Multi-scale thermo-electrochemical-mechanical coupled model for the swelling of lithium-ion cell.

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Developing safe batteries with high energy capacity and long lifetime is a key issue for automotive industry in electric and hybrid vehicles. To this end, the prediction of the swelling of batteries under charge-discharge loading is a very relevant topic worthy for investigation. In fact, during charge and discharge the overall volume of a cell varies with the state of charge [1]. Hence, the battery thickness changes during one cycle due to various reasons: (i) expansion and contraction of host materials due to lithium intercalation resulting in a mechanical deformation generated by change of ion concentration in particles and leading to mechanical stresses ; (ii) pressure variation within the cell case depending on battery design [2] (iii) temperature gradients [3]. In the literature, stresses are analyzed to predict cracks on particles [4, 5]. However, the overall volume change of the cell has not been considered. Other researchers analyzed the variation of thickness of particles with free mechanical boundary conditions [1, 6] by neglecting the effect of the external mechanical loads on the cell.

The purpose of our study is to develop a multi-scale thermo-electrochemical-mechanical coupled model to predict the swelling of lithium-ion cell swelling during one charge-discharge cycle taking into account the external mechanical load. The model equations are discretized and solved using finite element method. Furthermore, a sensitive analysis with respect of current rates, temperature operational conditions, and external mechanical loads applied on the cell is performed. It is found that the thickness change of the cell is highly dependent on external conditions. Numerical swelling results are validated by comparison with experimental data provided by Renault. The model will be generalized for the case of cyclic charge-discharge in order to predict the thermo-electrochemical-mechanical fatigue of the batteries.

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