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Experimental study of the thermal buffer tube temperature gradient and onset temperature in a loop-tube-type thermoacoustic system

ループ管型熱音響システムにおける熱緩衝管温度勾配と発振温度に関する実験的検討

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1. Introduction

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

However, one of the problems of a thermoacoustic system is a high onset temperature. To that end, some previous studies investigated. Focusing on the study of temperature distribution, there are heat leak from a thermal buffer tube[4-6] and heat phase adjuster[7, 8] etc. Among them, we investigated thermal leak in more detail. When temperature gradient occurs at both sides of the stack, the thermoacoustic prime mover converts heat energy to sound energy. In addition, inputting heat to the stack causes unwanted heat flows through the tube wall and through the working gas, i.e., heat leak. The section, where the temperature distribution is formed, is called the thermal buffer tube.

In this paper, we investigated the effect on a loop-type-tube thermoacoustic system by cooling its thermal buffer tube. We measured the onset temperature and temperature distribution of the outer wall of the thermal buffer tube. Moreover, changed the potision of circulating water and measured them again.

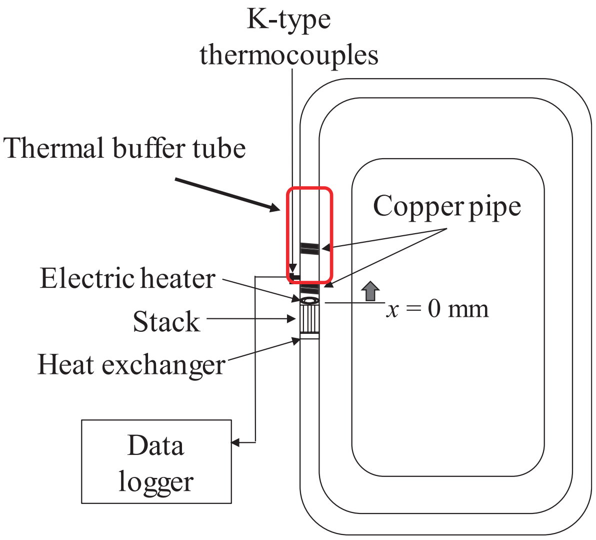

Fig. 1 (a) Schematic of experimental system.

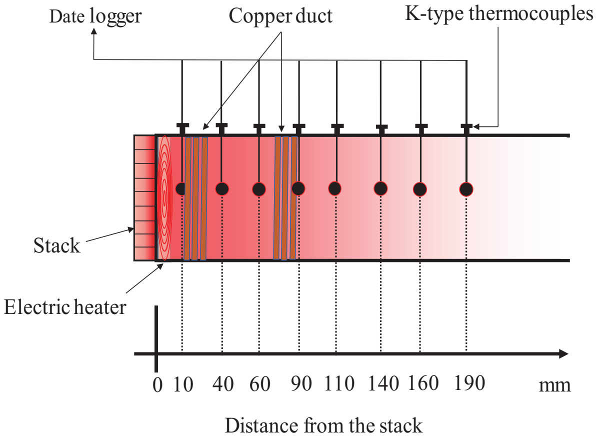

Fig. 1 (b) Schematic of thermal buffer tube.

2. Experimental method

The schematic of the experimental system is depicted in Fig.1 (a). The schematic of the thermal buffer tube is depicted in Fig.1 (b). The tube in the loop-tube-type thermoacoustic system was made of stainless steel. The total length of the tube was 3300 mm, and its inner diameter was 42.6 mm. Atmospheric air was filled into the tube. The length and channel density of the stack were 50 mm and 600 channel/inch^2, respectively. The high-temperature side of the stack was a spiral electric heater, and its low-temperature side was cooled by circulating water at 24 °C. In addition, we covered the outer wall of the thermal buffer tube with a copper pipe at 10~30 mm and 70~90 mm distances from the high-temperature side of the stack. To cool the outer wall of the thermal buffer tube, we circulated water through the copper pipe. We define Type A as the case in which water did not circulate through the copper pipe, Type B as the case in which water circulated through the copper pipe at 70~90 mm, and Type C as the case in which water circulated through the copper pipe at 10~30 mm. To confirm the temperature of the thermal buffer tube during the experiment, the thermocouples for the thermal buffer tube were placed at 10, 40, 60, 90, 110, 140, 160, and 190 mm on the outer wall of the thermal buffer tube.

To determine the onset temperature, the temperature of the high-temperature side of the stack was maintained constant by adjusting the power supplied to the electric heaters of the temperature controller and was then gradually raised from the room temperature (24 °C). Upon confirming the oscillate of the system at certain temperature, the temperature was gradually lowered. After the oscillate of the system stopped, the temperature raised again. The onset temperature was determined as the temperature of the high-temperature side of the stack immediately after the system started oscillating again. To confirm the oscillation, pressure sensors (PCB Piezotronics 112A21) were mounted on the tube wall.

3. Results

The temperature of the outer wall of the thermal buffer tube just when the system oscillated is depicted in Fig. 2. It can be seen that the temperature of the outer wall of the thermal buffer tube decreased up to 40 K by the circulating water; the figure confirms a considerable change in temperature distribution depending upon the position of the circulating water.

Next, the onset temperatures obtained from the experiment are depicted in Table 1. The onset temperatures of Types A, B, and C were 630, 644, and 654 K, respectively. From the experimental results, it is evident that the onset temperature is increased upon circulating water. Moreover, the onset temperature of Type C, which circulated water quite near to the high-temperature side of the stack, was higher than that of Type B. This result shows that the chang of temperature distribution affected of system oscillation conditions.

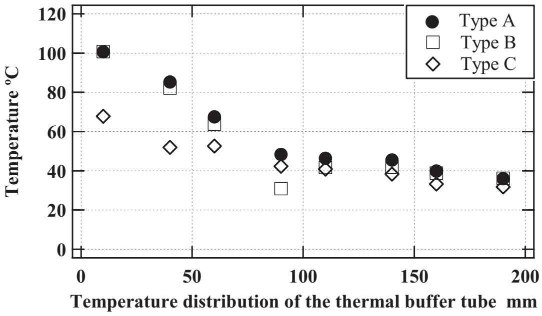

Fig. 2 The temperature of the outer wall of the thermal buffer tube.

Table 1 The onset temperature for each Type.

	Type A	Type B	Type C
onset temperature K	630	644	654

4. Summery

We investigated the resulting effect on a loop-type-tube thermoacoustic system by cooling its thermal buffer tube. We measured the onset temperature and temperature of the outer wall of the thermal buffer tube. We confirmed that onset temperature changed by circulating water through the copper pipeof the outer wall. Moreover, onset temperature was varied by changing the position of the circulating water.

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