FRACTURE TOUGHNESS MEASUREMENT OF MOLDED GRAPHITE BIPOLAR PLATE UNDER AN ATMOSHPHERE OF OPERATION CONDITIONS OF PEMFC

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Abstract:

It is found that mechanical strength of the molded graphite bipolar plates for proton exchange membrane fuel cell (PEMFC) affects on both test temperature and test speed. Such dependence of the strength on the surrounded atmosphere shows an effect of in-service factor of the bipolar plates for operation conditions of PEMFC. From the in-service factor effect, a measure for the durability and the reliability of the molded bipolar plates is provided. In the present work, fracture toughness of the molded graphite bipolar plate is measured by single edge notched bend bar method under various temperatures with different test speeds. This is an ex-situ test of the bipolar plate for operation conditions of PEMFC. The corrosion on the mechanical properties of the bipolar plates is studied from the dependence of the fracture toughness. It is attempted that these analyses may be available for durability test of component materials of PEMFC.

Keywords: Electrochemical application, Fuel cell, Graphite

Introduction

At present, particularly in Japan, proton exchange membrane fuel cell (PEMFC) is becoming the increasingly attractive options, based on expectations of it becoming a fuel cell propulsion system for electric vehicle and residential co-generation devices. However, there are some problems for business commercialization of PEMFC system, reliability and cost reduction. They say that the costs of fuel cell components and system need to be reduced to about $1/100^{th}$ of the current cost. It is urgent task to clarify some causes of corrosion of the fuel cell basic materials, such as catalyst and polymer electrolyte membrane. These mean that the basic materials should be radically reviewed by means of scientific elucidation.

It has been known that PEMFC inside indicates strongly acidic atmosphere, so that it is hard to use metals for the fuel cell components. On the other hand, carbon materials can be applied to the fuel cell components, because carbon materials are relatively resisted to acidic atmosphere. Molded carbon bipolar plates are fabricated by pressing a compound mixed with graphite powder and resin, in order to achieve a large-scale production. For the molded carbon bipolar plate, however, the cost will remain high. To find a breakthrough for the molded carbon bipolar plate, it is necessary to obtain the evaluation indices of properties of bipolar plates.

In the present work, effects of corrosion on the mechanical strength of the molded carbon bipolar plates for PEMFC are studied by measurement of fracture toughness under various test temperatures, as a pseudo operation condition of PEMFC. Moreover, effect of in-service factors of the mechanical strength of the carbon bipolar plate is evaluated by changing the crosshead speed in the bending tests under various test temperatures, as a pseudo operation environment of PEMFC. It is attempted to obtain a measure of the durability of carbon bipolar plate in short time.

Experimental

Bipolar plate sheet molded by pressing a compound of graphite powder and epoxy resin is used in the present work. Fracture toughness of the sample specimen is measured by single edge notched bend bar (SENB) method. The specimen shape is 3x4x30 mm and the initial notch length a is 2 mm (a/W = 0.5). The span length of the test is 16 mm, the crosshead speeds of 0.2 and 0.005 mm/minute are chosen. The measurement is carried out in the oven with a window cycle function. The test temperature is controlled at 90 and 120 ºC, as a pseudo environment of PEMFC.

In order to measure the strength of the bipolar plate, three-point bending test is carried out. The sample specimen for the bending test is 3x15x50 mm. On the three-point bending test with span length of 40 mm, the crosshead speeds of 0.2, 0.02, 0.01 and 0.005 mm/minute are chosen. The bending test is carried out in the oven controlled at 90 and 120 ºC. The photos of test machine and the three- point bending test zig in the oven is shown in **Figure 1**.

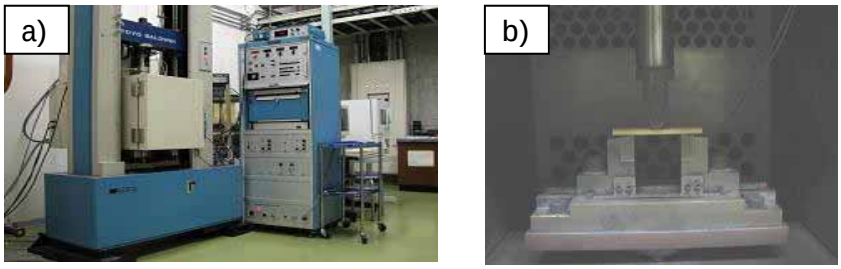

Figure 1. Photos of a): the test machine and b): three-point bending test

Results & discussion

The fracture toughness of the molded carbon bipolar plate is listed in **Table 1**. The value of fracture toughness of the present sample is about 1 MPa $m^{1/2}$. It is observed for the fracture toughness is dependent on the test temperature. The fracture toughness reduces with increasing in test temperature. At the room temperature and 90 ºC, the absolute value of fracture toughness is independent of test speed. At the test temperature of 120 ºC, however, it is observed that the value reduces with slowing the crosshead speed.

Table 1. Fracture toughness of the molded carbon bipolar plate.

	K_{IC} [MP·$m^{1/2}$]	
crosshead speed	0.2 mm/min	0.005 mm/min
RT	1.19 (0.04)	1.13 (0.01)
90℃	0.99 (0.06)	0.99 (0.03)
120℃	0.91 (0.06)	0.82 (0.02)

The numbers in brackets are standard deviation.

At room temperature, the mean values of flexural strength and modulus are 50 MPa and 16 GPa, respectively. Stress-strain curves for bending test of molded carbon bipolar plates with different crosshead speeds under different test temperatures are shown in **Figure 2.** The flexural strength of the molded bipolar plates decreases with increasing the test temperature. It is also characteristic that the flexural strength decreases with decreasing the crosshead speed in the bending test at 90 and 120 ºC.

The decrement of the flexural strength with the decreasing in the crosshead speed during bending test results from an effect of in-service atmosphere on the mechanical strength of the molded carbon bipolar plate. Thus, it may be assumed that the test atmosphere at the temperature of 90 and 120 ºC is corroded the molded carbon bipolar plate.

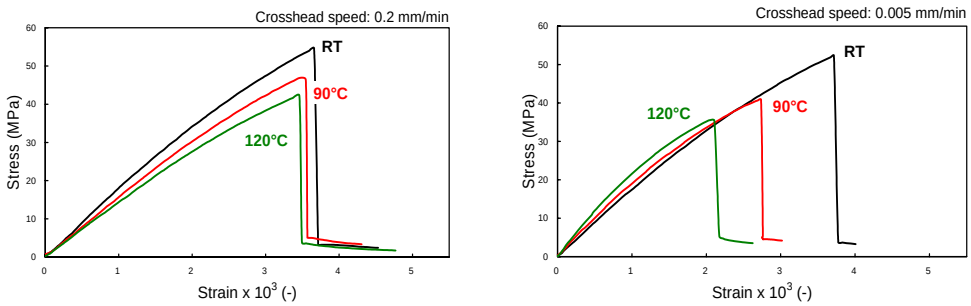

Figure 2. Stress-strain curves for bending test of molded carbon bipolar plates with different crosshead speed under different test temperatures.

In **Figure 3**, the log-log plot of the strength of the bipolar plate against the rate of stress loading is shown. Weibull plots of the strength of the molded carbon bipolar plate is shown in **Figure 4**. From the log-log plots, it is found that the decrement of the strength not only with the increasing in the test temperature, but also with lowering in the stress loading speed at the temperatures of 90 and 120 ºC.

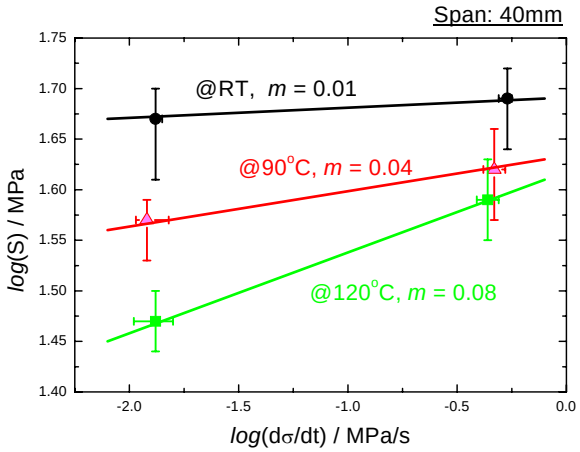

Figure 3. Log-log plots of flexural strength of molded carbon bipolar plates against the rate of stress loading under different test temperatures.

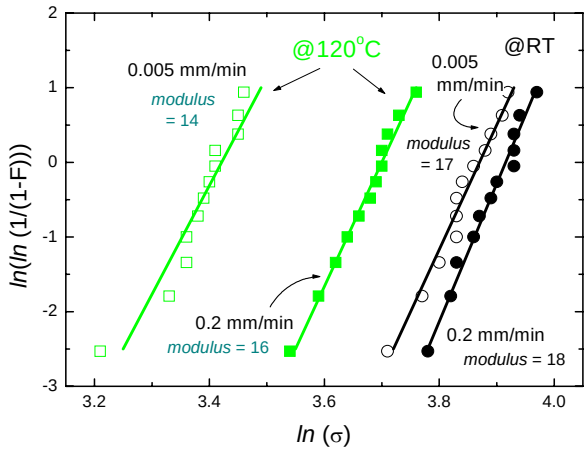

Figure 4. Weibull plots of flexural strength of molded carbon bipolar plate.

From Weibull plots (**Figure 4**), it is clearly observed that the decrement of the strength with increasing in the test temperature and with lowering test speed. The Weibull modulus of the strength of the molded carbon bipolar plate at room temperature is 18. The strength distribution of the bipolar plate at 120 ºC is slightly expanded, Weibull plot reduces to 14.

From fracture toughness measurement, the molded carbon bipolar plate has a relatively low toughness material, so that it is assumed for the molded carbon bipolar plate that brittle fracture is caused by crack generation on the surface of the bipolar plate. At the test temperature of 120 ºC, the crack growth on the surface of the bipolar plate is slightly accelerated. The stress loading is so slow that exposing the bipolar plate to the erosion environment becomes a long time. As the consequent of a long exposing time, the strength of the bipolar plate affects on the environment as an operation condition of PEMFC. Thus, it is supposed that the erosion of the molded carbon bipolar plate is accelerated by the stress loading to the specimen. In other point of view, the crack

generation and growth of the molded carbon bipolar plate is activated by exposing the erosion environment. However, Weibull modulus is almost no change even in a long exposing test under a high temperature (**Figure 4**), That is the present bipolar plate has an excellent uniformity.

The effect of in-service factor of the molded carbon bipolar plate can be evaluated by the log-log plots of **Figure 3**. The slope of the log-log plots, *m*, implies that it may be a measure of the durability of molded bipolar plates.

References

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