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Development of Exhaust device utilizing Solid Oxide Fuel Cell to collect electricity from exhaust gas and reduce emission

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Abstract

New exhaust device of Solid Oxide Fuel Cell (SOFC) had been developed in former study. the purpose of it is to collect electricity from exhaust gas and to reduce emission of exhaust gas by means of chemical decomposition of the gas itself.

The studies demonstrate that the function of electricity generation from exhaust gas so far [1-4]. The amount of generated power, however, is not sufficient to our estimation. Also It does not prove the other function of reduction of emission of exhaust gas.

Therefore, in order to increase the amount of electricity collection, and to prove the function of emission-reduction of exhaust gas, the new design, that more gas existence among SOFC cells can be expected when exhaust gas pass through the device, is proposed, and also monitoring of gas-shift reaction is executed. Although the device can not improve the amount of electricity generation, the experimental results shows 42% reduction of CO, 42.5% reduction of CO₂, and 66.3% reduction of NO in this paper.

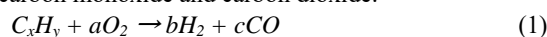
Keywords: Solid Oxide Fuel Cell (SOFC), internal combustion engine, emission reduction, exhaust- gas generation.

1. Introduction

For the purpose of electricity generation and purification of the exhaust gas, the SOFC device has been developed in the author's laboratory [1-4]. Along the development of SOFC, a stack structure that is focused on productivity and heat retaining property has been developed. However, its electricity generating ability is ten times lower than our estimation and its cause is not clear. Its function of emission reduction also has not been verified. Upon having those obscure results, the improvement of electricity generating ability after making a design change to improve retention of exhaust gas during its transit through an exhaust pipe and exhaust gas purifying function by using a laminated fuel cell stack are experimented in this paper.

2. Three chemical reactions in an exhaust pipe

The inside of an exhaust pipe becomes more than 600 °C , which is very similar to an operating environment of SOFC. If the unburned hydrocarbon exists in an exhaust pipe Reforming reaction occurs from steam which is caused by burning gasoline, carbon monoxide and carbon dioxide:



SOFC is able to generate electricity by reacting oxide ion in cathode to CO and H₂ in anode. This theory is supported since electricity generation was recognized in the former experiments. Therefore, the fact that SOFC is able to generate electricity means that it is

also able to purify air pollutants such as hydrocarbon and carbon monoxide. This suggests that an existence of a purifying function can be verified by measuring these substances at an inlet and outlet of the SOFC unit.

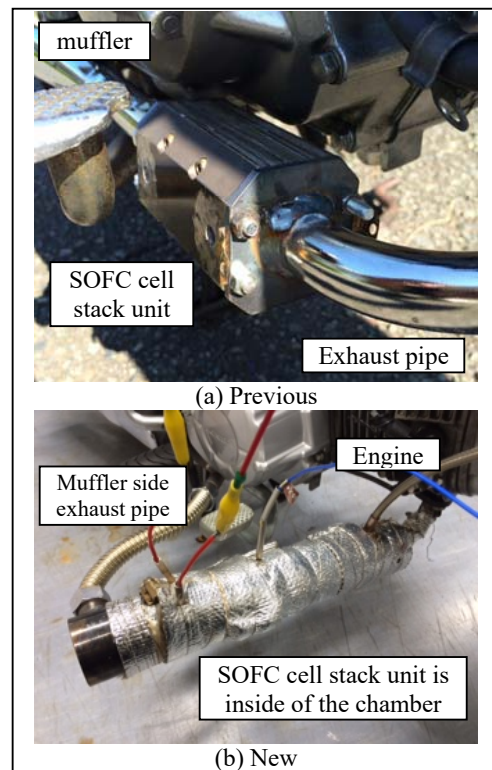


Fig. 1 Experimental device

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3. Experimental instruments

3.1 Improvements of a SOFC unit

The unit developed in the former study [1-4] was the kind that was connected directly to an exhaust pipe as shown in Figure1(a) and had the structure that exhaust gases pass through the inside of the unit. For this reason, it has been observed that exhaust gases pass through the unit in a moment and that fuel cells in the unit are vibrated by the engine's exhaust pressure fluctuation.

To solve these problems, the unit is re-designed by installing an expansion chamber as shown in Figure1(b) to avoid exhaust gases from directly touching fuel cells in this research. Simultaneously, longer retention of exhaust gases in the exhaust pipe is expected from this design change.

3.2 Experimental vehicle

A small-size motorcycle, which has 110cc air-cooled four-stroke single-cylinder engine (Honda Motor Co., Ltd.), is used in this research (Fig.2). The SOFC unit is installed of Fig.2. Table1 indicates specifications of the motorcycle.



Fig. 2 Experimental vehicle

Table 1 Specification of experimental vehicle

Model	Honda EBJ-JA07
Displacement	0.109 L
Weight	93 kg
Starting method	Kick type self-service features
Engine type	4cycle air cooling single cylinder
Cylinder number and layout	1 • horizontal storage
Maximum output	6.0 kW (8.2 PS) / 7500 rpm
Maximum torque	8.4 N • m (0.85kgf • m) / 5500rpm

4. Experimental results

4.1 Experiment 1: Measuring improvement of electricity generation characteristics

Fig. 3 indicates an overview of voltage measurement system. This experiment is carried out on a 110cc air-

cooled four-stroke single-cylinder engine of the experimental vehicle.

In order to obtain basic performance of new unit, the I-V characteristic of the unit is measured under two conditions: supplying regular gasoline and keeping the engine speed 5000rpm.

Figure5 shows the I-V characteristic of former design of SOFC unit, and Figure 6 shows that of the new design. Our research group has already reported in another paper, that describes current density is tens of times greater than that of Figure 6 when the device is applied for an engine of a 400cc medium-size motorcycle.

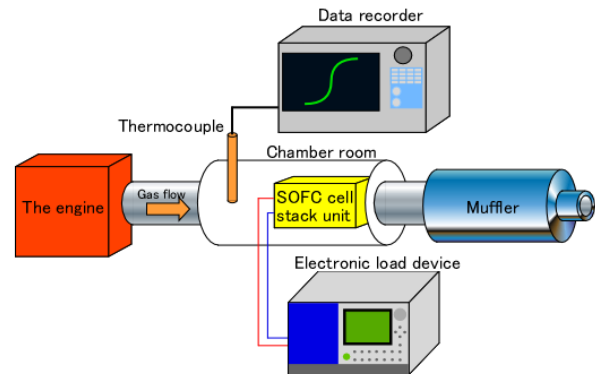


Fig. 3 Measurement system



Fig. 4 Electronic load device

Table 2 Specification of electronic load device

Model	PLZ164WA
Operating voltage (DC)	0V~150V
Current	33A
Power	154W
Minimum starting voltage	over 0.3V and over

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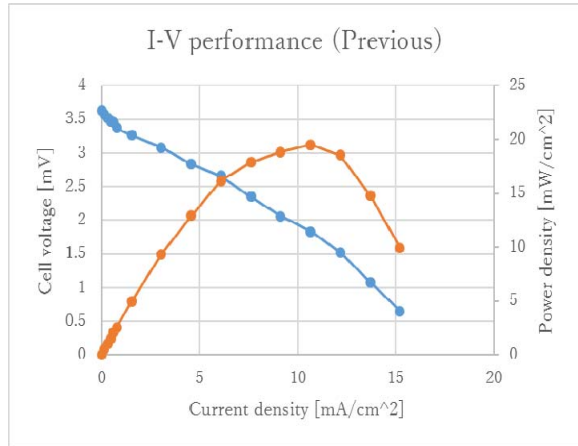


Fig. 5 I-V performance (previous)

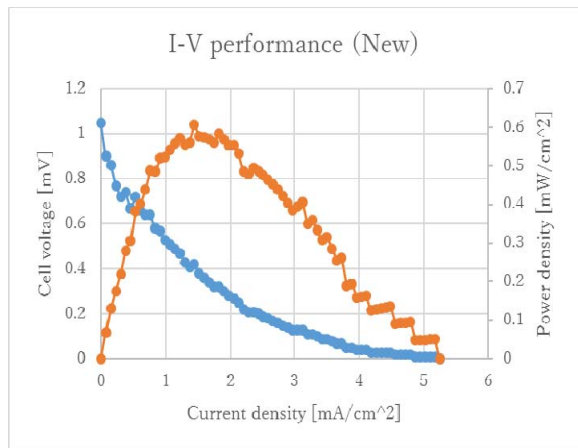


Fig. 6 I-V performance (new)

However, no improvement of electricity generating performance is found in this experiment. One of the causes of the result is that existence of exhaust gas in the unit can be considered. Therefore it is necessary that to check from the assembling of the cell-stack unit to experiment procedures.

4.2 Experiment 2: Verifying function of emission reduction

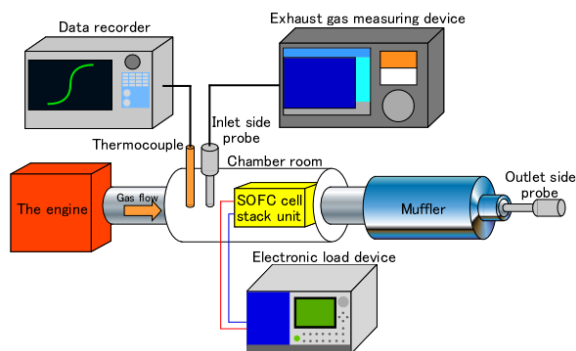


Fig. 7 Measuring set-up



Fig. 8 Exhaust gas measuring device

In this experiment, three different devices that measure voltage, temperature, and components of exhaust gas were installed into the exhaust pipe to measure components of exhaust gas as shown in Figure7. Voltage and temperature of a SOFC unit and components of exhaust gas (CO, HC, CO₂, O₂) at an inlet and outlet of the unit are measured. An exhaust gas measuring device (HORIBA, Figure8) is employed in this experiment. Fig.9 is the obtained results.

These experiments resulted in 42% reduction of CO, 42.5% reduction of CO₂, and 66.3% reduction of NO. Through this experiment, it is proved that the SOFC device has an emission reducing function.

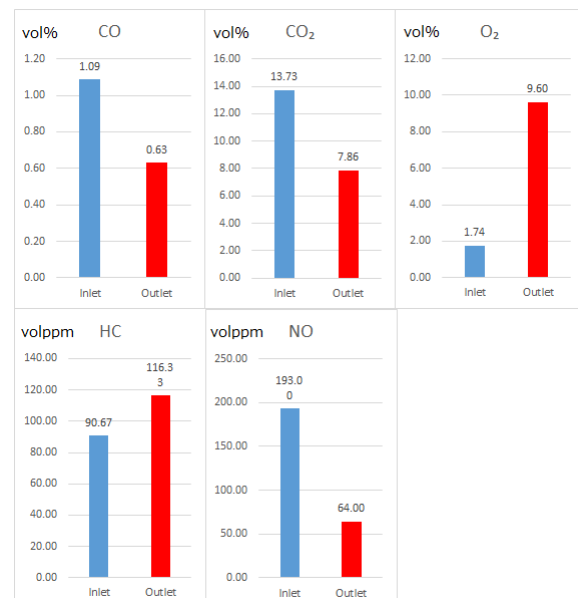


Fig. 9 results of purification experiment of exhaust gas

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5. Conclusions

In order to increase the amount of electricity collection and to prove the function of emission-reduction of exhaust gas, the new design that more gas existence among each cell in SOFC unit can be expected when exhaust gas go through the device, is proposed. The collection performance of electricity and emission-reduction is investigated in this reports. In the experiment, the developed SOFC device is installed to 110cc small displacement of single-cylinder engine. The experiment is executed at 5000 min^{-1} of engine speed. Although the new design is aiming about preservation of exhaust gas to bring about electro-chemical reaction between components of gas and cells, no improvement of performance of electricity-collection is obtained. Meanwhile it is proved that electro-chemical reactions under high temperature of exhaust gas condition helps to solve emission gas such as CO, CO₂ and HC. Therefore, performance of emission reduction is confirmed.

6. Acknowledgement

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7. References

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