A Variational Approach to

Structural Growth and Adaptive Material Orientation

Philipp Junker*, Dustin R. Jantos†, Klaus Hackl†

* Institute of Continuum Mechanics
Ruhr-Universität Bochum
Universitätsstr. 150, 44801 Bochum
Email: philipp.junker@rub.de

† Institute of Mechanics of Materials
Ruhr-Universität Bochum
Universitätsstr. 150, 44801 Bochum
Email: dustin.jantos@rub.de, klaus.hackl@rub.de

ABSTRACT

Variational techniques have proven to be a powerful tool for material modeling. They have successfully been applied to, e.g. plasticity, damage modeling, and phase transformations. Several different variational techniques originate from Hamilton's famous extremal principle. In our work, we apply this principle to the "inverse damage problem" and derive a model for structural growth and remodeling [1]. A non-convex underlying Hemlholtz free energy penalizes the so-called gray solution in which a distinct identification of mass is difficult. This non-convexity has the drawback of numerical instabilities which manifest in the checkerboard phenomenon. To resolve this numerical artifact of the ill-posed mathematical problem, we perform a regularization that operates only at the element level and neglects gradients over element boundaries [2]. Finally, the model possesses a structure known from material modeling which can be solved at the Gauß point (or material point) level in a finite element scheme. Introducing a Lagrange parameter allows for the direct control of mass generation yielding even finer structures [3]. In this contribution, we present an additional material non-linearity by accounting for the material orientation. To this end, we make use of the Euler angles describing the local coordinate system and the local material stiffness. The general scheme is adapted from [4] and gives additional evolution equations for the Euler. Finally, the density field and the Euler angles describing the material orientation are no additional field unknowns and can be calculated locally which strongly reduces the calculation effort. We present solutions of structural growth for different boundary problems to show the potential of our model.

REFERENCES

[1] Junker, Philipp and Hackl, Klaus. "A variational growth approach to topology optimization", *Structural and Multidisciplinary Optimization*, Vol. 52: pp 293-304 (2015).
[2] Junker, Philipp and Hackl, Klaus. "A discontinuous phase field approach to variational topology optimization", *Structural and Multidisciplinary Optimization*, pp. 1-14 (2016).
[3] Jantos, Dustin R. and Junker, Philipp and Hackl, Klaus. "An evolutionary topology optimization approach with variationally controlled growth", *Computer Methods in Applied Mechanics and Engineering*, Vol. 310: pp. 780-801 (2016).
[4] Junker, Philipp. "A novel approach to representative orientation distribution functions for modeling and simulation of polycrystalline shape memory alloys", *International Journal for Numerical Methods in Engineering*, Vol. 98: pp 799-818 (2014).