Recent Progress on Numerical Simulation of Fast Charging Nickel Metal Hydride Traction Batteries

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Fast charging provides a plausible solution to the limited range drawback experienced in the use of electric vehicles (EVs). Therefore how to fast, reliably, and effectively charge the EV battery pack is an interesting challenge for the industry. Experimental study of fast charging is usually complicated and limited, due to safety concern, hardware constrain, cost issue, and technical difficulty in control of the test conditions. Computer simulation can be an interesting alternative for rapid charging technology development, which can provide detailed temporal and spatial information of the battery to help us understand and accurately control the fast charging processes.

This paper will discuss a computer simulation model that can accurately describe and simulate a commercial nickel metal hydride (Ni-MH) battery cell under rapid charging conditions. The model can account for not only voltage and current changes but also temperature and pressure behaviors in the system. This is particularly important in the rapid charging control, since high rate charging often encounters scenarios involving overcharging and gas evolution side reactions, therefore significant temperature and pressure swings.

The simulation model allows us to deal with possible side reactions and heat effects, under high rate charging. To accurately predict the battery performance, especially in rapid charging conditions, we have to consider these two critical issues, i.e., increasing changes of temperature and pressure in the Ni-MH traction battery. Along with the main battery reaction, the side reactions included in the present model are the evolution and recombination of oxygen and hydrogen. The heat effects originating from the contributions of electrochemical impedance of both main and side reactions, the enthalpy changes of such reactions, and the Joule heating from the internal Ohmic resistance. The model is derived from the previous thermal-electrochemical coupled model[1-3] to include the variation of kinetic properties of the system primarily from temperature fluctuation.

In the mathematical model, a set of partial differential equations in time and spatial coordinates was solved based upon general computational fluid dynamics (CFD) technique. Fig. 1 shows good agreement between the simulation and test data of an 85 Ah Ni-MH battery under 2C rate (170 A) constant current charge. Fig. 2 shows contours of the surface concentration of hydrogen at the nickel and MH electrode, respectively. The concentration of proton decreases with the charging time. From the simulation, we estimated that there is a large gradient in the concentration of hydrogen within each electrode. Reducing thickness of the electrode will benefit the fast-charge capability of the Ni-MH battery.

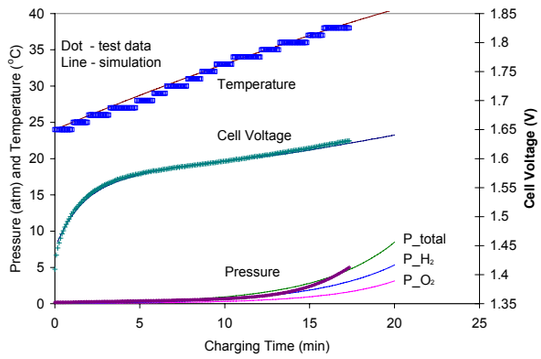

Fig. 1. Comparison between the experimental data (dot) and simulation (line) of the cell temperature, pressure and cell voltage of an 85 Ah Ni-MH battery under 2C constant current charging.

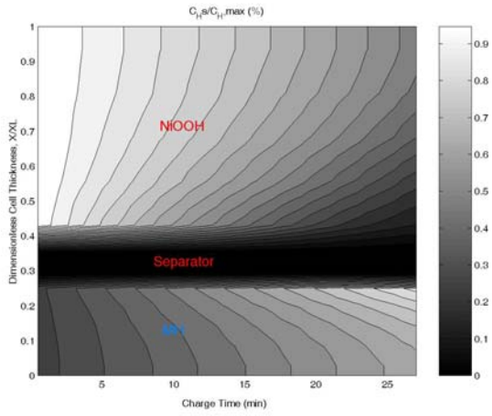

Fig. 2. The simulated surface concentration of hydrogen under 2C constant current charging.

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