A Study on Damage to Lithium-Ion Battery Separator using Nonlinear Finite Element Analysis

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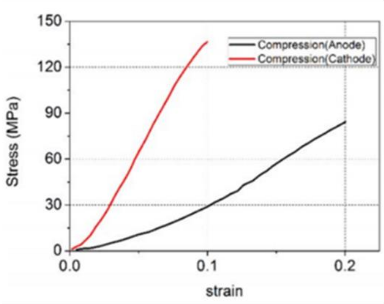
Abstract. In this study, a nonlinear mechanical detailed layer (NDL) model was developed to predict the mechanical nonlinear behavior of lithium-ion battery cells and the nonlinearity of internal short circuits due to separator damage. The load-displacement curve, the moment and location of internal short circuit, and the type of separator breakage were compared with the experimental results by simulating indentation test of lithium-ion battery with three spherical indenters, and the nonlinear mechanical behavior and separator breakage mechanism were accurately predicted.

Introduction

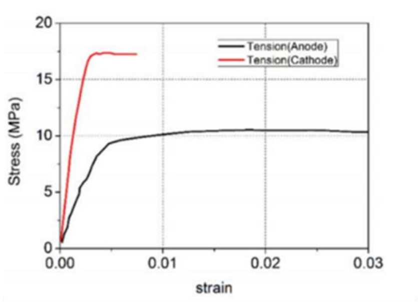
Due to the recent increase in electric vehicles in accordance with environmental regulations, cases of thermal runaway and capacity degradation of lithium-ion batteries due to mechanical loads are increasing. Accordingly, there is a trend to utilize mechanism analysis using numerical analysis techniques. However, the numerical analysis model used in previous studies has limitations in that it cannot accurately calculate the mechanical response that causes thermal runaway and capacity loss by using a homogenized model that only considers linear features. In this study, a nonlinear mechanical detailed layer (NDL) model was developed to predict the mechanical nonlinear behavior of lithium-ion battery cells and the nonlinearity of internal short circuits due to separator damage. The NDL model reflected the material nonlinearity and anisotropy of the positive electrode, negative electrode, separator, and current collector, as well as the number and thickness of each layer, identical to those of the actual battery.

Result and discussion

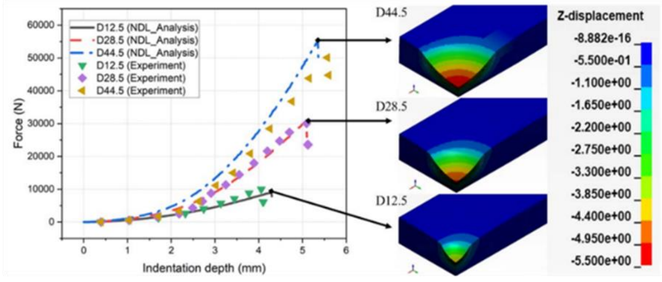
The load-displacement curve, the moment and location of internal short circuit, and the type of separator breakage were compared with the test results of Sahraei et al. [1] and Chung et al. [2**]** by simulating indentation test of lithium-ion battery with three spherical indenters. The analysis results showed that as the diameter of the spherical indenter increased, the peak value of the reaction force increased, and the indentation depth at which the internal short circuit occurred also increased, and the mechanical deformation and separator breakage mechanism were accurately predicted.



(a)



(b)



(c)

Figure 1: Nonlinear stress-strain curve of anode and cathode of (a)compression and (b) tension and (c) nonlinear load-displacement responses for three different diameter indentation tests

References

[1] G. Kermani and E.Sahraei (2017) *Energies*,**10** ,1730.

[2] S. H. Chung, T. Tancogne-Dejea, J. Zhu, H. Luo, and T. Wierzbicki (2018) *J.Power Sources*, **389**, 148