RELCoBatt – Reclaimed electrolyte, low-cost soluble lead battery

A lead acid battery based on an electrolyte with soluble lead

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Abstract

The purpose of the RELCoBatt project is to develop a low-cost soluble lead battery using electrolyte from recycled lead-acid batteries. The battery developed under the project differ from other flow batteries as it uses the same solvated Pb^{2+} ions for both electrode reactions, meaning it would not require a membrane and uses a single electrolyte, pumped through the stack of cells during operation (Figure 1). In this work, the influence of the state of charge was investigated by carrying out experiments with 3 different electrolyte compositions, simulating different states of charge:

25 % SoC = 0.18 mol dm^{-3} Pb^{2+} and 2.05 mol dm^{-3} methanesulfonic acid

50 % SoC = 0.35 mol dm^{-3} Pb^{2+} and 1.70 mol dm^{-3} methanesulfonic acid

75 % SoC = 0.53 mol dm^{-3} Pb^{2+} and 1.35 mol dm^{-3} methanesulfonic acid

Motivation

- Energy storage systems are becoming increasingly important as an essential component in power efficiency and distribution systems. Large-scale storage devices will be required for full and effective integration of renewable sources into the current production/distribution networks.[1]

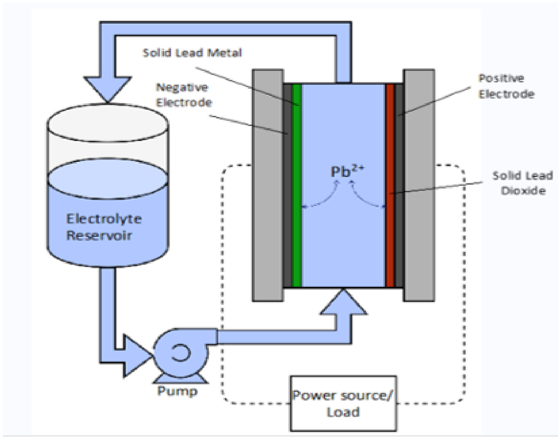


Figure 1. A drawing showing how a soluble lead flow battery operates

Methods

- Analyzing the battery at 25%, 50% and 75% states of charge, taking advantage of the changes in redox potential of the electrolyte (according to Nernst equation)
- Mixing electrolyte using lead dioxide (PbO_2) and methanesulfonic acid in concentrations of 25%, 50% and 75% (Figure 2)

Figure 2. Three bottles of electrolyte in different concentrations

Results

- The polarization curves for the 25%, 50% and 75% states of charge are plotted using the data obtained from the experiment performed using the MACCOR machine. A charging voltage was applied to the battery and varied using a potential sweep rate of 0.1 V s^{-1}.
- Another experiment was carried using an MTI battery analyser, where a step charge and discharge was performed by gradually incrementing the current from 50 to 500mA cm^{-2}.
- The data from these experiments is presented in Figure 3. The discrepancy in the data for the 75% state of charge is presumed to be due to the relatively rapid sweep rate used with the voltametric analysis method, which was 4 times quicker than that applied in the constant current ramping. A slower scan rate, would also mean the battery would charge for periods, resulting in a larger change in electrolyte composition. There is a therefore a lower lead concentration, which makes the mass transport considerations important to investigate in further work.
- Constant current charging was undertaken with each electrolyte (Figure 4), which shows the difference in voltage for different states of charge at a 200 mA cm^{-2} current density. It takes longer for the voltage to rise from open circuit potential to steady charging voltage at higher states of charge, showing the mass transport effect of lower lead concentrations.
- The battery was then cycled, from an initial zero state of charge for 20 cycles, while monitoring the coulombic, voltage and energy efficiency. This is plotted in figure 5, which shows. Cycling was performed using the MACCOR battery analyser (Figure 6). The flow battery shows quite a high efficiency at a fully uncharged state. There's a high Coulombic efficiency initially, which drops down after 15 cycles, with the energy efficiency following it just below 70%. The voltage efficiency stays stable throughout the cycles.

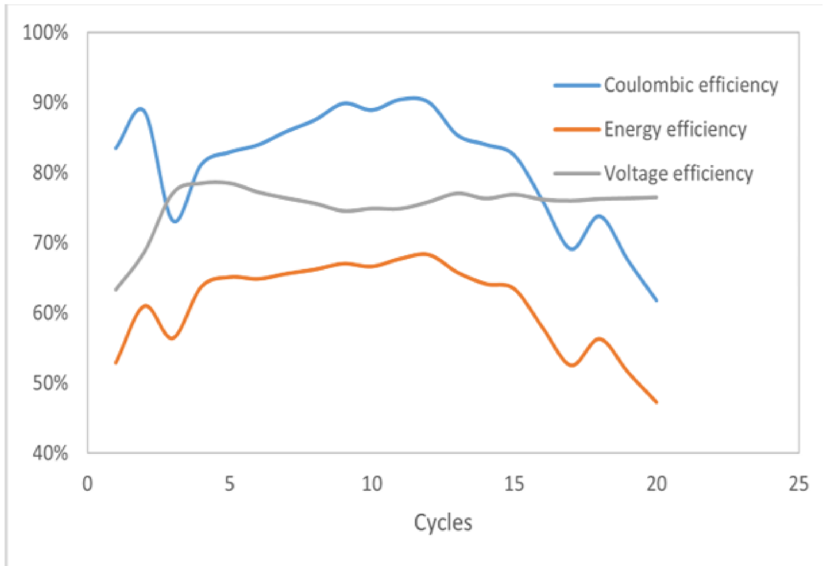
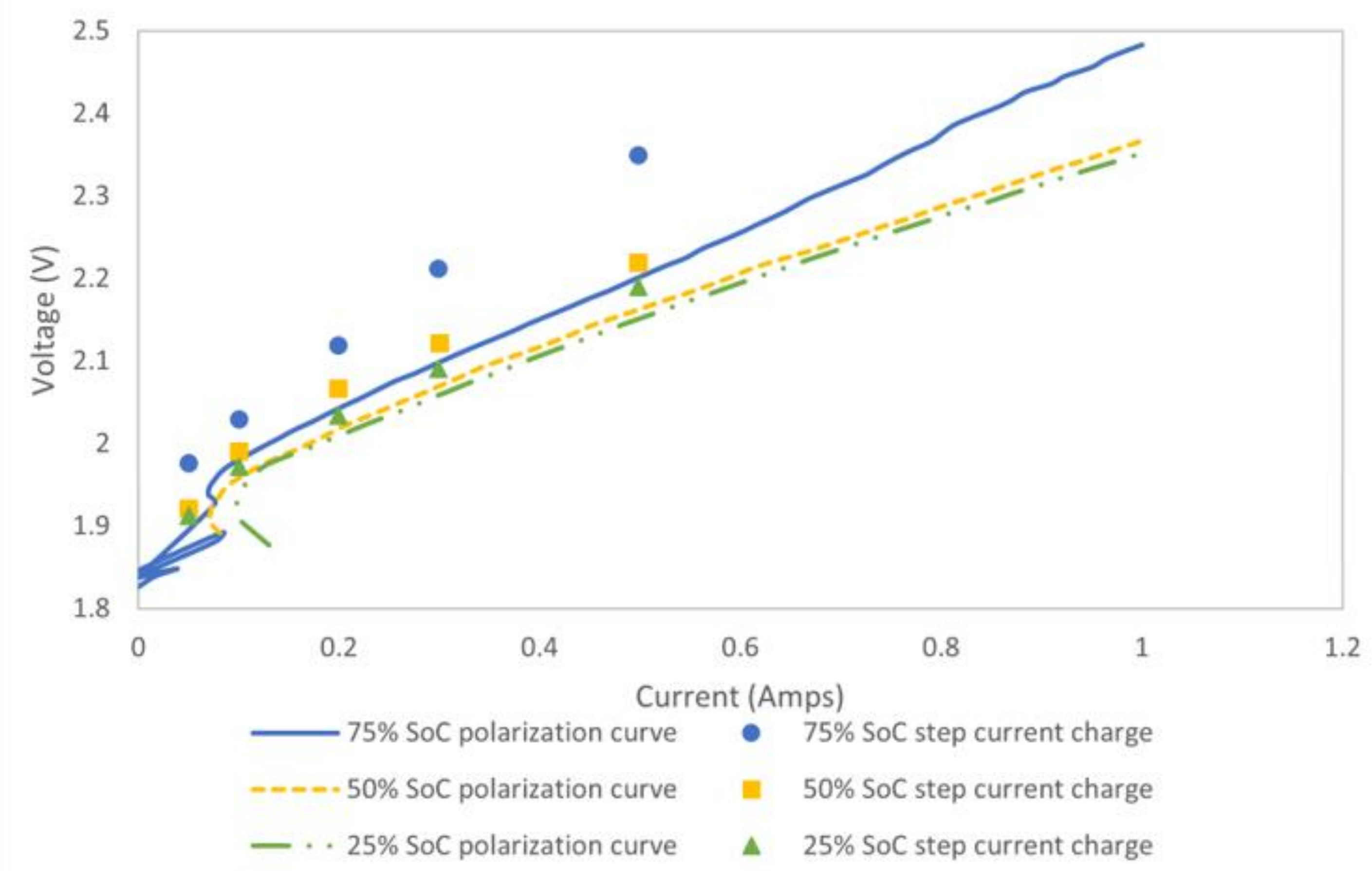


Figure 5. Coulombic, energy and voltage efficiencies over 20 cycles

Figure 6. A picture showing the MACCOR machine

Conclusions

- The effect of state of charge of the elecotrlyte used within the soluble lead flow battery has been assessed using voltammetry and constant current cycling.
- It was found that the voltage and open circuit potential increases with state of charge, which is consistent with the Nernst equation.
- Mass transport of lead too the electrode surfaces becomes increasingly important at higher states of charge (lower lead concentrations in the electrolyte)



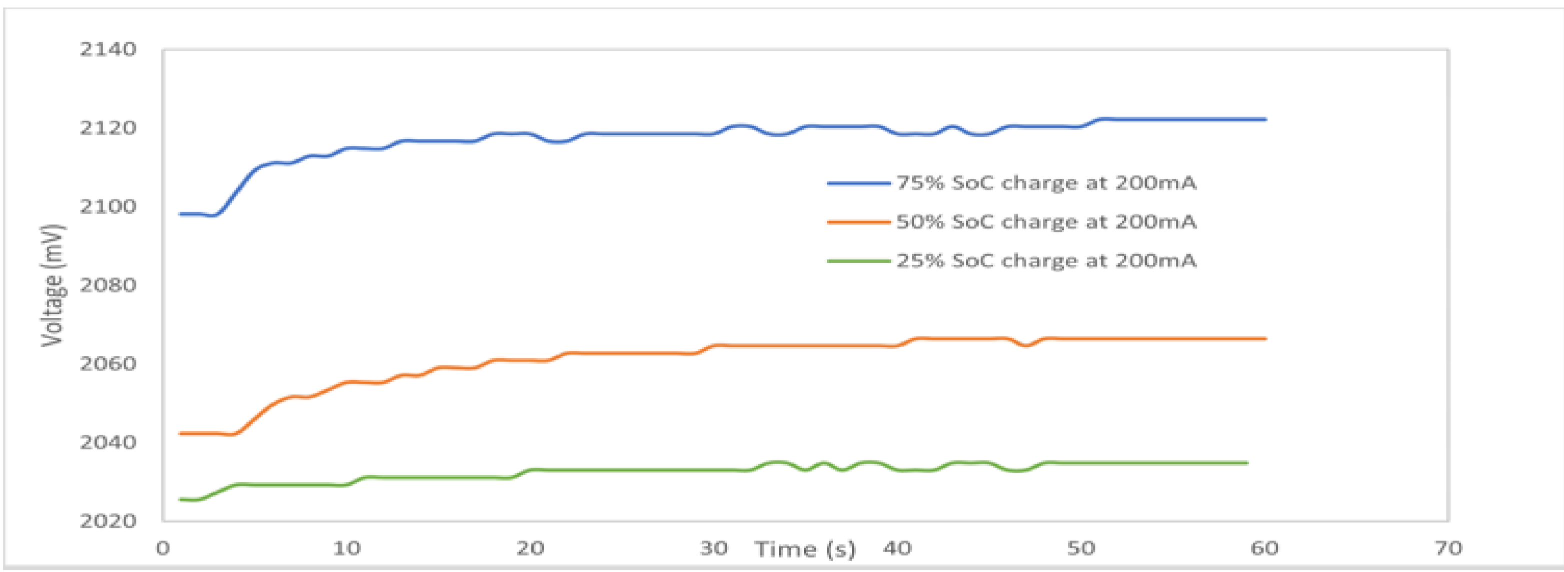


Figure 4. Constant current charge voltage difference for different states of charge

Impact / Next steps

- Obtain necessary resources (recycled lead paste) for large scale testing
- Test the full-sized soluble lead flow battery and obtain data for further improvements
- 4 kWh (16 kWh) lower cost batteries are to be deployed to Sierra Leone
- Exploit existing lead recycling process for low-cost electrolyte feedstock.

References

- Wills, R. G. A., Collins, J., Stratton-Campbell, D., Low, C. T. J., Pletcher, D., & Walsh, F. C. (2010). Developments in the soluble lead-acid flow battery. Journal of Applied Electrochemistry, 40(5), 955-965.
- Fraser, E. J., Ranga Dinesh, K. K. J., & Wills, R. (2021). A two dimensional numerical model of the membrane-divided soluble lead flow battery. Energy Reports, 7(2), 49-55

Intern bio

Anghelina Escov is studying Mechanical Engineering at the University of Southampton. Interested in aiding to build a more sustainable future. Aspiring to pursue a career in renewable energy technology.

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