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DEVELOPMENT OF HONDA FCX

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Abstract
Honda has been researching and developing fuel cell to resolve issues we face such as air pollution and energy conservation. In October 2003, Honda announced the original fuel cell stack, and in November 2004 delivered the Honda FCX to New York State. In addition, Honda developed FCX CLARITY that is applied with technology of next generation fuel cell system and the body. And we started to deliver the FCX CLARITY for an individual user as a lease sale in July 2008.Honda could get various knowledge and experience about fuel cell stack by running FCX at the various regions, and it becomes clear about some problems of durability. This paper describes the durability of the FCX fuel cell stack.

Keywords :fuel cell, PEM fuel cell, hydrogen, materials

1 Introduction

In response to environmental issues such as air pollution and global warming stemming from the use of fossil fuels and energy-related issues such as the high cost of oil, Honda has worked to reduce exhaust emissions through the development of environmental technologies including natural gas vehicles, electric vehicles, and hybrid vehicles. Honda believes that fuel cells represent the ultimate technology enabling resolution of the issues named above, and has been conducting fundamental research to develop fuel cells and reduce their cost since the 1980s. Since it installed its first original fuel cell stack in a test vehicle in September 1999, Honda has worked to increase the practical value of fuel cell vehicles, aiming towards the realization of high-power and compact designs and the achievement of a high level of environmental performance. In October 2003, Honda announced a next-generation fuel cell stack, and in November 2004 commenced leasing the 2005 Model FCX to New York State. In addition, Honda developed FCX CLARITY (Fig.1) that is applied with technology of next generation fuel cell system and the body, was announced in November 2007. Honda commenced leasing the Clarity to private users in July 2008. This rapid introduction of the FCX to the market has enabled extensive vehicle data to be obtained in a wide range of actual use environments. The vehicles have been used under diverse climatic, traffic, and road conditions, providing significant feedback enabling the enhancement of durability and environmental performance. The data has also clarified new issues in relation to the durability of the stacks. This paper discusses research on the durability of the stacks, which has proceeded the development of new analytic techniques.

Figure1: FCX CLARITY

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2 Durability Issues in Market Operation

2.1 Vehicle Operating State and Changes in Fuel cell Stack Environment

The operation of the FCX in Japan and the United States has clarified a variety of issues. A considerable amount of knowledge in relation to the durability of the stacks in particular has been obtained, including verification of the fact that changes in the environment of the stacks in actual use are a factor in their degradation. Figure 2 shows the state in the environment of a fuel cell stack under conditions of normal vehicle use. Gas mixing due to gas crossover during the shutdown of the fuel cell system, generation during fluctuations in load such as rapid acceleration, and changes in the temperature environment of the fuel cell stacks across the entire range of vehicle operation can be indicated as factors in the degradation of the stacks originating in changes in the stack environment. Gas mixing when the system is started and changes in the electric potential in the electrode with fluctuations in load in particular can be considered to be major factors in fuel cell stack degradation. Low-temperature startup when the vehicles are used in cold environments is a further factor in the degradation of the stacks.

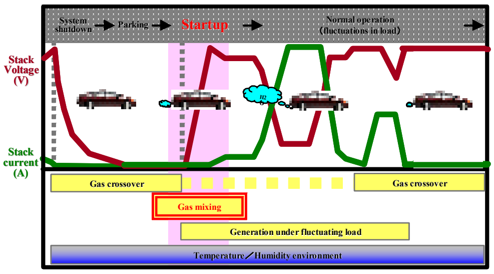

Figure2: Vehicle operation state in the fuel cell stack environment

2.2 Degradation Resulting from the Start/Stop Process

Degradation resulting from the start/stop process is closely related to the gas environment in the fuel cell stacks, and is in particular highly dependent on the gas environment in the fuel cells. Figure 3 shows a model of the gas environment inside the cells from system shutdown to restart. At normal system shutdown, the anodes and cathodes are filling with hydrogen and air respectively. However, after a certain amount of time elapses, consumption of a gas mixture resulting from crossover through the electrolytic membrane and air diffusion from the cathode outlet result in the formation of an environment consisting largely of air at both electrode. When the system is restarted in this state, an air-hydrogen mixture forms in the anode. This forms a partial battery, resulting in a localized state of high electric potential at the cathode.

Figure 3 Image of gas mixing in the electrode during system shutdown/startup process

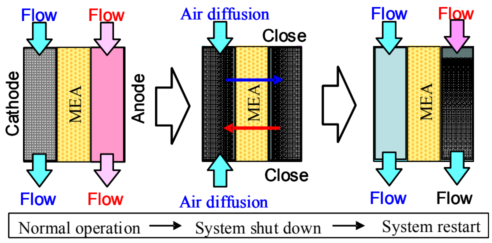

Figure3: Image of gas mixing in the electrode during system shutdown/startup process

Electric potential measurement sensors were positioned inside the anodes and cathodes, and measurements were taken in order to determine the status of the localized electric potential in the electrode at system startup. As Figure 4 shows, at system startup, the air at the anode is replaced by hydrogen. At this time, the electric potential of the anode changes from the electric potential of air (approx. 1.0 V), to the electric potential of hydrogen (0 V). The measurements showed that mixing the gases at the anode resulted in the formation of areas of localized high electric potential (1.0 V and higher) at the cathode, and that the high electric potential environment lasted longest at the cathode outlet, where gas replacement was slow. As Figure 5 shows, CO_2 is produced at the cathode at this time, indicating support carbon corrosion.

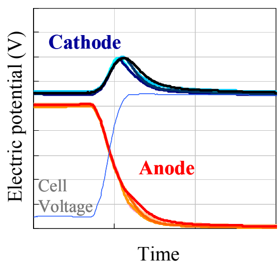

Figure4: Behavior of electric potential at fuel cell system startup

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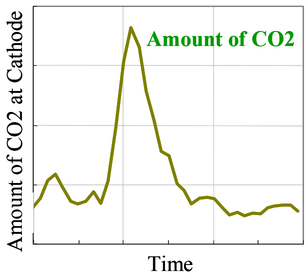

Figure5: Behavior of CO_2 generation at fuel cell system startup

Local current measurement sensors inside the electrode also enabled the corrosion current resulting from the increase in electric potential to be measured. Figure 6 shows the concentration of corrosion current when a high electric potential is generated by the gas replacement discussed above. As hydrogen flow from the anode, the gas mixture boundary shifts, and a reduction current flows inside the electrode. An oxidation current, which results in the corrosion of the support carbon, concentrates at the cathode outlet.

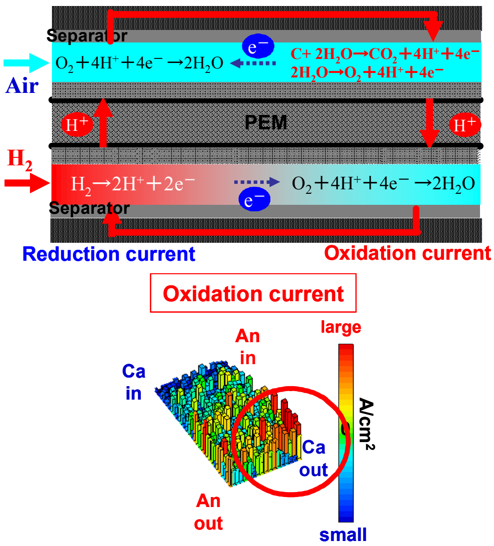

Figure6: Measurements of corrosion current at fuel cell system startup

Figure 7 shows a TEM image of electrode in a fuel cell stack, which had been subjected to a repeated start/stop cycle, as an example of a factor resulting in stack degradation. The image shows that the volume of the pores is reduced following the durability test, this is believed to be the result of corrosion of the support carbon and reduction of gas dispersion. Figure 8 shows TEM image of the stack catalyst. The Pt particle size is larger at the gas outlet than the gas inlet, indicating a higher level of degradation at the gas outlet.

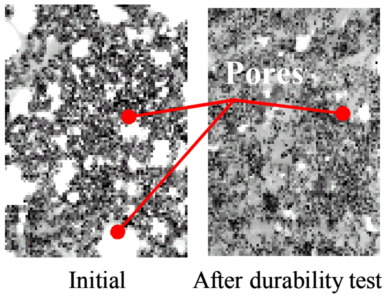

Figure7: TEM image of electrode following start/stop cycle

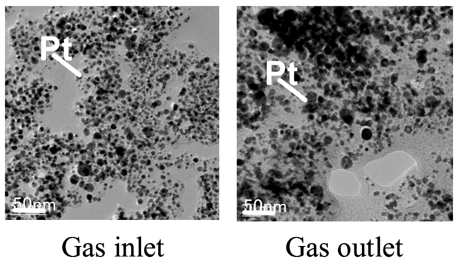

Figure8: TEM image of catalyst following start/stop cycle

The effect of the high electric potential and the corrosion current in the electrode at system startup to the degradation of the fuel cell stack corresponds well with the result of analysis of degradation of the cell materials, indicating that reduction of the activity of chemical reactions and reduction of gas dispersion result in a decline in the output of the cells.

2.3 Degradation Resulting from Low-temperature Startup

The FCX vehicles put on the market to date have been used in a variety of regions and climates, under a range of use conditions. In Japan and the U.S., the vehicles have been used in regions with cold climates (in Hokkaido in Japan and New York State in the U.S.). As in the case of the start/stop process, degradation of materials due to fluctuation of the electric potential in the electrode of the fuel cell stack – in this case due to startup at low temperatures – is considered to be a factor in the degradation of the stacks under low-temperature conditions. Measurements of the state of electric potential in the fuel cell stack electrode were therefore taken under low temperature conditions. These measurements indicated that localized areas of high electric potential were produced during the

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startup process at low temperatures. However, as Figs. 9 and 10 show, simultaneously conducted measurements indicated that as the startup temperature down, the amount of CO_2 and corrosion current produced also reduced. It was conjectured that at low temperatures, a lower level of catalyst reaction activity and slower mass transfer resulted in a lower level of CO_2 production and corrosion current, and that there would also be a lower level of degradation due to changes in the electric potential of the fuel cell stack electrode under these conditions.

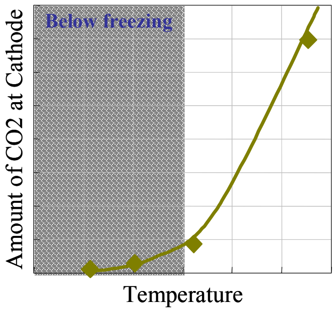

Figure9: Fuel cell system startup temperature and behavior of CO_2 generation

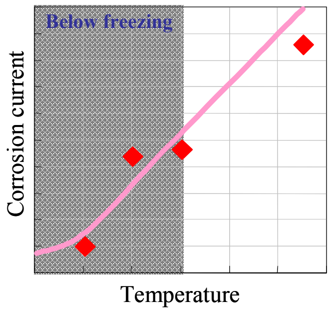

Figure10: Fuel cell system startup temperature and amount of corrosion charge

These results showed that the state within the electrode could also be studied under low-temperature conditions, indicating that the method could be judged to be effective as a method of analyzing degradation of the stack. However, under low-temperature conditions degradation also occurs due to mechanical factors such as damage to the structure of the MEA as a result of freezing of residual water in the stack, and research therefore continued on the development of analytic tools such as in-situ analysis via visualization of cross-sections of the MEA.

2.4 Degradation due to Generation under Fluctuating Loads

As Figure 11 shows, generation under fluctuating loads due to repeated acceleration and deceleration during vehicle operation results in a higher level of degradation than generation under fixed loads. It was conjectured that the fluctuation in the electric potential in the electrode under these conditions would have a significant effect on stack degradation despite the fact that the range of electric potential was same that in durability tests. The electric potential in the electrode during generation under fluctuating loads was therefore measured. The results indicated that only the electric potential of the cathode fluctuated within the range assumed for vehicle operation, and it was therefore concluded that the effect of the electric potential in the cathode was strong, as in the case of the startup process.

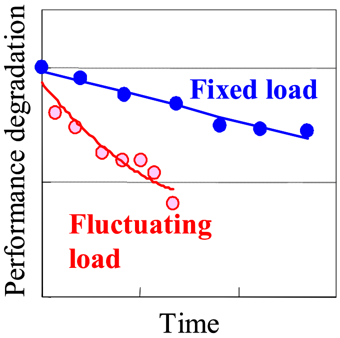

Figure11: Comparison of durability for generation under fluctuating and fixed loads

The amount of CO_2 generated at the cathode during fluctuations in electric potential at this time was also measured (Fig. 12). Measurements also showed that the dissolution of Pt increased in the range of electric potential fluctuation (cathode upper limit electric potential), as shown in Fig. 13. This indicates that, as in the case of the startup process, degradation of the electrode and the catalyst also occurs as a result of generation under fluctuating loads.

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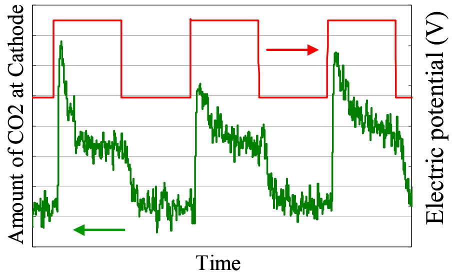

Figure12: Behavior of CO_2 generation during electrical generation under fluctuating loads

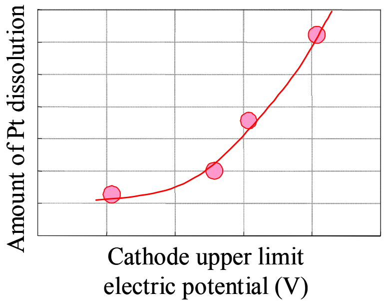

Figure13: Range of fluctuation of electric potential and amount of Pt dissolution

With regard to this fluctuation in electric potential due to load fluctuations during vehicle operation, a method of optimally controlling electric potential using system control has been introduced, and research will continue in the future to attempt to clarify the mechanism of degradation of the electrode, catalysts and membranes due to fluctuations in electric potential and to develop further countermeasures.

The degradation of environments within the fuel cell stack electrode is believed to develop due to differences in the environments resulting from the gases and water produced during generation, and this is considered to have a significant effect on the durability of the fuel cell stack. In addition, the fuel cell stacks fitted in fuel cell vehicles are made up of layers of several hundred cells, and it is therefore essential for stack design to take into consideration in gas distribution, water management, temperature environments, and other parameters. To monitor the electric potential and the corrosion current in the electrode enables the state of the interior of the cells to be understood, and this method has been verified as providing important indicators for the design of cell flow paths for good gas replacement and material design for durability to electric potential and corrosion. On-board measurements have also been conducted on the control of electric potential via methods of introducing gases and methods of controlling high electric potentials using system control. Efforts will continue to achieve a higher level of durability and reliability, looking towards the use of these methods in the next-generation model.

3 Conclusion

◆The research discussed in this paper has enabled measurement of the high electric potential environment and corrosion current produced in fuel cell stack electrode by the startup process, and has clarified the relationship between the production of high electric potentials and corrosion currents and the type of degradation of the materials (the catalysts, support carbon, etc.) and areas of degradation within the stack electrode.

◆ Measurements conducted during the startup process under low-temperature conditions showed a reduced amount of production of the CO_2 that indicates degradation of materials is occurring, and indicated that the type of degradation differed from that occurring during the normal startup process.

◆The electric potential in the electrode of the fuel cell stack during generation under fluctuating loads was measured, and degradation of the electrode catalysts and support carbon was verified, as in the case of the startup process.

◆ The use of electric potential and corrosion current measurements to understand the internal state of the electrode of the fuel cell stack provides important indicators for the design of the cells and the MEA materials; in addition, on-board measurements were an effective method in enabling countermeasures for degradation to be implemented using vehicle system control.

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