Master’s Internship Subject
(Possible Continuation in PhD thesis)

In situ 3D imaging of Proton exchange membrane fuel cell assembly (PEMFC) and multi-physical FE modeling.

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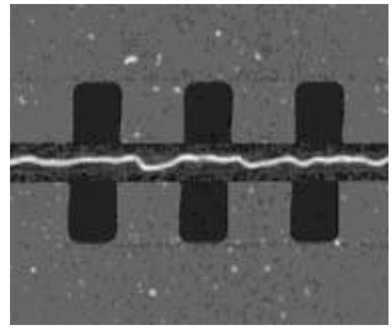

Figure 1: Vertical slice of a 3D reconstruction of an in situ fuel cell micro-assembly under compression loading.

Proton Exchange Membrane Fuel Cell (PEMFC) is a possible substitute of combustion engine owing to its high efficiency and low level of pollutions by converting chemical energy of hydrogen directly onto electricity.

A PEMFC cell is composed of a proton-conducting membrane electrolyte, separating two electrodes, which on each side is placed a porous layer (Gas diffusion layer - GDL) ensuring the uniform distribution of the reactants and facilitating the water and thermal management within the pile. This membrane-electrode assembly (MEA) is insert between two flowfield plates allowing the distribution of reactants and clamping (no leak) within the cell. An Xray tomography picture of the all assembly is presented Figure 1. The generated compression on flowfield plate ensures the good contacts between all elements and sealing of the cell. An optimum clamping pressure for performance and robustness is observed. This optimum is obtained experimentally and is part of the know-how [1,2]. If the effects of the assembly force are understandable, their modeling and control is a scientific lock because it uses multiple couplings effects at different scales.

The PEMFC’s operating characteristics, specifically durability, necessitate significant improvements [3]. Among the different parameters to optimize their performance, the mechanical pressure used to compress the assembly is particularly tricky to control: As the pressure increases, the electric contact increases whereas gas and water diffusion decreases. Moreover, thermal expansion caused by Joule effect can increase stress concentrations in the assembly and induce damages in polymer membranes and finally to failure of the fuel cell.

A better comprehension of local stresses in the assembly can be obtained by observing the 3D bulk deformations of the different layers constituting the cell.

In situ 3D compression loading tests on a micro fuel cell assembly were conducted in an X-Ray micro computed tomographic system available at Pprime Institute Laboratory. 3D volume images of the cell assembly along the tests (see Figure 1) allows to visualize the 3D heterogeneous deformation of the gas diffusion layers (GDL) and Nafion membrane with graphite plates displacements. Quantitative image based Finite Element Model of the fuel cell assembly is under development and will allow to a better understanding of the link between the global cell behavior and local constituents deformations.

The objective of this internship is:

- to conduct image analyses of the in situ experiments
- to develop the image based finite element model and to analyse the behavior of the cell,
- to analyze the mechanical and diffusion behavior of the GDL

Skills: finite element methods and image analyses may be appreciated.

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References:

[1] J.J. Kadjo, Caractérisation et contribution à l’optimisation des performances électriques des PEMFC, PhD Thesis (2006)
[2] D. Bograchev et al. / Journal of Power Sources 180 (2008) 393–401
[3] F. Barbir, PEM Fuel Cell, Academic Press, Waltham, MA, USA (2012)