2P4-12

Measurement of temperature distribution with 3D-printer and etching meshes stack in thermoacoustic heat pump

熱音響ヒートポンプにおける 3D プリンターとエッチングメッシュスタックの温度分布測定

Shintaro Kataoka[1†], Shin-ichi Sakamoto[1] ([1]Univ. of Shiga Prefecture)
片岡 慎太朗 [1†], 坂本 眞一 [1] ([1] 滋賀県立大)

1. Introduction

A thermoacoustic system[1, 2] uses the thermoacoustic phenomenon, which is a mutual energy conversion between heat and sound. For mutual energy, a device called a stack with a very narrow flow path is required. A system that uses sound energy to heat energy is a thermoacoustic cooling system[3, 4]. One of the thermoacoustic cooling systems is a forced-drive straight-tube-type thermoacoustic cooling system[5]. This system is composed of a loud speaker, a stack, and a stainless steel tube, and cools the stack by forcing sound waves from the speaker. For the practical application of the system, improvement of energy conversion efficiency is an issue. To solve the problem, we focused on the material and shape of the stack.

Ordinary, stacks were made of honeycomb ceramic or metal meshes[8-10]. Previous researches focusing on stacks in cooling systems have 3D-printed stack[6, 7]. By using a 3D-printer, the flow path shape of the stack can be easily performed. However, there are few researches to combine 3D-printed stack and metal meshes stack.

In this research, we studied the stacks in the straight-tube thermoacoustic cooling systems. The temperature difference between both ends of the fabricated stack was confirmed.

2. Experimental method

A schematic of the experimental system is shown in Fig. 1, which employed a stainless steel tube. Air at atmospheric pressure was used as the working fluid. The total length of the straight tube was 1500 mm. The resonator had an inner diameter of 42.6 mm and wall thickness of 3.0 mm. The stack material that was fabricated using the 3D-printer was PLA (polylactic acid) resin. The stack of metal meshes was fabricated by etching SUS304. The stack length was 20 mm. The flow channel diameter of the stack was 2.0 mm (minimum flow channel in a 3D-printer), while the flow diameter of the metal meshes was 0.6 mm. Figure 2 shows the stack produced by the 3D-printer and metal meshes. Four types of stacks were used in the experiment. Figure 3 shows the four types of stacks that were produced. The Type 1 stack is created only using the 3D-printer. The Type 2 stack is made with a metal meshes for the former 10 mm and a 3D-printer for the latter10 mm. The Type 3 stack is made with a 3D-printer for the former 10 mm and a metal meshes for the latter10 mm. The Type 4 stack is created only using the metal meshes.

The temperature distribution along the axial direction of the stack was measured using K-type

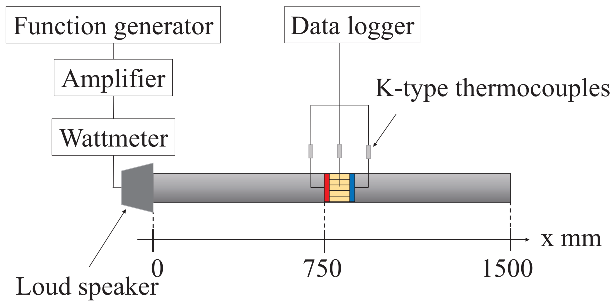

Fig. 1 Schematic of the experimental system.

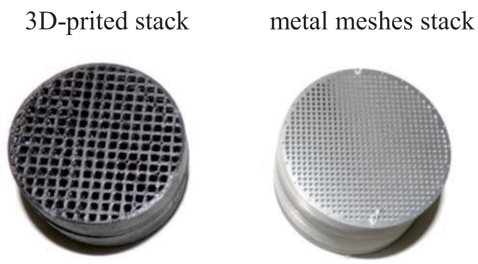

Fig. 2 The stacks produced by 3D-printer and metal meshes.

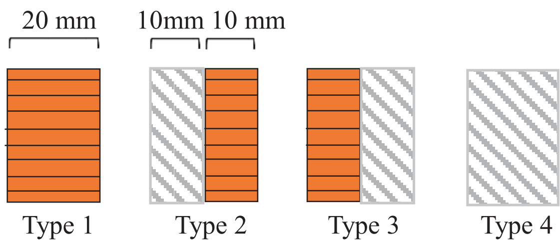

Fig. 3 Four types of stacks produced in this study.

thermocouple probes (CHINO). The thermocouple probes were used at three measurement points, namely 0, 10, and 20 mm from the left end of the stack. The frequency of the sound in the tube was set to 223 Hz to ensure resonation at one wavelength over the entire tube length, using of a function generator (Agilent 33250A). The electrical power was set to 10 W using a power amplifier (SOUND HOUSE CLASSIC PRO CP1400), and the sound wave was output from the loud speaker (TOA TU-750).

3. Experimental results

Table 1 shows the value of stack temperature difference from room temperature. Figure 4 shows the stack temperature distribution. The horizontal axis represents the distance from the stack left edge. The experimental results indicate that the temperature rises at the left end of the stack, while cooling occurs at the right end. The temperatures at the left end, center, and right end of the stack are T_H K, T_M K, and T_C K, respectively. The temperature difference between the stack ends $(T_H - T_C)$ is T_{all} K. The temperature represents the difference from room temperature. Thus, T_H and T_C have positive and negative values, respectively. The temperature difference T_{all} corresponding to each of the four types of stacks was 15.0, 13.3, 10.9, and 11.3 K, respectively. Types 1 and 4 showed a linear temperature gradient. Each stack was considered to be composed of one material. Type 2 had a small temperature gradient from T_H to T_M, and a large temperature gradient from T_M to T_C. In contrast, Type 3 had a large temperature gradient from T_H to T_M, and a small temperature gradient from T_M to T_C. The hot end of Type 1 had a temperature of 11.6 K, which indicates that the ratio of the hot temperature was larger than that of the cool temperature. In Type 2, the ratio of the cold temperature was determined to be large.

4. Summary

We measured the stack temperature distribution by changing the material of the stack in straight-tube thermoacoustic cooling systems. We combined metal meshes stack and 3D-printed stack. The experimental results confirmed the temperature distribution along the axial direction of each stack.

Acknowledgment

This work was supported by JSPS Grant-in-Aid for Young Scientists (A) (22686090), JSPS Grant-in-Aid for Challenging Exploratory Research (23651072), Grant-in-Aid for Scientific Research (C) (40449509), and Program for Fostering Regional Innovation.

References

1. A. Tominaga: Fundamental Thermoacoustic, (Uchida Rokakuho, Tokyo, 1998), pp. 9-30, [in Japanese].
2. T. Yazaki, T. Biwa and A Tominaga: Appl. Phys. Lett. **80** (2002) 157.
3. S. Sakamoto and Y. Watanabe: ASJ. **27** (2006) 361-365.
4. A. Widyaparaga and T. Hiromatsu *et al.*: Appl. Therm. Eng. **101** (2016) 330-336.
5. Na Pan, Chao Shen and Shuangfeng Wang: Energy Convers. Manag. **65** (2013) 84-91.
6. Nor Atiqah Zolpaker, Normah Mohd-Ghazali, Robiah Ahmad and Thierry Mare: ICAE. **105** (2017) 1382-1387.
7. S. Kataoka and S.Sakamoato *et al.*: HTSJ (2018) P1437
8. S. Backhaus and G. W. Swift: Nature. **399** (1999) 335-338.
9. Y. Ueda, T. Kato and C. Kato: J. Acoust. Soc. Am. **125** (2009) 780-786.
10. S. Hasegawa, Y. Ashigaki and M. Senga: Appl. Therm. Eng. **104** (2016) 237-242.

Table 1 Temperature difference from room temperature.

	T_H K	T_M K	T_C K	T_{all} K
Type 1	11.6	4.6	-3.4	15.0
Type 2	6.6	2.0	-6.7	13.3
Type 3	6.7	-2.9	-4.2	10.9
Type 4	7.2	2.5	-4.1	11.3

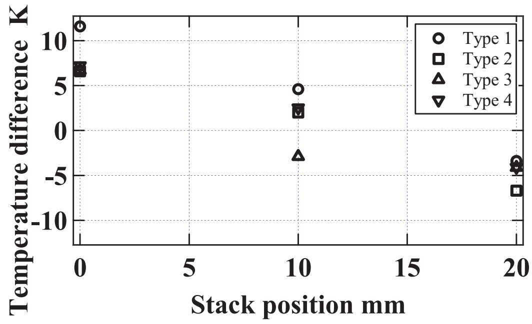

Fig. 4 Temperature distribution in each stack.

E-mail: of23skataoka@ec.usp.ac.jp