# Finite Element Modelling of Tensile Tests of Geometrically Well-Characterized Single Wood Fibres

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## ABSTRACT

Mechanical testing on single-fibre level is essential and very useful to relate the microstructure to macroscopic engineering (mechanical) properties of wood materials or wood-fibre based composites. Since wood cells are hardly prismatic, i.e. their cross-section varies along the length, and they are provided with pits, the deformation on tensile loading is non-uniform. This structural inhomogeneity results in local variations in buckling and twist along the fibre loaded in tension from end clamps. The aim of the present work was to investigate how the cell-wall stiffness transfers to that of the fibre, in the presence of natural cross-sectional variation along the fibre, characterized by microtomy.

The results presented here come mainly from the MS thesis of Dennis Wilhelmsson (KTH Solid Mechanics), supervised jointly by the author, Cristian Neagu (now EPFL) and Stig Bardage (SLU). From microtomed axial section of wood fibres, CAD software was used and the 3D geometry was exported to Abaqus FEM software, where the cell-wall layers $S_1$, $S_2$ and $S_3$ were accounted for, with varying microfibril angles. Shell elements were compared with solid elements, and virtual tensile tests were performed, with and without twist constraints. The stiffness of an exact analytical model for concentric prismatic cylinders was invariably about 10% higher than that from the finite element simulations of geometrically characterized softwood fibres. This can be explained by the additional buckling and twist deformation mode present in fibres due to the variation in cross-section along the fibre axis. It can be concluded that stiffness measures from tensile tests of single fibres can not directly be transferred to that of the cell-wall material. Furthermore, stress analysis with a experimentally calibrated failure criterion could indicate locations of failure (see figure), which were in concert with fractographic investigations.

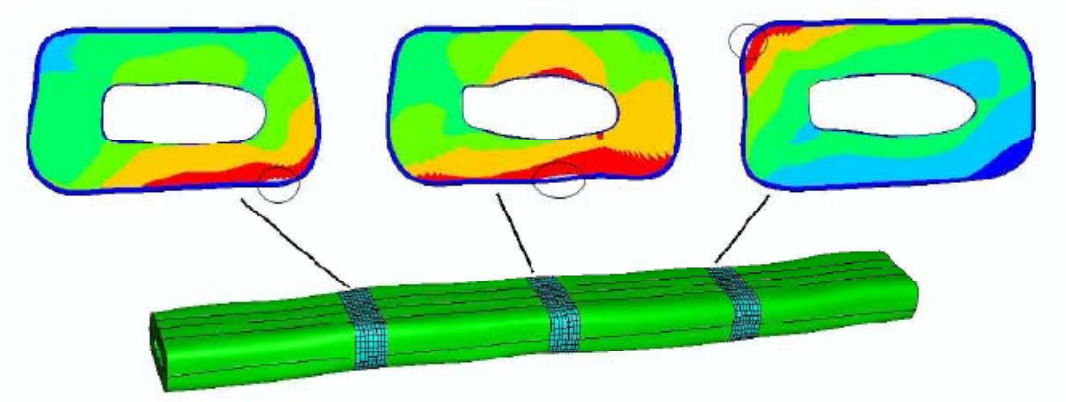

Figure 1: Three dimensional stress analysis and comparison with a Tsai-Hill failure in tensile loading of a geometrically well-characterized wood fibre. Hot-spots indicate zones of probable failure.