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Relationship Between the Fundamental Wavelength and the Phase-Adjuster Length in the Looped-Tube Thermoacoustic System

ループ管型熱音響システムにおける波長とフェーズアジャスタ長さの関係

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1. Introduction

The thermoacoustic[1)] phenomenon i.e. the interconversion between heat energy and sound energy, enables the realization of a cooling system powered with unused energy such as waste heat. The looped-tube thermoacoustic system (loop-tube)[2)] includes two energy-converting components called the prime mover and heat pump. A stack consisting of numerous narrow channels has an important role in each component. Sound waves are generated by forming a steep gradient of temperature at both ends of the stack in the prime mover. When sound waves are generated in the prime mover, one side of the stack in the heat pump is cooled while passing through the heat pump. The benefits of the system are its low cost, maintenance-free operation and driving source of waste heat. However, few practical examples exist because of its low cooling efficiency. It was previously reported that the cooling efficiency can be improved by setting a Phase-Adjuster (PA)[3)] in the system. The higher efficiency can be realized. However the factors which can improve the energy conversion efficiency have many unsolved factors. In this report, we examined the relationship between the fundamental wavelength and the PA length in the loop-tube.

2. Experimental setup

Figure 1 shows the experimental system. The stainless-steel tube in the system has inner diameter of 42 mm and total length of the system was 6600 (Type A) and 3300 mm (Type B) respectively. The working fluid was air at 1 atm. The prime mover consists of an electric heater, a stack, and a circulating water device which keeps it the room temperature stably. The channel radius of the 50-mm-long ceramic stack was 0.45 mm. Inner diameter of the PA was 26 mm. It was previously reported that it can be controlled resonance mode by the position of the PA[4)]. Installation position is shown in **Table I**. Setting the PA at these positions make it possible to select the resonance mode from one to three wavelengths. The length of the PA has changed in 15 - 160 mm. The power of 330 W was supplied to the electric heater of the system. When both ends of the stack in the prime mover reach steady temperature, the sound pressure was measured using the pressure sensors (PCB Piezotronics Inc.). The distribution of sound intensity and the Standing-Wave-Ratio (*SWR*)[5)] were calculated from the measured pressures, using the transfer matrix method[6)] and the two-sensor power method[5)]. The heat supply and the measurements of the pressure are simultaneously started. The measurements are continued for 600 seconds and conducted in all cases.

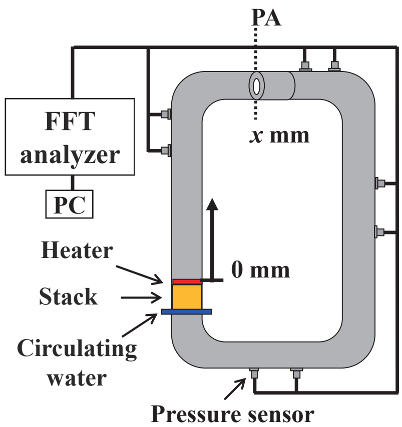

Fig. 1 Experimental system.

Table I. The PA position from the electric heater in the case of each resonance mode.

Loop-tube (Total length)	Setting position of the PA *x* [mm] (Resonance mode)		
Type A (6600 mm)	2225 (1-wavelength)	4425 (2-wavelength)	575 (3-wavelength)
Type B (3300 mm)	1125 (1-wavelength)	575 (2-wavelength)	1950 (3-wavelength)

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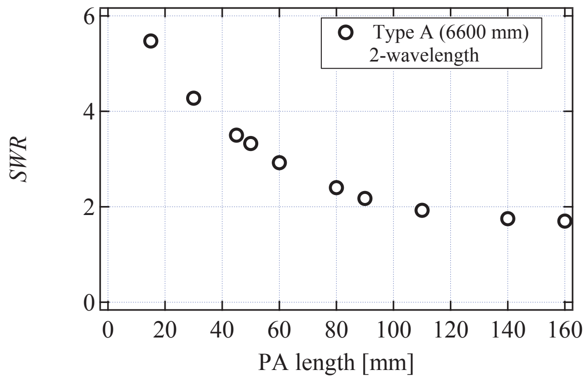

Fig. 2 The relationship between the PA length and the *SWR* (Type A, 2-wavelength resonance mode).

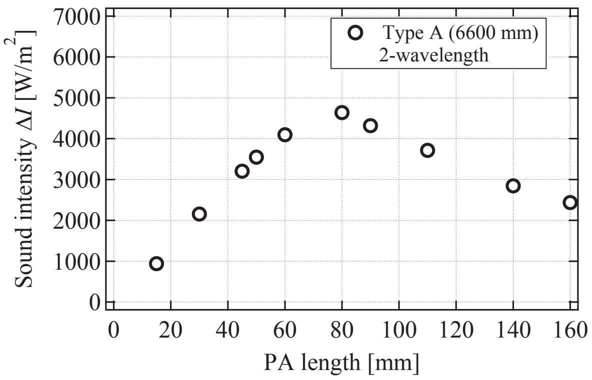

Fig. 3 Sound intensity ΔI in each of the PA length (Type A, 2-wavelength resonance mode).

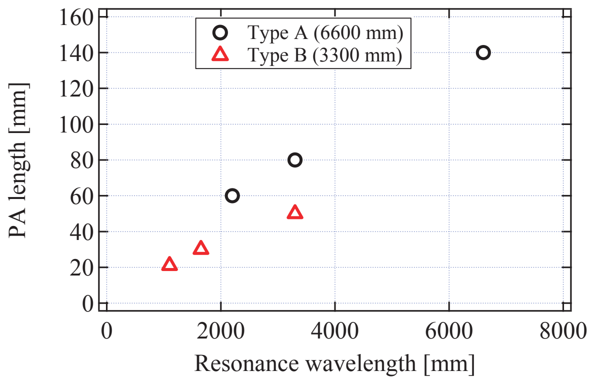

Fig. 4 The optimum length of the PA with respect to the wavelength.

3. Results and Consideration

It is considered that the following factors by increase of the length of the PA.

1. Dissipation of kinetic energy is increased uniformly with respect to the PA length by the wall effect in the PA unit.

2. The *SWR* is decreased in the system. **Figure 2** shows the relationship between the PA length and the *SWR* in the loop-tube of type A under the resonance mode of two-wavelength. As can be seen, the *SWR* decreased with the increase of the PA length. The same tendency was obtained in the other conditions. As the reason for the decline of the *SWR*, it is considered that the PA acted as the attenuator and the reflector of sound waves.

From the above reasons, it can be considered that the optimum length of the PA for each resonance wavelength would be existed by the mutual relationship the *SWR* and energy dissipation. **Figure 3** shows the sound intensity ΔI in each of the PA length in the loop-tube of type A under the resonance mode of two-wavelength. In this case the sound intensity shows the maximum value in the PA length of 80 mm.

The peak PA-lengths aggregated under the each wavelength conditions is gathered. **Figure 4** shows the relationship between the resonance wavelength and the peak PA-lengths of type A or type B. The linear relationships can be found both type A and type B. It was confirmed that we can be estimated the optimum PA length by using suitable linear relationship.

4. Conclusion

In this report, we discussed the relationship between the fundamental wavelength and the PA length in the loop-tube.

These results can indicate that the optimal length of the PA for each wavelength is determined by the mutual relationship between the *SWR* and energy dissipation. It can be found that there is the linear relationship. It was confirmed that we can be estimated the optimum PA length by using suitable linear relationship.

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References

1) S. Backhaus and G. W. Swift: Nature **399** (1999) 335.
2) T. Yazaki, T.Biwa and A.Tominaga: Appl. Phys. Lett. **80** (2002) 157.
3) S. Sakamoto, Y. Imamura and Y. Watanabe: Jpn. J. Appl. Phys. **46** (2007) 4951.
4) G. Inoue, S. Sakamoto, K. Taga and Y. Watanabe: IEICE Tech. Rep. US69-73 (2014) [in Japanese].
5) A.M.Fusco, W.C.Ward and G.W.Swift: J. Acoust. Soc. Am. **91** (1992) 2229.
6) Y. Ueda: J. Power Energ. Syst. **2** (2008) 1276.