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Basic study of HPA temperature and onset temperature in thermoacoustic prime mover by stability analysis

熱音響プライムムーバーにおける HPA 温度と発振温度についての安定性解析による基礎検討

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1. Introduction

Thermoacoustic systems are expected to find application in new types of cooling and power generation systems. This system boasts several advantages, such as the exploitation of unused heat energy and the absence of moving parts (1, 14-16). A great number of researchers, including us, have been investigating how to further develop the potential of this system (1-22).

However, there are two issues that are impeding further progress in the field. The first one is how to increase the energy conversion efficiency between heat and sound (3, 5, 7, 10, 11, 13-22). The second one is how to reduce the onset temperature, which is the temperature at which thermoacoustic phenomena occur (4, 7, 11, 13, 19-22).

In this paper, we investigated how the use of Heat Phase Adjuster (HPA) helped reduce the onset temperature of the loop-tube-type thermoacoustic prime mover (7-11, 13).

The HPA is a device that transfers the surrounding heat to the tube of a thermoacoustic system and adjusts the phase difference of sound pressure and particle velocity. The HPA is a device that adjusts the phase by heating the system from outside. Since the HPA is installed outside the pipe, it is easy to adjust the installation position and driving conditions of HPA (7-11, 13). Additionally, since a heat source is present outside the thermoacoustic system, exhaust heat can be used as a heat source.

We conducted a stability analysis to calculate the onset temperature when the HPA was installed in the loop-tube-type thermoacoustic prime mover (7, 13). The stability analysis was reported by Ueda et al. (20) and has been used for research and development of thermoacoustic systems. Using this stability analysis, we have achieved many good results (7, 8, 13).

2. Experimental Setup and Method

The analysis model used in this stability analysis is shown in Fig. 1(13). The total length of the loop-tube-type thermoacoustic prime mover was 3300 mm, in which the system used atmospheric air as a working fluid. The system consisted of a tube with an inner diameter of 42.6 mm. The stack length and the cell number were 50 mm and 900 cpsi, respectively. The high-temperature end side of the stack was heated using an electric heater (T_H). The temperature on the low-temperature end side of the stack was kept constant by circulating water at 20°C (T_C) in the heat exchanger. The HPA was fixed with a refractory putty by wrapping an electric heater around a flange with a length of 100 mm. This electric heater helped control the HPA temperature (T_{HPA}).

we consider the onset temperature when the HPA temperature is changed. The relationship between the HPA temperature and the onset temperature in the loop-tube-type thermoacoustic prime mover was calculated using stability analysis. The HPA installation position was set to 1990 mm. The HPA temperature was changed from 50°C 250°C.

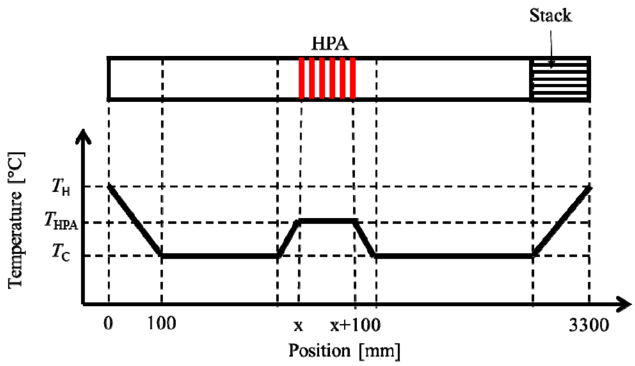

Figure 1 The analysis model used for the stability analysis.

Fig. 2 presents the calculation results (13). As the figure shows, the onset temperature tends to decrease as the HPA temperature increases. When the HPA temperature was 50°C, the onset temperature was 370°C. When the HPA temperature was 250°C, the onset temperature was 127°C. We found that by increasing the HPA temperature by 200°C, namely from 50°C to 250°C, the onset temperature decreased by 243 °C (from 370°C to 127°C).

We investigated the reduction of the onset temperature of the loop-tube-type thermoacoustic prime mover using the HPA. Based on stability analysis, we conducted numerical calculations using a loop-tube-type thermoacoustic prime mover. Numerical calculations confirmed that the HPA temperature had a significant effect on the onset temperature of the loop-tube-type thermoacoustic prime mover. Under these calculation conditions, we demonstrated that the onset temperature decreased by 243°C by increasing the HPA temperature by 200°C.

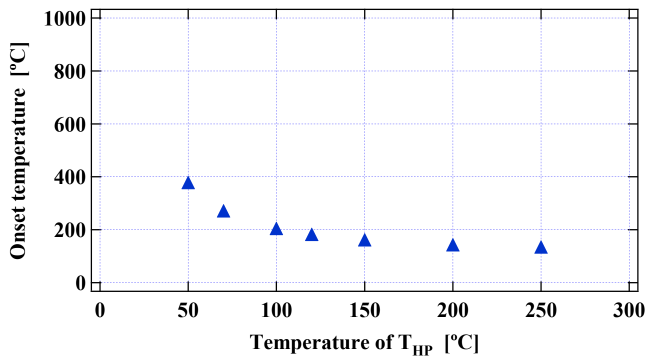

Figure 2 The calculation results of the relationship between the HPA temperature and the onset temperature using stability analysis in the loop-tube-type thermoacoustic prime mover.

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