INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 39 (2014) 8861–8867

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Simulation and study of proposed modifications over straight-parallel flow field design

Gerardo Martín Imbrioscia [a,b,*], *Héctor José Fasoli* [c]

[a] *Departamento de Investigación y Desarrollo de Energías Renovables (CITEDEF-EST), San Juan Bautista de La Salle 4397, Villa Martelli B1603ALO, Provincia de Buenos Aires, Argentina*

[b] *Laboratorio de Simulación y Diseño, Escuela Superior Técnica del Ejército General Manuel Nicolás Savio, Cabildo 15, C1426AAA Ciudad Autónoma de Buenos Aires, Argentina*

[c] *Escuela Superior Técnica del Ejército General Manuel Nicolás Savio, CITEDEF-EST, Cabildo 15, C1426AAA Ciudad Autónoma de Buenos Aires, Argentina*

ARTICLE INFO

Article history:
Received 6 November 2013
Accepted 17 November 2013
Available online 23 January 2014

Keywords:
PEMFC
Simulation
Bipolar plate

ABSTRACT

Diverse CAD (Computer aided-Design) 3D bipolar plates model are presented. By using the OpenFOAM software, an open source CFD (Computational Fluid Dynamic), hydrogen flow simulations were carried out, obtaining velocities and pressure maps for each model.

Main objective resides on predict the flow behavior in response to the modifications proposed on the bipolar plate geometry, such as width, depth and shape of the distributing channels (collectors) as over the main channels. Channelers fins are also besought with the purpose of direct the flow towards different zones, in order to homogenize the flow distribution.

1. Introduction

Bipolar plates, constitutive elements of PEM fuel cells, have different slotted designs on their faces in order to allow the flow of the reactant gases. These channels have distinctive patterns, being the "straight-parallel" design the case of study of this paper. The main functions of bipolar plates are: distributing the reactant gases inside the cell avoiding their mixture, collecting the electric current outside the cell, managing the water formed by the electrochemical reaction and preventing the cell from flooding and transfer the heat produced inside the cell to the environment.

The gas flow field design has a fundamental role on the gases pressure variation along the channels. This pressure variations affect directly the amount of gases driven through the Gas Diffusion Layer (GDL) to the catalytic reacting layer, as is stated in Barreras [1], thus achieving a better cell performance.

In this work several flow field designs are presented and studied by Computational Fluid Dynamic technique (CFD). All the designs shown in this research were devised with the aim of solving problems detected by the author in a previous work [2] and making it possible the manufacture in our facilities. Different angle inlets, channel collectors configurations and

* *Corresponding author.* Departamento de Investigación y Desarrollo de Energías Renovables (CITEDEF-EST), San Juan Bautista de La Salle 4397, Villa Martelli B1603ALO, Provincia de Buenos Aires, Argentina. Tel.: +54 11 4709 8100x1472.

E-mail address: gmimbrioscia@gmail.com (G.M. Imbrioscia).

http://dx.doi.org/10.1016/j.ijhydene.2013.11.079

channel ratios (width to depth) are evaluated using OpenFOAM, an open source finite volume code with remarkable results.

2. Mathematical model

In order to numerically study the proposed flow field designs, Navier–Stokes (NS) equations were solved, considering laminar flow in all cases. Steady-state was considered. GDL was not taken into account here; water formation and heat transfer have been neglected.

In the models, a 3D steady version of the incompressible Navier–Stokes equation is used as described in equations (1) and (2), where ρ is the density, υ the kinematic viscosity and u_i the $i = 1,2,3$ component of the velocity field:

Momentum:

$$u_j \frac{\partial u_i}{\partial u_j} = -\frac{1}{\rho} \frac{\partial p}{\partial x_i} + \mu \frac{\partial^2 u_i}{\partial x_j \partial x_j}, \quad (1)$$

Continuity:

$$\frac{\partial u_j}{\partial x_j} = 0. \quad (2)$$

By using the SIMPLE (Semi-Implicit Method for Pressure Linked Equations) algorithm [3], the result is reached when the specified convergence criterion takes the value of 10^{-6}. The resulting system of linear equations is solved using a Geometric Agglomerated Algebraic Multigrid (GAMG), jointly with the relaxation factor of pressure (0.3) and velocity (0.7).

Even though flow was considered steady, the numerical scheme needs a velocity and pressure initial conditions to start the calculation, which can be seen in Table 1. The flow selected was hydrogen at NTP (Normal Temperature and Pressure) conditions.

3. Bipolar plates

Taking into account the modifications suggested by Dong Hyup [4] related to collector dimensions in order to improve the uniformity of the velocity fields and pressure drop, a wider collector than that used in Ref. [2] is common through all models shown below.

Bipolar plates presented consist of an active area of 40 × 40 mm, with 20 channels; where both inlet and outlet ducts are square shaped with an area of 2 mm^2. Models BP1, BP3, BP4 and BP5 have inlet and outlet ducts oriented in the same way as the channels, criterion which was changed after the early results, as will be discussed in Section 4.

Designs were meshed using hexagonal elements, with non-uniform mesh size due to a bell type biasing with a compression factor of 1.5 in order to refine the mesh close to the walls intersection.

Table 1 – Initial conditions for simulation.

Inlet velocity [m/s]	2
Pressure at exhaust [Pa]	101.325

Detailed information is attached to each model:

3.1. *BP1*

The relation between collectors and channel width is 2 to 1, being the channel size of 1 × 1 mm.

3.2. *BP3*

The upper collector was designed with a negative slope line from the inlet duct to the farthest channel, beginning with 2 mm and finishing with 1 mm width. Regarding the downstream collector, its shape is the exactly the inverted opposite to the upstream one.

3.3. *BP4*

In this case, the upper collector was designed with a negative slope curve from the inlet duct to the farthest channel, beginning with 2 mm and finishing with 1 mm width, but with a more pronounced decrease. About the downstream collector, its shape is exactly the inverted opposite to the upstream one.

3.4. *BP5*

This model, the upper collector, was designed with an arc curve with its maximum located over the central channels. As regards the downstream collector, its shape is exactly the opposite to the upstream one.

3.5. *BP6*

This design has several changes with respect to the models presented before, in the way that the inlets as well as the outlet ducts were collinear with the collectors and both collectors width were increased to 4 mm.

A special arrangement was carried out over the channels, increasing width over the central channel and decreasing it towards the sides. This configuration was kept for models BP6, BP7, BP9 and BP10.

3.6. *BP7*

A special intake design was applied at the channels entrance. This modification was implemented to add resistance in the first two channels where flow path was noticed to be more evident [2]. Channelers were placed in the rest of the entrances, except in the last two channels, with the objective of capturing and directing the largest amount of gas flow to the central area of the cell.

3.7. *BP9*

This cell structure is similar to BP6. The difference lies on the collectors depths, which were increased 0.5 mm.