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NUMERICAL SIMULATION TOOL FOR WOODEN BOARDS WITH KNOTS

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In wooden boards knots and the resulting fiber deviations have a large influence on the effective stiffness and strength behavior. Depending on the arrangement of knots/knot groups, certain mechanical properties can remain unaffected or decrease significantly. Knowledge of these effects will improve the wood grading process and may become crucial for the design of wood-products to remain competitive with respect to other less sustainable building materials.

For this purpose, a previous developed Finite Element (FE) simulation tool has been refined and extended to allow a 3D virtual reconstruction, including all growth- and production-induced defects, of different solid-wood based products [1]. To approximate the 3D fiber course in the vicinity of knots a geometrical model was implemented [2]. By using the algorithm for the fiber course the principal material directions are calculated at each integration point of the Finite-Element mesh. A damage initiation criterion for orthotropic materials was adapted for wood and used in the framework of the eXtended Finite Element Method (XFEM) to capture the main fail-

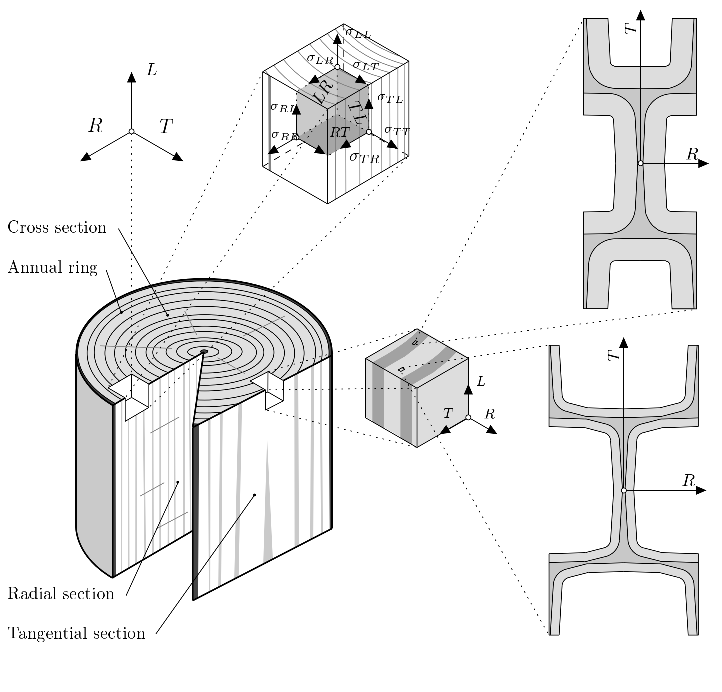

Figure 1: Multiscale approach for the determination of the global crack direction.

ure mechanisms up to the onset of global failure: the formation of cracks in the vicinity of knots due to tensile failure in radial and/or tangential direction and shear failure, respectively.

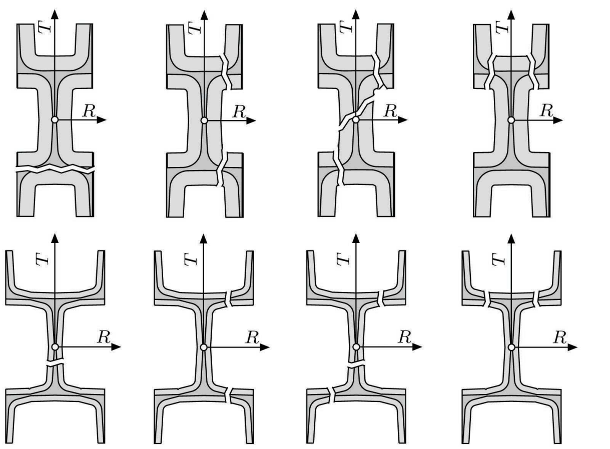

Figure 2: Failure mechanisms at single cell level for latewood (upper row) and earlywood (lower row) cells.

To obtain the global crack direction, a multiscale damage approach was taken (see Figure 1). First, the failure mechanisms at the single cell level were identified for late- and earlywood cells, respectively, (see Figure 2) to obtain the crack direction for several loading conditions at the lowest length scale by using the unit cell method in combination with XFEM. In a next step, these results were combined at the annual year ring level, where late- and earlywood cells form a layered structure. This finally leads to predefined global crack directions for varying loading conditions, which were implemented in a subroutine of the commercial FE software Abaqus.

By combining a model for the description of the fiber course in the vicinity of knots and a multiscale approach for the determination of the global crack directions, the influences of different knot (groups) configurations on several effective properties, like modulus of elasticity or bending strength, can be determined. The resulting effective stiffness properties are used to study strengthening and load-transfer effects between lamellae in Glulam and CLT elements, whereas the results are also opposed to comparable, fully discretized models of such elements, i.e. models including knots and the resulting fiber course in their vicinities. The enhanced understanding of load transfer and failure mechanisms, which is delivered by this tool, should allow for a better utilization of the raw material wood through tailored grading and mechanics based design of solid-wood based products.

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