

A numerical and experimental methodology to investigate morphological changes in wood exposed to fire temperatures

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The response of wood under fire temperatures is strongly dependent on its material microstructure and chemical composition [1]. Due to its non-homogeneous porous structure and hygroscopicity, the hygro-thermal behaviour of wood is characterized by several coupled processes. For timber components of buildings the moisture content inside wood remains below the fiber saturation point and is constrained in the wood cell walls as bound water, while the water vapour is distributed in the lumens, rays and canals in addition to the other gaseous components. The two phases of water are coupled through sorption. Furthermore, the heat of sorption includes the latent heat of condensation/evaporation due to the change between the two water phases. Finally, in the presence of fire temperatures, wood undergoes pyrolysis, a phenomenon of thermal degradation. This is characterized by weight loss due to moisture and pyrolysis products leaving the material that can highly affect the morphology of wood microstructure [2]. In this context, numerical models can integrate the experimental tests to deeply understand the effects of these complex phenomena in order to develop better methods to enhance wood durability under fire temperatures. Most of the numerical models developed in the nineties for wood under high temperatures were mainly aimed to simulate wood drying processes. In the last decade, there was an increasing interest in developing hygro-thermal models including also pyrolysis (see references in [1]) but the topic is still challenging above the charring temperatures.

In the present paper, the responses of 0.5×0.5×1cm spruce samples heated in a furnace under helium flow are investigated. A heating rate of 5 K/min from room temperature until final temperatures in the range of 250-550°C is used. To understand the effects of different charring temperatures on the material microstructure of wood, SEM pictures are taken from cuts made by a razorblade on perpendicular to grain wood sections (Figure 1, left). The morphological variations of vessels and wood cell layers are observed and discussed in relation to the corresponding increments of temperature and mass losses. These increments are evaluated by means of a multiphase hygro-thermal model including pyrolysis, as illustrated in Figure 1 (middle). Most relevant morphological changes are found for temperatures above 300 °C. In addition, to observe morphological changes for temperatures below 300 °C, microstructural finite element analyses (μFEM) [3] are carried out by taking into account thermal expansion and mass loss of cell walls (calculated with the hygro-thermal-pyrolysis model), and the decreasing values of elastic moduli measured by tensile tests. The μFEM analyses of representative microstructures (Figure 1, right) allow to identify the strain and stress distribution in wood cells before charring that could explain the reason of the successive morphological changes. The proposed methodology represents a further step for the future development of more complex hygro-thermo-chemo-mechanical models for wood exposed to fire.

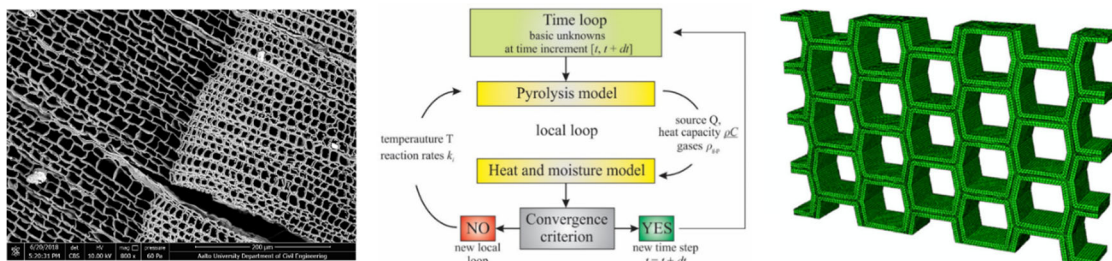


Figure 1: Left: SEM picture from wood sample heated until 400 °C. Middle: scheme of the proposed hygro-thermal-pyrolysis model. Right: meshed representative microstructure for the μFEM analysis.

References

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