AMG Preconditioning for Nonlinear Systems of DAEs Modelling Degradation in Lithium-Ion Batteries

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Lithium-ion batteries are exposed to a variety of different aging mechanisms resulting in capacity fade over time and in a reduction of cycle life. The growth of the Solid Electrolyte Interphase (SEI), a thin layer forming on top of the anode microstructure, is a major contributor to capacity fade and a product of chemical reduction reactions between anode and electrolyte. In our work, we consider the simulation of a thermodynamic consistent physical cell model [1] resolving the electrode microstructures of the battery, which is coupled with an SEI degradation model [2]. The cell model describes the evolution of lithium-ion concentrations and electric potentials within in the battery cell. These quantities are governed by a coupled system of parabolic-elliptic PDEs featuring highly nonlinear interface conditions given by Butler-Volmer reaction kinetics. The degradation model modifies the interface conditions between anode and electrolyte, introducing additional ODEs governing the growth dynamics of the SEI layer and implicitly defined interface currents given as solution to nonlinear algebraic equations.

Utilizing our previous solution approach [3] for the battery model without degradation, which deploys a full implicit discretization combined with an inexact Newton method and an inner AMG preconditioner for the arising sparse linear systems, we notice that the inclusion of the degradation model leads to a significant decrease in performance as well as less stable iterations.

Thus, we propose an alternative discretization and preconditioning strategy in order to recover the performance of the AMG preconditioner that is observed for the model without degradation. This is realized by constructing a semi-implicit scheme separating the newly introduced computational variables of the degradation model from the main system. We present a comparison of the full implicit and semi-implicit scheme for a variety of simulation scenarios, showing the ability of the proposed scheme to reduce the computational impact of the degradation model.

References:

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