1P4-12

Resonance control of coaxial thermoacoustic system by an additional stack
-Examination using an identical thermal input-
同軸型熱音響システムの追加スタックによる共鳴制御
-同一熱入力での検討-

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1. Introduction

A coaxial type thermoacoustic system has been proposed as one of the systems[1]. This type is construced by coaxially setting an internal tube opening both ends in an external tube. The coaxial type is capable of forming a travelling-wave sound field with high efficiency energy conversion similar to a loop-tube type system. In addition, because of its linear shape and more compactness compared to the loop-tube type, the coaxial type has a possibility to solve an issue of system downsizing for the practical use.

Although PM set close to the tube end was expected to enhance the cooling ability in the coaxial type, PM too close to the end was found to result in the degradation of cooling ability by making the resonance mode of the system shift from the fundamental to the second[2]. In this report, a method to add another stack is proposed for controling the resonance mode. The control of the resonance and the sound pressure change to give an index of the cooling ability are experimentally investigated with the identical heater temperature and total input electric-power.

2. Determination of additional stack position

The sound pressure distribution formed in the annular area is focused. The distribution is shown in **Fig. 1**. Since both the fundamental and second modes are on the ascending slope at PM postion too close to the tube end, unneccesary second mode is supposed to be easily excited. So, by additionally setting PM at the position a quarter length distant from the end where both the antinode of the fundamental and the node of the second appear, the suppression of the second mode is attempted.

3. Experimental method

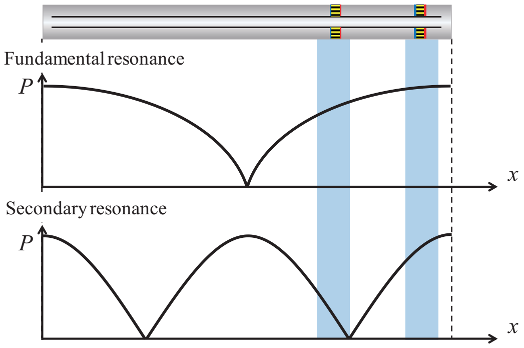

Fig. 1. Sound pressure distribution in the annular area.

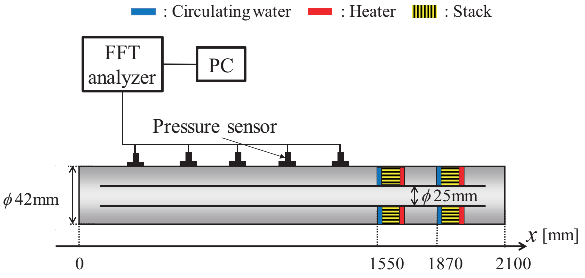

Fig. 2. Experimental setup.

The experimental system is shown in **Fig. 2**. A stainless steel tube with a 42 mm inner diameter and a 2100 mm total length is used for the outer tube closed at both ends. A coordinate whose origin ($x = 0$) is set at the left end of the outer tube is defined. Another stainless tube with a 27 mm outer diameter, a 2000 mm total length and a 1 mm thickness is used for the inner tube open at both ends. The inner tube is set in the range 50 mm $\le x \le$ 2050 mm coaxially with the outer tube. A toroidal stack made from a honeycomb ceramics with a 50 mm length and a 0.65 mm flow-path radius is used for PM. An electric heater is attached to the hot end of PM while 20°C water is circulated around the cold end of PM. One of stacks is set so that the cold end is at $x = 1870$ mm where the cooling ability began to drop in the previous report. To reduce the second mode, another stack is set at $x = 1550$ mm. The electric input power to each PM is set at 165 and 330 W. The sound pressure in the annular flow path is measured with pressure sensors (product of PCB Co.) after time sufficiently lapses so as to arrive at the stationary state. In addition, a similar experiment

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is conducted for the system where PM is set only at 1870 mm for comparison.

4. Results and Discussion

The excitation of the sound wave whose wavelength is the flow-path length is confirmed in every condition. To confirm the control effect on the resonance by adding a stack, the sound pressure difference P_Δ between the fundamental and second modes and the thickness δ_v of viscous boundary layer formed at the hot end of the stack are focused attention. Executing FFT on the waveform of the sound pressure observed with a pressure sensor set at the position 200 mm distant from the left end of the outer tube, P_Δ is obtained. Then, using the temperature at the hot end of PM measured with a K-type thermocouple, δ_v is calculated. The result is shown in **Table I**. Comparing with the single stack system, P_Δ is demonstrated to be enhanced in the dual stack system in either condition. In addition, at the identical input to the heater, the dual stack system has a smaller δ_v than the single stack system. Although δ_v in the case of 330 W input to the dual stack system is almost the same as that of 165 W input to the single stack system, P_Δ increases and the resonance shift to the second mode can be inhibited by the increased δ_v. Consequently, the resonance control by adding the stack is assumed to be effective even in the case of the input to induce high temperature. By adding a stack in the position of the second mode node and the fundamental mode antinode, the second mode is supposed to be suppressed without inhibiting the excitation of the fundamental mode. Hence, the validity of the resonance mode control by the additional stack is suggested.

In either case, the sound pressure in the annular flow path is confirmed to be higher in the dual stack system comparing with the single stack system. As an example, the sound pressure distribution is shown in **Fig. 3** for the case setting the total electric input power to be 330 W for both the dual and single stack systems. Since the total electrical input power is common to both systems, the improvement of the cooling ability due to the resonance control is suggested. The fluid particles with an attenuated vibrational amplitude in the viscous boundary layer hardly works for the heat exchange with the flow path wall. When the heater input is the same, since δ_v decreases in the dual stack system, the fluid particles capable of exchanging the heat with the flow-path wall increase. The effect of the resonance control that the thermal input is well concentrated to amplify the fundamental mode and the thinner viscous boundary layer increases the fluid particles capable of the heat exchange is assumed to cause the enhancement of the sound pressure.

Table I. Difference of sound pressure level and thickness of viscous boundary layer.

	P_Δ[dB]	δ_v at 1550 mm [mm]	δ_v at 1870 mm [mm]
Single stack with 165 W	9.4		0.58
Dual stack with 165 W	21.3	0.44	0.50
Single stack with 330 W	8.7		0.71
Dual stack with 330 W	14.2	0.51	0.61

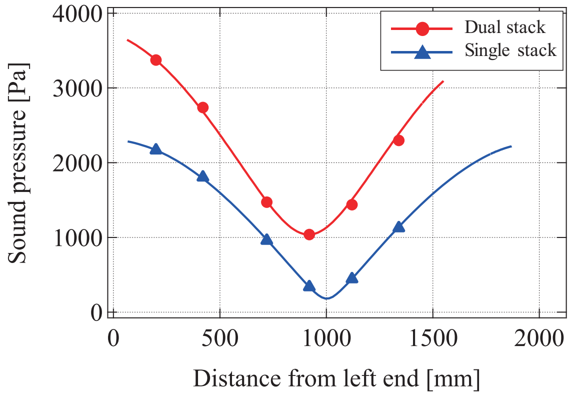

Fig. 3. Distribution of sound pressure.

5. Conclusion

To improve the quality of the coaxial-type thermoacoustic cooling system, the resonance control was attempted by adding another stack. In order to suppress the fundamental mode without inhibiting the excitation of the fundamental mode, the stack was added in the position of the pressure node of the second mode and the pressure antinode of the fundamental mode. By virtue of this, the resonance shift to the second mode could be suppressed. Furthermore, it was suggested that the improvement of the cooling performance is attained by the concentration of the thermal input to the fundamental mode as well as the increased fluid particles capable of heat exchange.

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