Faculty of Mechanical, Process and Energy Engineering
Institute of Mechanics and Fluid Dynamics
Chair of Engineering Mechanics – Solid Mechanics

Proposal for a Master Thesis

Modular implementation of AI-based models for multi-scale FE simulations

Traditional constitutive models often fall short in capturing the complex, non-linear inelastic behavior of foam-like structures, especially under multiaxial loading conditions while purely AI-based models have insufficient generalization capabilities to capture inelastic effects. That is why a hybrid model [1] was proposed which employes a neural networks to approximate yield surfaces and flow rules. Currently, a simple feed-forward neural network is employed for this purpose within a user-defined material routine (UMAT) in Abaqus. Replacing the FF-NN by more sophisticated techniques promises to leverage the predictive capabilities at reduced amount of required training data.

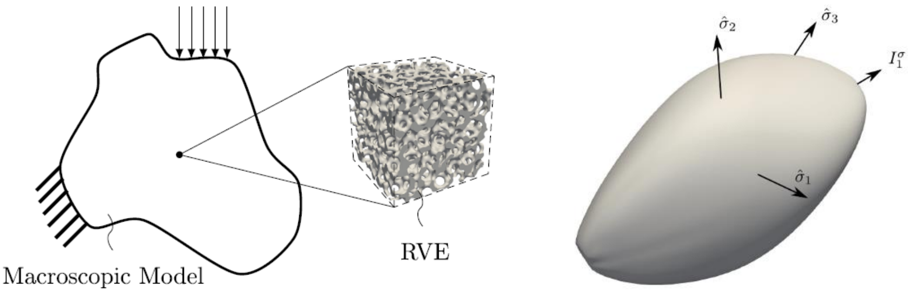

Fig.1: Multi-scale simulation of foam structure (left) and yield surface (from: [1])

The aim of this work is to make the approach more flexible by replacing the FF-NN by a call to TensorLow/Keras C API. Having established this link, different alternative regression models like input-convex neural networks or support vector machines shall be implemented and tested regarding the aforementioned criteria.

Subtasks:

1. *TensorLow/Keras C API*
2. Implementation of stand-alone test program in Fortran
3. Implementation into the existing UMAT
4. Studies on predictive capabilities and amount of required training data

Requirements:

- Interest in simulative material research using AI
- Excellent or good grading in Nonlinear Finite Element Methods
- Programming experience in C and/or Fortran

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References

[1] A. Malik, M. Abendroth, G. Hütter, B. Kiefer: *A Hybrid Approach Employing Neural Networks to Simulate the Elasto-Plastic Deformation Behavior of 3D-Foam Structures*, 2021, Advanced Engineering Materials, Vol. 24, No. 2, p. 2100641