

# PHASE-FIELD AND GRADIENT DAMAGE MODELS FOR FRACTURE IN COMPLEX MATERIALS

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## ABSTRACT

Many modern materials, such as additively manufactured materials, architected and meta materials, composites, wood and foams have a pronounced microstructure which dominates their constitutive behaviour. It allows their use in specialised applications in mechanical and civil engineering, but also medicine. One particularly desired property of the microstructure is the resistance against fracture and failure, which, however, cannot be described with standard models.

Phase-field and, in general, gradient damage approaches are highly suitable to model fracture in these complex structures due to their flexibility, which allows to account for a wide range of phenomena including crack nucleation and propagation in arbitrary crack patterns. In this framework, the extension to behaviours such as plasticity, rate-dependent constitutive laws and anisotropy are straightforward as well as the coupling with environmental conditions, especially in terms of temperature or diffusion/reaction processes. Moreover, the effects of cyclic or dynamic loadings can be easily included, making thus the phase-field method an appealing technique to model complex materials.

A characteristic of heterogeneous materials often is their inherent multiscale nature, which greatly influences their fracture behaviour. Indeed, effective fracture resistance and crack paths are governed by the microscopic fracture behaviour, whose inclusion in a computational framework comes at the price of the computational burden. This is further increased by complex geometries and/or loading histories. Therefore, efforts have been made to reduce the computational cost with adaptive meshing strategies and new approaches to solve the system of coupled equations.

The topics of this MS of interest include, but are not limited to the following:

- Phase-field and gradient damage models for complex fracture behaviour, including viscous and ductile fracture
- Material failure under various loading conditions (e.g., dynamic and cyclic loading)
- Modelling of coupled multi-physics problems, including thermo-, chemo- and electro-mechanical systems in fracture mechanics
- Simulation of fracture in microstructures, taking into account the effects of texture and anisotropy
- Multi-scale approaches and macroscopic effective fracture properties
- Advances in algorithms and solver technologies (e.g., staggered/monolithic schemes, reduced order models and meshing/discretisation techniques) to reduce computational time