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Effects of Two Different Inner Diameter Tubes on Onset Temperature in a Loop-Tube Thermoacoustic Prime Mover.

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1. Introduction

The thermoacoustic phenomenon[1-3] is a highly captivating subject of study. Its successful application could potentially address critical challenges such as energy crises and global warming. Our team is conducting research aimed at the practical application of thermoacoustic systems[4-17]. We are exploring improvements in the energy conversion efficiency between sound and heat, reducing the onset temperature of the systems, and investigating various system configurations. In this study, we experimentally investigated a loop-tube thermoacoustic prime mover connected with two tubes of different inner diameters.

Similar investigations have been conducted previously. Past studies have particularly focused on enlarging the prime mover section of the loop-tube thermoacoustic prime mover[10, 11]. By expanding the prime mover section, we aimed to increase the input thermal energy and improve the efficiency of energy conversion from heat to sound, achieving a certain degree of success. It was confirmed that the enlargement of the prime mover section improved the onset temperature and the efficiency of energy conversion from heat to sound. However, it was also found that the step at the enlarged section significantly affected the system's conversion efficiency and onset temperature. Additionally, in straight-tube stepped thermoacoustic systems, the inner diameter and length of the step have been found to affect the system's onset temperature and energy conversion efficiency[12].

Therefore, in this study, instead of merely enlarging the prime mover section, we fabricated and experimentally investigated a loop-tube thermoacoustic prime mover using two tubes: one with a large cross-sectional area (expansion tube) and one with a standard tube (medium tube). Specifically, we set the prime mover section in the tube with a large cross-sectional area and experimentally evaluated its performance. We also conducted stability analysis through numerical calculations under the same conditions and compared the results with experimental findings to analyse the system's characteristics in detail.

2. Experiment and Analysis

Figure 1 shows an overview of the loop-tube thermoacoustic system. The total length of the system is 4.2 m, with the inner diameter of the expansion tube being 95.6 mm and a length of 2.2 m, while the inner diameter of the medium tube is 42.6 mm and a length of 2 m. Both the expansion tube and the medium tube are made of stainless steel (SUS304). The working fluid inside the tubes is atmospheric air. A stack with a flow path density of 900 cells/inch² and a length of 50 mm was inserted into the expansion tube. The hot end of the stack was heated by a spiral electric heater (SANKO MH), and a stainless steel (SUS304) metal mesh was inserted between the hot end of the stack and the electric heater to ensure even heat distribution over the entire surface of the stack. A brass heat exchanger was installed at the cold end of the stack, with 20°C water circulating to maintain a constant temperature.

A pressure sensor (PCB, Piezotronics 112A21) was fixed to the wall of the medium tube to measure the sound pressure inside the tube. Considering the minimum resolution and noise of the pressure sensor, the system was designed to oscillate at pressures above 50 Pa. The onset temperature of the system was measured experimentally, and the system successfully achieved self-excited oscillation with an onset temperature of 382 K. Stability analysis was also performed under similar conditions to determine the onset temperature[18, 19]. The onset temperature obtained from the stability analysis was 384 K, and a comparison between the experimental and analytical values showed a difference of a few K.

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3. Summary

We fabricated a loop-tube thermoacoustic prime mover using two tubes of different inner diameters and evaluated its onset temperature. The system successfully achieved self-excited oscillation with an onset temperature of 382 K. Stability analysis performed under similar conditions also yielded an onset temperature of 384 K. The comparison between the experimental and analytical values showed a difference of a few K. The numerical calculations and experimental values were in good agreement, confirming that stability analysis can be utilised for predicting system performance. The results of this study provide important insights for the design and operation of loop-tube thermoacoustic systems.

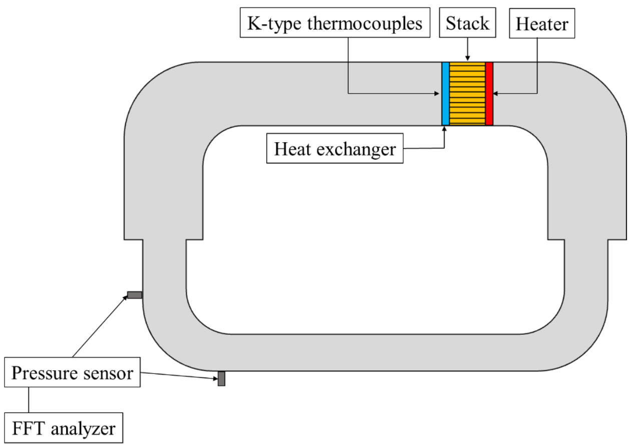

Fig. 1 Experimental system.

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