2P4-9

A Study on the installation position of semilunar PAs in thermoacoustic prime movers.

Shin-ichi Sakamoto1†, Takumi Matsumoto1* ([1] Univ. of Shiga Prefecture)

1. Introduction

Numerous studies have explored the application of thermoacoustic phenomena to develop new systems [1-16], including those utilizing unused energy and innovative cooling systems. Enhancing energy conversion efficiency and exploring the feasibility of operating the system at lower temperature differences are crucial for realizing these systems. It has been proposed by us and succeeded in improving the energy conversion efficiency and low temperature difference drive [8-12, 14-16]. However, the detailed principles of the PA are still being investigated. While previous research has focused on cylindrical PAs, few studies have examined the impact of PAs with different cross-sectional shapes on the system. This paper concentrates on the aperture cross-section of the PA, comparing a conventional cylindrical PA with a Semilunar Phase Adjuster (SPA) [14] that possesses a semilunar cross-sectional shape and a similar aperture area. The locations of the SPA and PA were studied using stability analysis [5,6,11,14].

2. SPA (Semilunar Phase Adjuster)

This paper proposes a Semilunar Phase Adjuster (SPA) [14]. It differs from conventional cylindrical PAs in that it has a semilunar cross-sectional shape. A photograph of the SPA and a PA with an inner diameter of approximately 30 mm when installed in a system tube is shown in Figure 1 [14]. Local tube reduction in a thermoacoustic system increases the particle velocity in the tube, but there are few studies on its effect on the system in the cross-sectional shape of the tube. This paper discusses the effect of the installation position of a semilunar phase adjuster (hereafter referred to as SPA), which has approximately the same cross-sectional area as a PA with an inner diameter of 30.1 mm (hereafter referred to as Φ30PA), on a loop tube thermoacoustic system, using a stability analysis.

E-mail: † sakamoto.s@e.usp.ac.jp,
*ov23tmatsumoto@ec.usp.ac.jp

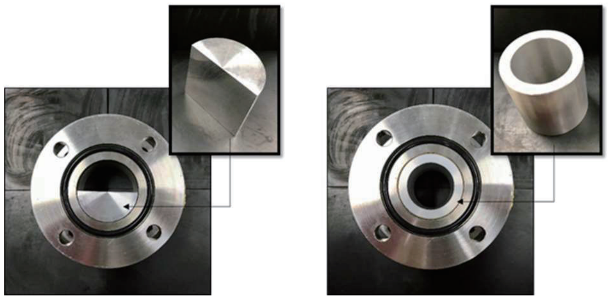

Fig.1 SPA(left) or PA of inner diameter 30 mm (right) installed in the tube. [14]

3. Stability Analysis for installation position of semilunar

SPA and Φ30PA have the same aperture cross section. Currently, stability analysis using the transfer matrix method [5,6,11,14] cannot distinguish between SPA and Φ30PA based on the shape of the cross section. Therefore, in this paper, stability analysis was performed assuming that SPA and Φ30PA are equivalent. The total system length and pipe inner diameter were set to 3.3 m and 42.6 mm, respectively, and the working fluid in the pipe was atmospheric air at 0.1 MPa. The stack was 50 mm long with a channel diameter of 0.75 mm and a porosity of 900 cells/inch2 with a porosity of 0.856. The inner diameter of the PA was 30.1 mm and its length was 45 mm because the SPA and Φ30PA are equivalent. The part of the stack where the temperature decreases continuously from the high-temperature end of the stack to the temperature inside the resonance tube is defined as the thermal buffer tube. The temperature distribution in the thermal buffer tube and the stack was assumed to be linear.

The results of the analysis are shown in Figure 2 [14], and show that the onset temperature differs depending on the position of the PA. 600 K is reached at around 0.7 m, and the onset temperature decreases in a convex shape. The onset temperature was 600 K again at 1.7 m, and then it decreased in a convex shape downward from there. The temperatures between 0.9m and 1.5m and between

2.4m and 3.0m were almost flat with little change. There were two points at which the minimum onset temperature was reached. At 1.175 m, the onset temperature was about 388 K, and at 2.850 m, the onset temperature was about 386 K. The difference between the two points was 2 K, and the difference between the two points was about 1 K. The onset temperature of the PA at 1.175 m was about 388 K, and the onset temperature of the PA at 2.850 m was about 386 K. The difference between the two points was about 2 K, and the onset temperature of the PA at 2.850 m was about 386 K.

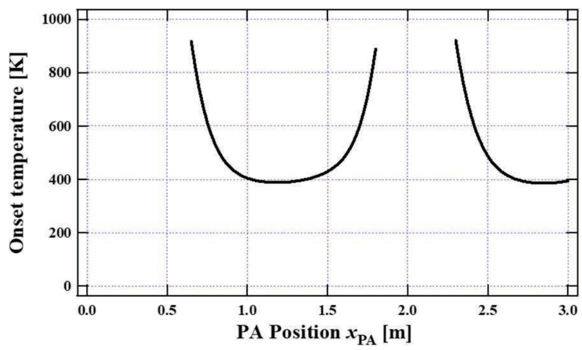

Fig.2 Onset temperature results for position of PA in the stability analysis onset temperature results of SPA and Φ30PA. [14]

Acknowledgment
This work was partly supported by a Grant-in-Aid for Scientific Research (C) [grant number 17K06234, 23K03730] and the University of Shiga Prefecture Fund for Specially Promoted Research.

References

1) A. Tominaga, Netsu Onkyo Kogaku No Kiso (Fundamental Thermoacoustics) (Uchida Roukakuho, Tokyo, 1998) [in Japanese].
2) T. Yazaki, A. Iwata, T. Maekawa, and A. Tominaga, Traveling Wave Thermoacoustic Engine in a Looped Tube, Phys. Rev. Lett., Vol. 81, 3128-3131, 1998.
3) S. Backhaus, and G. W. Swift, "A thermoacoustic Stirling heat engine," Nature, Vol. 399, 335-338, May 1999.
4) Y. Ueda, T. Biwa, U. Mizutani, and T. Yazaki, "Experimental studies of a thermoacoustic Stirling prime mover and its application to a cooler," J. Acoust. Soc. Am., Vol. 115, 1134-1141, 2004.
5) Y. Ueda and C. Kato, "Stability analysis of thermally induced spontaneous gas oscillations in straight and looped tubes", J. Acoust. Soc. Am., Vol. 124, pp. 851–858, 2008.
6) Y. Ueda, "Calculation method for the prediction of the performance of a traveling-wave thermoacoustic cooler," J. Power Energy Syst., Vol. 2, 1276-1282, 2008.
7) T. Biwa, D. Hasegawa, and T. Yazaki, "Low temperature differential thermoacoustic Stirling engine" Appl. Phys. Lett. Vol. 97, No. 3, 034102, 2010.
8) S. Sakamoto, Y. Imamura, and Y. Watanabe, "Improvement of Cooling Effect of Loop-Tube-Type Thermoacoustic Cooling System Applying Phase Adjuster", Jpn. J. Appl. Phys.,Vol. 46, No.7B, 2007, pp. 4951-4955.
9) S. Sakamoto and Y. Watanabe, "Reduction in Temperature Difference of Prime Mover Stack in Loop-Tube-Type Thermoacoustic Cooling System by Applying Phase Adjuster" Jpn. J. Appl. Phys., Vol. 47, pp. 3776–3780, 2008.
10) S. Sakamoto, M. Nishikawa, T. Ishino, Y. Watanabe, and J. Senda, "Effect of Inner Diameter Change of Phase Adjuster on Heat-to-Sound Energy Conversion Efficiency in Loop-Tube-Type Thermoacoustic Prime Mover", Jpn. J. Appl. Phys., Vol. 47, No.5, 2008, pp. 4223-4225.
11) Y. Orino, S. Sakamoto, Y. Inui, T. Ikenoue, and Y. Watanabe, "Numerical analysis of the effect of local diameter reduction on the critical temperature of thermoacoustic oscillations in a looped tube," Jpn. J. Appl. Phys., Vol. 53, 07KE13, 2014.
12) Tatsuya Ishino, Shin-ichi Sakamoto, Yuichiro Orino, Yoshitaka Inui and Yoshiaki Watanabe, "Effect of the relative installation position of two enlarged prime movers on the onset temperature in loop-tube-type multistage thermoacoustic system," Jpn. J. Appl. Phys. 54, 07HE11 (2015).
13) Shin-ichi Sakamoto, Yuji Ise, and Yuichiro Orino, "Measurement of heat flow caused by a standing-wave component generated by a thermoacoustic phenomenon" AIP Advances 9, 115006 (2019).
14) T. Matsumoto, Bachelor thesis of University of Shiga Prefecture in 2020[in Japanese].
15) Takumi Matsumoto and Shin-ichi Sakamoto, "Study of the reduction of the onset temperature in a loop-tube-type thermoacoustic prime mover using conical phase adjuster.—Based study on the installation position and onset temperature of conical phase adjuster", Japanese Journal of Applied Physics, Vol. 61, SG1045 (2022).
16) Takumi Matsumoto and Shin-ichi Sakamoto, "An approach to low-temperature oscillation and high efficiency of thermoacoustic prime mover: influence of end face and reduction area of phase adjuster", Japanese Journal of Applied Physics, Vol. 62, SJ1010 (2023).