3P4-12

Fundamental study on enlarge of a loop-tube-type thermoacoustic system
— Measurement of the onset temperature by experiment —
ループ管型熱音響システムの大型化に関する基礎検討
— 実験による発振温度測定 —

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1. Introduction

Use of a thermoacoustic system[1,2] has attracted attention as one of the techniques for utilizing unused low-temperature waste heat. This system is based on thermoacoustic phenomenon,[1,2] which are induced by mutual conversion between thermal energy and sound energy. In a flow channel that is sufficiently narrower than the wavelength of sound waves, sound waves are generated when a temperature gradient is created between the two ends of the flow path. Contrariwise, a temperature gradient occurs between the two ends when a sound wave propagates through the flow channel. A cylindrical device in which countless flow paths are bundled is called a stack; it is an essential device for the occurrence of thermoacoustic phenomenon in a thermoacoustic system. Thermoacoustic systems have advantages that are not possessed by other energy systems. For example, a thermoacoustic system is an external combustion engine that does not need to select a heat source, it is inexpensive because of its simple structure, and it has a long lifetime because of the absence of moving parts. If this system can be put into practical use, it can serve as a novel, environmentally friendly energy system.

However, thermoacoustic systems have a practical disadvantage of a high onset temperature. Lowering of this high onset temperature is necessary in order to enable the thermoacoustic system to efficiently utilize unused low-temperature waste heat as a heat source. Numerous studies have been conducted to lower the onset temperature.[3–9] The onset temperature varies depending on the type of stack used for the driving part, the shape of the system, other devices mounted on the system, the working fluid, and so on. However, it is difficult to study the influence of all these factors simultaneously; the influence of each factor needs to be examined individually. Among these factors, the influence of the inner diameter of the tube constituting a loop-tube-type thermoacoustic system on the onset temperature has not yet been experimentally investigated.

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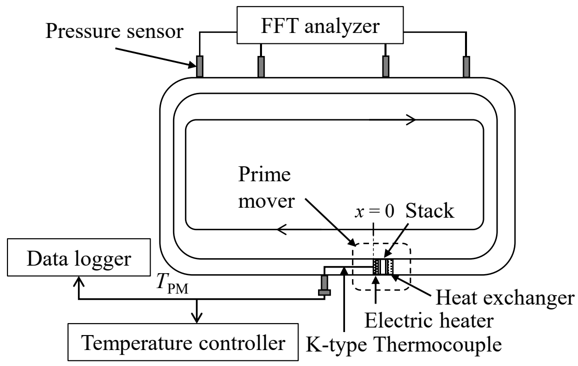


Fig. 1 Schematic of the experimental system.

Therefore, in the present study, the influence of the inner diameter of the tube constituting a loop-tube-type thermoacoustic system on the onset temperature was investigated experimentally. In the experiment, the total length of the tube was kept constant and its inner diameter was varied among three values. The experimental results showed that the onset temperature decreased as the inner diameter increased.

2. Experimental system

A schematic of the experimental system is shown in **Fig. 1**. The tube constituting the loop-tube-type thermoacoustic system was made of stainless steel. Atmospheric pressure air was used as the working fluid. The total length of the loop-tube was 3.3 m. The resonator had a wall thickness 3.0 mm; the inner diameter of the tube was changed to 24.2, 42.6, and 95.6 mm. Hereinafter, loop tubes with these three inner diameters are referred to as SID, MID, and LID, respectively. The stack placed in the prime mover was made of ceramic and had a honeycomb structure with square channels. The length and channel density of the stack were 50 mm, and 600 channels/in^2, respectively. A spirally wound electric heater was used as a heat exchanger to heat the high-temperature side of the stack. Water at 20°C was circulated to maintain a constant temperature at the low-temperature side of the stack.

To confirm the thermoacoustic oscillation in the tube, pressure sensors (PCB Piezotronics 112A21) were mounted on the tube wall and signals were transmitted to a fast Fourier transform (FFT) analyzer for measuring the sound pressure. The temperature in the central area of the high-temperature side of the stack, T_{PM}, was measured using K-type thermocouple (CHINO SCHS1-0).

To determine the onset temperature, the temperature of the high-temperature side of the stack was maintained constant by adjusting the power applied to the electric heaters of the temperature controller and was then gradually increased from room temperature (25°C). Once the onset of the system at a certain temperature was confirmed the temperature was gradually lowered. The onset temperature was determined as the temperature of the high-temperature side of the stack immediately before the system stopped oscillating.

3. Experimental Results

The onset temperatures (T_{PM}) of the tubes with different inner diameters are shown in **Fig. 2**. The onset temperatures of SID, MID, and LID were 623, 329, and 121°C, respectively. The onset temperature was the lowest for LID, and it increased as the inner diameter of the loop-tube decreased.

The FFT waveforms of sound waves generated inside the tubes with different inner diameters are shown in **Figs. 3**. MID and LID resonated at one wavelength, whereas SID resonated at two wavelengths. The onset frequencies of SID, MID, and LID were 211.68, 106.12, and 107.18 Hz, respectively.

4. Conclusions

In this study, the influence of the inner diameter of the tube constituting a loop-tube-type thermoacoustic system on the onset temperature was investigated experimentally. The results showed that the onset temperature decreased as the inner diameter increased. In particular, it was demonstrated that SID resonated at two wavelengths.

Acknowledgment
This work was supported by JSPS Grant-in-Aid for Young Scientists (A) (22686090), JSPS Grant-in-Aid for Challenging Exploratory Research (23651072), Grant-in-Aid for Scientific Research (C) (40449509), Program for Fostering Regional Innovation, and JST Super cluster program.

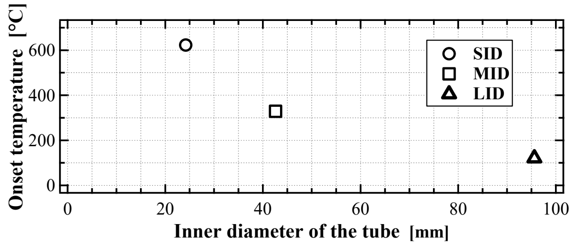
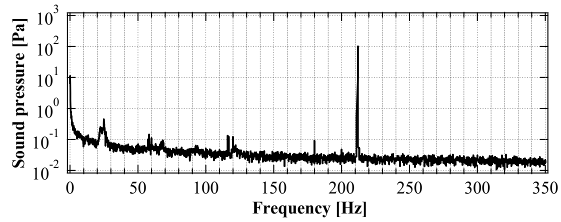
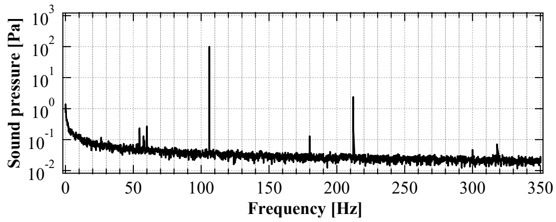


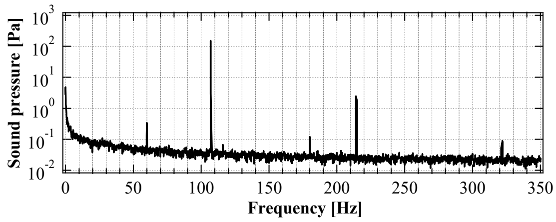
Fig. 2 Onset temperatures of tubes with different inner diameters.



(a) SID



(b) MID



(c) LID

Figs. 3 FFT waveforms of sound waves generated inside tubes with different inner diameters.

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