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# Overcoming the Limits of Local Continuum Models for Li-ion Batteries Using a Gradient-Informed Plasticity Theory

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## Abstract

The jelly-stack of Li-ion battery cells has a layered, periodic structure that can be idealized as a stack of layers with limited interfacial bonding. Bending of individual layers and interlayer sliding drive the macroscopic response, yet these kinematics are not captured in conventional local models. We show that as a result, local homogeneous models have limited predictive capability across different loading modes and length scales. In this work, we propose a gradient-informed elasto-plastic continuum framework to capture the observed kinematics. The proposed model tracks interlayer sliding and separation through internal variables and enables the continuum to distinguish between in-plane and out-of-plane shear. The theory is validated using hemispherical indentation experiments on stacks of aluminum sheets serving as a mechanical analog for battery jelly-stacks. Out-of-plane indentation reveals a characteristic lift-up of the laminate outside the contact region, as also observed in batteries. This response is reproduced by the gradient-informed model but is absent in classical local formulations. In addition, in-plane indentation simulations show the formation of shear bands that are consistently captured by the proposed model, in contrast to calibrated local plasticity models. Overall, the gradient-informed framework provides equally meaningful predictions as the layer-resolved model for both in-plane and out-of-plane indentation.

**Keywords:**

Graduent plasticity Constitutive Modeling Batteries Multilayered Structures