akiyama[1] ([1] Faculty of Advanced Engineering, Univ. of Shiga Prefecture; [2] School of Engineering, Univ. of Shiga Prefecture; [3] Graduate School of Engineering, Univ. of Shiga Prefecture)

1. Introduction

Thermoacoustic phenomena have the potential to be applied to a wide variety of systems. Thermoacoustic phenomena are based on the energy conversion between sound and heat[1-6]. The most important device for this conversion is called a stack. Stacks have a structure similar to a bundle of thin pipes.

In previous studies, stacks of honeycomb ceramics with small holes or metal meshes such as stainless steel have been widely used. Many studies have been conducted on the shape of the stacks, such as the total length, the size of the holes, the location of the stacks, and the material of the stacks. There are multiple heat flows in a stack[7-10]. Accurate measurement of these heat flows is very important to study the efficiency of heat and sound conversion. In our team, we have succeeded in establishing a method to measure the heat flow caused by the standing wave component, which is one of the heat flows[10]. Based on these results and the know-how obtained, we are continuing research to improve the stacks. We have been studying the materials and surface conditions of the stacks.

In this report, we firstly report the effect of the channel radius of the honeycomb ceramic stacks on the heat flow using our established method of measuring the heat flow by the standing wave component.

2. Experiments

Figure 1 shows the thermoacoustic heat pump of the measurement system[10].

The pipe is made of stainless steel with an inner diameter of 42.6 mm and a total length of 3.32 m. A loudspeaker was installed at the left end to generate sound energy. The right end was sealed with a stainless steel plate. The working fluid in the pipe was atmospheric air. The frequency was set to 104 Hz to achieve one-wavelength resonance. The input power to the loudspeaker (TOA TU-750M) was set to 30 W. The stack was set up in the sound field where the standing wave component is dominant (3.15 m from the loudspeaker) [10]. A heat exchanger was installed at the hot end of the stack. The temperature of the water in the heat exchanger was adjusted and circulated so that the temperature at the hot end was the same as the room temperature.

Pressure sensors (PCB 112A21) were installed at 1.9 m, 2.2 m, 2.6 m, and 3.32 m from the speaker to measure the sound field in the pipe. The sound field was recorded using an FFT analyzer (OR34-S). Stacks of 400, 600, and 900 cells /inch² of honeycomb ceramics were used, and their channel radii were approximately 0.64 mm, 0.52 mm, and 0.42 mm, respectively. When sound waves are generated from a loudspeaker, a standing wave of one-wavelength resonance is formed in the system.

The resulting thermoacoustic effect decreased the temperature on one side of the stack. Temperatures at both ends of the stack were measured using k-type thermocouples. The cooling

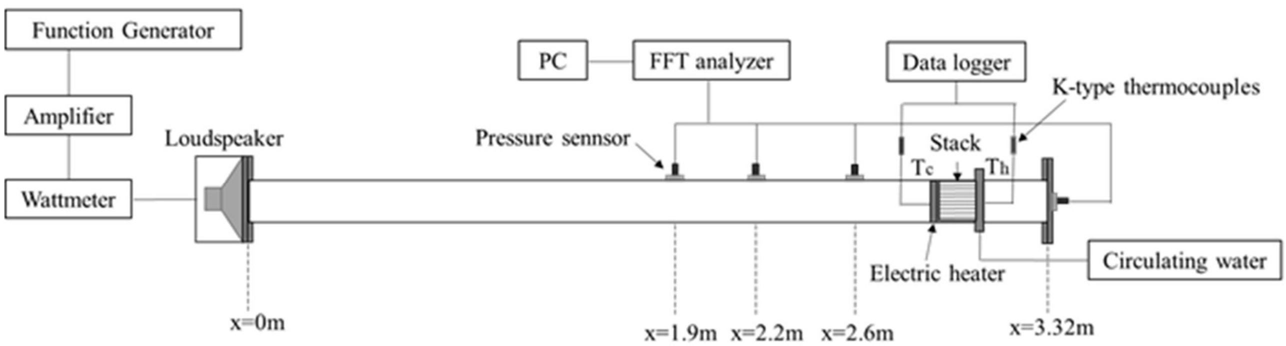

Figure1 Experimental set up[10].

sakamoto.s@e.usp.ac.jp

temperatures in each stack were compared 10 minutes after the sound energy was applied.

3. Results

Table 1 shows the hot end temperature Th, cool end temperature Tc, and their differences for stacks with different numbers of cells. The hot end temperatures of the stacks shown in **Figure 1** are maintained at the same temperature as room temperature by circulating water. The temperatures were 23.1°C, 23.1°C, and 23.0°C for the 400, 600, and 900 cells /inch², respectively. The stack cooling end temperatures were 18.3°C, 17.9°C, and 17.3°C for the 400, 600, and 900 cells /inch², respectively. The temperature difference between the hot end and the cool end of the stack was confirmed to be 4.8°C for 400 cells, 5.2°C for 600 cells, and 5.7°C for 900 cells. From these experimental results, it was confirmed that the heat flow in the standing wave component is affected by the flow radius of the stack.

Table 1 Th, Tc, and their differences for stacks with different numbers of cells.

cells /inch²	Th[℃]	Tc[℃]	Th-Tc[K]
400	23.1	18.3	4.8
600	23.1	17.9	5.2
900	23	17.3	5.7

Acknowledgment

This work was supported by a Grant-in-Aid for Scientific Research (C) [grant number 17K06234]; University of Shiga Prefecture Fund for Specially Promoted Research.

References

1. G. W. Swift, J. Acoust. Soc. Am. 84, 1145 (1988).
2. S. Backhaus and G. W. Swift, Nature 399, 335 (1999).
3. A. Tominaga, Cryogenics 35, 427 (1995).
4. T. Yazaki, A. Iwata, T. Maekawa, and A. Tominaga, Phys. Rev. Lett. 81, 3128 (1998).
5. T. Yazaki, T. Biwa, and A. Tominaga, Appl. Phys. Lett. 80, 157 (2002).
6. S. Sakamoto and Y. Watanabe, Ultrasonics 42, 53 (2004).
7. Y. Ueda, T. Kato, and C. Kato, J. Acoust. Soc. Am., Vol. 125, pp. 780-786, 2009.
8. Y. Tsuji, S. Sakamoto, T. Ishino, Y. Watanabe, and J. Senda, Jpn. J. Appl. Phys., Vol. 47, No. 5, pp. 4231-4234, 2008.
9. N. Miya, S. Sakamoto, and Y. Watanabe, Jpn. J. Appl. Phys., Vol. 47, No. 5, pp. 4235-4238, 2008.
10. S.Sakamoto et al., AIP Advances 9, 115006 1-3, 2019.