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Applying Sub-Loop Tube to control the sound field in a Loop-Tube-Type Thermoacoustic System

熱音響システムにおけるサブループチューブを用いた音場制御に向けた検討

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1. Introduction

Thermoacoustic[1-8] systems applying thermoacoustic effects offer solutions to environmental problems. By applying the thermoacoustic effect, it is possible to construct a new system having many unique advantages[1-8]: the effective use of waste heat and the absence of poisonous cooling media and moving parts. However, this system presents some issues that must be overcome before this method's practical use. As described herein, we specifically examine the energy conversion efficiency from heat to sound energy. Various examinations[1-5] were conducted to increase energy conversion efficiency. In the energy conversion component–the prime mover–the phase difference between the sound pressure and particle velocity must become a travelling wave phase. However, it is difficult for a thermoacoustic system to become a travelling wave phase in an energy conversion component because the generated sound in the system is a thermoacoustic self-sustained sound. We have proposed some methods[6-8] to control the sound field and to become a traveling phase in the prime mover in a loop tube. As described in this report, we propose a loop-tube-type thermoacoustic system with a diverging sub-loop tube to control the sound field. The sub-loop tube diverges from the main loop tube and rejoins it; thereby, the sub-loop tube forms a loop. The sub tube positions were changed.

2. Experiment

A block diagram of the measurement system is presented in Fig. 1. To determine the effect of the sub-loop tube, a heat pump was not used. The top of the stack is defined as a distance of 0 m. The tube center is the axis; clockwise is defined as the positive direction. The system was constructed with a stainless steel tube that was 0.85 m long and 0.5 m wide, with 3.3 m total length. Its inner diameter was 42 mm. The system was filled with air at atmospheric pressure. The stack was a 50-mm-long honeycomb ceramic with a channel radius of 0.45 mm. A spiral-type electrical heater inserted at the top of the stack served as the heat source; a heat exchanger to maintain the system at the reference temperature was placed at the lower part of the stack. The inner diameter of the sub-loop tube was equal to that of the loop tube: 42 mm. Figure 1 shows that the sub-loop tube's length from the upper side to the lower side was 0.45 m. The sub tube position was changed so that the distance from the heater to the upper part of the sub tube was 0.42, 0.52, 1.73, 1.83, 1.93, or 2.13 m. Heating power of 330 W was supplied for 600 s using an electrical heater. Pressure sensors were set on the system wall to measure the sound pressure in the loop tube. Measurements of sound pressure were started and continued for 900 s after the heat energy was supplied. The pressure, the phase difference between pressure and particle velocity, and the sound intensity in the system were calculated using a two-sensor power method[4] with pressure measurement results.

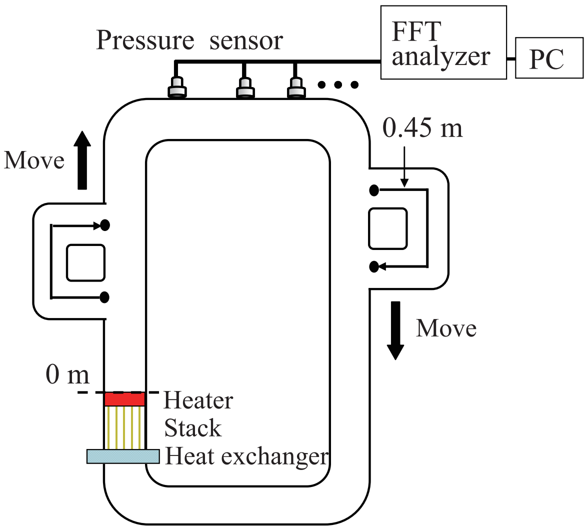

Figure 1 Experimental setup of the loop-tube-type thermoacoustic system.

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3. Results

Figures 2–4 show sound pressure distributions in a loop tube with and without the sub-loop tube. Figure 2 shows the sound pressure distribution without and with the sub-loop tube at 0.42, 0.52 m. Figures 3 and 4 respectively show sound pressure distributions without and with the sub-loop tube at 1.73, 1.83, 1.93 and 2.13 m.

The results show that the position of the antinode of sound pressure changes with the connecting position of a sub-loop tube. It is confirmed that the sound field in the loop tube is controlled by connecting the sub-loop tube from these results. It is considered that these movements of sound pressure antinode position by connecting the sub-loop tube have changed the phase difference in the prime mover.

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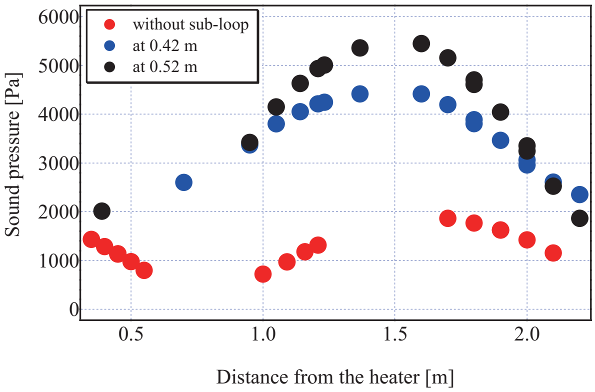

Figure 2 Sound pressure distributions without the sub-loop tube and with tube at 0.42, 0.52 m.

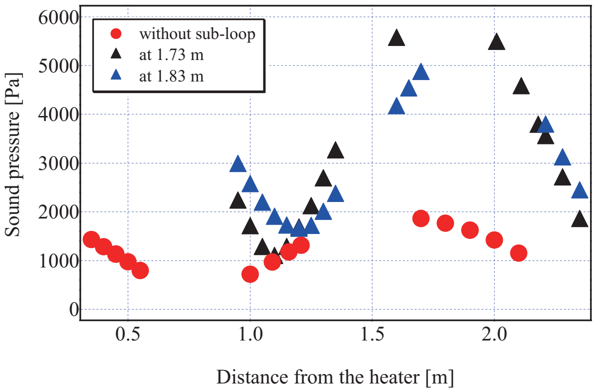

Figure 3 Sound pressure distributions without the sub-loop tube and with tube at 1.73, 1.83 m.

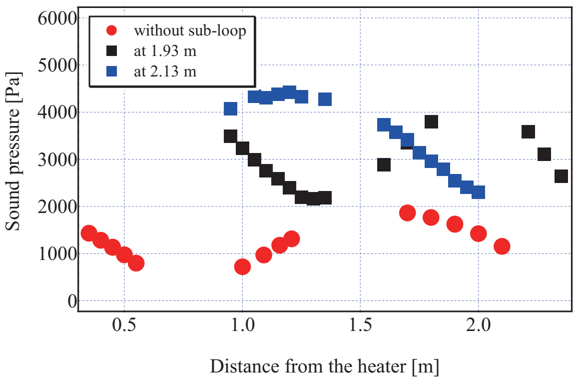

Figure 4 Sound pressure distributions without the sub-loop tube and with tube at 1.93, 2.13 m.