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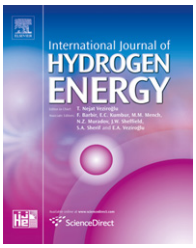

# Effect of driving cycle on the performance of PEM fuel cell and microstructure of membrane electrode assembly

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ARTICLE INFO

*Article history:*
Received 8 April 2009
Accepted 5 May 2009
Available online 9 June 2009

*Keywords:*
Driving cycle
MEA
CV
EIS
SEM

ABSTRACT

Driving cycle effect on proton exchange membrane fuel cell (PEMFC) performance and microstructure of membrane electrode assembly (MEA) is simulated to predict the lifetime of PEMFC. The single cell performance after different simulated cycles (100, 150 and 200 cycles) was evaluated by *I–V* curves. Electro-chemical impedance spectroscopy (EIS) was used to characterize the electro-chemical properties of fuel cell and the active surface area was characterized by cyclic voltammetry (CV). It was found that after 100, 150 and 200 cycles the electro-chemical surface area (ESA) for electro-chemical reaction decreased about 13.6%, 15.4% and 38.9%, respectively, and the performance of PEMFC declined about 0.1 V at 500 mA $cm^{-2}$ after 200 driving cycles. Impedance analysis and equivalent circuit showed that ohmic and charge transfer resistance respectively increased from 2.06 to 2.13, 2.215, 2.435 $\Omega\,cm^2$ and from 0.7 to 0.905, 1.26, 1.915 $\Omega\,cm^2$ after three kinds of driving cycles, and they all increased with increasing driving cycles, which may be one reason for the decline of PEMFC performance. Besides, scanning electron microscopy (SEM) result revealed that the thickness of catalyst layer after cycle test was weakening much more than the fresh one.



## 1. Introduction

Proton exchange membrane fuel cells (PEMFCs) has considered to be a promising energy source because they offer a highly efficient, low operation temperature, rapid start-up and environmentally benign technology for energy conversion avoiding the Carnot limitations of combustion engines [1]. In the last years, significant technical progress has been made towards commercial applications. In spite of rapid progress being made, substantial cost reduction and durability of cell performance are required before PEMFC can reach widespread commercial use [2].

In order to confirm durability of cell performance, many papers reported to use driving cycle and constant current which affect cell performance. Performance degradation includes recoverable and unrecoverable mode. Recoverable degradation is caused by temporary and reversible changes in fuel cell performance due to events such as cell flooding, MEA dry-out, catalyst surface oxidation state change, and catalyst surface poisoning. An unrecoverable degradation is often caused by permanent changes in the physical properties of one or more fuel cell components. Such changes cannot be undone through corrective actions. Events leading to such irreversible changes include catalyst dissolution and

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doi:10.1016/j.ijhydene.2009.05.021

migration [3,4], catalyst sintering [5], catalyst surface chemical composition change, carbon oxidation and corrosion [6], loss of catalyst–ionomer–reactant three-phase regions, membrane weakening and breech, and delamination of MEA layers. Conditions can ultimately lead to low durability.

The characterization of the electrodes was performed by electro-chemical analysis as well as physical methods on both single electrodes and MEAs. *V–I* curves were to characterize performance of PEMFC. The electrodes were electrochemically measured by cyclic voltammetry (CV) and electro-chemical impedance spectroscopy (EIS). Scanning electron microscopy (SEM) was used to study the thickness of cross-section and the microstructure of the electrodes. The methods of characterization can determine the causes of loss of cell performance.

## 2. Experimental

### 2.1. *Preparation of membrane electrode assembly (MEA)*

The protocol for forming MEA is described here as follows: the catalyst ink was sprayed directly onto the Nafion membrane at 100 °C to form catalyst layer. After the applied ink was dried, the catalyst layer was formed [7]. The catalyst ink consisting of 40%Pt/C (Johnson Matthy), 5 wt.% solubilized Nafion (Dupont) and isopropanol, which was stirred while sonicated for at least 15 min; The ratio of Pt/C catalyst to Nafion is 3:1. The loading of Pt/C catalysts for cathode and anode was both 0.4 mg $cm^{-2}$. The MEA was followed by just physically placing gas diffusion layers (GDLs) without the need for a hot-pressing process.

### 2.2. *Driving cycle*

The driving cycles were designed by simulating real internal engine vehicle with the consideration about starting, idle running, constant load running, variable load acceleration, full power running and overload running. Overload was pointed out as it normally existed when the vehicles run on the road and play a role of accelerating degradation. In our experiment, every cycle consisted of six periods (by simulating cold starting, idle running, full power running, continuous loading running and even overload running conditions) and lasted 1184 s. The capacity of overloading was set at 50 A. Driving cycle protocol consisted of continuously running the above cycles. The evolution of the current related to driving cycle protocol in one cycle was presented in Fig. 1.

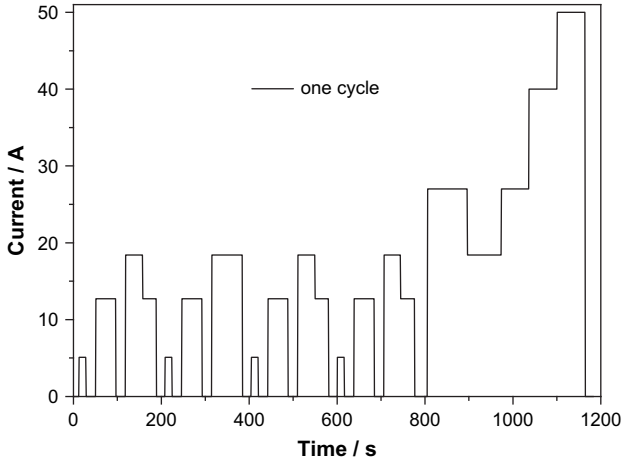


**Fig. 1 – Driving cycle protocol in one cycle, evolution of current with time during 1184 s, capacity of overloading was set at 50 A.**

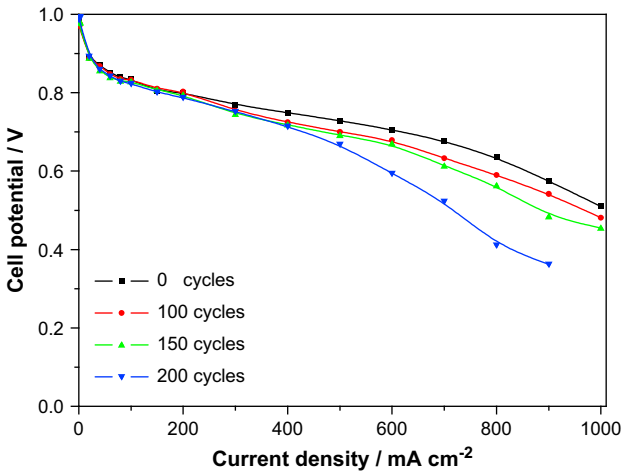


**Fig. 2 – Current–voltage characteristics of electrode with 50 $m^2$ of different driving cycles.**

### 2.3. *Characterization of fuel cell*

#### 2.3.1. V–I *curves*

The Single cell (50 $cm^2$) test on the PEMFC was performed on a steady-state behavior of the fuel cell. An electronic load (Sun-Fel200a, Sunrise Power) was used for discharging. The *V–I* discharge performance was carried to test the effect of the driving cycles on the performance of fuel cell. When *V–I* test was carrying out, the utilization ratios of $H_2$ and air were kept invariable. The cell was operated at 70 ± 5 °C and 0.1 MPa. The

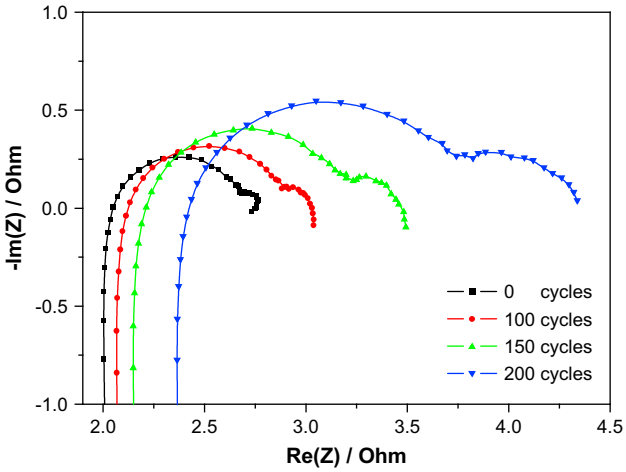


**Fig. 3 – Electrode impedance plot with varying cycles (0, 100, 150 and 200 cycles).**