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Improving Thermoacoustic System Efficiency
– Measurement of a Sound Field in the Phase Adjuster –
熱音響システムの効率向上に向けた研究
－フェーズアジャスター内の音場の測定－

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1. Introduction

Sound waves that propagate in a sufficiently narrow tube compared to their wavelength exchange heat at the tube wall. This process, known as thermoacoustic phenomenon, and thermoacoustic systems using the thermoacoustic phenomenon have entered practical use in many fields[1-8]. These systems are useful especially when driven by underutilized energy sources such as waste heat and solar heat because they are external combustion engines. They are useful as a technology supporting global environment maintenance. Nevertheless, their energy conversion efficiency is low and examples of their practical use are few. The advantages of thermoacoustic systems are that they use waste heat as a driving source. They require no maintenance because they have no moving parts. However, several challenges remain before these systems can be developed for practical use. Especially, improvement of their energy conversion efficiency is important at energy conversion parts.

We proposed a phase adjuster (PA) to improve their energy conversion efficiency[5-7]. The Phase Adjuster minimizes the inner diameter of the system locally. Setting PA in a loop-tube type thermoacoustic system, which is a thermoacoustic system, greatly improves the energy conversion efficiency. Nevertheless, it improves the energy conversion efficiency for reasons that remain unclear. It is necessary to clarify the reasons for establishing a PA design method to maximize the energy conversion efficiency.

Phases near PA and near the prime mover have been measured to date, and the mechanism of PA operation has been considered. However, physical information in PA can not be measured from restrictions on measurements. The cross sections of the thermoacoustic system were made small, and conditions resembling those of the PA were prepared. Detailed measurements were taken for the sound field: sound pressure distribution, particle velocity distribution, sound intensity distribution, and the phase difference using the two-sensor power method. The PA operation mechanism was considered based on the results reported herein.

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 served as the hot heat-exchanger. The reference heat-exchanger is placed to maintain the prime mover at ambient temperature. Electric power of 330 W is supplied to the electric heater. The PA is set 1 m distant from the upper end of the prime mover stack in a clockwise direction. The sound pressure is measured using pressure sensors (PCB Piezotronics Inc.). Using a two-sensor power method[4, 8], 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.

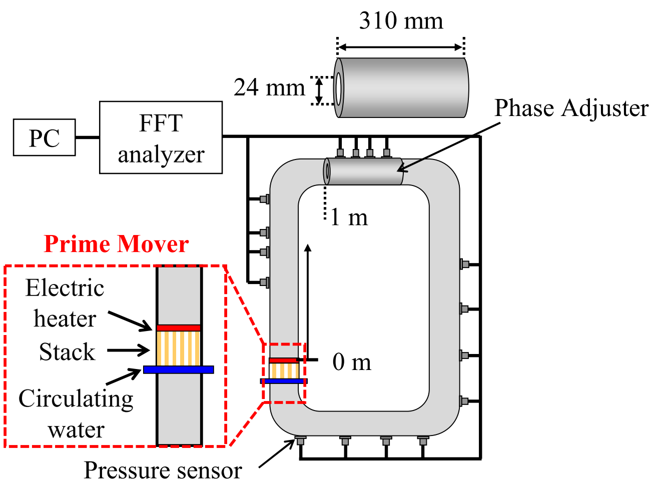

Fig. 1 A thermoacoustic heating system

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3. Experimental results and discussions

Figures 2, 3 shows the particle velocity distribution with PA and without PA respectively.

Figure 2 shows that the resonance mode of the system is not one wavelength resonance. The highest particle velocity of the parts without PA was 3.8 m/s. The highest particle velocity in PA was 11 m/s. The particle velocity is increased in PA according to the expectation. The sectional area of PA is φ26 mm. The sectional area in the part without PA is φ42 mm. The ratio of a sectional area in PA and other sectional areas in the parts without PA is about 2.6 times. The ratio of the particle velocity was also the same. It is regarded that the particle velocity distribution between Prime Mover and PA is different from the distribution of other sectional areas. This might be true because a reflection exists between the prime mover and PA, causing the standing wave.

Figure 3 shows that the resonance mode of the system is one wavelength resonance. The largest particle velocity is about 3.8 m/s, at 0.8 m from the top of the prime mover.

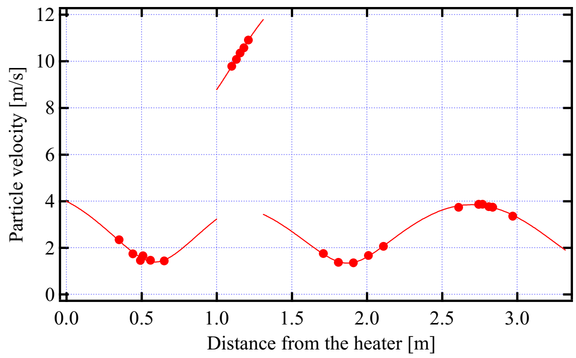

Fig. 2 Particle velocity distribution with PA

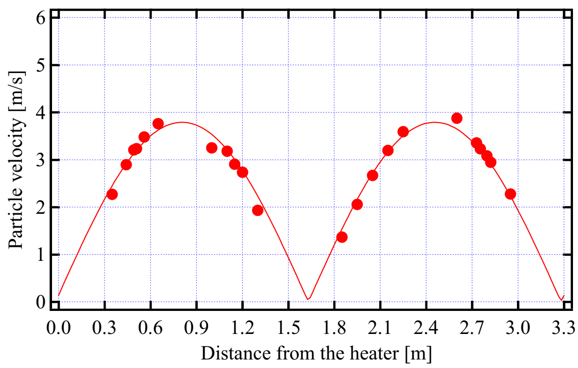

Fig. 3 Particle velocity distribution without PA

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