esi get it right™

BALLARD®

Flow Simulation Improves Robustness of Fuel Cell Design

THE CHALLENGE

- Improving the efficiency and life of a fuel cell
- Understanding the complex flow inside the tiny individual cells

THE STORY

Fuel cells represent one of the most important automotive design challenges of the 21st century because of their potential to eliminate dependence on fossil fuel sources and to eliminate carbon emissions that are theorized to be responsible for global warming. Yet fuel cells provide enormous design challenges, primarily increasing their power and robustness while reducing their cost to levels that will make them competitive with internal combustion engines. Flow simulation is playing a major role in this process by enabling engineers to understand and visualize the complex flow within with the fuel cell which plays a critical role in its performance.

"Simulation has helped us significantly increase the efficiency and life of proton exchange membrane fuel cells (PEMFCs) by reducing variations in flow between the individual cells, and within individual cells,"

Sanjiv Kumar,
Ballard Power Systems,
Burnaby, British Columba.

THE BENEFITS

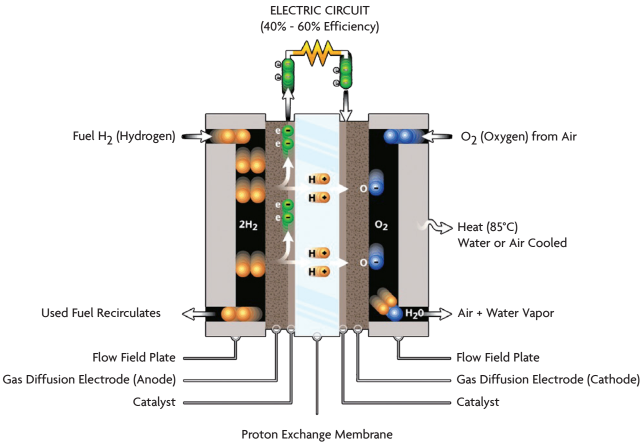
- Increase power generation efficiency
- Increase in life of cell
- Engineering time savings

Ballard Power Systems, Burnaby, British Columbia, is a leader in the design, development and manufacture of PEMFCs. PEMFC is considered the most promising fuel cell technology for automobiles because of their high power density. Today, approximately 130 Ballard-powered fuel cell vehicles have accumulated more than 3.9 million kilometers on roads around the world, and have delivered more than 4.5 people safely to their destinations.

Courtesy: Ballard Power Systems

Ballard's PEMFCs use a complex design with a stack consisting of multiple cell rows, each cell row having multiple cell plates, and each cell plate having many channels. The extreme variation in scale, which is a key factor in the power density of the device, creates major design challenges. One of the key design goals is to provide a uniform flow distribution in the approximately 20 kilometers of total flow circuits in a stack because the stack performance is often limited by the unit cell with the worst performance.

Ballard uses CFD-ACE+ software including its PEMFC module to perform comprehensive 3D simulations of fuel cells. The full stack model is too large to run as one job so Ballard has created several different models that the company uses to optimize fuel cell performance at different scales.

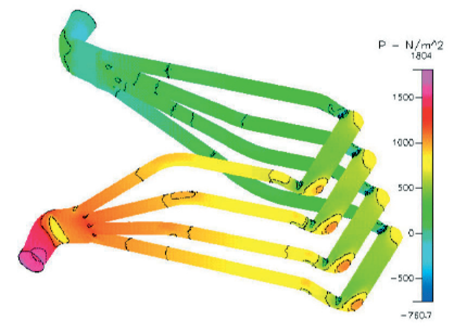


Proton exchange membrane fuel cell

OPTIMIZING MANIFOLD AND HEADERS

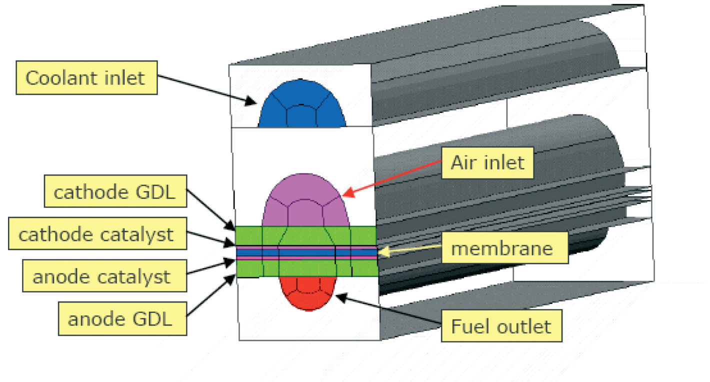
One key task is to design the manifold to balance mass flow between all cell rows and optimize pressure drops. This required a large-scale model that did not need to account for the details of the flow in the individual cells. First, manifold segments were optimized for pressure drop through CFD simulation. After optimizing the bends, CFD was used to analyze the complete manifold and ensure that mass flow between all cell rows is equally distributed.

The next step in the flow path is the headers which distribute gases to the individual cells. Optimizing the headers required a model that simplifies each cell flow field to an equivalent flow resistance to represent pressure drop in active cells. The CFD-ACE+ model of the header showed that flow



CFD used to optimize flow distribution in manifold

exiting the cells hit the outside wall of the header and formed two vortices. Flow separated towards the dead end of the inlet header leading to poor flow distribution for the last cells. Based on these insights, the header geometry in the model was changed several times and then the model was re-run until the flow field in the header was substantially improved.



Single channel CFD model

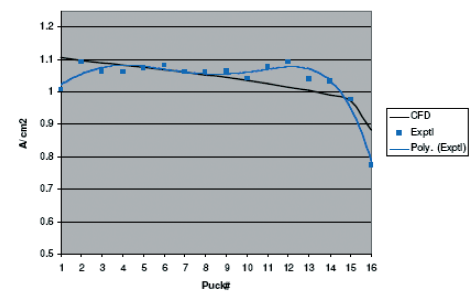
OPTIMIZING CELL PLATE GEOMETRY

The fuel cell must be modeled at even a smaller scale in order to optimize the cell plate geometry. A structured grid block with about 150,000 cells was created by extruding a 2D face mesh consisting of 700 quad cells along the length of a 200-node channel. The model was verified by comparing simulation predictions with experimental results for key metrics including cell voltage vs. current density, plate current distribution, MEA water content, coolant temperature rise, and sensitivity to operating conditions and material properties. The simulations closely matched the experiments.

After verifying the model, Ballard analysts varied geometric parameters that affect transport including channel cross-section area, channel hydraulic diameter, channel length, and ratio of channel width to land area. They gained many insights such as that predicted cell performance increases with increasing gas channel width and channel pitch, which indicates that coupled transport in the gas diffusion layer is dictated by electrical conduction.

CFD HAS BECOME TOOL OF FIRST CHOICE

"The net result was a substantial improvement in the robustness of our fuel cells designs," Kumar concluded. "We are continuing to improve our modeling techniques in order to increase the accuracy of our models and reduce computation time. Other potential improvements include filament based models to communicate with porous media and using simple path length lookup tables to capture the shape of the channels. As a result of these advancements, CFD has become the tool of first choice for fuel cell designers at Ballard."



Simulation matches experimental measurements of current density

ABOUT ESI GROUP

ESI is a world-leading supplier and pioneer of digital simulation software for prototyping and manufacturing processes that take into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behavior during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on product performance. ESI's products represent a unique collaborative and open environment for Simulation-Based Design, enabling virtual prototypes to be improved in a continuous and collaborative manner while eliminating the need for physical prototypes during product development. The company employs over 750 high-level specialists worldwide covering more than 30 countries. ESI Group is listed in compartment C of NYSE Euronext Paris. For further information, visit www.esi-group.com.

info@esigroup.com

EUROPE

CZECH REPUBLIC & EASTERN EUROPEAN COUNTRIES
MECAS ESI s.r.o.
Brojova 2113/16
326 00 Pilsen
Czech Republic
T. +420 377 432 931
F. +420 377 432 930

FRANCE
ESI France
Parc d'Affaires Silic
99, rue des Solets - BP 80112
94513 Rungis cedex
France
T. +33 (0)1 49 78 28 00
F. +33 (0)1 46 87 72 02

GERMANY
ESI GmbH
Sales & Technical Headquarters
Mergenthaleralle 15-21
D-65760 Eschborn
Germany
T. +49 (0)6196 9583 0
F. +49 (0)6196 9583 111

ITALY
ESI Italia srl
Via San Donato 191
40127 Bologna
Italy
T. +39 0516335577
T. +39 0516335578
F. +39 0516335601

SPAIN
ESI GROUP HISPANIA, S.L.
Parque Empresarial Arroyo de la Vega
C/ Francisca Delgado, 11 – planta 2ª
28108 Alcobendas (Madrid)
Spain
T. +34 91 484 02 56
F. +34 91 484 02 55

SWITZERLAND
Calcom ESI SA
Parc Scientifique
EPFL / PSE-A
1015 Lausanne-EPFL
Switzerland
T. +41 21 693 2918
F. +41 21 693 4740

UNITED KINGDOM
ESI-UK Ltd.
The Magdalen Centre
Oxford Science Park
Oxford OX 4 4GA
United Kingdom
T. +44 (0) 1865 784 829
F. +44 (0) 1865 784 004

SOUTH AMERICA

SOUTH AMERICA
ESI Group South America Ltda.
Rua Artur de Azevedo, 1857 cj. 45
São Paulo - SP 05404-015
Brazil
T/F. +55 11 3062-3698

ESI Group Headquarters
ESI Group
100-102 Avenue de Suffren
75015 Paris
FRANCE
T. +33 (0)1 53 65 14 14
F. +33 (0)1 53 65 14 12

NORTH AMERICA

USA
ESI North America
Commercial Headquarters
36800 Woodward Avenue
Suite 200
Bloomfield Hills, MI 48304
USA
T. +1 (248) 203 0642
F. +1 (248) 203 0696

USA
ESI US R&D
6767 Old Madison Pike
Suite 600
Huntsville, AL 35806
USA
T. +1 (256) 713-4700
F. +1 (256) 713-4799

ASIA

CHINA
ESI-ATE Holdings Limited
Room 16A,
Base F Fu Hua Mansion
No. 8 Chaoyangmen
North Avenue
Beijing 100027
China
T. +86 (10) 6554 4907
F. +86 (10) 6554 4911

CHINA
ZHONG GUO ESI CO., LTD
Unit 401-404, bldg G,
Guangzhou Soft-Park No. 11, Caipin Road, Guangzhou
Science City (GSC)
Guangzhou 510663
China
T. +86 (020) 3206 8272
F. +86 (020) 3206 8107

INDIA
ESI India
Indrakrupa #17, 100 feet ring road
3rd phase, 6th block,
Banashankari 3rd stage
Bangalore 560 085
India
T. +91 98809 26926
F. +91 80401 74705

JAPAN
Nihon ESI K.K.
Headquarters and Sales Division
5F and 16F Shinjuku Green Tower Bldg, 6-14-1,
Nishi-Shinjuku
Shinjuku-ku, Tokyo 160-0023
Japan
T. +81 3 6381 8490
F. +81 3 6381 8488

KOREA
Hankook ESI
157-033, 5F MISUNG bldg., 660-6,
Deungchon-3Dong,
Gangseo-ku,
Seoul
South Korea
T. +82 2 3660 4500
F. +82 2 3662 0084

SOUTH-EAST ASIA
ESI Group South-East-Asia Office
12A-2, Persiaran Puteri 1
Bandar Puteri Puchong
47000 Puchong, Selangor
Malaysia
T. +603-80607993
F. +603-80607661