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Comparison of onset temperature by stability analysis and experiment in changing inner diameter expansion position of loop tube type thermoacoustic system

ループ管型熱音響システムの内径拡大位置変更による安定性解析と実験値の発振温度比較

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1. Introduction

A thermoacoustic phenomenon[1)] is a phenomenon caused by mutual conversion of thermal energy and sound energy. Research and development of thermoacoustic systems is being promoted as a next-generation energy system that can utilize waste heat. However, the onset temperature is regarded as a problem for practical applications. As a study to reduce the onset temperature, multistage installation of a prime mover, which is the energy conversion part[2,3)], and installation of the phase adjuster (PA), which is a device for locally reducing the inner diameter[4,5)], are being addressed. Although significant reductions in the onset temperature have been reported, further study is required for practical applications.

The PA has a structure to reduce the inner diameter, and because the cross-sectional area of a part is changed, reflection and transmission occur at the boundary surface, and the vibration mode changes. Decrease in the onset temperature has been realized by adjusting the inner diameter reduction ratio, length, and installation position of the PA. However, when the inner diameter is locally reduced, dissipation of energy due to viscosity increases. Installation of an expanding phase adjuster (EPA), which is a device for locally expanding the inner diameter, thereby reducing energy dissipation due to viscosity, has been proposed.[6-8)] EPA is considered to change the vibration mode by changing of cross-sectional area like a PA. For these reasons, research has been conducted on energy conversion efficiency of the prime mover with an EPA installed. On the other hand, little research has been done on the onset temperature control.

In this study, an EPA was installed in a part of a loop tube type thermoacoustic system for the purpose of reducing the onset temperature. The installation position was changed by experiment and stability analysis[5,9)], and the onset temperature was compared.

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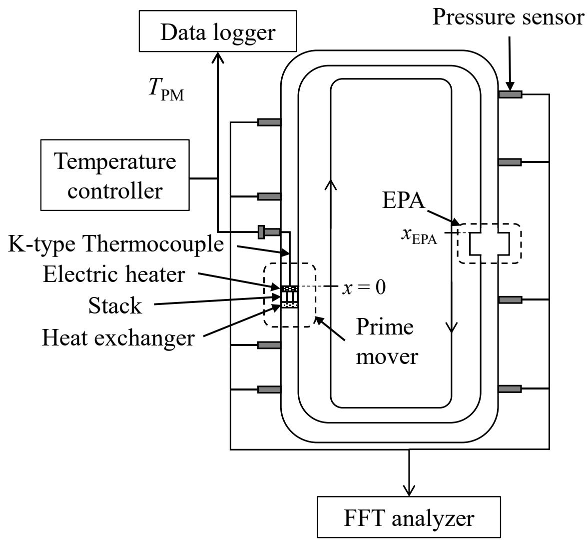

Fig. 1 Experimental system.

2. Analysis system and experimental system

A schematic of the loop tube type thermoacoustic system used for the stability analysis and experiment is shown in **Fig. 1**. Stability analysis is a numerical analysis using a transfer matrix. Stainless steel tubes having a total length L = 5 m and an inner diameter D = 42.6 mm were connected in a loop shape, and atmospheric pressure air was used as a working fluid. The stacks placed in the prime movers were made from ceramic and had a honeycomb structure. The length, and channel density of the prime mover stack were 50 mm and 600 channels/in^2, respectively. The stack in the stability analysis was a parallel cylindrical flow path group with a flow path radius of 0.5185 mm and an opening ratio of 0.85. In the prime mover, an electric heater was used as a high-temperature source. Water at 20°C was circulated in the heat exchanger, and the temperature on the low-temperature side of the prime mover was maintained. In the stability analysis, a linear temperature gradient was assumed for the stack and thermal buffer tube adjacent to the hot end of the prime mover, and the other temperatures were assumed to be uniform. The length of the thermal buffer tube was 0.30 m. The EPA length was 100 mm, and x_{EPA}, which is the distance from the high-temperature end of the prime mover, was changed to 2.75, 2.95, and 3.10 m. In the stability analysis, it was assumed that the EPA cascaded cylindrical flow paths with expanded inner diameters. Regarding the boundary condition of the connecting surface, only the continuity of sound pressure and volume velocity was taken into consideration as with other flow path elements. The installation position was moved between x_{EPA} = 0.30 and 4.80 m at 0.01 m intervals, and the onset temperature was obtained at each installation. For the measurement of the onset temperature in the experiment, the input power to the heater was controlled with a temperature controller so that the temperature of the high-temperature end of the prime mover became constant. The temperature was gradually raised to oscillate the prime mover. Thereafter, the temperature was gradually reduced, and the minimum temperature at which continuous oscillation was confirmed was taken as the onset temperature.[10)]

3. Results

The onset temperatures of each EPA installation position x_{EPA} determined by stability analysis and experiment are shown in **Fig. 2**. In the experiments, the oscillation temperatures at x_{EPA} = 2.75, 2.95, and 3.15 m were 145, 131 and 154°C, respectively. The onset temperature was the lowest at x_{EPA} = 2.95 m, and increased as it moved forward and backward. In the stability analysis, the onset temperatures at x_{EPA} = 2.75, 2.95, and 3.15 m were 144, 121 and 130°C, respectively. The experimental onset temperature was higher than that of the stability analysis, and the difference widened as x_{EPA} increased. However, as can be seen from the fact that the installation position at which the onset temperature is lowest is the same, it was confirmed that stable-temperature analysis is an effective means for determining the installation condition of EPA at which the onset temperature falls.

4. Conclusion

Stability analysis and experiments were carried out to locally expand the inner diameter of a loop tube type thermoacoustic system and change its position. Although the experimental temperature was higher than the oscillation temperature determined by the stability analysis, the trends agreed. In other words, stability analysis is effective for examining the EPA installation conditions.

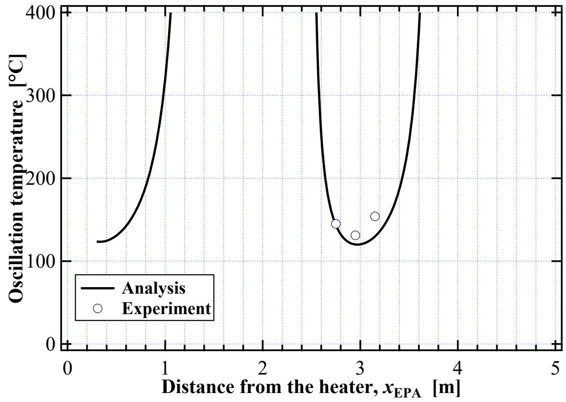

Fig. 2 EPA position dependency of onset temperatures.

Acknowledgment

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