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Study of the onset conditions for a thermoacoustic engine

熱音響エンジンの自励発振条件の検討

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1. Introduction

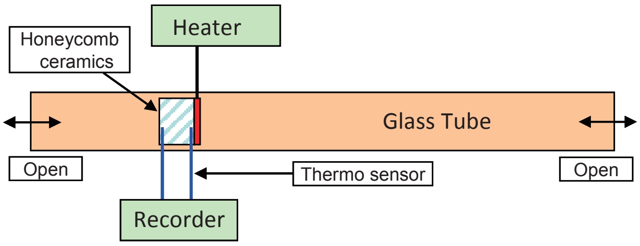
In recent years, the maintenance of the global environment is needed, because there are problems of the global warming and decreasing energy resources. A thermoacoustic system is a unique system for conversion of heat and acoustic energy. There are two energy conversion systems for thermoacoustics. One is thermoacoustic engine which converts heat into sound, another is thermoacoustic heat pump which converts sound into heat (difference of temperature). Unused heat such as waste heat from a factory, the solar heat etc. could be used as the source energy in a thermoacoustic engine. It is expected in future as energy reuse and energy saving. Many researchers have conducted such researches [1-3].

The authors made a basic thermoacoustic engine with a glass tube and a honeycomb ceramics with a heater. In the present paper, it was studied the influence of the tube size, the position of the honeycomb ceramics and the temperature difference.

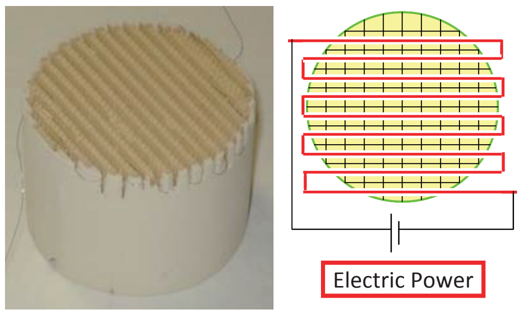
2. Experimental System

Figure 1(a) shows a basic experimental system. The glass tube is 41 mm inside diameter and the length is 800 mm, 600 mm or 400 mm. The both side is opened. A honeycomb ceramics of 30 mm or 20 mm in length is inserted into the glass tube. The edge face of the honeycomb ceramics was twined with nichrome wire which is electric heater in Fig. 1(b). Furthermore, two thermocouple devices were placed at the both ends of the honeycomb ceramics, and the temperature was measured by a recorder.

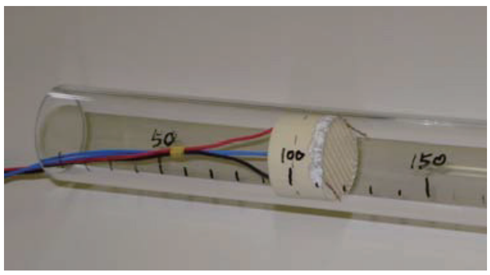
The photograph of the honeycomb ceramics settled in the glass tube shows Fig 1(c). When the heater is on, the temperature difference between the both sides of the honeycomb ceramics increases and it generates beep sound. The sound frequency is decided that the glass tube length is a half wave length. Figure 1(d) is the sound captured by microphone from the beginning of the experiment.



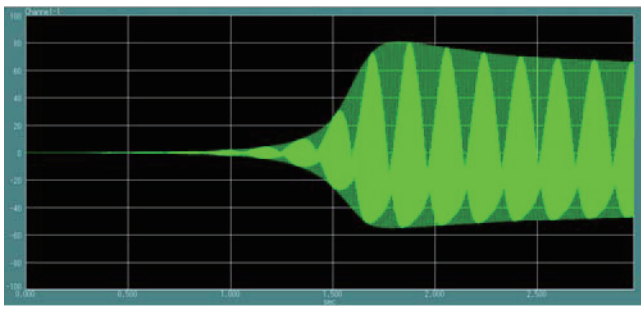
(a) Experimental system.



(b) Honeycomb ceramics with heater.



(c) Photograph of the experimental apparatus.



(d) Recorded sound vibration.

Fig. 1 Experimental apparatus.

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3. Experiment and Discussion

Figure 2 shows the experimentally measured temperature-time curves between the both ends of the honeycomb ceramics. The temperature difference reached 200 degrees after 35 seconds from the start of the heating. The temperature suddenly fluctuated. Then, sound was generated. After the vibration became stable, the temperature increased slowly because heat turns into vibration.

Figure 3 shows the temperature difference between two ends of the honeycomb ceramics as a function of the position of honeycomb ceramics. The tube length was varied as 800 mm, 600 mm and 400 mm. For 400 mm, sound was not generated. However, a reflector was added to the right edge of the tube of 400 mm, sound was generated. This condition is equivalent to 800 mm tube which the both side is opened. The horizontal axis of the graph is normalized to the length of the tube. “0.25” means a quarter of the length of the tube. Theoretically, sound is generated near the quarter point (0.25) for all cases. As the distance from the quarter point increases, the larger temperature difference is required to generate sound.

Next, the length of the honeycomb ceramics was changed to 20 mm in Fig. 4. The results was similar to the case of 30 mm. The sound was generated at lower temperature difference for 20 mm compared to the case of 30 mm. It is probably because the temperature gradient is higher for 20 mm with the same temperature difference compared to the case of 30 mm.

Table 1 show the onset temperature difference for the sound generate on as well as its frequency for various tube length. The length of 1200 mm and 1600 mm in Table 1 means the actual length of 600 mm and 800 mm, respectively with a reflector. The onset temperature difference for sound generation was lower for longer tube. The sound frequency is just to be determined as the tube length being a half wavelength.

4. Conclusion

A simple thermoacoustic engine was made using a glass tube, honeycomb ceramics and the electric heater. The system successfully converted heat into sound. The influence of the position of the honeycomb ceramics as well as the tube length was experimentally studied on the onset temperature for sound generation.

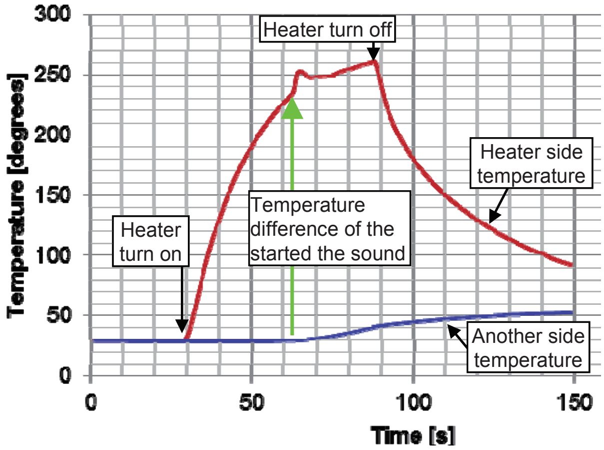

Fig. 2. Temperature-time curves.

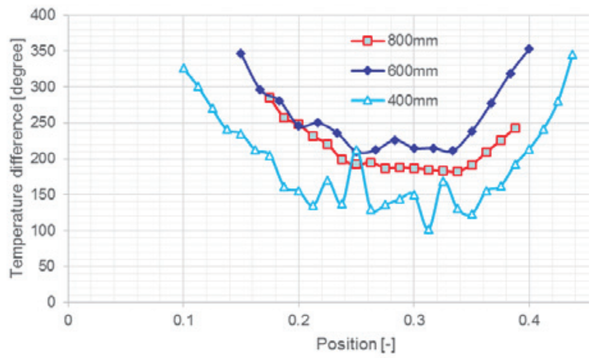

Fig. 3. 30 mm of the honeycomb ceramics.

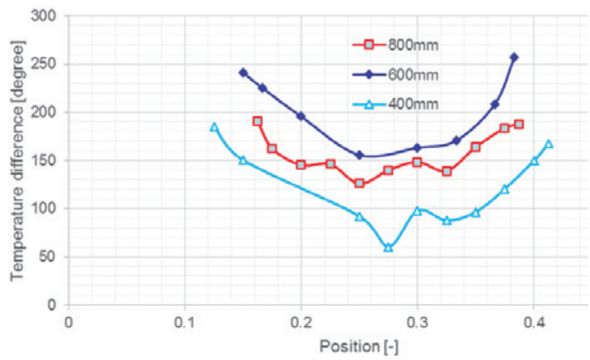

Fig. 4. 20 mm of the honeycomb ceramics.

Table 1.Experimental results

Length of the tube [mm]	Temperature difference [℃]	Frequency [Hz]
400	-	-
600	147	285
800	126	215
1200（600）	74	142
1600（800）	62	107

References

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