Stable Performance of PEFC in a Closed Environment without Humidification

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1. Introduction

The Japan Aerospace Exploration Agency (JAXA) is developing fuel cell systems for aerospace missions like high-altitude balloons, transfer vehicles, and reusable spacecraft. Fuel cells used for such missions must be able to operate under isolated micro-gravity conditions. It is also very important to make the simplest system for space applications.

Our previous study using 100 W and 1 kW-class fuel cell stacks revealed that the polymer electrolyte fuel cells could be operated without humidification by using a combination of pure hydrogen and oxygen. To continuously generate electricity, hydrogen and oxygen must be supplied from the opposite directions. This is possible even when the hydrogen outlet port is dead-ended and oxygen gas is recycled to increase consumption of the reactants.[1, 2]

In this report, we present the performance of a fuel cell system for closed environments. The system has a dehydrator that can remove the produced water without using the effect of gravity. We also demonstrated the performance of the system in simulated Space Shuttle operations.

2. Experimental

We prepared the separator of the fuel cell stack using graphite with a serpentine gas flow channel, and an off-the-shelf Membrane Electrode Assembly (MEA) obtained through a Japanese agent. The MEA, which is reinforced and 30 μm thick, was sandwiched by the separators. The effective surface area of the Pt catalyst layer on the MEA was 162 cm^2.

We used six pairs of cells. Two cells shared a separator with water coolant to keep the fuel cell temperature at 60 to 65 degrees C. We used high-grade hydrogen (99.99999%) and oxygen (99.999%) when we simulated the closed-environment conditions to minimize the degradation of cell performance.

The dehydrator consists of two cylinders. It is located in the oxygen outlet line, and excess oxygen passes through it. Humid oxygen passing through one of the cylinders is cooled to 5 degrees C. The humidity in the gas is absorbed as water by the wick inside the cylinder, and the water is ejected by a piston. When one cylinder ejects water, oxygen flows to the other cylinder.

When we tested the performance of the fuel cell system continuously, the oxygen line was looped to circulate the excess oxygen. The hydrogen outlet port was closed, and purging was repeated at specific intervals.

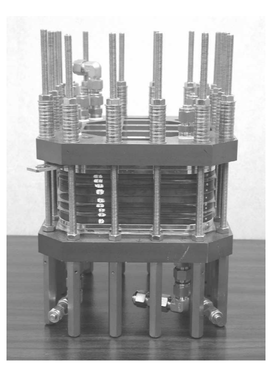

Fig. 1 A photograph of a six-cell-stack.

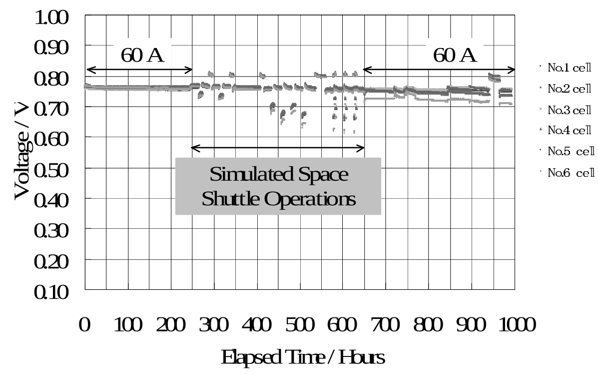

Fig. 2 The continuous operation of a fuel cell. Six cell voltages are listed.

3. Results and Discussions

Fig. 1 illustrates the fuel cell we tested. We supplied hydrogen and oxygen from opposite ports of the fuel cell in our conventional way and achieved stable fuel cell performance without humidification.[1), 2)]

Fig. 2 presents the performance of the fuel cell system. First, the performance of the fuel cell was checked for 250 hours while it continuously generated 60 A. We then simulated Space Shuttle operation for 400 hours. In this test, we varied the current level from 30 to 150 A. Though we did not change gas flow or circulation rate, we did not observe any performance degradation. Fig. 3 depicts the relationship between current and voltage when we changed the current level. As this figure demonstrates, the voltage dropped when the current increased. This was caused by the slight drying of the proton conducting membrane, but the fuel cell performance was restored when equilibrium between the current and the production of water was established. When the current decreased, we also observed the opposite tendency as depicted in Fig. 3.

We then returned to continuous operation at 60 A. One cell began to show a slight drop in voltage, but the difference of performance among the cells never increased during the operation. This degradation might have been caused by flooding during the rest state.

Through these operations, we were able to demonstrate the performance of the fuel cell without humidification in isolated conditions.

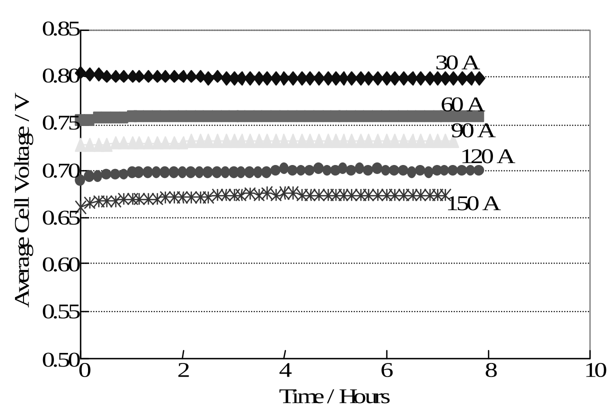

Fig. 3 Change in average cell voltage at different current levels with the elapse of time

References

1) Y. Sone, M. Ueno, and S. Kuwajima, Elctrochemistry, 71, 938 (2003) (in Japanese)
2) Y. Sone, M. Ueno, and S. Kuwajima, J. Power Sources, in press.