An experimental and numerical investigation of fracture characteristics of acetylated Scots Pine

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Modification methods have proven successful in limiting the hygroscopic nature of wood, and are less harmful to the environment than toxic preservatives. Acetylation is a modification method based on a chemical reaction between acetic anhydride and the cell wall polymers. Extensive research over the past decades has demonstrated its success in improving both dimensional stability and durability of various wood species. The change of chemical composition of the cell wall affects mechanical properties as well. Numerous studies of basic mechanical properties, e.g. bending stiffness and strength, have been conducted [1]. However, only a few studies concerning the influence of acetylation on fracture characteristics have been performed. A study conducted in 2002 [2] indicates a significant decrease of both the fracture energy and the critical stress intensity factor for acetylated spruce. In structural applications fracture characteristics are of importance due to the occurrence of holes, notches, moisture gradients etc., inducing large stress concentrations which may lead to crack propagation. In designing mechanical joints, they are decisive for avoiding brittle failure modes [3].

Experimental tests on fracture characteristics were carried out at Lund University, during the fall 2018. The fracture energy was determined for mode I in tension perpendicular to the grain. Single edge notched three-point-bending (SEN-TPB) tests were performed according to the test standard described in NT-BUILD 422 [4]. Scots Pine (*Pinus Sylvestris*) originating from young stands was examined and evaluated based on four test groups: unmodified sapwood; acetylated sapwood; unmodified heartwood; acetylated heartwood. The results demonstrate a significant decrease of the fracture energy for acetylated specimens, where the mean value decreased with approximately 50% for sapwood and 30% for heartwood. Additionally, the modulus of elasticity in compression parallel to the grain and tensile strength perpendicular to the grain were examined. No significant influence related to these properties could be concluded.

The SEN-TPB tests will be further examined through finite element analyses. The nonlinear fracture behavior will be modelled by a fictitious crack approach. This will be done by introducing a cohesive zone along a predefined crack path, aligned with the initial notch. In order to calibrate proper material models, different strain-softening properties will be evaluated in relation to experimentally achieved load-displacement curves. The aim is to establish appropriate material models to, further on, be able to implement these in the analysis of structural elements and evaluation of joints. Additionally, finite element analyses will be used to estimate the critical stress intensity factor, i.e. evaluate the effects of acetylation on notch sensitivity.

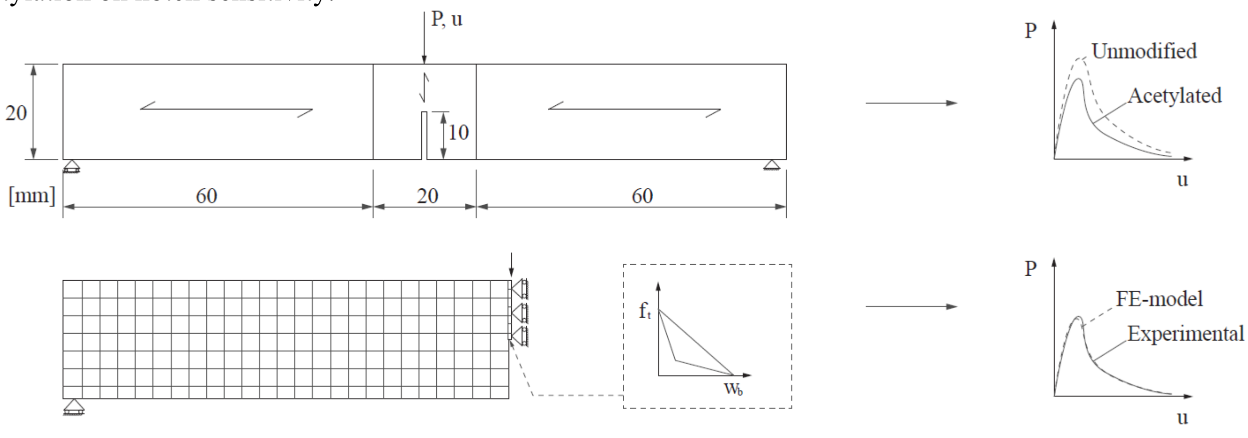

Figure 1: Illustration of SEN-TPB test set-up (a), typical load-displacement curves from experiments (b), FE-model with strain-softening properties for the cohesive zone (c) and numerical versus experimentally found load-displacement curves (d).

References

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