3P4-11

Influence of the acoustic impedance in local high temperature range on thermoacoustic system
局所的な高温領域における音響インピーダンスの変化が熱音響システムに与える影響

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1. Introduction

One of the difficulties to realize a thermo-acoustic system is the sound field changeable with the operation environment and subsequent instability of the resonance mode in the loop-tube-type system. As a technique to solve this problem, a heat phase adjuster (HPA) that controls the resonance mode by forming a local high-temperature region in the acoustic tube has been presented. [1] A phase adjuster (PA) [2] and an expanding phase adjuster (EPA) [3] have also been proposed as the methods controlling the resonance mode until now. Comparing with EPA, HPA and PA have the advantage that the setting position and the input heat quantity can be externally changed easily after starting driving the system and the resonance mode is finely tunable corresponding to the driving environment. However, the full picture of HPA has not clarified yet. In this paper, by measuring the reflection ratios at PM and HPA and evaluating the acoustic impedance, the primary factor for enhancing the energy conversion efficiency of the thermoacoustic engine with HPA is discussed.

2. Enhanced Efficiency by HPA

The system used for the experiment is shown in **Fig. 1**. A stainless tube with a 3300 mm total length and a 42 mm inner diameter filled with the working fluid of atmospheric air is used. An electric heater and circulating water are set at the ends of the stack whose length and flow path radius are 50 mm and 0.45 mm, respectively, to construct PM. The input to the heater is kept at 330 W and the cool end is kept at 20°C by circulating water. HPA with a width of 30 mm is set 2000 mm distant from the PM hot end. The input Q_{HPA} of HPA is changed in the range of 0-240 W with a 40 W step. The temperature in the system is measured with a K-type thermocouple. The sound pressure in the tube is also measured with a pressure sensor (product of PCB Co.).

Figure 2 shows the amplified acoustic intensity ΔI for various Q_{HPA}. ΔI attains the maximum at 160 W and decreases for Q_{HPA} over 200 W. Since the high temperature region due to HPA has a different acoustic impedance from other region, this boundary with the discontinuity of acoustic impedance is assumed to contribute to the change of ΔI. According to the increase of Q_{HPA}, the boundary effective for one-wavelength control is created below 160 W and further the boundary to disturb the one-wavelength control is assumed to be created over 200 W. Furthermore, since PM also works for the impedance difference, the boundaries are created at two positions and ΔI is assumed to be determined by the interaction between PM and HPA. Hence, by observing the reflection of a burst wave at PM and HPA, the effect of the boundaries is discussed in the next section.

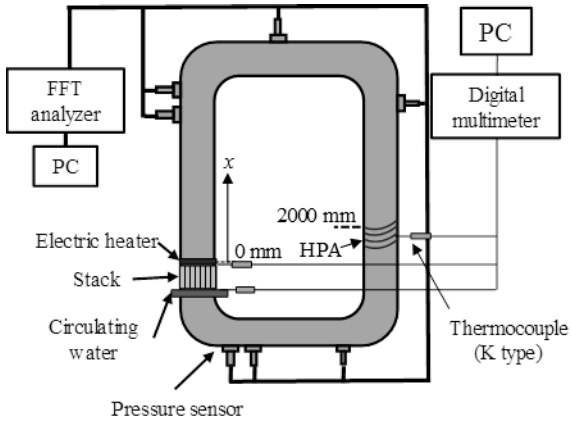


Fig. 1. Experimental setup.

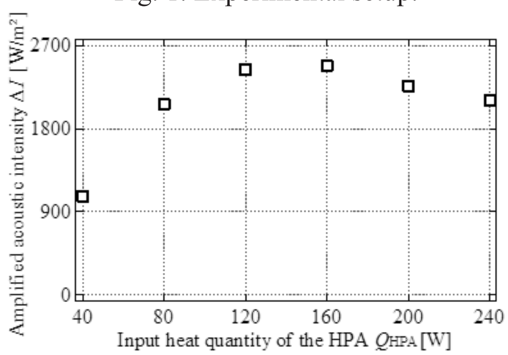


Fig. 2. Amplified acoustic intensity for various Q_{HPA}.

3. Reflection in Thermoacoustic Engine

The system employed for the reflection measurement is shown in **Fig. 3(a)**. Using a stainless tube, a straight acoustic tube with a 7380 mm total length and a 42 mm inner radius is constructed. The working fluid is atmospheric air. A loudspeaker (Fostex 125WK) is set at the left end and a 318 Hz burst wave whose signal voltage is 15 V is fed to the speaker. The sound wave in the tube is measured with a pressure sensor (product of PCB Co.) set on the tube wall.

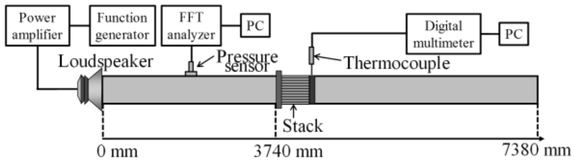
PM stack is set so that the cold end is 3740 mm distant from the loudspeaker. The composition is the same as that used in the previous section. The temperature at the hot end of the stack is adjusted to the same as those observed for Q_{HPA}=40-240 W in the experiment of the previous section and the temperatures at both ends are measured with K-type thermocouples.

Furthermore, by using the same acoustic tube as that used for the measurement of the reflection at PM, the reflection at HPA is measured. The experimental system is shown in **Fig. 3(b)**. The HPA with a 30 mm width is set at the position 3640 mm from the loudspeaker. The input to HPA is varied with a step of 40 W in the range of 40-240 W where the one-wavelength resonance is obtained in the previous section. The temperature at the HPA setting position is measured with a K-type thermocouple.

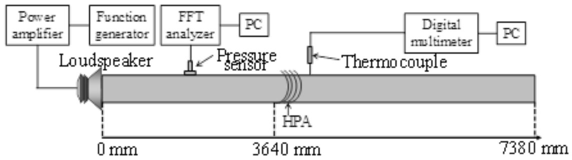
Figure 4 shows the waveform of the sound pressure at HPA with an input of 160 W. Considering the setting positions of the sensor and HPA as well as the sound speed, the first wave is the incident wave from the loudspeaker and the second wave is the reflected wave from HPA. The incident and reflected waves are similarly observed under various conditions for PM and HPA. From these results, calculating the reflection ratio using the peak-peak values of the incident and reflected waves, the acoustic impedance is estimated. The relation between the acoustic impedances and the reflection ratio is expressed by $Z_2/Z_1=(1+R)/(1-R)$, where R is the reflection ratio of the sound that travels from medium 1 to medium 2 whose acoustic impedances are Z_1 and Z_2, respectively. By using the above equation, the impedance ratio of the PM stack and HPA, Z_{PM}/Z_{HPA}, is calculated. **Figure 5** shows Z_{PM}/Z_{HPA} for various inputs to HPA. Since Z_{PM}/Z_{HPA} becomes smaller than unity when Q_{HPA}=200 or 240 W where ΔI decreases, the situation that the acoustic impedance of HPA becomes greater than that of PM is assumed to greatly affect the sound field. Therefore, ΔI is supposed not to increase for Q_{PHA} over 200 W.

4. Conclusion

To discuss the primary factor for enhancing the energy conversion efficiency of the loop-tube-type thermoacoustic engine using HPA, the acoustic impedances of PM and HPA were focused in this report. As a result, to set the input to the HPA so that the ratio of the acoustic impedances of PM and HPA, Z_{PM}/Z_{HPA} did not fall below unity was suggested to be important.



(a) Measurement of reflection at PM



(b) Measurement of reflection at HPA

Fig. 3. Experimental setup.

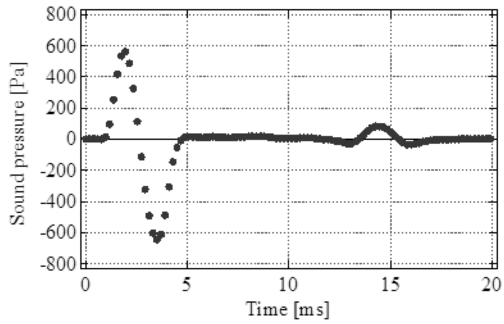


Fig. 4. Sound waveform at HPA.

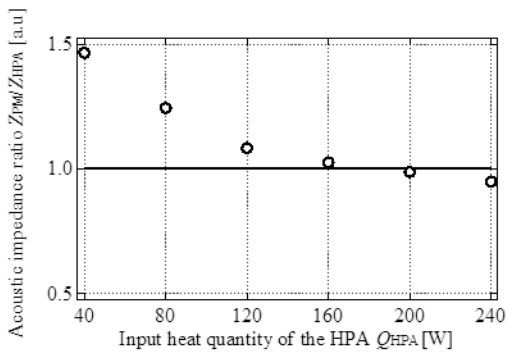


Fig. 5. Acoustic impedance ratio for various Q_{HPA}.

Acknowledgment

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