Master's thesis; Physics-enforced machine learning surrogate modelling of electrochemical-mechanical battery simulations

Background

Battery simulations are becoming increasingly complex, often coupling electrochemical, thermal, and mechanical aspects. While high-fidelity models offer excellent accuracy, they are computationally expensive, limiting their use in design iterations and real-time monitoring applications.

Recent developments in physics-informed and physics-enforced machine learning (PIML/PEML) provide promising opportunities for creating fast simplified, but interpretable surrogate models that retain physical consistency. Such models can support rapid assessment of early design variations or operational conditions during service. However, state-of-the-art battery models for these purposes often lack key multiphysical aspects, e.g., coupled electrochemical-mechanical

Description

This thesis aims to develop a physics-enforced machine learning framework that approximates the behaviour of coupled electrochemical-mechanical battery simulations. The long-term goal is to enable rapid, physically consistent simulations that support design, control, and analytical model extraction.

Key Responsibilities

- *Simulation data generation:* Use a detailed existing multiphysics model to generate training data, focusing on geometry, material response, and external forces. Non-linearities will stem from electrochemical kinetics and mechanical constitutive laws.
- *Surrogate model training:* Train a physics-enforced machine learning model to replicate simulation outputs while enforcing physical constraints.
- *Analytical model extraction:* Apply symbolic regression to derive interpretable, physically meaningful expressions from the trained ML model.
- *Design variation exploration:* Investigate the model's ability to generalize across selected design variations, enabling early-stage design evaluation.
- *Geometric Deep Learning (GDL):* Explore GDL techniques for efficient sampling and training data generation.

Qualifications

We are looking for master's students with a background in mechanical engineering, engineering physics, applied mathematics, or computational science. Experience or coursework in numerical methods, machine learning, and continuum mechanics is highly valuable. Familiarity with Python, MATLAB, or similar simulation environments is a plus, as well as an interest in multiphysics modeling. The thesis requires analytical thinking, curiosity, and the ability to work independently as well as in collaboration with research teams.

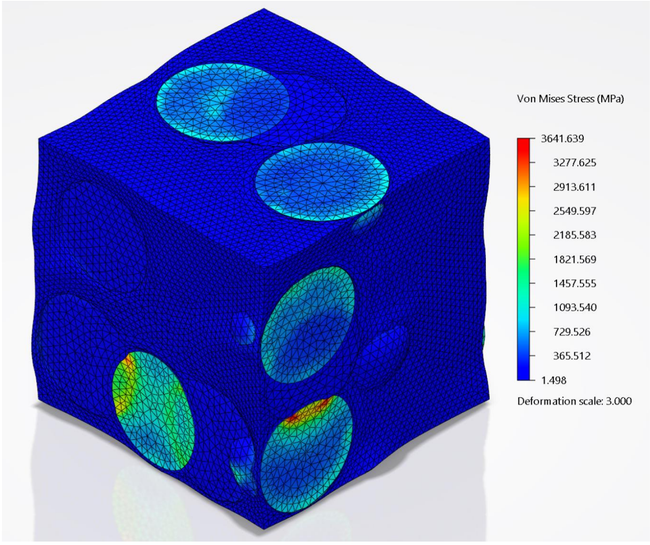

Figure: Electrochemical-mechanical FE-simulation of battery microstructure (from: Matty, MSc thesis, 2025)

Terms

The thesis is suitable for 1-2 students.
The work will be conducted at the unit of Mechanical Research and Innovation at RISE, in close collaboration with the division of Material and Computational Mechanics at Chalmers.
The duration of the thesis is 20 weeks and corresponds to 30 ECTS (academic credits), subject to agreement with your university thesis advisor. Planned start: January 2026.
Compensation: 10,000 SEK for travel, materials and the like after the project is completed and approved.

Welcome with your application!

Last day of application; 30 November, 2025. Apply Online via link: https://www.ri.se/sv/om-rise/jobba-hos-oss/lediga-jobb/masters-thesis-physics-enforced-machine-learning-surrogate

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