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Effect of heat exchanger with parallel plate fins on temperature gradient on straight-tube-type thermoacoustic system

直管型熱音響ヒートポンプにおける平行平板フィン付き熱交換器が温度勾配に与える影響

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1. Introduction

Use of a thermoacoustic[1)] system is one of the solutions to overcoming various energy-related problems. A thermoacoustic system occurs mutual conversion between thermal energy and sound energy. Hence, it can possibly be applied for the transport or generation of heat via sound vibration. Because thermoacoustic system is a kind of external combustion engine, it can be driven using waste heat or solar heat as a heat source. For this reason, a thermoacoustic system is expected to be effective in the utilization of unused waste heat. Because a thermoacoustic system is driven by external heat, efficient design of the heat exchanger inputting heat into the system is important. Simulations and experiments on the heat transfer of the heat exchanger fin have conducted.[2–4)] However, experimental investigations of the effect of the heat exchanger shape on the output power of a thermoacoustic system have not yet been performed.

We previously explored heat input to a thermoacoustic system by means of a heat exchanger with parallel plate fins with the aim of increasing the system output.[5)] In another previous study, we confirmed that sound power varies with the fin interval of the heat exchanger.[6)] With regard to this result, we considered that the sound power was affected by the heat flow in the heat exchanger; specifically, this heat flow changed the temperature distribution around the prime mover, which subsequently caused a change in the sound power. In the present study, we measured the temperature distribution around a thermoacoustic heat pump in a forced sound field to confirm the effect of a heat exchanger on the temperature gradient of the heat pump.

2. Experimental system

A schematic illustration of the experimental system is shown in **Fig. 1**. The thermoacoustic system, whose length was 2000 mm, was a stainless steel resonance tube with an inner diameter of 42.6 mm. A sound generator was installed at the left end of the system, and the right end was closed. A detailed schematic illustration of the heat pump is shown in **Fig. 2**. The stack was made of ceramic. The channel density and length of the stack were 600 channels/in^2 and 50 mm, respectively. Temperature of the heat pump was measured using

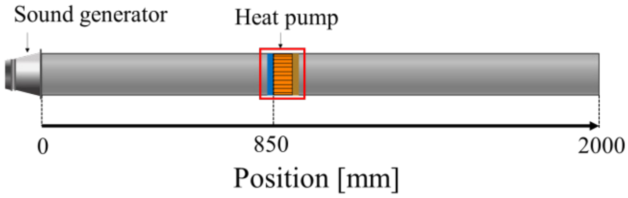

Fig. 1 Schematic illustration of experimental system.

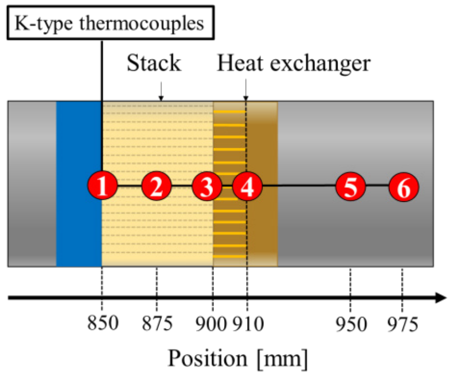

Fig. 2 Detailed schematic illustration of heat pump.

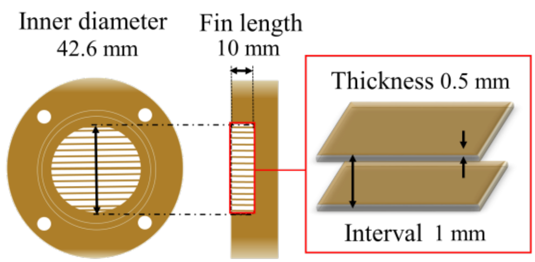

Fig. 3 Schematic illustration of heat exchanger with parallel plate fins.

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K-type thermocouples, which were installed at the following six positions: (1) left end of the stack, (2) center of the stack, (3) right end of the stack, (4) end of the fin, (5) a position at a distance of 50 mm from the right end of the stack, and (6) a position at a distance of 75 mm from the right end of the stack. A low-temperature heat exchanger was installed at the right end of the stack. The temperature of water circulated in the heat exchanger was equal to the temperature of the room. A schematic illustration of the heat exchanger with parallel plate fins was shown in **Fig. 3**. Its inner diameter was 42.6 mm. The fin length and thickness were 10, and 0.5 mm, respectively. The fin interval was 1 mm.

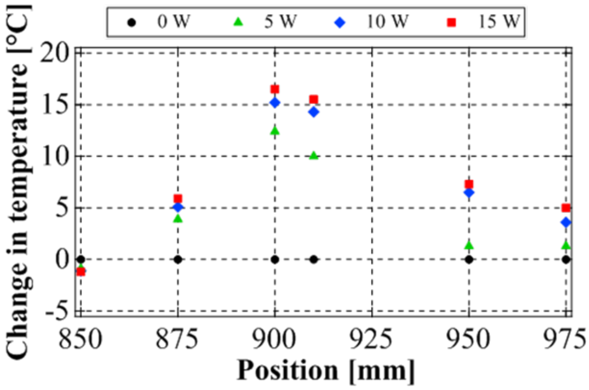
The stack was positioned at a distance of 850 mm from the sound generator. The input powers of the sound generator were 0, 5, 10, and 15 W. Initially, a heat pump comprising only a stack was constructed and used, and the temperature of the heat pump was measured. Subsequently, a heat pump comprising a stack and a heat exchanger was constructed and used, and the temperature of the heat pump was measured.

3. Experimental results

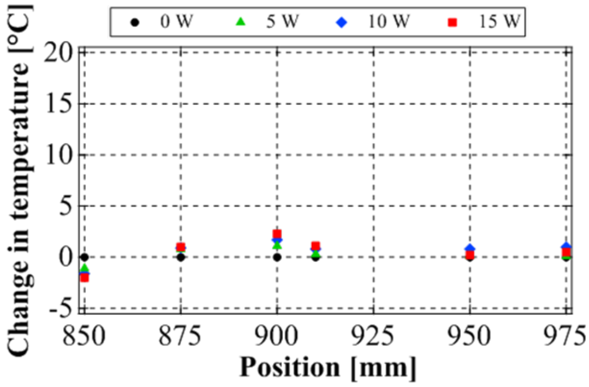
The distribution of temperature of the heat pump is shown in **Figs. 4**. In this figures, the horizontal axis represents the measurement position and the vertical axis represents the temperature. Specifically, Figs. 4, (a) and (b) show the results for the heat pump comprising only the stack, and that comprising both the stack and the heat exchanger, respectively. In both these cases, the temperature of the left end of the stack reduced and that of the right end of the stack increased. Furthermore, at all inputs powers and measurement positions, the temperature increment was smaller for stack and heat exchanger. At the input powers of 15 W, temperature of the right end of the stack increased by 16.5 K in the case of the heat pump comprising only the stack. On the other hand, temperature of the right end of the stack increased by 2.3 K in the case of the heat pump comprising the stack and heat exchanger.

4. Conclusion

In this study, we investigated the effect of a heat exchanger with parallel plate fins on the temperature gradient of a thermoacoustic heat pump. We found that the temperature increment of the heat pump comprising both a stack and a heat exchanger was smaller than that of the heat pump comprising only a stack. This result suggests that heat flow around the fin affected the temperature distribution around the heat pump. It is necessary to further investigate the heat flow around the stack and the fin.



(a) Heat pump constructed of only stack.



(b) Heat pump constructed of stack and heat exchanger.

Figs. 4 Temperature distribution

Acknowledgment

This work was supported by JSPS Grant-in-Aid for Young Scientists (A) (22686090), JSPS Grant-in-Aid for Challenging Exploratory Research (23651072), Grant-in-Aid for Scientific Research (C) (40449509), Program for Fostering Regional Innovation, and JST Super cluster program.

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