IMPROVEMENT OF FUEL CELL DIAGNOSIS BY MAGNETO-TOMOGRAPHY WITH MAGNETIC FIELD CONCENTRATION

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Abstract

This paper deals with the diagnosis of a fuel cell (FC) by magneto-tomography. The magnetic field generated by any electromagnetic device such as a FC can give important information about the health state of the FC. The magnetic field around the FC is directly connected to the current density distribution inside the FC. In this paper, the innovation consists in moving a ferromagnetic concentrator, composed of 2 Mu-metal elements separated by an air-gap where a Hall effect sensor is embedded, around the FC. This high-performance tool will enable to detect and locate more precisely a defect and, consequently, to establish a health state of the FC. The numerical analysis and comparison will validate the interest of the mobile magnetic field concentrator.

1 Introduction

Hydrogen energy (zero-carbon) is a promising alternative to conventional energies. The FC system has the advantage of combining high-energy efficiency and environmental friendliness compared to other more mainstream technologies. To improve this technology, it is necessary to diagnose an FC quickly and efficiently.

The magneto-tomography is one of the most effective and easiest non-intrusive methods to diagnose the health state of an electrical device. Knowing the magnetic field measured around an FC, it is possible to determine the current density distribution inside the FC using an inverse model to predict whether the FC is healthy or faulty.

Hauer *et al.* (2005) applied this method to a FC for the first time [1]. During the last two decades, some researchers have developed inverse methods based on Biot–Savart law. Recently, Plait *et al.* (2020), proposed an innovative tool to increase the performance of the method [2]. To summarize this research, Plait and Dubas (2022) provide an exhaustive review of the different studies performed in the domain of magneto-tomography applied to FC [3].

2 Magnetic field studies

Any electromagnetic device generates a magnetic field. A healthy FC shows a homogeneous current density distribution, which differs (becomes non-homogenous) with the occurrence of defects [4].

2.1 Fuel cell magnetic field

A FC bipolar plate consists of an active surface (viz., electrochemical active cell) where the gases flow, surrounded by an inactive part (Figure 1).

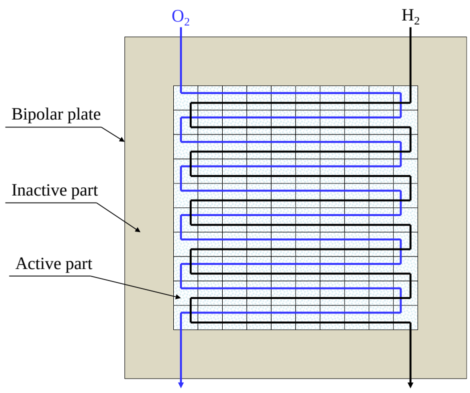

Figure 1: Schematic view of a bipolar plate.

2.2 Ferromagnetic mobile concentrator

In order to improve the magneto-tomography and to develop a general-purpose tool that could be adapted to any FC (viz., size, type…), a ferromagnetic mobile concentrator composed of 2 Mu-metal elements spaced 1 mm apart is placed around the FC as shown in Figure 2. A micro-Hall effect sensor is inserted inside the 1 mm air-gap. The ferromagnetic concentrator is moved around the FC to determine the magnetic field.

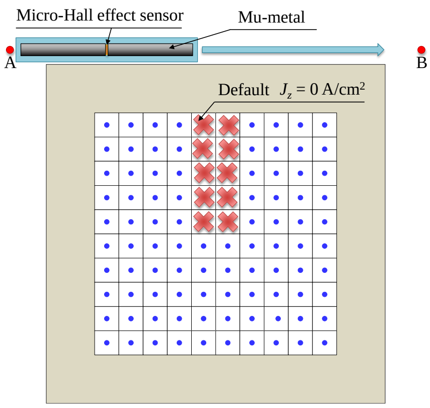

Figure 2: Concentrator tool near the FC bipolar plate.

2.3 Finite-element model

In order to demonstrate the effectiveness of this innovative tool, a numerical model under the FEMM software is developed. A bipolar plate with an active part of 100 cm^2 is considered and discretised into 100 segments. In a first step, a healthy FC is simulated with a total current of 100 A and consequently a homogenous current density J_z of 1 A/cm^2. The magnetic field H is measured along a path (between the red points A et B in Figure 2) with and without concentrator.

In a second step, a fault of 10 % of the active area is simulated as shown in Figure 2 by red cross. The total current of 100 A is maintained, so the current density J_z of the remaining 90 % is about 1.11 A/cm^2. The magnetic field is also compared with and without concentrator.

In addition to increasing the performance of magneto-tomography, a ferromagnetic mobile concentrator reduces the measurement to a single component of *H*.

3 Results and interest discussion

The interest of the ferromagnetic mobile concentrator is exposed by the use of the equipotential magnetic field lines (Figure 3). It can be observed that the flux concentrator meets the expectations through the concentration of several lines. The magnetic field module obtained without a concentrator on the A-B path, for healthy and faulty FC is shown in Figure 4.

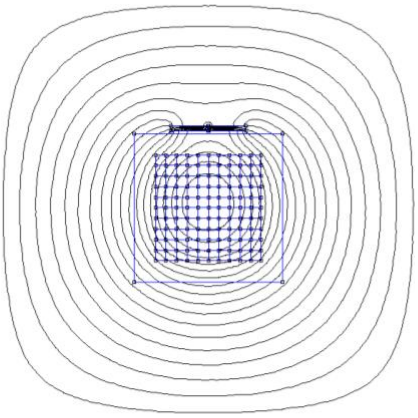

Figure 3: Equipotential lines of healthy FC with the ferromagnetic mobile concentrator.

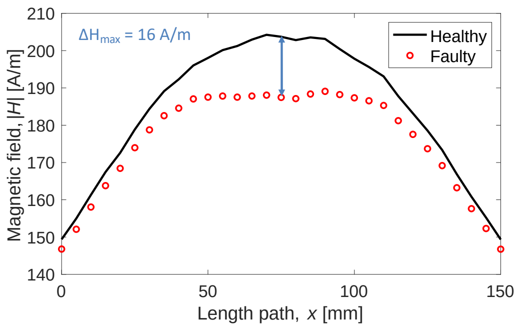

Figure 4: Magnetic field measured without concentrator.

The concentrator is added and displaced along the same A-B path. The magnetic field module obtained for the 2 cases (viz., healthy and faulty) is exposed in Figure 5.

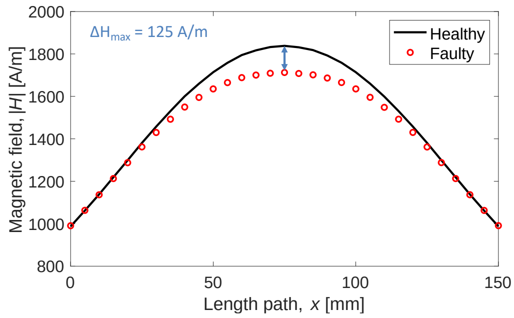

Figure 5: Magnetic field measured with concentrator.

A fault results in a decrease in the magnetic field closest to it and an increase away from it. Without the concentrator, the maximum difference ΔH_{max} is about 16 A/m, while with the concentrator ΔH_{max} is 125 A/m.

4 Conclusion

An innovative tool is developed to perform an efficient diagnosis of the life state of a FC based on magneto-tomography. The ferromagnetic mobile concentrator increases the magnetic field difference between normal and abnormal FC operation, which allows for more accurate fault detection and localization.

These interesting results offer many perspectives such as experimental validations on an FC. But also, the development of a (semi-)analytical model for the magnetic field calculation in order to develop an inverse model to predict the internal current density distribution.

Acknowledgements

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