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Study of heat input in a loop-tube-type thermoacoustic system — Fundamental study of the temperature distribution of the thermal buffer tube —

ループ管型熱音響システムにおける熱入力に関する研究
— 熱緩衝管温度分布の基礎検討 —

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1. Introduction

A thermoacoustic system[1–3] is based on the thermoacoustic phenomenon, wherein acoustic waves showing adiabatic behavior in free space propagate in a narrow flow path such that mutual conversion in between heat energy and sound occurs. Thermoacoustic systems are advantageous in that they do not have moving parts and are maintenance-free because of which they do not incur maintenance costs; they also have a simple structure and long lifetime, which can enable further cost reduction.

One of the possible application areas of thermoacoustic systems is in the effective utilization of unused waste heat. Presently, the temperature of factory waste heat is in the range of 20°C to 1000°C or higher; effective use of the high-temperature part of waste heat is possible. However, since waste heat with a temperature of 200°C or lower is often discarded because remains unused, it can possibly be reused using a thermoacoustic system.

One of the problems of thermoacoustic systems is their low heat-energy conversion efficiency. Specifically, the heat applied to the system is lost because of various factors and it becomes smaller than the input heat. Some previous studies[4–7] investigated thermal leakage from a thermal buffer tube in a straight-tube-type thermoacoustic system. In these studies, the authors attempted to improve the design accuracy of the thermoacoustic system by using the experimental determined temperature distribution of the thermal buffer tube for analysis purposes, and they investigated the influence of the temperature distribution on the sound field by heating the thermal buffer tube using a heater. In the present study, heat to a loop-tube-type thermoacoustic system was investigated by changing its input power and measuring the temperature of the high-temperature side of the stack and the temperature distribution of the thermal buffer tube.

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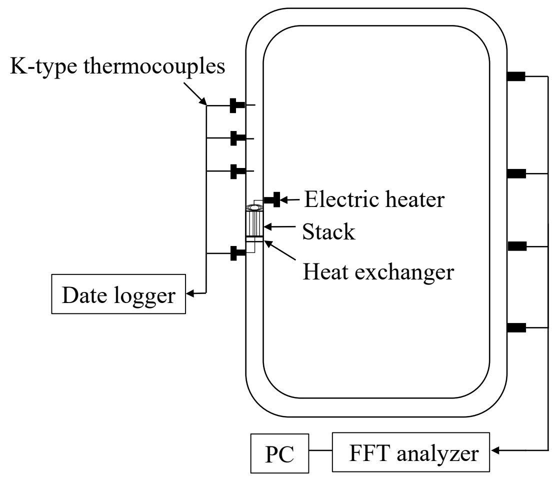

Fig. 1 Schematic of experimental system.

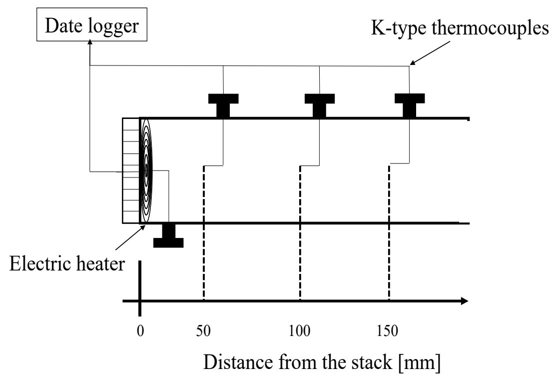

Fig. 2 Schematic of thermal buffer tube.

2. Experimental system

Schematics of the experimental system and the thermal buffer tube are shown in **Figs. 1** and **2**, respectively. The loop-tube-type thermoacoustic system consisted of stainless steel tube. The total length and inner diameter of the tube were 3300 and 42.6 mm, respectively. The tube, whose ends were closed, was filled with air at atmospheric pressure. The stack was made of ceramic and had a honeycomb structure. The length and channel density of the stack were 50 mm and 600 channels/in^2, respectively. The high-temperature side of the stack was heated using an electric heater. The temperature of the low-temperature side of the stack was maintained by circulating water at 20°C inside the heat exchanger. The sound pressure in the tube was measured using four pressure sensors and thermoacoustic oscillation was confirmed. The four pressure sensors (PCB Piezotronics 112A21) were installed at distances of 1020, 1420, 1720 and 2170 mm from the high-temperature side of the stack. The temperatures of the thermal buffer tube and the high-temperature side of the stack were measured using K-type thermocouples (CHINO SCHS1-0). Thermocouples used temperature measurement of the thermal buffer tube were installed at distances of 50, 100 and 150 mm from the high-temperature side of the stack.

The experimental procedure was as follows. The input power of the electric heater on the high-temperature side of the stack was set at 75 W. After the sound pressure in the tube and the temperature distribution of the thermal buffer tube reached a steady state, the input power of the electric heater was changed to 100 W and the temperature distribution of the thermal buffer tube again reached a steady state.

3. Experimental results

Figure 3 shows the temperature distribution of the thermal buffer tube at input powers of 75 and 100 W. It can be seen that the temperature distribution of the thermal buffer tube decreased with increasing distance from the high-temperature side of the stack. The temperature of the high-temperature side of the stack at the input power of 100 W (360.9°C) was lower than that at 75 W (388°C). From this result, it is considered that the amount of heat energy converted to sound energy increased with increasing input power. It could also be seen that the temperature of the thermal buffer tube increasing input power and became close to the temperature of the high-temperature side of the stack. When the input power was increased from 75 W to 100 W at distances of 50 and 100 mm from the high-temperature side of the stack, temperature increases of 117.5 and 79 K, respectively, occurred.

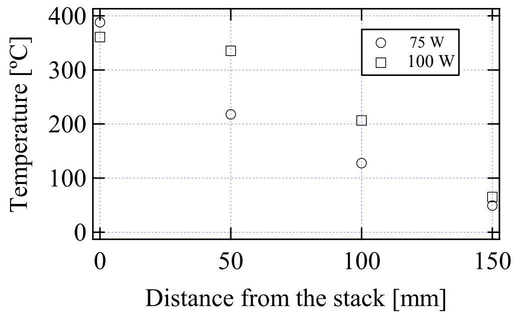

Fig. 3 Steady-state temperature distribution of thermal buffer tube.

4. Conclusions

In this study, the temperature distribution of a thermal buffer tube in a loop-tube-type thermoacoustic system was measured. From the measurement results, it was confirmed that the temperature distribution of the thermal buffer tube changed with increasing input power. The temperature of the thermal buffer tube increased with increasing input power and became close to the temperature of the high-temperature side of the stack.

Acknowledgment
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