Development of portable power unit with catalytic micro-combustor

K Higuchi¹, T Nakano¹ and S Takahashi¹

¹Department of Mechanical Engineering, Faculty of Engineering, Gifu University, 1-1 Yanagido, Gifu-shi, Gifu 501-1193, Japan

E-mail: shuhei@gifu-u.ac.jp

Abstract. A prototype of the portable power unit with coupling catalytic microcombustor, thermo-electric modules and air/fuel supply devices was developed. The developed power unit was completely self-standing; the air supply system was driven by a part of electricity generated at the generator unit. When the thermal input from the combustor was 12W, the total electricity is 330 mW and the net output electricity was 225 mW, which corresponded to the back work ratio of 32%. The final conversion efficiency of the total system reached 1.87%, which was order of world record.

1. Introduction

Hydrocarbon fuels have large energy density and therefore, their potentials for microscale power units have been attractive for decades [1, 2]. In the previous research, we have developed a very small combustor which has a monolithic porous catalyst layer on the inner wall of the ceramic tube whose inner diameter is 1.5mm or less [3]. (see Fig. 1) The developed microcombustor can continuously convert the fuel’s chemical enthalpy to thermal energy for hours. If the thermoelectric (TE) modules are coupled with the combustor, we can obtain very small power unit that generate a certain amount of

Figure 1. Developed catalytic microcombustor working at 11.7W of thermal output. The inner diameter is 1.5mm, which is smaller than the quenching distance of butane-air mixture.
electricity and the rest heat as thermal energy.

In the previous PowerMEMS conference, we have discussed the feasibility of a micro-cogenerator which could self-stand with coupling our microcombustor, TE modules and micro-blower that supplied necessary air to the combustor [4]. In the present paper, we introduce a completely self-standing micro power unit with 12W class combustor which drives fuel and air supply system and generates 225mW as the net electricity.

2. Experimental setup

Figure 2 shows the components of the portable power unit and the microcombustor used as the heat source. The nominal thermal output of the microcombustor was 12.2 W at 7.0 sccm of fuel flow rate, and the fuel was mixture of propane and butane (propane/butane = 30/70 in vol%); the compressed liquid fuel for conventional gas lighter was stored in a small gas tank. The combustor was inserted the heat receiver made of copper, and 6 TE modules (1MD04-017-1, RMT Ltd., 3.8 × 3.8 × 2.3 mm) were set between the heat receiver and the heat sinks. The size of the heat receiver was 4 × 4 × 18 mm, and it has a hole whose diameter was 2.7 mm and the depth was 15mm. The microcombustor was inserted in to the hole and the temperature difference about 200K was achieved between the heat receiver and the heat sinks. The heat sink was cooled by ice blocks in order to set the low temperature side constant.

![Figure 2. Components of micro-power unit and the dimensions of the power generator unit.](image)

The schematic of the flow system power unit is shown in Fig. 3. The fuel is supplied by its vapor pressure and the flow rate was monitored by the mass flow meter. In order to stabilize the flow rate, the fuel tank was put into the water bath of 310K. The flow rate was adjusted by the small valve installed in the tank and the valve clearance was fixed though the experiment. The air is supplied by the micro-blower (Murata Manufacturing Co., Ltd., 20 × 20 × 1.85 mm) which is driven by a part of electricity generated at the TE modules and the rest was consumed at the variable resistor, which is accounted as the net output. The electricity consumed at the micro-blower including DC-DC converter was also recorded. In order to start the developed power unit, we first ran the micro-blower by an external power device. After the combustor attained steady state and generate sufficient electricity from the TE modules, then we switched the input of the blower to TE modules and removed the external power device.

The fuel flow rate was adjusted to be 7.0 sccm by the micro-valve of the fuel tank, and the air flow rate was controlled by the driving voltage of the blower. The relation between the driving voltage and the air flow rate was investigated in advance. In the present experiment, the driving voltage was set to be 12V, which can supply the stoichiometric air to the combustor. The variable resistor was set at 70Ω in order to maximize the net output. The net output was calculated by measuring the voltage
between the resistor, and the consumed electricity at the blower with DC-DC converter was calculated by measuring the voltage and the current at the junctions of DC-DC converter.

3. Results and discussion

Figure 4 shows the histories of fuel flow rate. It is found that the flow rate slightly decreased from 7.5 to 5.8 sccm with time, but combustion was kept more than 20min and quenched finally. Because the air flow rate was constant, the equivalence ratio of the supplied mixture also gradually decreased in time, and it was the reason for the quenching.

The total output from the generator unit, the consumed power at the micro-blower and the net output consumed at the variable resistor were shown in Fig. 5. For the first 12min, the voltage at the TE modules was constant, which was 3.9V. The open-circuit voltage was about 7.8V, therefore it was thought that the variable resistor was adjusted properly. The net output was almost 225mW during the first 12min whereas the fuel flow rate varied from 7.5 to 6.9sccm. It was because the air flow rate was adjusted to be stoichiometry when the fuel flow rate was 7.0 sccm. Therefore, during the first 12 min, the mixture was slightly rich and the thermal input from the combustor was almost constant, which was 12.0W near the nominal condition. During this steady period, the ratio of the power consumed at the blower to the total output, which corresponds to the back work ratio, was 32%.

![Figure 3. Schematic of the developed micro-power unit.](image)

![Figure 4. History of fuel flow rate.](image)

![Figure 5. Histories of the total/net outputs and the consumed electricity at the blower.](image)

![Figure 6. History of the voltage from the generator unit.](image)
Figure 6 shows the history of voltage from the generator unit. After 12 min, it is found that the voltage from the TE modules decreased, which caused the increase of the consumed power at the blower, and eventually caused the large drop of the net output. The final conversion efficiency of the developed power unit is shown in Fig. 7. It is found that final efficiency of the system including fuel and air supply units reached 1.87%.

![Graph showing efficiency over time]

**Figure 7.** Final conversion efficiency from thermal input to the net output electricity.

4. Summary

We developed a self-standing micro-power unit whose final conversion efficiency was 1.87%. For the thermal input of 12W, the total output from the generator unit was 330mW and the net output was 225mW, which correspond to the back work ratio of 32%. Although there was the issue of stable fuel supply, the prototype recorded reasonable performance.

References

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