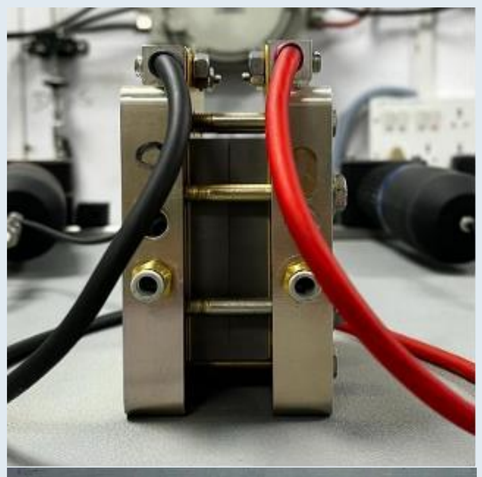

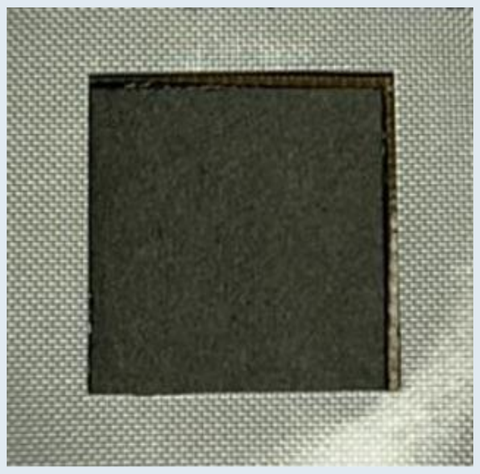

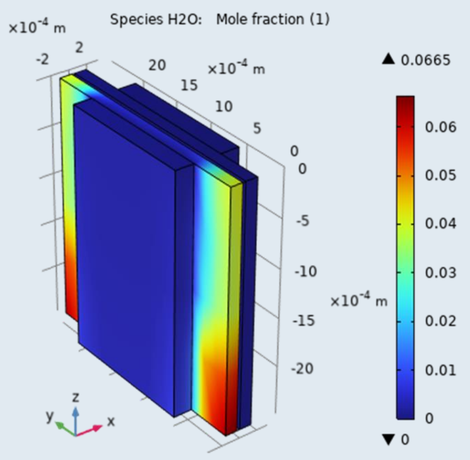

Numerical simulation of Proton Exchange Membrane Fuel Cell using COMSOL Multiphysics and elucidating the effect of different flow rates and temperatures

COMSOL Multiphysics is employed to develop a comprehensive numerical Proton Exchange Membrane Fuel Cell model

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Abstract

A comprehensive numerical model for a PEMFC was developed using COMSOL Multiphysics. The model was designed to explore how varying fuel flow rates at the anode and cathode within a defined temperature range can impact the performance attributes of the PEMFC. The model integrates phenomena like mass transport, momentum transport, electrochemical reactions, and fluid dynamics, to capture the complex interactions within the PEM fuel cell structure.

The electrochemical reactions are represented using appropriate kinetics (Butler-Volmer) and thermodynamics. As a result, difference in the current and power density values observed while varying fuel flow rates is due to fuel starvation or flooding which limits reactants transportation. The model is studied and validated by comparing with experimental results obtained from operating a PEM fuel cell.

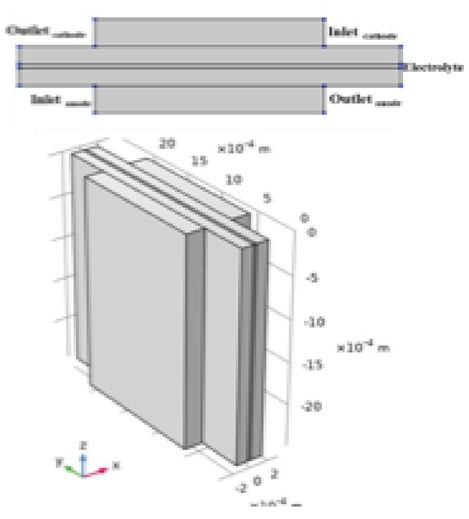

Figure 1: Left - Photograph of the HT-PEM Fuel cell test bench, Fuel cell assembly and the Membrane Electrode Assembly (MEA). Right - Geometry of PEMFC model constructed using COMSOL Multiphysics in 2D and 3D domains

Methodology

Experimental method: High-temperature PEMFC performance was conducted using Magnum H&H-Gmbh FC Midi test bench and a fuel cell with MEA of 5cm^2 active area. Polarization and power curves at varying conditions by altering cathode and anode flow rates and temperature was generated.

Modelling Method: COMOSL Multiphysics version 6.0 is employed to develop comprehensive numerical PEMFC model. Both 2D and 3D layout with all the fuel cell components was designed for in-depth analysis. A segmented step-by-step approach, utilizing the PARDISO solver with an overarching relative tolerance set at 0.001 was adopted.

Results

- The model is composed of five distinct domains, featuring 30 faces and 56 edges. The mesh for this model consists of 1704 elements, each with a minimum element quality of 0.8293.
- Electrolyte potential exhibits a gradual increase with rising temperature suggesting an improvement in mass transport, attributed to enhanced ion mobility.
- As the temperature is elevated from 303.15 K to 363.15 K, the production of water vapor gradually diminishes because at higher temperatures, water vapor may undergo more rapid diffusion through the PEM and into the gas streams.
- The simulated and experimental data showed comparable results.

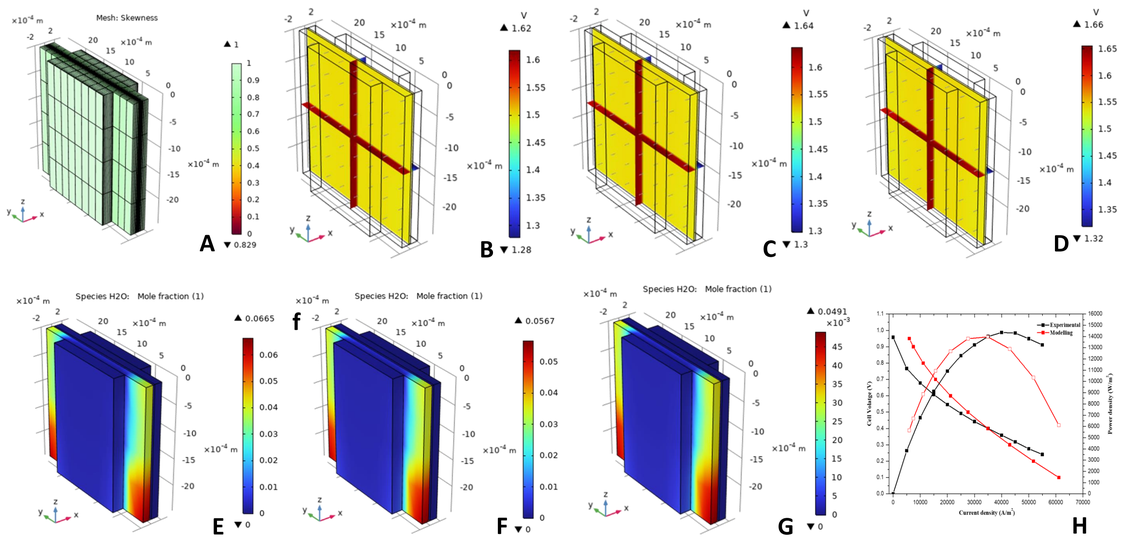

Figure 2: A - Mesh quality distribution of PEMFC Model; **Figure B, C, D** - Distribution of electrolyte potential and electrolyte current density vector at temperature of 303.15 K, 333.15 K and 363.15 K, Flow rate: 200-100 mL/min (case III) and Voltage: 0.1 V. Multislice: Electrolyte potential (V) & Arrow volume: Electrolyte current density vector; **Figure E, F, G** - Mass distribution of H2O at a voltage and flow rate of 0.1 V and 200-100 (H2-O2) mL/min at 303.15 K, 333.15 K and 363.15 K; **Figure H** - Comparison of Experimental and Simulation Results: Polarization and Power Curves of PEMFC at 303.15 K

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