Proceedings of the 12th International Conference on Fluid Flow, Heat and Mass Transfer (FFHMT 2025)
July 15, 2025 - July 17, 2025 | Imperial College London Conference, London, United Kingdom
Paper No. 147
DOI: 10.11159/ffhmt25.147

Design of Bio-Inspired Novel Flow Fields for Effective Distribution of Electrolyte in Large-Scale Redox Flow Batteries

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Extended Abstract

Redox flow batteries are emerging as promising energy storage devices in the modern energy sector. These are distinguished from conventional batteries like Li-ion and Lead-acid in the rating of power to energy ratio [1]. Power is translated from the number of cells in a battery stack whereas the energy is quantified based on the amount of electrolyte stored in external tanks. In view of de-coupled feature of power and energy, these devices show flexibility in designing for various power utility applications ranging from dwellings, charging stations to grid-level storage. These devices are free from fire hazard, catastrophic thermal run-away and have long-life of about 15 years or 10000 plus charge-discharge life cycles. Nevertheless, flow batteries are known for low power density. In order to make the flow batteries market favourable, it is critical to improve its power density. One way to improve power density without altering its economics is the design of flow fields on bipolar plate for *effective distribution of electrolyte* i.e., supply of reactants to all the active sites of the electrode with low mass transport resistance (low pumping losses) and simultaneously replenishing the active cites of electrode with reactants by quick evacuation of reaction products. As the electrolyte stored outside the battery, it needs to be pumped to each and every electrode of cells. The cell potential arising from the electrochemical reaction in the electrode depends on availability of reactants on active sites of the electrode. As per the practical implications that required at stack level battery systems, cell active area (i.e. the area of electrode) should be as large as possible subject to pumping losses, shunt current losses and mechanical fabrication issues. Larger the size of the cell, harder the maintaining uniform distribution of electrolyte throughout the electrode. For this, one need to design a flow field for effective distribution of electrolyte. Authors have investigated bio-inspired flow fields like lung-pattern, leaf-pattern [2] and compared them with standard conventional flow fields like serpentine and interdigitated. For a standard flow rate of 1 $ml/min/cm^2$ of cell area, the serpentine flow field is favourable with flow uniformity but at the cost of huge pressure drop of 72000 Pa, whereas the interdigitated is favourable with low pressure drop of 7500 Pa but at severe flow non-uniformity [3, 4]. The designed lung-pattern and leaf-pattern have resulted in low pressure drop of about 6000 Pa with improved flow uniformity compared to the interdigitated and still far-away from the serpentine in flow uniformity index. The results guided to incorporate the features of serpentine and interdigitated into lung/leaf pattern to obtain both the flow uniformity and low pressure drop [5]. The design of inter-serpentine in lung shape have shown flow-uniformity index similar to the serpentine with reduced pressure drop from 72000 Pa to 5000 Pa. This can lead to significant savings in pumping losses in stacks of flow batteries thus improving system level energy efficiency and improves power density in view of improved electrochemical kinetics associated with flow-uniformity.

Keywords: Flow Batteries, Flow fields, Power density, Electrolyte distribution, Pumping losses

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