Finite-Element-Modelling of moisture-induced cracks in wood and wooden structures

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Wood is characterized by heterogeneity at different length scales. Knots or growth-related annual rings determine the material-specific characteristics at the macroscopic level. Lignin, hemicellulose and cellulose are the main components of the microscopic cell structure of wood. Cellulose fibers form the cell walls and are enclosed by hemicellulose and lignin as the matrix material, see [1].

Deformation of wooden structures and stresses in wood materials might be caused by changes of moisture content. Moisture transport as well as moisture inclusion mainly occurs in the inter-micellar and inter-fibrillar void system. Especially the water at the microscopic pore system, bounded due to chemical sorption, adsorption and capillary condensation, causes changes of the microscopic structure of wood. These changes induce swelling and shrinkage deformation, which might be accompanied by stress formation in wooden materials. If tensile stresses exceed the appropriate tensile strength, brittle failure occurs, compare [1]. At compressive stresses beyond the yield strengths, wood shows ductile failure modes.

The contribution at hand presents an approach to model moisture-induced cracks in wooden structures by the Finite-Element-Method (FEM). The displacement, moisture and temperature dependent constitutive description of wood is taken from [2] and is used as basis for evaluating the load dependent stress state. The crack initiation criterion developed captures brittle failure at tensile stresses above the yield level. A node duplication algorithm within the FEM-framework is formulated and implemented in order to model crack propagation within wooden materials. The formulation captures the modelling of load dependent crack paths as well as possible crack branching.

The numerical verification of the crack modelling approach is carried out by convergence studies with respect to mesh dependency and numerical behaviour of the solution of the global finite element equations. Appropriate examples, based on experiments from literature, are presented, see e.g. Figure 1.

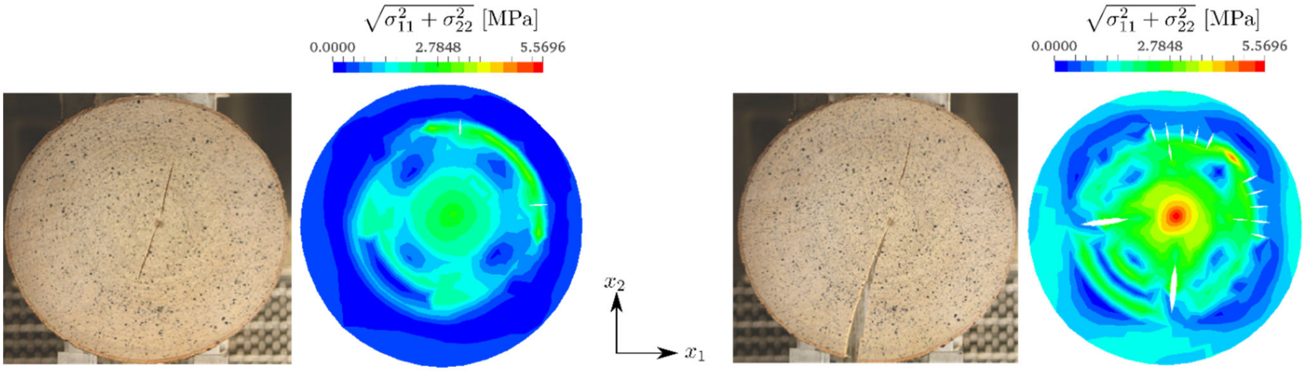

Figure 1: Comparison of numerical simulation and experimental investigation (taken from [3]) of a 20-year-old Norway spruce (*Picea Abies*) tree slice at drying process

The drying experiment in Figure 1 is carried out in a climate chamber for Norway spruce, see [3] for details. Figure 1 shows simulation results, which are computed by the contribution at hand. As can be seen, a qualitatively agreement between the position of the crack initiation as well as the crack propagation steps can be observed. The discrepancies between simulation and experiments are caused by the uncertain material properties and the applied initial conditions, used in the simulation, as well as the differences in the annual ring positions.

A further validation of the fracture modelling is presented and carried out by drying experiments for beech wood (*Fagus Sylvatica*), in cooperation with the Chair of Timber Engineering and Construction Design of Technische Universität Dresden.

References

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