The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

Phase Field Method-based Modeling of Fracture in Wood

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Key Words: *Wood, Phase field, Fracture.*

As a naturally grown material, wood exhibits an inhomogeneous material structure as well as a quite complex material behavior. Thus, the modeling of fracture processes in wood is challenging and requires a careful selection of numerical methods. Promising approaches like limit analysis [1] or the extended finite element method (XFEM) in combination with microstructure materials models [2] deliver good but not yet satisfying results. For example, the latter has difficulties with complex crack paths, e.g., around knots. Therefore, we focus on the recently emerging and very popular phase field method [3]. Especially geometric compatibility issues can be avoided, as the crack is not discretely modeled but smeared over multiple elements. This allows the formation of complex crack patterns, defined by the underlying differential equations and boundary conditions but not restricted by the mesh.
The present implementation contains a stress-based split [4] which allows proper decomposition of the strain energy density for orthotropic materials. Furthermore, the geometric influence of the wood microstructure on crack propagation is taken into account by a structural tensor scaling the length scale parameter of the phase field [5]. A staggered approach is used to solve the system of differential equations where the phase field equation and deformation problem are solved separately. The staggered approach is enhanced with an additional Newton-Raphson loop that ensures convergence. The developed algorithm was tested on various problems. Compared to XFEM more computation time was needed as the phase field method requires a finer discretization. However, crack patterns, including branching and merging, could be modeled very stable and accurately, even in the vicinity of knots where the material structure of wood is particularly complex, and interface zones exist.

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