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Life Modeling of NCM Composite/Graphite Cell: a Semi-empirical Approach

John Wang[1], Justin Purewal[1], Ping Liu[1], Jocelyn Hicks-Garner[1], Elena Sherman[1], Souren Soukiasian[1], Jason Graetz[1]
Harshad Tataria[2] and Mark Verbrugge[3]

[1]HRL Laboratories, LLC, Malibu, CA 90265
[2]General Motors, Vehicle Engineering, Warren, MI
[3]General Motors, R&D Center, Warren, MI

Lithium ion batteries are being targeted for use in the automotive, commercial aircraft, and space industries. For vehicular applications, understanding battery life performance is very important. Not knowing a battery's useful life increases business risk and warranty costs. The LiNCM(Ni-Co-Mn)-$LiMn_2O_4$/graphite cell chemistry is one of the more promising candidates due to its high energy and power density, and rate capability. Given the requirement for a long service life of more than ten years and thousands of cycles, the development of predictive life models is essential to enable their insertion into these applications.

In this talk, we describe a model developed to represent the capacity fade of a [$LiNi_{1/3}Co_{1/3}Mn_{1/3}$ + $LiMn_2O_4$]/Graphite battery along with data collected to determine the validity of the model. Experimental data for this study were collected using a large cycle-test matrix. The test matrix conditions included four different temperatures (10, 20, 34, 46°C), five levels of depth of discharge (DOD) (90%, 70%, 50%, 30% and 10%), and five discharges rates (C/2, 2C, 3.5C, 5C and 6.5C). We investigated and modeled three important experimental parameters: time, temperature, and discharge rate. The model equation included a square root of time relation to account for the diffusion limited capacity loss while an Arrhenius correlation accounted for temperature effects. To fit the model equation, we used low rate cycling tests at low depths of discharge to approximate the calendar life loss. For the cycle life model, the capacity loss was empirically fit with a generalized exponential function for the rate effects. The results indicated that the life model is a good representation of the experimental data for all conditions, as shown in Figure 1. More importantly, we were able to decouple the calendar life effect and cycle life effects and describe the capacity loss behaviors separately using the model equations (Figure 2).

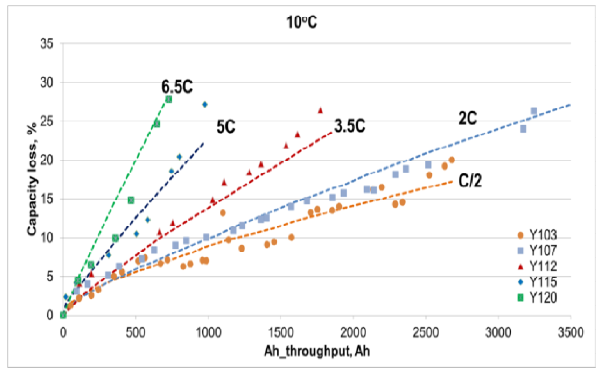

Fig. 1 Model simulations are compared with the experimental data (10°C) at different rates: C/2, 2C, 3.5C, 5C, and 6.5C.

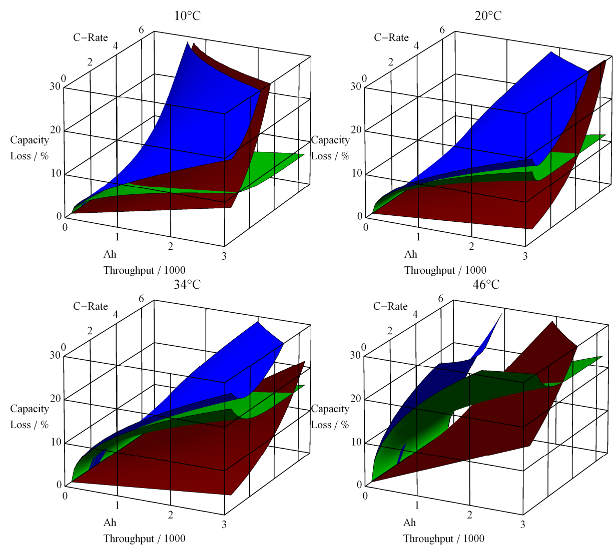

Figure 2. Simulations of calendar life and cycle life as a function of discharge rate and Ah throughput for all four temperatures: 10, 20, 34, and 46°C. (blue: total capacity loss; green: calendar life loss; and red: cycle life loss)