Modeling an Ejector for Hydrogen Recirculation in a PEM Fuel Cell

X. Corbella[1], R. Torres[2], J. Grau[2], M. Allué[3]

[1]Escola Universitària d'Enginyeria Tècnica Industrial de Barcelona (Universitat Politècnica de Catalunya), Barcelona, Spain
[2]Fluid Mechanics Department (Escola Universitària d'Enginyeria Tècnica Industrial de Barcelona - Universitat Politècnica de Catalunya), Barcelona, Spain
[3]Institut de Robòtica I Informàtica Industrial (Consejo Superior de Investigaciones Científicas – Universitat Politècnica de Catalunya), Barcelona, Spain

Abstract

One of the issues that needs to be studied in order to improve the durability of a PEM fuel cell system is the management of the hydrogen feeding procedure. It has been demonstrated that its efficiency and durability are improved when using a hydrogen recirculation system. In the recirculation mode, the unused gas is returned to the inlet by a pump or a compressor or using a passive device such as an ejector.

Ejectors are devices used to induce a secondary fluid by momentum and energy transfer from a high energy primary jet. Their application for the recirculation system of a fuel cell is very beneficial due to their low maintenance, no moving parts and no parasitic power.

In this work, an ejector has been designed to be implemented in a PEM fuel cell test station to analyze how ejector based hydrogen recirculation systems affect PEM fuel cells. The proper design of an ejector must take into account several geometrical parameters that can only be studied using Computational Fluid Dynamics (CFD). Thus, a CFD model has been implemented using the High Mach Number Flow interface in COMSOL Multiphysics with the CFD Module.

The model proposed solves the problem of the ejector using an axisymmetric 2D geometry. As the density of the fluid is variable, the Favre averaged Navier-Stokes equations are used. These equations are approximated using the standard k-ε turbulence model and assuming that the gas follows the ideal gas law. The thermodynamics and transport properties for the gas are held constant. Both consistent and inconsistent stabilization methods are used. Isotropic diffusion is added to obtain an initial solution and then the problem is solved again without using it.

An experimental ejector has been designed using the model and manufactured. Then, it has been tested experimentally with air to validate the model. Results showed that the model is capable of capturing the mass flows obtained for different operative conditions (Figure 1).

After validating the model, the geometry of the ejector to be implemented for the PEM fuel cell test station has been obtained by carrying out a parametric study to find the optimum geometrical parameters.

All the experimental tests were performed at the PEM Fuel Cells Laboratory of the "Institut de Robòtica i Informàtica Industrial" (CSIC-UPC, Barcelona, Spain) and only possible due to its advanced equipment and proficient technical staff. This work has been partially funded by the Spanish national project MESPEM (Ref. DPI2011-25649) and the Spanish Ministry of Education, Culture and Sport and UPC Fluid Mechanics Department "Beca de Colaboración".

Reference

He S et al. , Progress of mathematical modeling on ejectors, Renewable and Sustainable Energy Reviews 13, 1760-1780 (2009).

Zhu Y, Li Y, New theoretical model for convergent nozzle ejector in the proton exchange membrane fuel cell system, Journal of Power Sources 191, 510-519 (2009).

Zhu Y et al. , Numerical investigations of geometry parameters for design of high performance ejectors, Applied Thermal Engineering 29, 898-905 (2009).

Figures used in the abstract

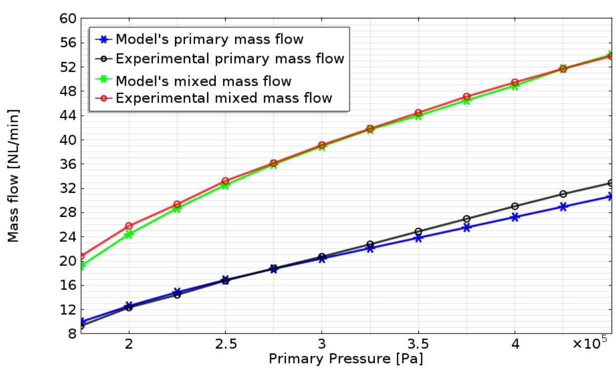

Figure 1: Mass flows vs primary pressure obtained experimentally and with the model. The gas used is air.

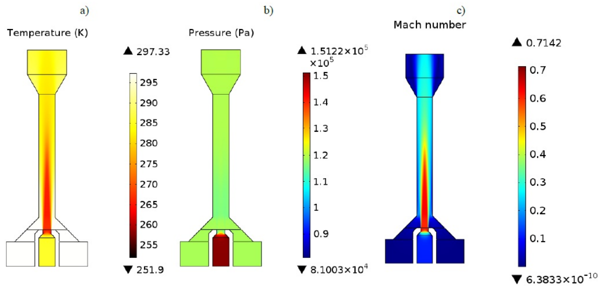

Figure 2: Results for primary pressure equal to 1.75 bar absolute. a) Temperature. b) Pressure. c) Mach Number.

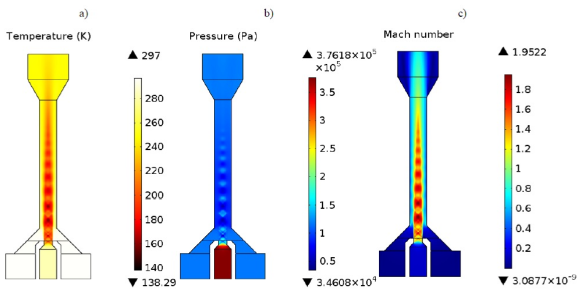

Figure 3: Results for primary pressure equal to 4.5 bar absolute. a) Temperature. b) Pressure. c) Mach Number.