Analytical bipolar modelling for redox flow battery design

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Introduction

This study proposes a novel bio-inspired bi-polar plate design to minimise losses due to electrolyte transport. Using numerical simulations, we simulate electrolyte flow in two bi-polar plate designs: 1) serpentine channel and 2) a leaf-inspired channel. We evaluate each design's effectiveness in addressing issues related to mass transport and pressure drop using numerical simulations of fluid flow in the channel and porous electrode. We aim to compare the pressure drop across the channel and the volume flux into the porous electrode to assess a design's efficacy.

Fig. 1: Depiction of leaf veins[1]

Numerical model

The simulation domain comprises of two key regions: 1) the porous electrode and 2) the bi-polar plate with an inlet and an outlet. The porous electrode is modelled using the free and porous media flow, Brinkman equations. The permeability of a porous material on its porosity is described by the Kozeny-Carman equation. The incompressible Navier Stokes equation is modelled in the bi-polar plate.

Results

Electrolyte flux in the serpentine pattern increases with increasing flow rates, peaking at a 0.6 porosity and decreasing with higher porosity. The leaf-inspired pattern shows increased half-flux with higher flow rates and porosity. The pressure drop for both patterns increases with the increasing electrolyte flow rate. Serpentine pattern generally higher volume flux at low porosities than the leaf-like pattern, while the opposite trend is observed at higher porosities. Leaf-like pattern achieves significantly better outcomes in terms of pressure drop compared to the traditional serpentine pattern.

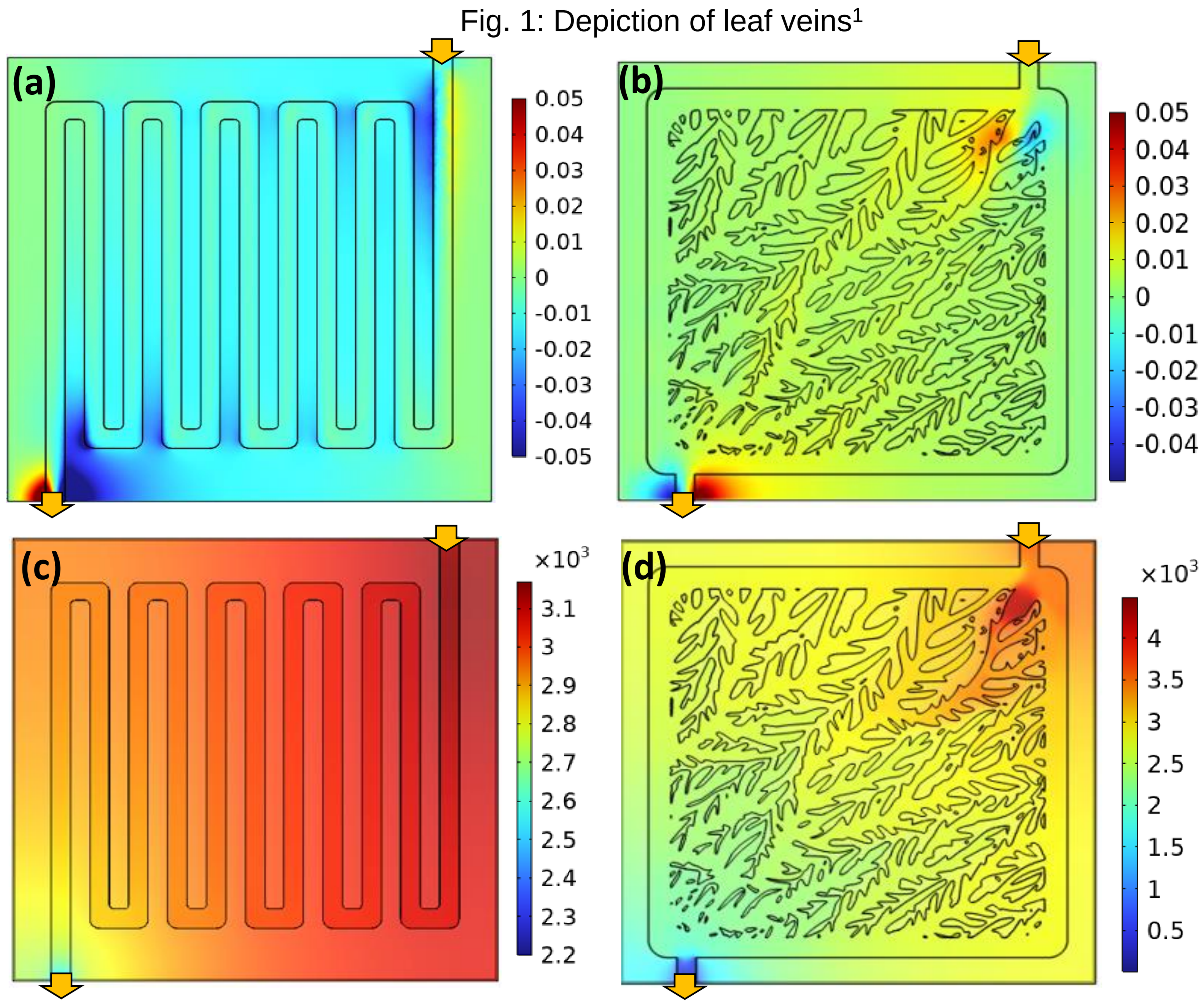

Fig. 2: Velocity into the porous electrode (perpendicular to plane) in (a) Serpentine and (b) Leaf-vein inspired channel. Pressure distribution in the foam in (c) Serpentine channel, (d) Leaf-vein inspired channel at 120 ml/min flow rate and 0.6 porosity.

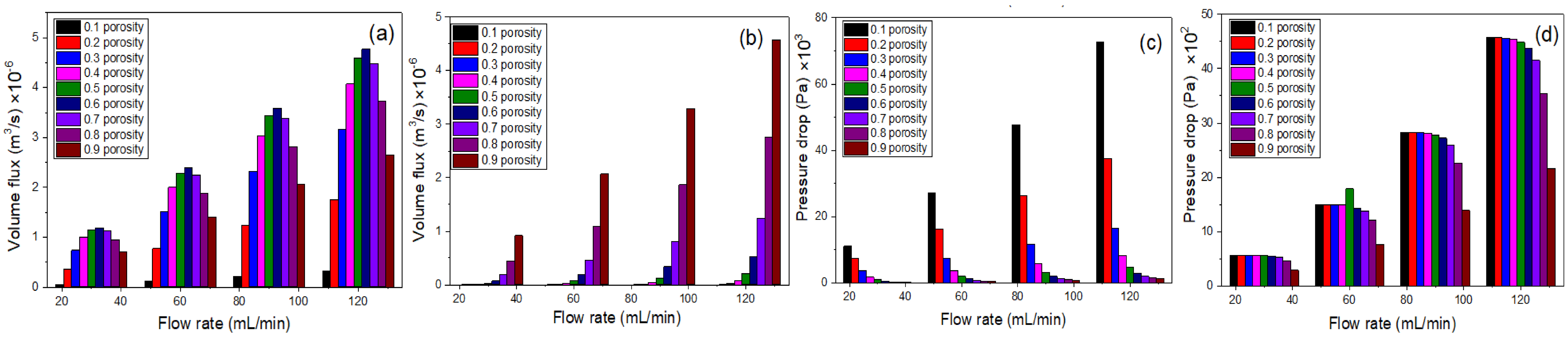

Fig. 3: Volume flux in the electrode in (a) Serpentine channel, (b) Leaf-vein inspired channel. Pressure drop across the (a) Serpentine channel, (b) Leaf-vein inspired channel.

Conclusion

Our results demonstrate that the leaf-like pattern achieves significantly better outcomes in terms of pressure drop compared to the traditional serpentine pattern.

We believe that this leaf-like structure could be key to enhancing the performance of Redox Flow Batteries (RFBs) by reducing pressure drop and improving ion distribution within the electrode, the leaf-like pattern could lead to substantial improvements in the overall performance of RFBs.

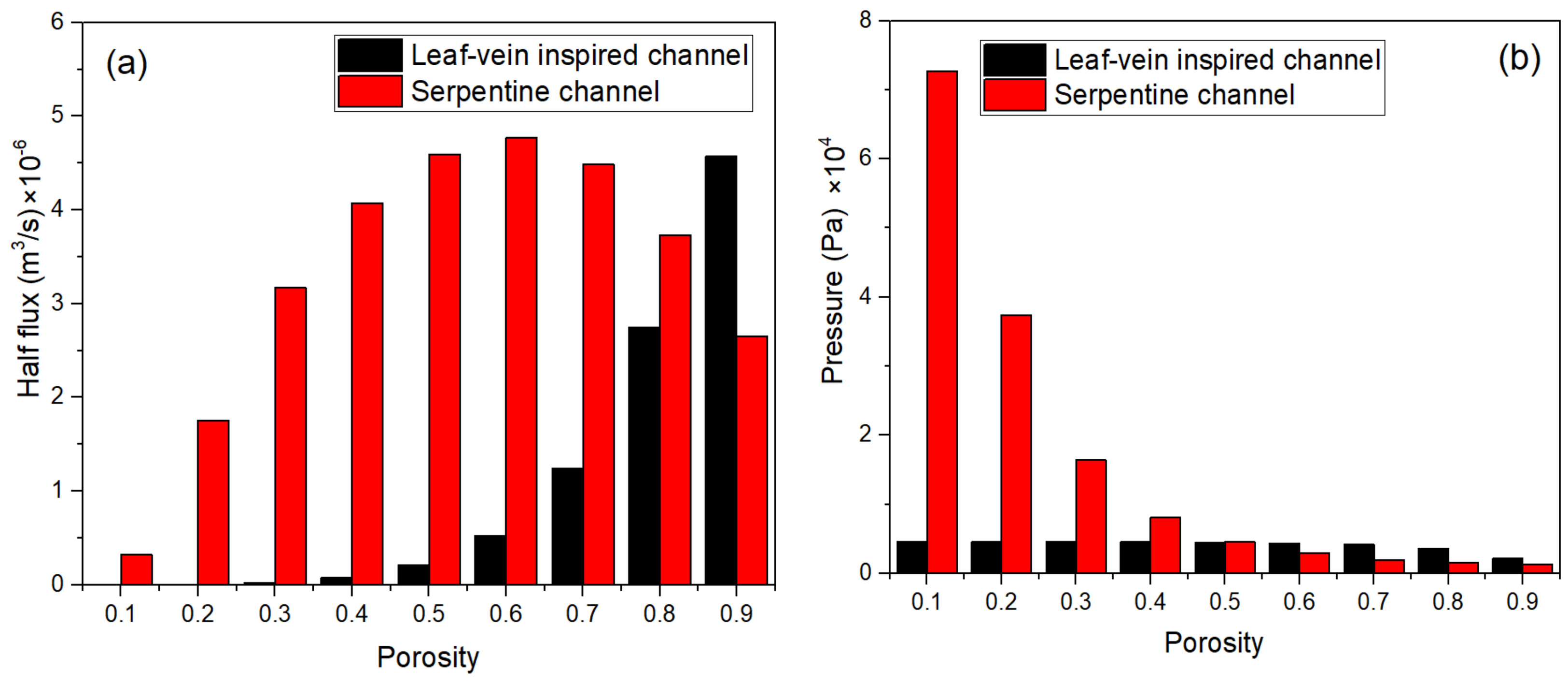

Fig. 4: Comparison of (a) Volume flux in the electrode and (b) the pressure drop across the channel in a serpentine channel and a leaf-vein inspired channel.

Reference

1. Adobe Stock images: www.stock.adobe.com
2. Ke, X. et al, Redox flow batteries with serpentine flow fields: Distributions of electrolyte flow reactant penetration into the porous carbon electrodes and effects on performance. *Journal of Power Sources* **2018**, *384*, 295-302.

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