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Study of a stack made by a 3D printer in the thermoacoustic system

３Ｄプリンタを用いた熱音響変換素子の造形の試み

Teruyuki Kozuka[1†], Kyuichi Yasui[1], Masaki Yasuoka[1], Kazumi Kato[1], and Shin-ichi Sakamoto[2] ([1]National Institute of Advanced Industrial Science and Technology (AIST); [2]Univ. of Shiga Prefecture)
小塚晃透 [1†]，安井久一 [1]，安岡正喜 [1]，加藤一実 [1]，坂本眞一 [2] ([1] 産総研, [2] 滋賀県立大)

1. Introduction

A thermoacoustic system is a unique system for conversion of heat and acoustic energy. The source energy can be taken from waste heat from a factory. It is expected in future as energy reuse and energy saving. In the previous paper [1], a standing wave field was formed by a speaker in a stainless steel pipe as a thermoacoustic cooler. When there is a stack with a lot of narrow tubes in a standing wave field, difference of temperature occurs at the both ends of the tubes. Some researches of the thermoacoustic have been conducted [2], but it is still necessary to improve the efficiency of thermoacoustic systems for the practical use. Honeycomb ceramics are used as stacks in many researches. The honeycomb ceramics is fabricated by a metallic mold, and it is difficult to change a shape because the mold is expensive. Therefore stacks are molded using a 3D printer in this study. Using 3D printer, new kinds of stacks of various strange shapes for narrow regions are studied to improve energy efficiency of a thermoacoustic system.

2. Stacks

Figure 1 shows a honeycomb ceramics. The honeycomb ceramics are used as stack in many researches in the thermoacoustics. Because, it is made of many penetrating square holes separated by thin walls. Stainless steel mesh has been used as the devices of the energy converter for a long time. There are many varieties of metal meshes such as diameter of a wire, mesh diameter, and metal materials. But, it is difficult to fit each mesh straightly to make the thermoacoustic process work efficiently and to avoid the reflection of sound wave.

By using recently developed 3D printer, an object of any shape could be produced by designing with a PC. The foundation of the 3D printer was presented in 1981, and the 3D printer of various types have been commercialized.

The 3D printer used in the present study uses the FDM method which is used heat dissolution laminating law. This dissolves resin becoming the materials by heat and is the method that melted material was push out through a thin nozzle and laminate.

At first, the object of mesh type was produced with 66 % in aperture rate (②). Next, the object of the slit type was produced. Figure 2 shows a stack by plastic using a 3D printer. They are slit shape of wall-thickness 0.5mm. The distance of the wall was changed from 0.5mm to 3.0mm (③: 3.0 mm, ④: 2.5 mm, ⑤: 2.0 mm, ⑥: 1.5 mm, ⑦: 1.0 mm, ⑧: 0.5 mm).

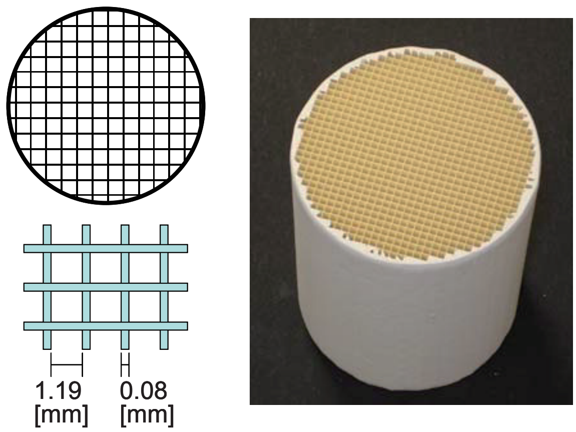

Fig. 1. Honeycomb ceramics　(①)

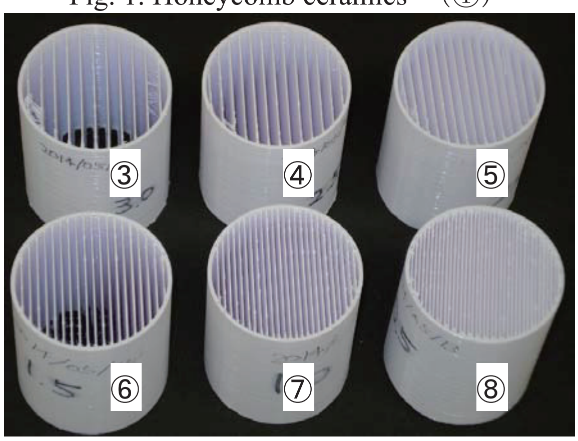

Fig. 2. PLA stacks by 3D printer

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kozuka-t@aist.go.jp

3. Experiment

Figure 3(a) shows a basic experimental system. A stainless steel tube is 42 mm in inner diameter and 1,500 mm in length. There is a speaker (TOA, TU-750) at the left end and a reflector which is a stainless steel board is at the right end of the tube. When the speaker is driven by a function generator and an amplifier, it radiates a sound wave into the tube, and a standing wave field is generated in the tube. The frequency was coordinated so that the wavelength equals the length of the tube. A stack of 50 mm in length is inserted into the measurement pipe. The temperature of both ends of the stack was measured by the thermocouples through the thermocouple ports. It was found that the large difference of temperature occurs in a previous experiment at a position of around 800 mm from a speaker [1]. The stack set around at 800 mm from speaker in this experiment.

Figure 3(b) shows an experimental result. When the speaker was turned on, the temperature of the stack at the speaker side (T1) increased, and the temperature at the reflector side (T2) decreased. The temperature was saturated in about one or two minutes. The maximum of temperature difference |T2-T1| was 25 degrees.

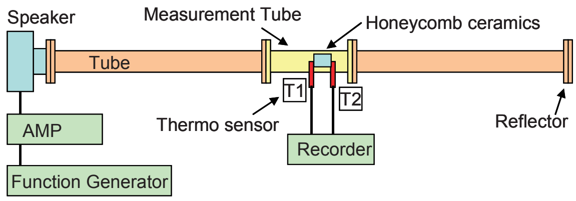
4. Result and Discussion

Figure 4(a) shows the dependence of the temperature difference T2-T1 between two ends of the stack of ceramics (①), PLA-mesh (②) and PLA-slit (③) on its position. Maximum temperature difference of 25 degrees was observed for honeycomb ceramics ①. Next one is PLA-slit formed one, and last is PLA-mesh one. It is thought that the honeycomb ceramics are advantageous to heat exchange with thin wall and slight narrow tubes. Although PLA-mesh and PLA-slit are same aperture ratio, the slit formed one is large surface area than mesh one to contribute to heat exchange.

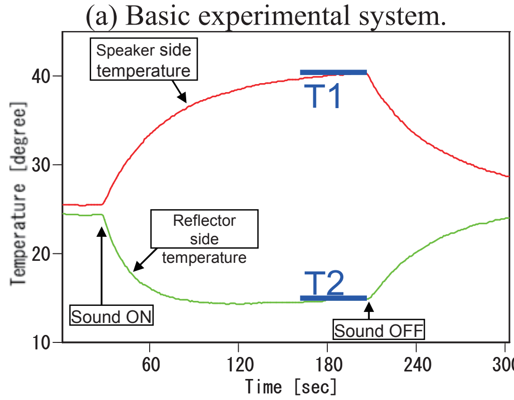
Figure 4(b) shows the effect of the distance of the wall. When the distance is large, the surface area is small and the effect of the heat exchange is little. When the distance between of walls is small, it will interrupt the propagation of the sound wave. Therefore, there is the most suitable distance which is 1.0mm.

3. Conclusion

In conclusion, a stack was molded using a 3D printer in this study. Using 3D printer, new kinds of stacks of various strange shapes for narrow regions are studied to improve energy efficiency of a thermoacoustic system.

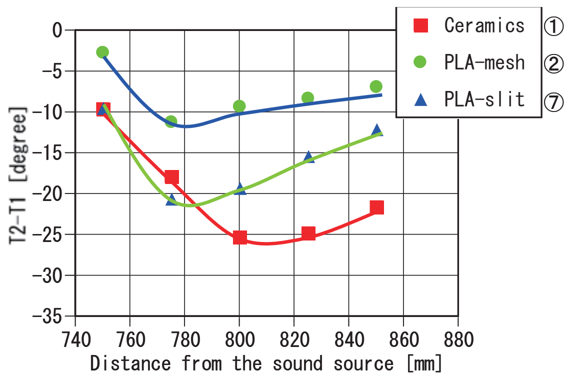


(a) Basic experimental system.

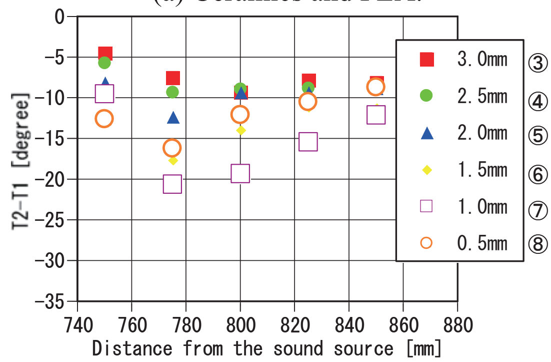


(b) Temprrature-time curves (in experimental).

Fig. 3. Experimentalresults.



(a) Ceramics and PLA.



(b) Dependence of different in the slit distance.

Fig. 4. Experimental results.

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References

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