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Life Modeling and Reliability Analysis of Lithium-ion Batteries Used in Electric Vehicles

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Abstract

Lithium-ion batteries have gradually become the mainstream of batteries used in electric vehicles due to their advantages such as high energy density and long lifetime. This research aims to establish a reliability-based mathematical model that considers uncertainties of the degradation of lithium-ion batteries. The model can be used to evaluate the lifetime distribution and reliability of a selected type of lithium-ion battery. Based on the actual battery test data, this research considers battery performance under different operational environments as well as the uncertainty existed for each battery and proposes two capacity loss formulas to describe respectively the declines of battery capacity along with time when it is in storage and charge-and-discharge cycle when it is in use. According to the model, the battery lifetime distribution and reliability can be evaluated, and the failure probability of the battery at any given time can be obtained. This research also converts a vehicle's daily driving distance into a random depth of discharge, and explores the impact of different driving habits and charging methods on battery degradation. Research results show that state of charge (SOC) is one of the main factors affecting battery degradation. It is also found that selecting a lower battery charging limit and avoiding frequent shallow discharge under high SOC can slow down the degradation, and greatly extend the lifetime and improve the reliability of the battery.

Keywords
Electric vehicle, Lithium-ion Battery, Capacity Loss, Lifetime Distribution and Reliability Analysis.

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Pin-Chien Chao is a graduate student at National Taiwan University working toward her M.S. degree in Industrial Engineering. She is currently engaged in research related to the predictive maintenance of battery system of electric vehicles.
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Wen-Fang Wu received his B.S. degree from National Taiwan University (NTU) in 1977 and Ph.D. from University of Illinois at Urbana-Champaign in 1985. He had worked at Florida Atlantic University and Columbia University before joining NTU as a faculty member in 1988. He is now a professor of Mechanical Engineering and Industrial Engineering. His research interests include vibration, reliability engineering and probabilistic risk assessment.