Time-efficient models for flow fields design in Iron and Vanadium Flow Batteries

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Research Objectives

Context

- Flow field design is critical for Flow Batteries, affecting power density, efficiency, corrosion and overall cost
- Evaluating new configurations requires computationally expensive simulations and time-consuming experiments, limiting the alternatives explored
- VFBs mostly rely on the simplest flow-through design; alternative solutions remain rarely adopted at industrial scale

Objectives

- Develop a cost-effective methodology to efficiently evaluate and optimize different flow field designs
- Overcome the limitations of traditional approaches, also enabling geometry customization for emerging chemistries (e.g. iron-based, organic-based)

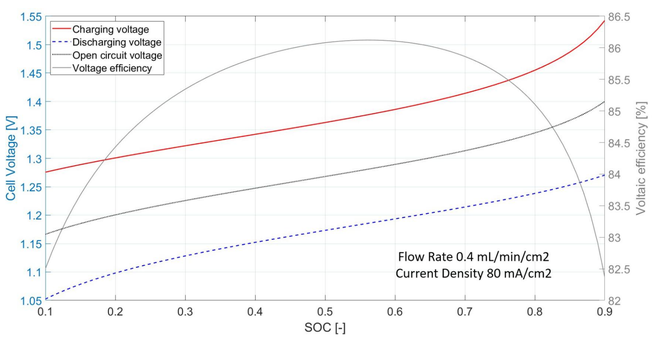
Method

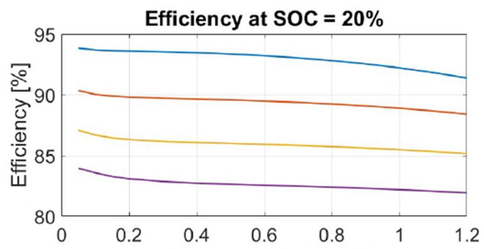
- Lumped-parameter model replicating FB cell voltage at given operating conditions, used for parameter identification
- Fast CFD-assisted model for a complete and reliable assessment of flow field mechanical and electrochemical behaviour
- The two methods are intertwined, by using in the CFD-assisted model the parameters fitted with the lumped one on a flow through geometry

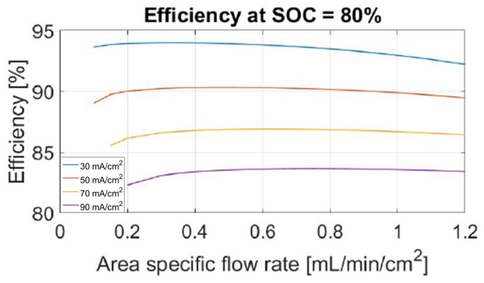
Lumped Model

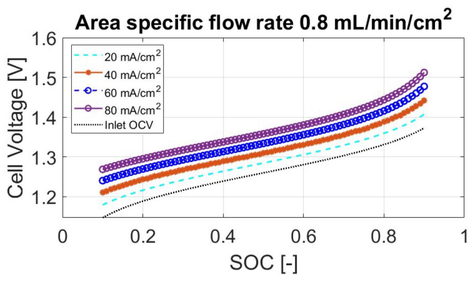
Features

- Physics-based replication of FB cell voltage
- Inputs: current, SoC, electrolyte flow rate
- Calculates pressure drops across electrodes and hydraulic circuits
- Requires identification of viscosity, porosity, and permeability
- Computes overall FB efficiency including pump losses
- Compatible with flow-through, interdigitated, and any chemistry







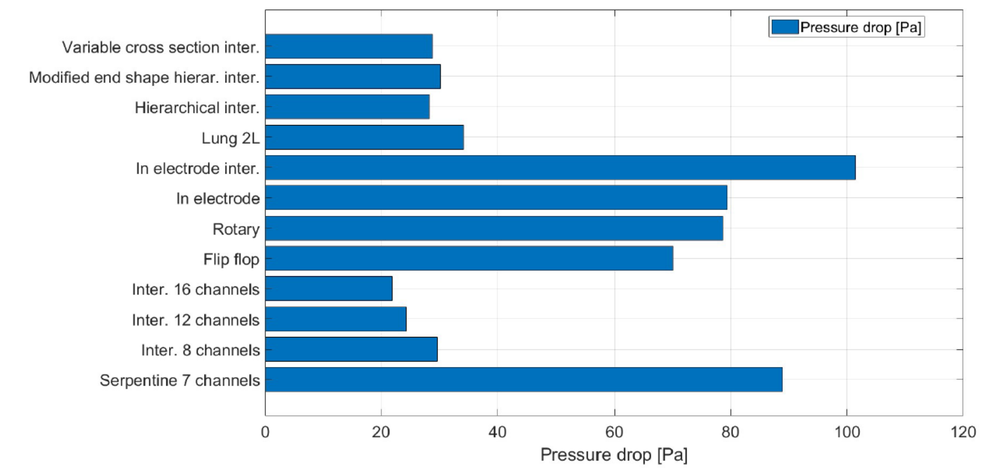


Flow Fields Comparison

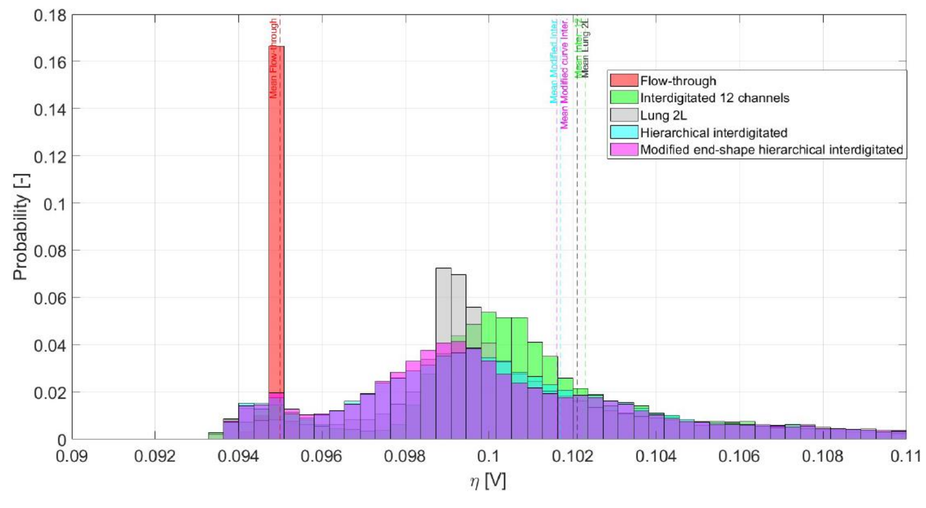
Application

- Applied to 12 geometries: interdigit, flow-by, in-electrode
- Model implemented for both iron and vanadium electrolytes
- Evaluation of statistical distribution of overpotentials
- Interdigitated flow fields showed best overall compromise

Cell pressure drops per configuration



Statistical distribution of overpotentials

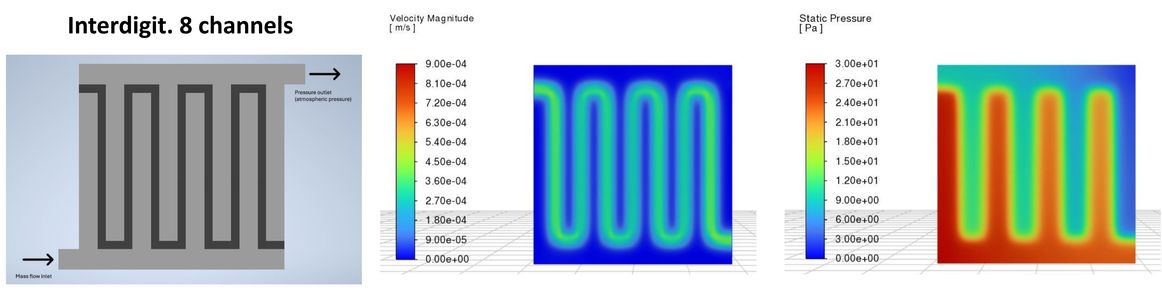


CFD-assisted Model

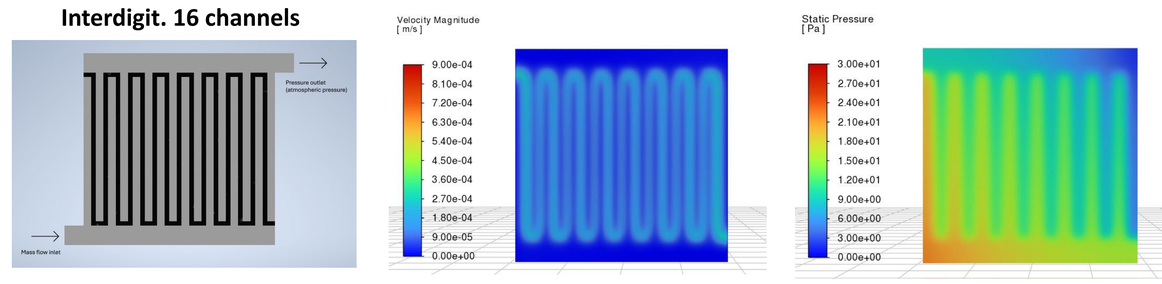
Features

- Assesses mechanical and electrochemical behaviour of any flow field geometry
- CFD part computes pressure drops and velocity fields within electrode and channels
- Electrochemical part calculates local overpotentials using CFD velocity as input
- Uses parameters fitted from the lumped model on simpler configurations
- Enables fast evaluation of multiple geometries with low computational cost

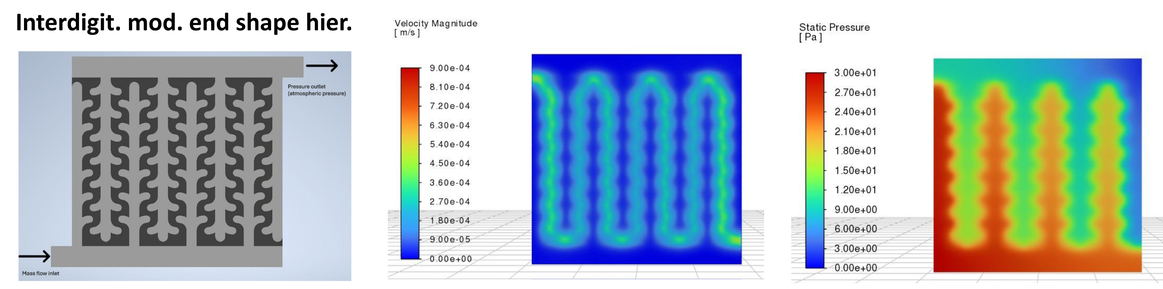
Interdigit. 8 channels



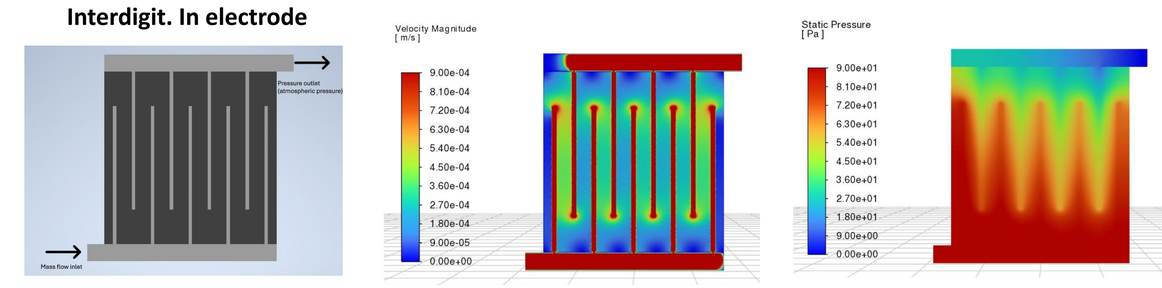
Interdigit. 16 channels



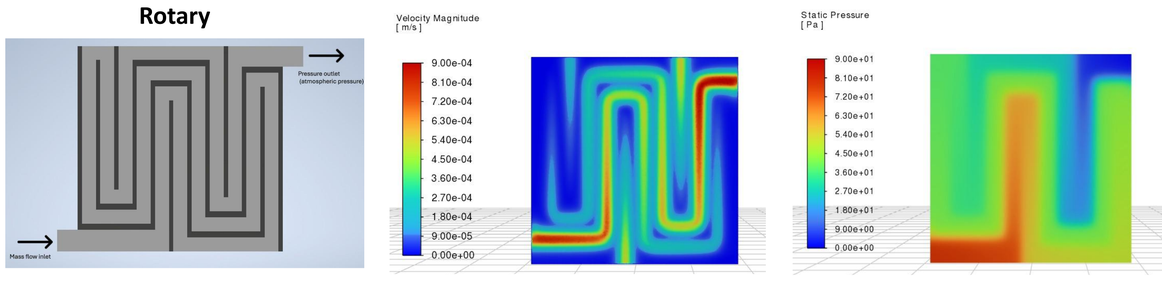
Interdigit. mod. end shape hier.



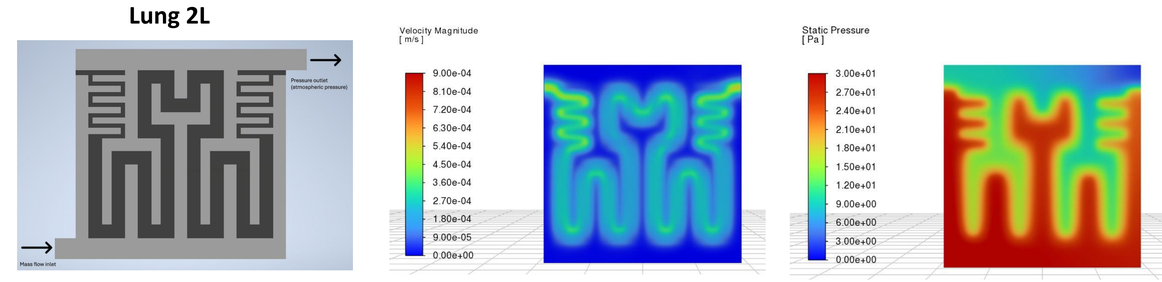
Interdigit. In electrode



Rotary



Lung 2L



Results

- Developed an efficient methodology for flow field performance evaluation
- Applied to conventional and novel fluid path geometries
- Detailed prediction of hydraulic and electrochemical performances
- Interdigitated flow fields designs yield best overall efficiency
- The methodology enables significant reduction of development costs

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