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The Importance of Cell Compression Pressure for Redox Flow Battery Performance

Abstract Draft:

Compared to fuel cells, which possess similar cell architecture, redox flow batteries have poor performance. For example, conventional fuel cells can easily achieve current densities of 1.5 A cm^{-2} whereas the corresponding figure for the all vanadium redox flow battery is an order of magnitude less, often less than 0.2 A cm^{-2} [1]. A direct comparison is unfair because redox flow batteries operate at higher efficiencies than fuel cells. However, typical vanadium redox flow batteries cannot achieve 1.5 A cm^{-2} even at low efficiencies [2-4]. Consequently, relatively large flow battery cells are required for a given power, increasing the cost of the technology.

There are a few noticeable exceptions to the relatively poor performance of flow batteries, including the work of Zawodzinski et al. who achieved current densities in excess of 0.8 A cm^{-2} with a vanadium system [5]. Most impressively, Weber and co-workers recently achieved current densities as high as 4 A cm^{-2} with a H_2-Br_2 flow battery [6]. In both cases, the researchers used fuel cell components and fuel cell assembly techniques to minimize the cell ohmic resistance. A key component of cell resistance is the contact resistance between the cell parts, particularly the electrodes, bipolar plates and current collectors. Typically, fuel cells are assembled using compression pressures of above 8 bar to minimize the contact resistance to levels that allow high current densities to be achieved.

In comparison, redox flow batteries mostly employ carbon fibre felt as the electrode material and use compression pressures of around 1 bar during cell assembly, hence contact resistance values are relatively high. A number of studies have measured the effect of felt compression on battery performance [7-9]. In these studies, the felt compression is often increased from 0 to 30%, resulting in a decrease in cell resistance and a noticeable improvement in performance (i.e. higher current densities for a given cell potential). However, increasing compression pressure decreases the felt thickness and permeability such that larger pumping pressures are required to deliver the required volumetric flow rates. In addition, membrane punctures become increasingly likely as the compression pressure is increased. Consequently, little work has been carried out with highly compressed felts.

This study builds on previous felt compression work by exploring a much wider range of compression pressures using a vanadium redox flow battery system with a novel cell design [10] that allows compressions from 0 to beyond 50% to be explored with relative ease, helping establish a value for the lowest cell resistance that can be achieved with carbon fibre felt. An in-situ reference electrode combined with electrochemical impedance allows the study of

each half cell under different compression pressures, the latter being accurately measured with pressure mapping technology. The effect of compression on felt permeability is also quantified and compared with mass transport insights gained from the impedance measurements. Durability test cycles with different felt compressions followed by analysis of the membrane provide insights into the damage caused by high compression pressures. Finally, other electrode materials are assessed using the same flow battery system at compression pressures up to 10 bar with the aim of achieving cell resistance values similar to that in conventional fuel cells.

The results of the study highlight the importance of cell compression and demonstrate a key factor in redox flow battery development is decreasing contact resistance within cells, effectively making a flow battery more like a conventional fuel cell.

References:

[1] P. Leung, X. Li, C. Ponce de León, L. Berlouis, C. T. John Low, F. C. Walsh, RSC Advances, 2 (2012) 10125.

[2] M. Kazacos, M. Skyllas-Kazacos, Performance Characteristics of Carbon Plastic Electrodes in the All-Vanadium Redox Cell, J. Electrochem. Soc., 136 (1989) 2759.

[3] D. Chen, S. Wang, , M. Xiao, Y. Meng, Preparation and properties of sulfonated poly(fluorenyl ether ketone) membrane for vanadium redox flow battery application, J. Power Sources, 195 (2010) 2089;

[4] E. Kjeang, R. Michel, D. A. Harrington, N. Djilali, D. Sinton, A Microfluidic Fuel Cell with Flow-Through Porous Electrodes, J. Am. Chem. Soc. 130 (2008) 4000;

[5] D. S. Aaron, Q. Liu, Z. Tang, G. M. Grim, A. B. Papandrew, A. Turhan, T. A. Zawodzinski, M. M. Mench, Dramatic performance gains in vanadium redox flow batteries through modified cell architecture, J. Power Sources, 206 (2012) 450;

[6] K. T. Cho, P. Albertus, V. Battaglia, A. Kojic, V. Srinivasan, A. Z. Weber, Optimization and Analysis of High-Power Hydrogen/Bromine-Flow Batteries for Grid-Scale Energy Storage, Energy Technology, 1 (2013) 596.

[7] S.-K. Park et al., The influence of compressed carbon felt electrodes on the performance of a vanadium redox flow battery. Electrochimica Acta, 116 (2014) 447.

[8] K. Oh, S. Won, H. Ju, Numerical study of the effects of carbon felt electrode compression in all-vanadium redox flow batteries. Electrochimica Acta, 181 (2015) 13.

[9] T.-C. Chang, J.-P. Zhang, Y.-K. Fuh, Electrical, mechanical and morphological properties of compressed carbon felt electrodes in vanadium redox flow battery. Journal of Power Sources, 245 (2014) 66.

[10] http://c-flow.co.uk/wp-content/uploads/2015/07/C-Flow-LAB-datasheet.pdf