Ultrasound for assessing the state of health of cylindrical lithium-ion batteries: applied to pristine, accelerated degraded and second-life batteries

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ABSTRACT

Monitoring lithium-ion batteries (LIBs) degradation is essential for decarbonizing electricity generation and transportation. Key metrics include State of Charge (SOC) and State of Health (SOH). SOC measures the charge level, while SOH represents usable capacity. SOH is crucial in determining end-of-life. Even at 70-80% SOH, LIBs can still store energy, finding value as second-life batteries (SLBs). However, conventional estimation methods for SOC/SOH are time-consuming. Recent research suggests that degradation affects ultrasonic wave propagation in batteries. This study investigates quantitative ultrasound spectroscopy (QUS) to track SOC/SOH changes in cylindrical LIBs at three conditions: pristine, accelerated degraded, and SLBs.

Three pristine cylindrical LIBs underwent 40 degradation cycles at high C-rate (2C) and low temperature (5°C). Reference performance tests (RPTs) were conducted after certain number of cycles, at a low C-rate (C/5) and room temperature (25°C). Additionally, twelve SLBs were tested for 3 cycles under the same conditions as the RPT. RPTs were performed to assess the SOH by Coulomb counting and to acquire the ultrasound measurements every 30 seconds of the test using a 5 MHz linear array and a Vantage system. Power spectra were obtained from the ultrasonic data using a Hanning windowed signal of the longitudinal wave propagating around the cylindrical battery. QUS parameters; spectral slope (SS), 0 MHz intercept (I0), and mid-band fit (MBf), were derived from a linear fit to the spectral data between 3.8-5.5 MHz. The spectra were normalized using a reference spectrum from an empty cylindrical battery case.

Batteries submitted to accelerated degradation decreased their SOH from 100% to 83% after cycling while the SLBs' SOH ranged from 88% to 38%. MBf demonstrated the ability to track SOC and differentiate between SOH levels. Meanwhile, the SS and I0 are also affected by SOC, although the relationship with SOH is not fully understood yet. The underlying physical reasons for these findings and the differences on the ultrasound response between the batteries with known degradation path compared to SLBs (where the usage history is unknown) require additional analysis. However, the results showed that QUS parameters can be used to fast and noninvasively assess the SOC and SOH.