Data Article

Long-term dynamic durability test datasets for single proton exchange membrane fuel cell

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A B S T R A C T

This dataset collects the long-term dynamic durability test data and the polarization characterization test data used in our research article [1]. The dynamic durability test and the polarization characterization test of a single proton exchange membrane fuel cell (PEMFC) are all performed on the Greenlight 20 test station. The European harmonized test protocol is adapted to construct the fuel cell dynamic load test cycle (FC-DLC) used in this work. The overall durability test is composed of 3076 FC-DLC cycles, around 1008 h. To access the degradation information of the test fuel cell, the polarization characterization tests are performed periodically during the durability test. In this work, the characterizations were performed at time: 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 h. During the test period, G20 test station records all measured data, includes the dynamic load durability test dataset and the polarization test dataset. The output voltage degradation trend as well as the polarization curves are plotted and described in this work. This dataset provides the possibilities to study the degradation phenomenon of fuel cell operating by dynamic load cycles, moreover, this dataset can be directly used to various prediction models build for fuel cells.

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## Specifications Table

| Subject | Energy Engineering and Power Technology |
|---------|----------------------------------------|
| Specific subject area | Dynamic durability test for PEMFC based on G20 (Greenlight innovation, P17-2390, Burnaby, B.C. Canada) test station |
| Type of data | Table |
| How data were acquired | The long-term dynamic durability test for PEMFC was performed on the G20 test station. G20 test station offers a powerful and accurate control of the durability test. All durability test cycles and polarization test settings can be programmed into the emerald control software to control the fuel cell operation. The original test dataset is directly gathered by the G20 test station. |
| Data format | All discussed raw dataset available through online repository. |
| Parameters for data collection | The operating conditions for the tested single PEMFC during the long-term durability test were acquired based on the designed Orthogonal test. The optimum levels of the studied factors are chosen as the operating conditions for PEMFC. The data record frequency in this work is set as 1 Hz. |
| Description of data collection | The raw durability test data is collected directly through the G20 test station software. The polarization data is also recorded by G20 station during the characterization process. |
| Data source location | Clean Energy Automotive Engineering Center and School of Automotive Studies, Tongji University Shanghai 201804 China |
| Data accessibility | Directly URL access to data: https://data.mendeley.com/datasets/w65jjt8v5w/draft?a=5b37947d-ee28-48cd-a5f2-d8c61c8ed8b1 |
| Related research article | [1] Full information of the related article: Jian Zuo, Hong Lv, Daming Zhou, Qiong Xue, Liming Jin, Wei Zhou, Daijun Yang, Cunman Zhang, Deep learning based prognostic framework towards proton exchange membrane fuel cell for automotive application, Applied Energy, Volume 281, 2021, 115937, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2020.115937. (http://www.sciencedirect.com/science/article/pii/S0306261920313957) |

## Value of the Data

- The dynamic durability test dataset is rarely studied and provided in present fuel cell research work. This dataset can help to study the degradation mechanism of PEMFCs under dynamic load operating conditions. Polarization curve characterization test is one of the key performance testing techniques for fuel cells. The polarization curve dataset provides performance degradation information of PEMFC during the long-term durability test.
- Researchers in fuel cell fields can utilize the dataset provided to study the degradation mechanism of PEMFCs. Besides, the dataset can be applied to PHM techniques and serves as a unique dataset to help develop more robust and accurate prognostic models.
• The dataset provides the whole data recorded during the durability test, as well as the polarization curve characterization test data. It can be directly used to study the fuel cell degradation phenomenon. Researches can refer to the experiment design and collection process to design a new dynamic durability test, enrich the basic datasets for fuel cell research.

1. Data Description

The dynamic load durability test dataset and the polarization curves data are summarized and presented in this work. The complete shared dataset is available on the Mendeley data repository. All data files of the dynamic load durability test dataset are provided in the “Durability_test_dataset” fold. There are twenty excel data files for the durability test dataset which was recorded during the test period. The twenty dataset files were named according to the experiment time order, from “50_h.csv” to “1000_h.csv”. For example, “50_h.csv” represents the data within this file was recorded from 0 to 50 h. The overall voltage data is plotted and shown in Fig. 1b). Fig. 1a) depicts one dynamic load cycle (FC-DLC), and the whole durability test is to repeat this cycle as a current load and record the durability test data for PEMFC. From “50_h.csv” to “950_h.csv” (nineteen excel data files), each file contains 152 FC-DLC cycles. The last file named “1000h.csv” contains 188 FC-DLC cycles. To sum up, the overall twenty files contain 3076 FC-DLC cycles, approximately 1008 h in total.

Table 1 lists all parameters gathered during the durability test, the explicit physical meaning of the parameters was introduced. Durability time is recorded in the “time” column. The current, voltage, and power are the main parameters to characterize fuel cell performance. The current is set as the load applied to the test fuel cell and controlled by the G20 test station. The inlet and outlet gas (hydrogen and air) pressure are also controlled by the test station, the hydrogen and air inlet pressure are both set as 110 Kpa during the test and the outlet pressure is recorded. To control the relative humidity of hydrogen and air, the inlet gas temperature (hydrogen and air inlet temperature) and the two dewpoint water temperatures are set to a certain value. The hydrogen inlet temperature and hydrogen dewpoint water temperature are set as 70 and 55 °C; the air inlet temperature and air dewpoint water temperature are set as 70 and 65 °C. The operating temperature of the fuel cell is controlled by an external circulating water pump and recorded in “Temp_anode_endplate” column. The total anode and cathode gas flow are recorded in the “Total_anode_stack_flow” and “Total_cathode_stack_flow” columns respectively. All recorded values are controlled and monitored by Greenlight 20 test station during the durability test, therefore, it is normal for the recorded values slightly different from the desired control values as shown.

![Fig. 1. a) Current load level in one FC-DLC cycle and measure output voltage values; b) Complete output voltage data for PEMFC during the long-term durability test.](image-url)
Table 1
Aging parameters gathered during the long-term durability test.

| Index (as shown in the durability test dataset files) | Physical meaning |
|------------------------------------------------------|------------------|
| Time, Current, voltage, power                        | Aging time (s)   |
| Pressure_anode_inlet; Pressure_anode_outlet          | The operating load (A), output voltage (V) and power (W) of PEMFC |
| Pressure_cathode_inlet; Pressure_cathode_outlet      | Inlet and outlet pressure of Air (KPa) |
| Temp_anode_inlet; Temp_anode_outlet                  | Inlet and outlet temperature of H₂ (°C) |
| Temp_cathode_inlet; Temp_cathode_outlet              | Inlet and outlet temperature of Air (°C) |
| Temp_anode_dewpoint_water                            | Dewpoint water temperature of H₂ (°C) |
| Temp_cathode_dewpoint_water                          | Dewpoint water temperature of Air (°C) |
| Total_anode_stack_flow                               | Total stack flow of H₂ (NLPM) |
| Total_cathode_stack_flow                             | Total stack flow of Air (NLPM) |
| Temp_anode_endplate                                  | Operating temperature of PEMFC (°C) |

Fig. 2. Example of monitoring index during the durability test.

in the original dataset. Fig. 2 plots part of the monitored indexes during the whole test period, all data used here is from the durability test dataset as provided in the Mendeley repository. For example, according to Fig. 2, the recorded values of fuel cell anode inlet gas pressure are around 110 Kp. Fig. 2 shows the data evolving trend of various monitored indexes. The data plotted in Fig. 2 is the actual controlled values of all indexes, the corresponding setting values can be found in the experimental design section.

The polarization curves data was measured during the characterization phase and presented in the repository fold named “Polarization_curves_dataset”. Two separates excel files named “Polarization_curves.csv”, and “Polarization_curves_after_12_rest.csv” inside the polarization dataset fold provide all measured polarization curves data during the durability test. “Polarization_curves.csv” collects all polarization data measured directly after the dynamic load cycle, where the “Polarization_curves_after_12_rest.csv” file represents the polarization data measured after 12 h shutdown rest for PEMFC at each characterization time. These two files have a similar record structure. The time row with 0 h, 100 h, 200 h, 300 h, 400 h, 500 h, 600 h, 700 h, 800 h, 900 h, and 1000 h represent the polarization test performing time. As can be seen in the record files, for each measurement, the output voltage, power, and current load level are
recorded accordingly. The “current_set” column represents the set values, and the actual applied current load values were recorded at the “current” column.

Fig. 3 plots the polarization curves measured by the current ascending mode. Fig. 3 a) shows the polarization curves measured directly after the dynamic load cycle at each characterization time. Fig. 3 b) depicts the corresponding polarization curves after 12 h shutdown rest. As the shutdown rest for PEMFC is only executed after the durability test, therefore the polarization curves in Fig. 3 b) begin at 100 h.

2. Experimental Design, Materials and Methods

The Dynamic durability test and polarization characterization test [2] for PEMFC are all based on Greenlight 20 (G20, P17-2390, Burnaby, B.C. Canada) test station.

2.1. Long-term dynamic durability test experiment

The commercialized single PEMFC used in this work is produced by Wuhan New Energy Co., Ltd. The main parameter about this type of fuel cell can be found in [1]. The dynamic load durability test applies the European harmonized test protocol as the dynamic load cycle [3]. To adapt the dynamic load cycle for this test, the tested fuel cell is activated before performing the actual durability test, and the rated output power is estimated according to its initial polarization curve. The specific current load values used in the FC-DLC durability test are shown in the experimental part of the linked research article. The current load applied to PEMFC is controlled by the load control block of G20 test station. G20 is equipped with a built-in humidifier at the anode and cathode, which allows controlling the desired anode and cathode gas relative humidity. The PEMFC operating temperature is controlled by an external circulating water pump. The complete control functions provided by G20 test station play a key role in this durability test, which helps to acquire accurate and reliable durability test data.

As described previously, an orthogonal test and fuel cell activation test were performed before the durability test. The optimal operation parameters are decided based on the orthogonal test. The durability test is performed on the G20 test station controlled by a pre-set program. The test is periodically repeated every 152 FC-DLC cycles (approximately 50 h), followed by a
characterization test. And the shutdown rest is carried out every 304 FC-DLC cycles. Whenever the G20 test station is been shut down, the PEMFC is rest for 12 h, then the durability test is restarted after the polarization test.

2.2. Polarization curve characterization experiment

The polarization curves are measured during the durability test, and the test condition is set the same as the dynamic durability test. As shown in Fig. 4, the polarization characterization test in this work used a current load increasing and decreasing cycle measure approach. As can be seen in the figure, during the test period, the current density first experienced an increment process (current ascending mode), from 0 to maximum test current density, and then decreased from the maximum value back to 0 (current descending mode). Two kinds of current density changing steps are set for this experiment. From 0 to 0.1 cm$^{-2}$, the current density changing step is set as 0.02; from 0.1 to maximum test current density, the step is set as 0.2 A cm$^{-2}$. The step duration at open-circuit voltage (OCV) [4] is set as 30 s, for current density from 0 to 0.1 A cm$^{-2}$, the duration is set as 40 s and for current density above 0.1 A cm$^{-2}$, the duration is set as 190 s.

The averaged output voltage, power of each current density step is calculated and summarised as the final polarization dataset, which is provided in the dataset repository. As introduced in the Data description section, two types of polarization curve data are provided, allows to compare the fuel cell performance before and after shutdown rest. The current ascending mode polarization curves are shown in Fig. 3, the V-I curves before and after shutdown rest can help to further investigate the recovery phenomenon in PEMFC. Besides, the reversible degradation trend as shown in Fig. 1 b) can also be explained by the polarization curves.
CRediT Author Statement

Jian Zuo: Data curation, Conceptualization, Methodology, Formal analysis, Visualization, Validation, Writing - original draft; Hong Lv: Supervision, Project administration, Funding acquisition; Daming Zhou: Resources, Investigation, Writing - review & editing; Qiong Xue: Investigation, Writing – review & editing; Liming Jin: Conceptualization, Writing – review & editing; Wei Zhou: Writing – review & editing; Daijun Yang: Supervision; Cunman Zhang: Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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References

[1] J Zuo, H Lv, D Zhou, Q Xue, L Jin, W Zhou, et al., Deep learning based prognostic framework towards proton exchange membrane fuel cell for automotive application, Appl. Energy 281 (2021) 115937.
[2] B Wang, R Lin, D Liu, J Xu, B. Feng, Investigation of the effect of humidity at both electrode on the performance of PEMFC using orthogonal test method, Int. J. Hydr. Energy 44 (2019) 13737–13743.
[3] I Bloom, LK Walker, JK Basco, T Malkow, A Saturnio, G De Marco, et al., A comparison of fuel cell testing protocols—a case study: protocols used by the US Department of Energy, European Union, international electrotechnical commission/fuel cell testing and standardization network, and fuel cell technical team, J. Power Sources 243 (2013) 451–457.
[4] S-H Oh, M Lee, J Yun, H Lee, W Kim, I-C Na, et al., Durability evaluation of stationary PEMFC MEA by OCV holding method, Kor. Chem. Eng. Res. 57 (2019) 344–350.