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Development of a prototype thermoacoustic cooling system with diameter expanded prime movers
—A study on the relationship between input power and cooling properties—

内径拡大プライムムーバー型熱音響冷却システムの試作
—入力電力と冷却特性の検討—

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1. Introduction

We studied a thermoacoustic cooling systems1) driven at low temperatures. Thermoacoustic systems use the mutual conversion of energy between sound and heat (thermoacoustic phenomenon) to cool. A thermoacoustic system utilizes commonly unused heat sources. Typically, these systems need high temperatures to operate. We focused on the prime movers, which convert heat into sound, for decreasing the temperature needed to drive the system.2) We succeeded in developing a loop-tube-type thermoacoustic system with diameter expanded multi-stage prime movers driven at 67°C. In addition, this prototype of the loop-tube-type thermoacoustic cooling system had a heat pump applied. In the experiment, the cooling point temperature was decreased by 4.4°C from room temperature of 20°C. To make practical use of the system, it is necessary that cooling performance of the loop-tube-type thermoacoustic cooling system is improved.

In this study, we focused on input power for decreasing the cooling point temperature. In the prototype loop-tube-type thermoacoustic cooling system, we studied the effect of increasing the input power at the cooling point temperature through an experiment.

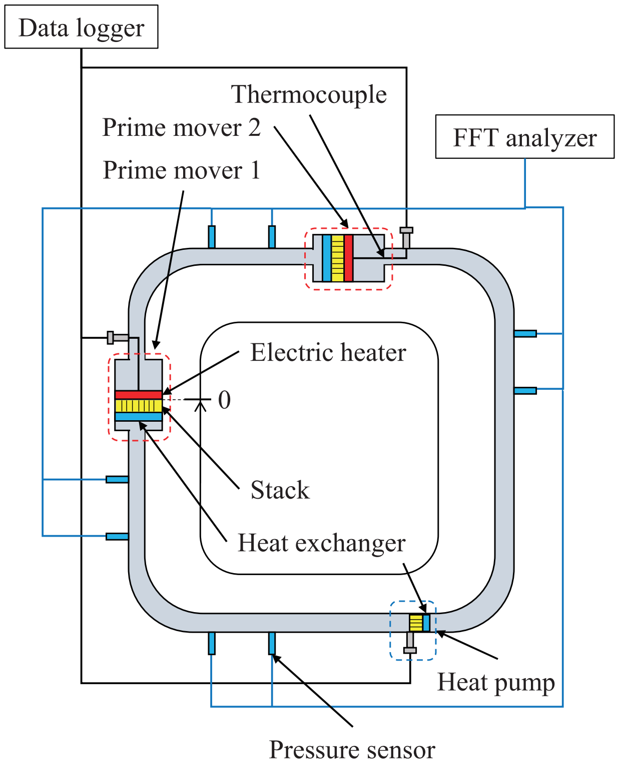

Fig. 1. Schematic illustration of experimental system.

2. Experimental system

Figure 1 shows a schematic of the experimental system. The loop-tube-type system was composed of a stainless steel tube, filled with atmospheric air. The total length of the loop-tube was 5.12 m. The inner diameter of resonance tube was 42.6 mm. The length and inner diameters of the prime movers were 300 mm and 100 mm, respectively. The stacks placed in the prime movers were made from ceramic and had a honeycomb structure. The length, inner diameter, and channel density of the prime mover stack were 50 mm, 94 mm, and 900 channel/in^2, respectively. In each prime mover, the electric heater was used as the high temperature source. Water at 20°C was circulated to maintain the temperature on the low temperature side of the heat exchanger. The distance between prime movers was 750 mm. These experimental conditions2) were referred from a previous experimental study and we were able to realize the lowest onset temperature without the heat pump installed. The stack placed in the heat pump was same as the stack used in the prime mover. The length, inner diameter, and channel

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density of the heat pump stack were 50 mm, 41 mm, 1200 channel/in^2. The installation position of the heat pump was 3.13 m from the high temperature side of prime mover 1 stack.

The input power was changed from 30 W to 300 W. The cooling point temperature of the heat pump was measured by a K-type thermocouple. Sound pressure in the loop-tube-type system was measured by eight pressure sensors. The distribution of phase difference between sound pressure and particle velocity by two-sensor method[3)] from the measured sound pressure.

3. Experimental results

The input power dependence on cooling performance is shown in **Fig. 2**. The vertical axis shows the temperature delta of the cooling point from room temperature of 20°C. The cooling performance increases as input power rises up to 50 W, above which it decreases.

Figure 3 shows the distribution of phase difference between sound pressure and particle velocity by a two-sensor method. It shows only 30 W and 300 W. **Figure 4** is a plot of the phase difference versus input power for both the heat exchanger and cooling section of the heat pump stack. This figure illustrates the distribution of phase difference depending on the input power. It is considered that phase difference in the heat pump stack had a significant effect on the cooling performance[4)] of the thermoacoustic cooling system. It is desirable not to change the distribution of phase difference even if the input power is changed. However, in this study, the distribution of phase diffference was changed, which was caused by the increased influence of viscosity due to a rise in temperature of the working gas.

4. Summary

We investigated the effect of increasing input power on the cooling point temperature. It was discovered that the distribution of phase difference between sound pressure and particle velocity changed depending on the input power. This resulted in deterioration of cooling performance.

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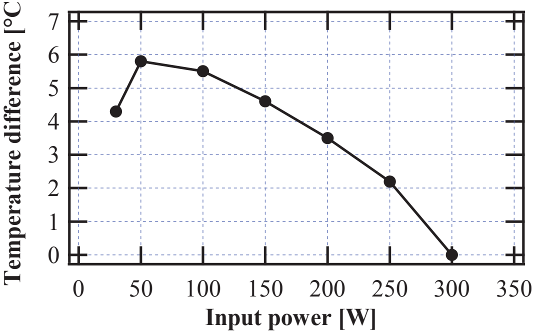

Fig. 2 Relationship between input power and cooling performance.

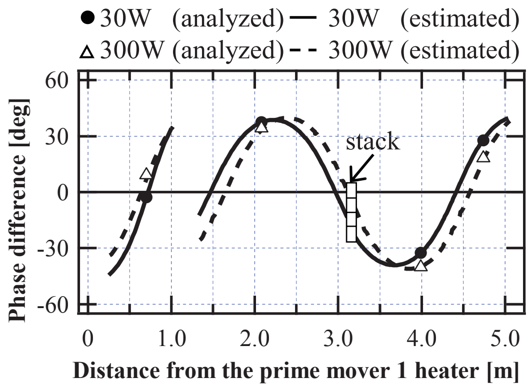

Fig. 3 Distribution of phase difference of sound pressure and particle velocity.

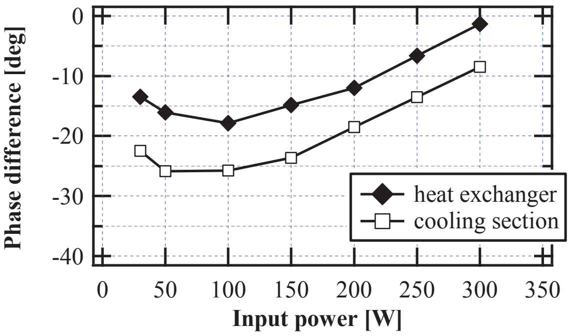

Fig. 4 Relationship between input power and phase difference around heat pump stack

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