Heat and Mass Transfer Model for Wood under real climate conditions

Maximilian Autengruber†*, Markus Lukacevic†, and Josef Füssl†

†IMWS TU Wien, maximilian.autengruber@tuwien.ac.at

Knowledge about the wood moisture condition in a timber component is essential to predict its mechanical behavior. Not only stiffness and strength properties are highly dependent on the wood moisture content but also diffusion coefficients, density, specific heat capacity and the thermal conductivity. Therefore, modern prediction tools, which are able to describe these effects, can be of great benefit for the development of new wood-based products. Especially if these products exhibit complex geometries and are made of materials with different moisture characteristics. Such products have to be tested in varying climate conditions. Different and direction-dependent coefficients of expansion of wood may lead to critical stresses due to deformation. The stress levels depend on geometric and climatic conditions.

Transport mechanisms below the fiber saturation point were developed by Krabbenhoft and Damkilde [1] and Fortino et al. [2]. Three coupled differential equations describe bound water, water vapor and energy conservation. Free water exists above the fiber saturation point with the corresponding transport mechanisms described in Perré and Turner [3]. Values of the free water content can be much higher than those of bound water and water vapor. Thus, within the areas, where the switch from the transport mechanisms below the fiber saturation point to those above occur, high gradients can exist. To deal with these high gradients in terms of the finite element method different procedures like upstreaming and mass lumping described in Eriksson [4] were used. A three-dimensional Abaqus User Element Subroutine was developed to describe these coupled equations. This model was validated with results from Frandsen [5] below the fiber saturation point and with results from Eriksson [6] during drying from a moisture content above the fiber saturation point to dry conditions.

Linear elastic stress calculations were conducted based on the obtained moisture content and temperature fields. Expansion due to swelling and shrinking as well as temperature were considered. Furthermore, a multi-surface failure criterion [7,8] was applied which leads to moisture induced failure.

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