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Data Article

Dataset of the liquid water distribution in a biomimetic PEM fuel cell

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ABSTRACT

This dataset gathers the initial formation and the evolution of water content and distribution, as well as water evacuation, within a lung-inspired PEM (proton exchange membrane) fuel cell with a 50 cm^2 active area for various operating conditions such as cell pressure, relative humidity of the reactant (anode and cathode), temperature, and cell current density. Neutron imaging was used since it has been shown to be an effective technique for quantitative analysis of water distribution, obtaining the thickness of the water with the Lambert-Beer law, thus obtaining the numerical data that composes the tables and graphs in this dataset. A series of videos compiling the individual images obtained through neutron imaging, showing the water distribution evolution are presented. Numerical and graphical compilation of the amount of water in a cell through time in different regions of the cell and for a total of 10 experiments are provided. This dataset provides a deeper knowledge on the complex phenomena that liquid

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water is subjected to in fuel cells along time, as well as a basis for an experimental validation for Computational Fluid Dynamics (CFD) simulations.

Specifications Table

Subject	Energy
Specific subject area	Behaviour of liquid water distribution in a biomimetic PEM fuel cell
Data format	Raw (file in .mpeg format), Analyzed (file in .pdf format)
Type of data	Tables Graphs Images Videos
Data collection	The images that compose the frames of the video were obtained through neutron imaging, with 10-seconds exposure time, circulating 2Nl/min and 1Nl/min of nitrogen through the cathode and anode respectively between tests. The radiographs were corrected and pixel-wise referenced compared to a dry cell to obtain the attenuation corresponding to water. The thickness of the water was calculated using the Lambert- Beer law, thus obtaining the numerical data that composes the tables and graphs.
Data source location	• Institution: University of Seville • City: Seville • Country: Spain
Data accessibility	Repository name: idUS Data identification number: https://doi.org/10.12795/11441/155254 Direct URL to data: https://hdl.handle.net/11441/155254
Related research article	Iranzo, A., Cabello González, G. M., Toharias, B., Boillat, P., & Rosa, F. (2024). Water liquid distribution in a bioinspired PEM fuel cell. *international journal of hydrogen energy*, 50, 221-233. doi: 10.1016/j.ijhydene.2023.08.103

1. Value of the Data

- This database contains the raw images of the evolution and accumulation of liquid water obtained through neutron imaging, which is not commonly available in customary labs.
- The studied data springs from the unique PEM Fuel Cell with a lung-inspired configuration.
- The dataset contains a detailed analysis of the water content and internal water distribution, at each operating condition in both flow field channels and gas diffusion layers (GDL).
- The proposed data can be used by researchers and engineers in the field of PEM Fuel Cell research and development. The dataset can be used to provide a deeper knowledge, information and understanding of the complex phenomena that liquid water suffers in fuel cells along time.
- The information set can be used as an experimental validation for CFD simulations of PEM Fuel Cells with this particular configuration or for comparison purposes with other configurations, as well as for water management analysis of PEM fuel cells.

2. Background

The main novelty of this dataset relies on the application of neutron imaging to investigate liquid water formation and evacuation in a novel biomimetic (lung-inspired) fuel cell under various operating conditions in a quantitative manner. Using graphene porous sponges with a structure of main channels, sub-channels and the porous medium in the cathode, resembles the function and structure of natural systems like trachea, bronchi and lung alveoli, having both an intricate network of smalls channels and high permeability, promoting oxygen transport. This porous composition results in a significant surface area, high gas permeability, and a notable area-to-volume ratio.

The dataset provides a deeper insight into the fuel cell water management in order to find how the operating conditions affect the liquid water distribution inside the bipolar plates channels, through detailed quantitative values.

3. Data Description

3.1. Data file: exp_1234_sta.mpeg

The data presented in this data file corresponds to a video that contains the images obtained through neutron imaging as frames for experiments 1 through 4 for the stationary study, where individual images of the accumulated liquid water for the different experiments can be seen in [1].

3.2. Data file: exp_5_trans.mpeg

The data presented in this data file corresponds to a video that contains the images obtained through neutron imaging as frames for experiment 5, used for the stationary and transient study. Individual images of the accumulated liquid water for the different experiments can be seen in [1], whereas images showing the qualitative evolution of liquid water content for 5 and 30 min are shown in [2].

3.3. Data file: exp_678910_trans.mpeg

The data presented in this data file corresponds to a video that contains the images obtained through neutron imaging as frames for experiments 6 through 10, used for the stationary and transient study. Individual images of the accumulated liquid water for the different experiments can be seen in [1], whereas images showing the qualitative evolution of liquid water content for 5 and 30 min are shown in [2].

3.4. Data file: Exp_Stationary.pdf

The data presented in this data file corresponds to raw and processed data from the stationary experiments in [1]. Firstly, the section “Stationary images and graphs paper” shows the unprocessed and unenhanced neutron images obtained for the different cases varying the relative humidity, pressure, temperature and current density are shown. The enhanced images for cases 9 and 10 are shown being compared to the unenhanced ones, displaying the position and division of the ribs and horizontals. All the graphs that are contained in [1] appear with the tables corresponding to the main parameters than vary among the cases, describing those tables in Table 1. This initial part ends with the enhanced neutron images divided into the ones with higher current density (CD=1A/cm^2), corresponding to experiments 1 through 4, the lower current density (CD=0.5A/cm^2), corresponding to experiments 5 through 8, both with their bar graphs, being differentiated by their pressure and relative humidity and the experiments with the temperature variation corresponding to experiments 9, 5 and 10.

Table 1
Description of the variables that appear in the tables of the file Exp_stationary.pdf.

Variable	Description
RH (%)	Relative humidity in anode and cathode
T (°C)	Temperature
P (bar)	Pressure
CD (A/cm^2)	Current density
Test #	The number identifying the experiment
Total (g)	The sum of the mass water content in outlet, foam and inlet
Outlet (g)	The mass water content in the outlet
Foam (g)	The mass water content in the foam
Inlet (g)	The mass water content in the inlet
Total (g/cm^2)	The sum of water density in outlet, foam and inlet
Outlet (g/cm^2)	The water density in the outlet
Foam (g/cm^2)	The water density in the foam
Inlet (g/cm^2)	The water density in the inlet
Length (mm)	The Y and X variable increment in the case of the ribs and horizontals respectively
Water (g)	The mass water content in ribs 1 through 5 and horizontals 1 through 7

The next section shows the amount of liquid water in the outlet, foam, inlet and in total in mass and water density. The cases are grouped according to the ones being compared in each graph, which all appear in [1]. The variables that appear in the tables that compose the graphs are shown in Table 1. The first graph compares the water density in the different regions for all cases. The next two graphs compare the amount of water in the regions for the cases with different current density, being differentiated by their relative humidity and pressure, divided into high (CD=1A/cm^2; for experiments 1, 2, 3 and 4) and low (CD=0.5A/cm^2; for experiments 5, 6, 7 and 8) current density. The following graph corresponds to the amount of liquid water in the temperature variation cases, with a table that group their values for experiments 5, 9 and 10. The subsequent graphs correspond to the high (p=1 bar; for experiments 1, 2, 5 and 6) and low (p=0.5bar; for experiments (3, 4, 7 and 8) pressure being identified by their current density and relative humidity.

In the subsequent section, a series of tables appear, which correspond to the raw data of the amount of water along the length of the anode ribs (5) and cathode horizontals (7), for experiments from 1 through 19, indicating to which test they correspond in the paper. The graphs that appear in this section show the evolution of the water content along the length of the ribs 1, 3 and 5 and the horizontals 2, 4 and 6 for tests 15 and 17, which correspond to tests 9 and 10 in the paper where the temperatures are 70 and 55°C respectively. All the variables that appear in the tables are detailed in Table 1.

3.5. Data file: exp_1234_trans.mpeg and Transitional.pdf

These data files correspond to the transient behavior, which also appears in the data repository, however they belong to another research article, [2]. The dynamic behavior exhibited in these experiments is studied in [2], observing the evolution through time of the liquid water distribution, instead of just its accumulation as seen in [1].

4. Experimental Design, Materials and Methods

A bio-inspired graphite 50cm^2 active area cell fuel was used to conduct the experiments, as reported in [3]. The design encompasses a cathode with an inlet and outlet collector connected in parallel with 6 groups of straight channels or anode ribs in sets of 7 channels each or cathode horizontals, meaning the gases circulate vertically in the cathode and horizontally in the

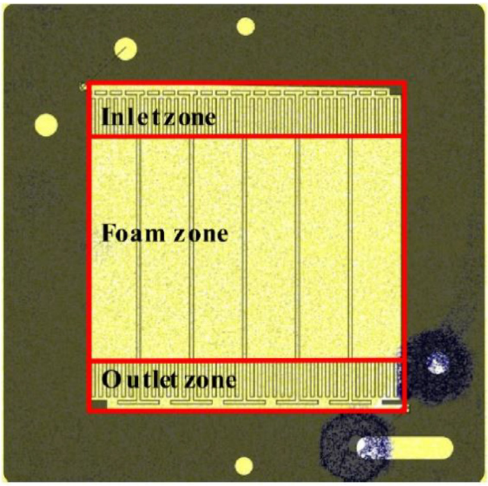

Fig. 1. Neutron imaging of the dry cell before operation showing the cathode design [1].

Table 2
Operating conditions for the set of experiments.

Test	Nomenclature	RH $_{a,c}$ (%)	T(°C)	P (bar,g)	F_a (NmL/miN)	F_c (NmL/min)	CD (A/cm^2)
1	P05_T65_RH60_CD10	60	65	0.5	444	2032	1.0
2	P05_T65_RH90_CD10	90	65	0.5	444	2032	1.0
3	P10_T65_RH60_CD10	60	65	1.0	444	2032	1.0
4	P10_T65_RH90_CD10	90	65	1.0	444	2032	1.0
5	P05_T65_RH60_CD05	60	65	0.5	222	1016	0.5
6	P05_T65_RH90_CD05	90	65	0.5	222	1016	0.5
7	P10_T65_RH90_CD05	60	65	1.0	222	1016	0.5
8	P10_T65_RH60_CD05	90	65	1.0	222	1016	0.5
9	P05_T70_RH60_CD05	60	70	0.5	222	1016	0.5
10	P05_T55_RH60_CD05	60	55	0.5	222	1016	0.5

anode, which can be seen in Fig. 1 [1,2]. The bio-inspired modification was made inserting in the central part of the vertical channels of each of the six groups graphene porous sponges with a density of 320mg/cm^3 and pore size of 580 μm. The membrane electrode assembly (MEA) used is a GORE® PRIMEA® MEAs A510.1/M665.15/C580.4 with a platinum loading of 0.1mg/cm2 at the anode side and 0.4mg/cm^2 at the cathode side and a 15μm thickness, with a Freudenberg H223C6 gas diffusion layer of 250 μm thickness being also assembled. The anode is a commercial graphite serpentine crossflow flow field from ElectroChem Inc.

The different operating conditions used to study the water distribution were temperature, pressure, cathode and anode relative humidity and current density, keeping constant the cathode and anode stoichiometry at 2.5 and 1.3 respectively. The relative humidity was kept symmetric in the anode and cathode in all tests. Air was fed to the cathode side instead of pure oxygen. The operating conditions for the set of experiments that appear in [1] are shown in Table 2.

The neutron imaging experiments followed the procedures explained in [4]: the SINQ-NEUTRA beamline at PSI with 10s exposure time was used at Paul-Scherrer Institut in Villigen (Switzerland). Before each test, the cell was dried out by flowing 2Nl/min and 1Nl/min dry nitrogen through cathode and anode respectively during at least 20 minutes to remove the influence of previous tests. In order to determine the liquid water content distribution in GDL/MEA exclusively, liquid water was flushed out the channels by performing a sudden purging in anode and cathode as described in [5]. It was adapted to neutron imaging by [6,7], decompressing the anode and cathode channels, flushing out the liquid water in the channels.

The radiographs were corrected and pixel-wise referenced by dividing the images by a dry cell image to obtain the attenuation area corresponding only to water. The thickness of the water was calculated suing the Lambert-Beer Law.

Limitations

This study was performed for a specific configuration and design with a small size (50cm^2 active area) and power (20W), having limited applications. This means this dataset cannot be reused by investigators looking for bigger application cells. A possibility for study could be using a bigger cell that could be used for a wider range of applications.

Although this is mainly a stationary study, since the related research article is stationary, the time exposure for taking the neutron imaging was 10s, which could be a limitation for transient studies since smaller time resolutions could be required.

A limitation in this study is that it is performed for a single cell, not having a full stack, which would provide a complete analysis. An improvement and further study would be redoing it for a full stack.

Further research could be carried out by varying the fuel cell components and their properties, such as the fuel cell design or GDL and/or MEA type.

Ethics Statement

This work does not contain any studies with humans, animals from protected areas or endangered animals. The authors declare that they have followed the general ethics rules for scientific research and publishing.

Data Availability

Dataset of the liquid water distribution and its transient behaviour in a biomimetic PEM fuel cell (Original data) (idUS)

CRediT Author Statement

Alfredo Iranzo: Conceptualization, Methodology, Software, Validation, Investigation, Supervision, Project administration; **Laura González Morán:** Data curation, Investigation, Writing – original draft, Writing – review & editing; **G.M. Cabello González:** Methodology, Validation, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing; **Baltasar Toharias:** Methodology, Validation, Data curation; **Pierre Boillat:** Data curation, Methodology, Software, Investigation; **Felipe Rosa:** Writing – review & editing, Supervision, Funding acquisition.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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