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Effect of Phase Adjuster Length Change on Sound Field in a Loop-Tube-Type Thermoacoustic System

フェーズアジャスターの長さ変化が熱音響システムの音場に与える影響について

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1. Introduction

Human society must confront problems such as global warming and energy resource depletion. We propose a thermoacoustic system[1,2] as a technique to address these problems.

Sound waves that propagate in a sufficiently narrow tube compared to their wavelength exchange heat at the tube wall. This process is known as the thermoacoustic effect. By applying the thermoacoustic effects, it is possible to construct a new system that has many unique benefits[1–4]. This system, for example, as a cooling system, employs no harmful medium such as chlorofluorocarbons. Furthermore, this system can use waste heat and sunlight as an energy source. In addition to these benefits, the system works with no moving parts. However, this system presents some issues that must be overcome for it to become practically useful.

Various experiments[3–6] have been conducted to increase energy conversion efficiency. Their results underscore the necessity of observing the state of the generated sound in a system. In the energy conversion component–the prime mover–the phase difference between sound pressure and particle velocity must become 0° or nearly 0°. This phase difference contributes to energy conversion through isothermal heat exchange process and makes a thermoacoustic system highly efficient for energy conversion. Nevertheless, it is difficult in a thermoacoustic system to control the phase difference in an energy conversion component because the sound generated in the system is a thermoacoustic self-sustained sound.

We have proposed several methods[1,2] to control the phase difference of the generated sound in the prime mover in a loop-tube-type thermoacoustic system. We have suggested various methods[1,2] to adjust the phase difference. For example, we reduced the loop-tube cross section, which we call the phase adjuster (PA). Setting PA in a loop-tube-type thermoacoustic system, which is a thermoacoustic system, greatly improves the energy conversion efficiency, but it does so for reasons that remain unclear. The reasons must be clarified to establish a PA design method to maximize the energy conversion efficiency.

As described in this paper, we present a discussion of the sound field in a loop-tube-type thermoacoustic system, particularly emphasizing the effect of PA length.

2. Experimental setup

A schematic of the experimental system is presented in **Fig. 1**. This thermoacoustic prime mover comprises a stainless steel cylindrical tube with total length of 3.3 m and 42 mm inner diameter. The system is filled with air at atmospheric pressure. The 50-mm-long stack has honeycomb ceramic cells (900 cell/inch^2). A spiral-type electric heater inserted at the top of the stack serves as the hot heat-exchanger. The reference heat-exchanger is placed to maintain ambient temperature of the prime mover. Electric power of 330 W is supplied to the electric heater. The PA conditions are presented in Table 1 and Fig. 1. The sound pressure is measured using pressure sensors (PCB Piezotronics Inc.). Using a two-sensor power method[5,6], the sound pressure, the particle velocity, the phase difference between sound pressure and particle velocity, and the sound intensity distributions are calculated from the measured pressure. The heat supply and the measurements of the pressure are started simultaneously. The measurements are continued for 480 s and conducted in five cases: without PA and with PAs of four kinds.

3. Experimental results

Figure 2 shows the particle velocity distributions with and without PAs. **Figure 3** shows the sound intensity distributions with and without PAs. Figure

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2 shows that the particle velocity varies with PA length. Figure 3 shows that the sound intensity with any PA is greater than that without PA. The particle velocity of 150 mm PA is the highest among these experimental conditions. Moreover, its sound intensity is the greatest. Results therefore confirmed that the sound field in a loop-tube-type thermoacoustic system is changed by the PA length change, and that the heat-to-sound energy conversion efficiency is changed by the PA length change.

4. Conclusions

As described herein, we presented a discussion of the sound field in a loop-tube-type thermoacoustic system, particularly emphasizing the effects of PA length using four PAs in different lengths.

The sound field in a loop-tube-type thermoacoustic system was confirmed to be changed by the PA length change. The heat-to-sound energy conversion efficiency is changed by changing the PA length.

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Table 1 PA conditions

Length (mm)	300	250	200	150
Left end from PM (mm)	1000	1050	1050	1100
Right end from PM (mm)	1300	1300	1250	1250

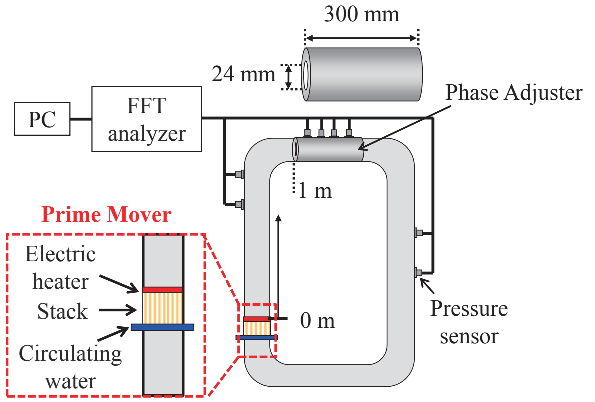

Fig. 1 Schematic of the experimental system.

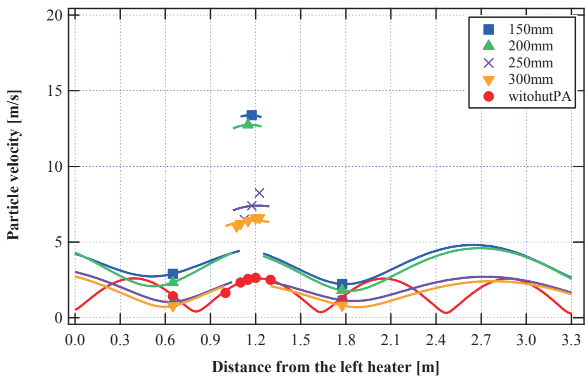

Fig. 2 Particle velocity distributions with and without PAs in the system.

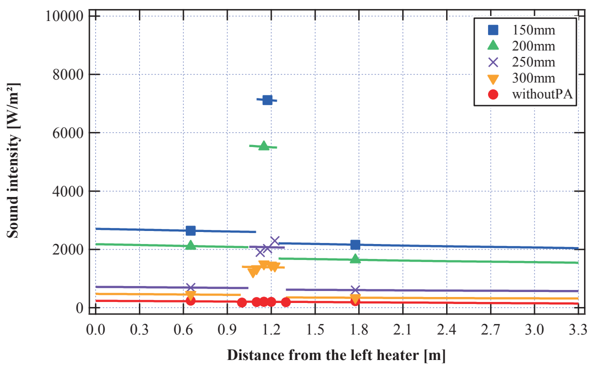

Fig. 3 Sound intensity distributions with and without PAs in the system.