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A Study on Loop-Tube Type Thermoacoustic Cooling System for Practical Use
- Effect of Heat Pump Heat Exchanger Cross-Sectional Area on Sound Field and Cooling Capacity -
ループ管方式熱音響冷却システムの実用化に向けた研究
- ヒートポンプ熱交換器の断面積変化が管内音場および冷却能力に及ぼす影響 -

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1. Background

In recent years, depletion of natural resources and global warming have come to present serious social problems. For resolution of those problems, ongoing research of loop tube type thermoacoustic cooling systems (loop tube[1]) is being conducted by this group. Loop tube is an applied thermoacoustic phenomenon[2.3]. Loop tubes emit no greenhouse gases such as carbon dioxide, and use solar heat and exhaust heat as heat sources, using no moving parts: loop tubes are an earth-friendly technology.

2. Purpose

Loop tubes have a system by which the input heat is converted to cold air. Therefore, efficient input of heat and output of cold air is a critical issue for practical use. We present a discussion about the cold air output: how to output cold air from a loop tube. We propose installation of metal at the bottom of heat pump and utilization of heat conduction. Past research has indicated that for determining the position at which the installed heat pump distribution of phase difference Φ in the loop tube is important. In this study, as basic research toward output of cold air in the loop tube, investigation of the effects of heat exchanger installed in a loop tube on the sound field and cooling capacity are conducted.

3. Experimental Method

A block diagram of the measurement system is shown in **Fig. 1**. The system was constructed with an 850-mm-long and 500-mm-wide stainless steel tube, with 3300 mm total length. Its inner diameter was 42 mm. The system was filled with argon; the pressure in the loop tube is 0.2 MPa. The prime mover stack was a 50-mm-long honeycomb ceramic with a 0.55 mm channel radius; the heat pump stack was a 50-mm-long honeycomb ceramic with a 0.35 mm channel radius. Heating power of 200 W was supplied for 600 s from a spiral type electrical heater. The heat exchanger was installed distant 1700 mm from the heater. A photograph and admeasurement of the heat exchanger are shown in **Fig. 2**. Pressure sensors (PCB Inc.) were set on the loop tube wall to measure the sound pressure in the loop tube. The pressure, the phase difference between the pressure and particle velocity, and the sound intensity in the loop tube were all calculated using a two-sensor power method with pressure measurement results[4]. The temperature at the bottom of the prime mover stack was measured using K-type thermocouples.

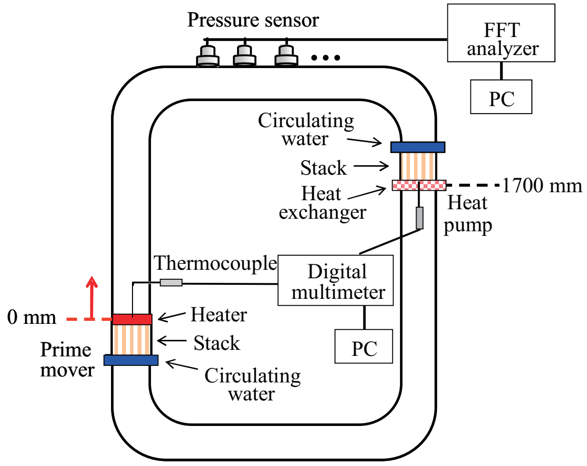
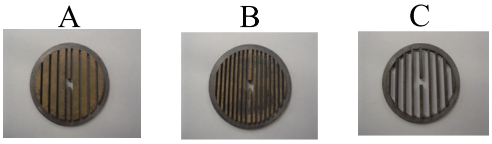


Fig. 1 Experimental system.



	A	B	C
Fin pitch :	1.25 mm	1.25 mm	3.75 mm
Fin width:	3.75 mm	1.25 mm	1.25 mm

Fig. 2 Configuration of heat exchangers.

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4. Results and Discussion

Figure 3 portrays the distribution of the phase difference between the pressure and particle velocity with and without the heat exchanger in the system. The distribution of phase difference with and without the heat exchanger are almost identical. In addition, the result that the distribution of the phase difference is almost identical, irrespective of the configuration of the heat exchanger. The factor is that the position at which installed heat exchanger is near the node of particle velocity. Because the particle velocity value is small at the position of the node of particle velocity at which heat exchanger was installed, the effect of the reflection of a sound wave at the cross-section surface and dissipation by viscosity at the wall surface became small. The distributions of the phase differences without the heat exchanger are almost identical. Therefore, it is not necessary to review the position of the installed heat pump stack circumstantially.

The result that pressure and particle velocity with the heat exchanger in the system decrease is confirmed. Especially, they decrease greatly with heat exchangers A and B. In heat exchanger A, the cross-sectional area is largest, so the pressure and particle velocity decreased by the reflection of the sound wave at the cross-section surface. In heat exchanger B, the wall surface area is largest, so the pressure and particle velocity decreased by dissipation because of the viscosity at the wall surface.

The result that the sound intensity decreases with the heat exchanger in the system is confirmed. The factor is a decrease of the energy conversion efficiency in the prime mover by installation of the heat exchanger. Equation (1) shows the sound intensity: p signifies the sound pressure, u denotes the particle velocity, and Φ stands for the phase difference between the pressure and particle velocity. In this measurement, the phase difference did not change; the pressure and the particle velocity decrease. Therefore, the decreases of pressure and particle velocity decrease the sound intensity.

$$I = pu\cos\Phi \qquad (1)$$

Figure 4 presents the relation between the pressure and temperature decrease. The pressure represents a maximal value. The temperature decrease represents it at the bottom of the heat pump stack. **Fig. 4** shows that the temperature decreases at the bottom of the heat pump stack decrease with decreased pressure. The temperature decrease is the index of cooling capacity. The pressure increase is necessary for development of the cooling capacity.

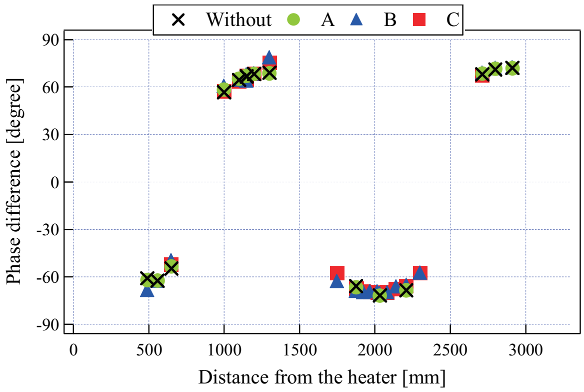

Fig. 3 Phase difference between the sound pressure and particle velocity..

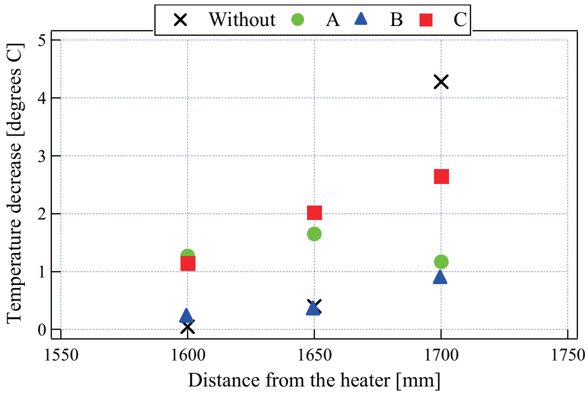

Fig. 4 Distribution of sound intensity.

5. Conclusion

For this study, we used heat exchangers of three kinds and investigated effects of a heat exchanger installed in a loop tube on the sound field and cooling capacity. In this measurement condition, the result confirmed that distribution of the phase difference did not differ irrespective of whether it is with or without the heat exchanger and irrespective of the configuration. It is not necessary to review the position of the installed heat pump stack circumstantially. It is important information for designing heat exchangers in loop tubes in the future.

Acknowledgment

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