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PROJECTION-BASED REDUCED ORDER MODELS FOR NONLINEAR THERMAL SIMULATIONS OF AUTOMOTIVE BATTERY PACKS

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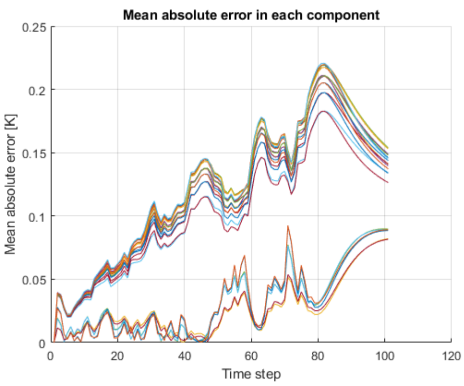
ABSTRACT

According to EU Regulations Battery Electric Vehicles (BEVs) shall constitute at least 55% of total vehicle sales in 2035. At the same time temperature and electric current are two most significant factors leading to premature battery degradation. Since automotive battery packs exhibit high level of geometrical complexity (often more than 400 cells build up the whole pack) and batteries need to be thermally simulated for transient cases, the usual CFD methods are practically useless for modelling complete battery packs of full, automotive, industrial maturity.



Thus, we have developed a projection-based thermal simulation model that is able to simulate the whole battery pack with a couple of hundred cells in approximately real time on a desktop computer.

The discretization of the heat transfer problem in all components of the pack is done with 3-D finite element method. The fluid flow in the cooling plate is solved by 1-D finite volume method and coupled with the heat transfer problem. The model order reduction is performed by projection onto the space of eigenvectors of the 3-D finite element discretisation. Additional set of functions is introduced to allow for accurate temperature calculations on the contact surfaces between components (e.g. a few hundred contacts of subsequent cells with the cooling plate). Furthermore, we have formulated the method in a way that accounts for nonlinear nature of thermal modelling of batteries. Hence, the model allows for time-varying mass flow rate of the coolant, time-varying heat transfer coefficients between the fluid and the cooling plates and nonlinear heat sources (heat generation in electrochemical cells depends strongly on temperature and state of charge of the cell).

Finally, we show in this work the complete algorithm, tricks for quick assembly of the nonlinear and time-varying terms of the reduced equations. Furthermore, we present the results of experimental and CFD validation of the computations for a real electric bus battery pack with 96 cells, experimental results for an electric aircraft battery pack and results of rigorous verification of the error introduced solely by the model order reduction method (see Figure).