Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 139 (2017) 322–327

Energy Procedia

www.elsevier.com/locate/procedia

International Conference On Materials And Energy 2015, ICOME 15, 19-22 May 2015, Tetouan, Morocco, and the International Conference On Materials And Energy 2016, ICOME 16, 17-20 May 2016, La Rochelle, France

Microscopic swelling analysis of spruce wood in sorption cycle

C. El Hachem*, K. Abahri, R. Bennacer

LMT-Cachan/ENS-Cachan/CNRS/Université Paris Saclay, 61, Avenue du Président Wilson, 94235 Cachan, France

Abstract

Depending on drying or humidification conditions, spruce wood tends respectively to shrink or swell, because of internal mechanical stresses that cause microscopic morphological changes. In the present paper, an experimental campaign is performed at the microscopic scale, in order to study the structural changes caused by relative humidity solicitations along the sorption cycle, for both early wood and latewood phases. That is why many specimens were scanned at different relative humidity levels using X-ray tomography. Relative humidity conditioning was successful by designing a specific device adapted to tomography. The obtained resolution using X-ray tomography was 3.3µm/pixel. After that, the reconstructed volumes were post-treated using adapted software to spruce wood, iMorph. Cell walls' thicknesses and lumens' diameters have been calculated at each humidity state. These results have given much better understanding of the localized phenomena that take place at the fiber's scale.

Keywords: Spruce wood; localized swelling; lumens' diameters; cell walls' thicknesses; X-ray micro-tomography

1. Introduction

Use of wood is essentially based on its energetic performances. In construction, spruce wood is particularly used for isolation and mechanical purposes, being a material that guarantees all functions: structural, thermal isolation and acoustic isolation.

Upon age, spruces grow by reproducing through layering. Each layer represents one year cycle in which early wood grows in spring and early summer, followed later by the latewood development [1]. However, spruce wood is

* Corresponding author. Tel.: +33-1-47406827.
E-mail address: elhachem@lmt.ens-cachan.fr

10.1016/j.egypro.2017.11.215

a hygroscopic material, which makes it very sensitive to humidity, especially when subjected to high relative humidity levels. At the macroscopic scale, sorption and desorption cycles are respectively marked with swelling and shrinkage [2]. Actually, these macroscopic dimensional changes are the consequences of many microscopic coupled phenomena, related to moisture and heat transfers, to the anisotropic and heterogeneous morphology, as well as the swelling and shrinkage stresses fields of fibers [3].

Although some authors achieved studies concerning the microscopic role of complex wood fiber interaction on swelling and shrinkage [4], these phenomena have not been mastered yet. On the other hand, some authors evaluated wood fiber mechanical behaviors. For example, Li et al [5] treated the internal wood's structure influence on its water-resistance. In addition, Gindl et al [6] evaluated the axial compression of spruce wood. Forsberg et al [7] have made a three point bending test on spruce wood. These works treat wood and more specifically fiber's responses due to either hygric or mechanical solicitations.

Hence the necessity of conducting new experimental campaigns, in order to have much better understanding of localized fiber's behaviors when subjected to humidity conditioning. Once the literature is provided with enough information describing these phenomena, all the experimental results will serve to develop a representative model on the microscopic scale.

In this paper, an experimental work has been achieved at the microscopic scale, concerning spruce wood swelling evaluation along the sorption cycle. A new device has been designed in order to maintain a constant relative humidity while scanning. Then, after achieving the tomography scans, the corresponding volumes were reconstructed and post processing was performed using iMorph software. Lumens' diameters, cell walls' thicknesses, and porosity were calculated for each relative humidity level, which led to have access to all these parameters' evolutions along the sorption cycle.

2. Materials and methods

On the microscopic scale, spruce wood is a heterogeneous material that contains tracheids, parenchyma and lumens (pores). Early wood cells are characterized by having relatively large cavities and thin walls. During a cycle, the transition from early wood to latewood is marked by the tendency of the cells reproduction to have smaller diameters and thicker walls. At the end of a cycle, latewood is characterized by the smallest cavities and the thickest walls [8] (Fig. 1).

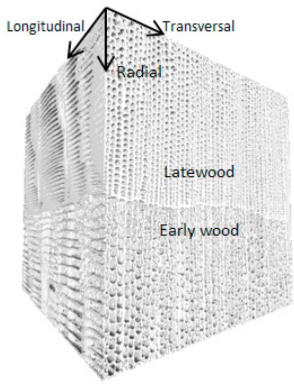

Fig. 1: 3D view of wood specimen containing both early wood and latewood phases.

2.1. Specimen preparation

First of all, and in order to select the correct specimens' dimensions, a morphological study was achieved. Early wood and latewood structural properties were studied by some researchers. For example, Trtik et al [9] calculated the walls' thickness of spruce wood for the transition early wood/latewood in tangential and radial directions, and respectively found average values of 2.99 µm and 3.16 µm. These authors calculated also the diameter of the tracheids for the same transition of wood in tangential and radial directions, and respectively found average values