Combining reduced-order modeling and machine learning for local-global simulation: Short circuit prediction in electric vehicle crash simulation

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Today, simulation is used by automotive engineering teams to design lightweight vehicle bodies that fulfill vehicle safety regulations and perform well in consumer testing. Legislation is rapidly evolving for the growing electric vehicle (EV) market, not least to account for the additional battery safety requirements. One of the most important safety considerations is the need to avoid internal short circuits (SCs) in the battery cell due to internal damage that can occur during a crash scenario. Such SCs represent a significant fire hazard. Assessing SC risk in crash simulation at the vehicle level is a complex task as it involves phenomena at different scales. During the impact, the vehicle deforms on a macroscale level, whereas the battery cells deform locally, damaging the extremely thin separator foil which can ultimately lead to a SC. To evaluate accurately the SC risk, it is therefore necessary to consider the behaviour on the (local) meso-scale. Integrating the meso-scale cell description in crash simulations is unfeasible, both because of the model size as well as the (resulting) very small stable timestep imposed by the explicit time discretisation. To account for the localised behaviour, a novel combination of reduced-order modeling (ROM) techniques and machine learning (ML) methods are used to bridge the diverse length scales in such simulations. Realistic boundary conditions on the cell level are obtained from standard EV crash simulations and cascaded down to the cells. A first application of ROM using the sparse proper generalised decomposition yields an enriched set of boundary conditions that can be applied to the cell model. Another ROM technique, incremental dynamic mode decomposition, that is well-adapted to treating large numbers of parameters, is applied to compute an equivalent stiffness of a representative macro-cell. Finally, the SC risk is evaluated by using ML which links the SC of the meso-cell to the macro-cell mechanical behavior. This work has been carried out as part of the EU-funded UPSCALE project.