get it right®

ACE+ SUITE

APPLICATIONS FOR FUEL CELL DESIGN, ANALYSIS, AND OPTIMIZATION

KEY BENEFITS

- Fully integrated and tightly coupled model of the fundamental physics of fuel cells
- Coupled stress, strain and deformation
- Advanced graphical user interface for effortless control of all functionalities
- Dual potential formation used for electrochemistry in catalyst layers
- Built-in membrane models
- Extensive parametric and optimization tools
- User defined functions not required, but available if needed
- Account for pore size and catalyst loading

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

Sanjiv Kumar, Ballard Power Systems, Burnaby, British Columbia

In order to properly design fuel cells, engineers must have tools that are application-focused and have the proper physics at their core. ESI's ACE+ Suite, an engineering design and analysis tool used by various organizations worldwide because of its unique ability to model a wide range of physical and chemical phenomena, provides the perfect solution to conceptualize, analyze and optimize fuel cell systems.

MULTIPHYSICS MODELING OF FUEL CELLS

The physical phenomena of a fuel cell are complicated by the non-linear dynamic interactions among porous media fluid flow, heat transfer, species transfer, ionic and electronic conduction and electro-chemical reaction in the catalyst layer.

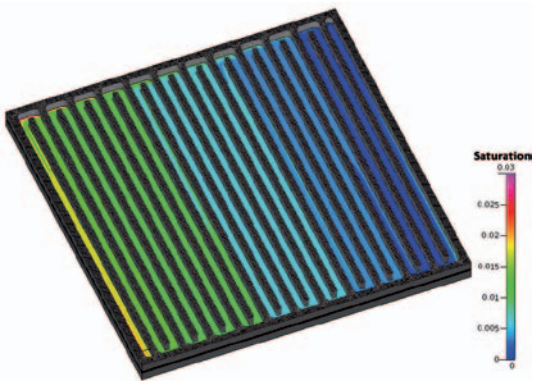
ACE+ Suite incorporates the proper mathematical models, for the relevant physics, and numerically solves the coupled equation set using a finite-volume based methodology. Currently three different types of fuel cells can be simulated using ACE+ Suite:

- Proton Exchange Membrane (PEMFC)
- Solid Oxide (SOFC)
- Direct Methanol (DMFC)

PROTON EXCHANGE MEMBRANE FUEL CELL (PEMFC)

ACE+ Suite provides unique capabilities to extensively model the fundamental physics of PEMFC. The fuel cell design engineer can use these tools to investigate the following issues:

- Membrane hydration, water formation and transport
- Effect of relative humidity, temperature, and pressure on cell performance
- Overpotential and ohmic losses in various regions of the membrane electrode assembly
- Effect of porosity, tortuosity, catalyst loading and other MEA properties on performance
- Design of fuel cell stack

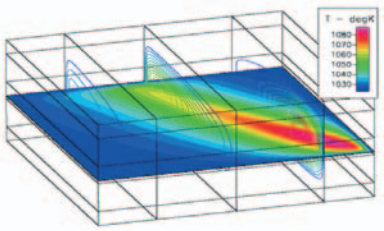


Water Analysis of PEMFC

SOLID OXIDE FUEL CELL (SOFC)

SOFCs present a unique challenge due to the high temperature operation and use of ceramics. ACE+ Suite addresses these issues by evaluating the following:

- Geometry and operating conditions and their effects on performance
- Efficiency of fuel utilization
- Effects of porosity , tortuosity, catalyst loading and other MEA properties on performance

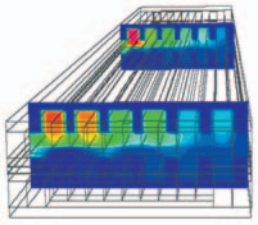


Temperature Distribution in SOFC

DIRECT METHANOL FUEL CELL (DMFC)

DMFCs produce electricity directly from liquid methanol, eliminating the need for a fuel reformer. ACE+ Suite incorporates the necessary physics to tackle the following critical issues:

- Electrode overpotential loss
- Complex parasitic reactions
- Effect of feed concentration
- Polarization behavior
- Methanol crossover effect
- Utilization of catalysts
- Power density
- Effects of porosity, tortuosity, catalyst loading and other MEA properties on performance

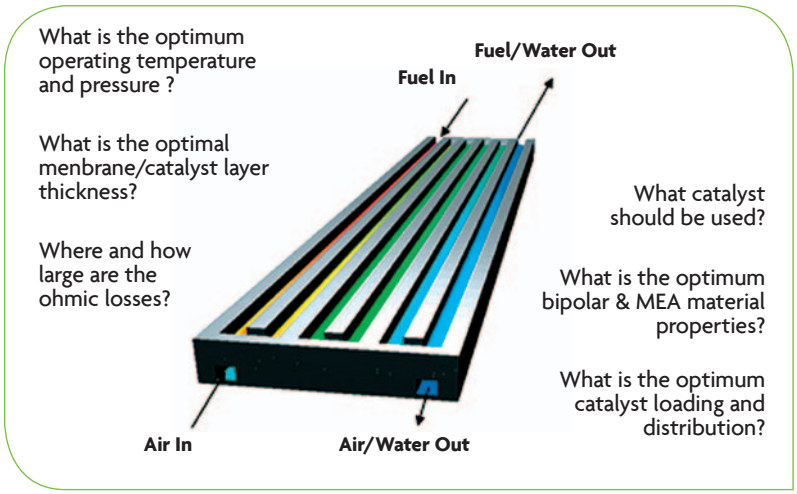


Methanol Crossover Effect for DMFC

FUEL CELL PHYSICS AT YOUR FINGERTIPS

- Full porous media flow formulation including acceleration of flow due to area constriction and pressure drop due to anisotropic linear and/or non-linear resistances
- Heat and mass transfer in porous media with the effect of tortuosity on diffusion included
- Perform electrochemistry in catalyst layers using a dual potential formulation
- Built in membrane models (e.g. Nafion 117 for PEMFC)
- Post-processor generates values for voltage-current
- Species transport described by Stefan Maxwell equations
- Heterogeneous chemical reactions within the catalyst layer are described by performing detailed reaction-diffusion balances at the pore-catalyst ionomer interfaces
- Liquid water transport is described by solving a separate transport equation for the liquid saturation in a PEMFC
- Full support for parallel processing

Fuel Cell Design Issues



ABOUT ESI GROUP

ESI is a pioneer and world-leading provider in virtual prototyping 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 performance. ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping, thus 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.

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