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Effect of forced temperature change at thermal buffer tube on sound field in a straight-tube-type thermoacoustic prime mover

直管型熱音響プライムムーバーにおける熱緩衝管の強制的な温度変化が音場に与える影響

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1. Introduction

Research on thermoacoustic systems[1)] utilizing the mutual conversion of energy between sound and heat has proceeded considerably. A thermoacoustic system utilizes unused heat sources, such as solar and factory exhaust heat, as the driving heat source. Several problems exist in practical applications of thermoacoustic systems. One of them is that the heat from the outside is not efficiently transferred to the stack in the system. Therefore, we focus on the leakage of the heat input to the prime mover of the thermoacoustic system from the outside, and study the system for driving it with high efficiency.

A thermoacoustic prime mover consists of a low temperature heat exchanger, stack, and a high temperature heat exchanger. The thermoacoustic oscillation is generated and converted from heat to sound by forming a temperature gradient in the stack. At the same time, heat leakage occurs indirectly through the working gas and tube wall, which is part of the system. As a result, the temperature distribution due to the heat leakage is caused in the outer direction from the heat input region. This section is called "thermal buffer tube," and it affects the driving condition of the system depending on the change in the temperature condition. Based on past studies[2-4)], the onset temperature of the system fluctuates depending on the temperature condition such as the gradient and the range of the thermal buffer tube in the stability analysis.[5,6)]

In this study, the effect of the temperature change in the thermal buffer tube on the thermoacoustic prime mover was confirmed under various conditions. Unusual temperature distributions were formed by forcibly heating the outer wall of the thermal buffer tube with an electric heater, and the effect on the sound field distribution due to the temperature change of the thermal buffer tube was examined.

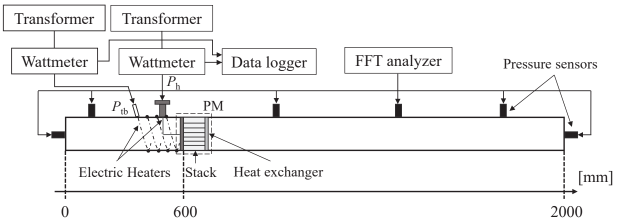

Fig. 1 Experimental system.

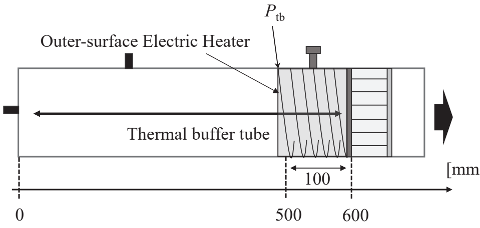

Fig. 2 Thermal buffer tube.

2. Experimental method

A schematic of the experimental system and the thermal buffer tube are shown in **Figs. 1** and **2**. The straight-tube-type thermoacoustic prime mover consisted of stainless steel tubes filled with atmospheric pressure air. The total length of the tube with closed tube was 2000 mm, and the inner diameter was 42.6 mm. The stack was made from ceramic and had a honeycomb structure; the length and channel density of the stack were 50 mm and 600 channels/in^2, respectively. The stack was installed at 600 mm from the closed end ($x = 0$ mm). The high-temperature side of the stack was heated from the inside of the tube by a sheath-type electric heater. The low-temperature side of the stack was maintained at approximately 24°C by circulating water at room temperature through the heat exchanger. In order to change the temperature condition in the thermal buffer tube, the sheath-type electric heater was installed at 500 to 600 mm from the closed end of the tube along the outer wall of the thermal buffer tube. K-type thermocouples were installed at the outer wall of the thermal buffer tube at x = 300, 400, 430, 470, 510, 550, and 590 mm and at the center of the thermal buffer tube at x = 300, 400, and 550 mm to measure the temperature

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change. The sound pressure in the tube was measured by installing six pressure sensors (PCB Piezotronics, 112A21) at x = 0, 200, 720, 1300, 1800, and 2000 mm. The distribution of the sound pressure in the tube was calculated by the two-sensor method[7] and the transfer matrix method[5], respectively, using the measured sound pressure. Where, the temperature gradient in the tube is not taken into consideration.

The experimental procedure was as follows. The input power P_h of the electric heater at the high-temperature side of the stack was set at 100 W. After the sound pressure in the tube and the temperature distribution of the thermal buffer tube reached a steady state, the input power P_tb of the electric heater installed on the outer wall of the thermal buffer tube was changed to 40, 80, and 120 W in a step-by-step manner.

3. Experimental results

The temperature changes at the outer wall and center of the thermal buffer tube is shown in **Fig. 3**. The horizontal axis shows the distance x from the closed end, and the input power P_tb to the outer wall of the thermal buffer tube is 0 and 120 W. Different temperature distributions were formed depending on the input power by heating the outer wall of the thermal buffer tube using the electric heater. In addition, the temperature greatly changed within the heating area of the thermal buffer tube. The temperature inside the tube (x = 550 mm) increased by 125 K when 120 W was input to the thermal buffer tube compared with the case where no heating was provided. At this time, the temperature at the high temperature side of the stack remained almost identical.

The sound pressure distribution in the tube for various values of input power from the electric heater installed on the thermal buffer tube is shown in **Fig. 4**. A change in the temperature distribution of the thermal buffer tube results in a change in the sound pressure inside the entire tube. Comparing the sound pressure at the closed end (x = 0 mm), the sound pressure for P_tb of 0 and 120 W was approximately 640 Pa and 740 Pa, respectively; that is, a sound pressure increase of approximately 100 Pa was observed by changing the temperature distribution of the thermal buffer tube.

4. Conclusion

In this study, we investigated the effect of the temperature change at the thermal buffer tube of a thermoacoustic prime mover system. A part of the thermal buffer tube was forcibly heated with an electric heater to change its the temperature distribution. Temperature distribution of the thermal buffer tube was changed by the forced heating. In addition, the sound pressure in the tube changed when the input power on the outer wall of the thermal buffer tube was increased, that is, when the temperature distribution was changed.

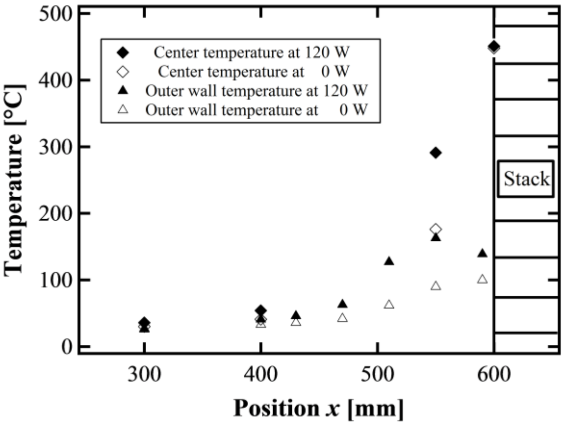

Fig. 3 Temperature changes at the outer wall and center of the thermal buffer tube.

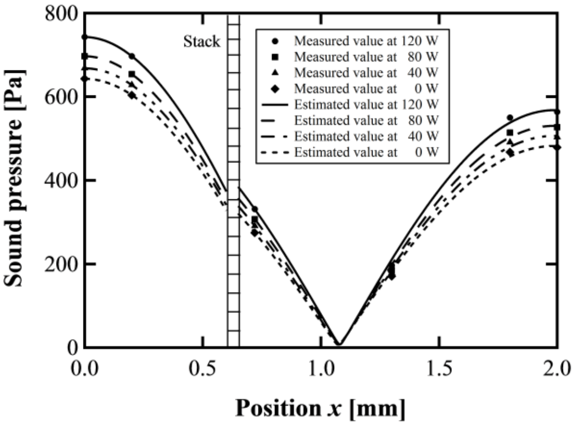

Fig. 4 Sound pressure distribution.

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