Physics of wood drying for reduction of CO_2 emissions

38% of CO_2 emissions are due to the construction industry and residential buildings. In this regard, the use of bio-based construction materials such as wood can greatly reduce carbon dioxide emissions through: their sustainable production, their contribution to air quality in housings, the reduction of energy consumption for heating or cooling in building which they induce, their partial or full recyclability, and their role of carbon sink.

The original hygrothermal properties of these materials are in part due to one remarkable property: their ability to absorb vapor thanks to hydrogen bonds, which form nanoscale water inclusions between the microfibrils of cellulosic fibers, and can represent up to 25% of the dry mass (associated with wood swelling or shrinkage). This bound water is transported by diffusion inside the structure, while vapor diffuses in the porosity. Additionally, a huge latent heat is associated with sorption or desorption of this bound water. The resulting hygrothermal properties could greatly reduce energy consumption if they were understood, controlled, and optimized.

However, prediction of this hygrothermal behavior is undermined by four critical problems: the local internal material structure is not taken into account, the diffusion coefficients of bound water and vapor are unknown, we have no information on the sorption dynamics, and arbitrary coefficients are used to describe boundary conditions.

The objective of this PhD work is to develop a model unlocking these problems in the specific case of convective drying (almost isothermal), thanks to several unique experimental innovations. We will use a proper quantification of boundary conditions relying on a complete fluid mechanics approach and systematic experimentation. The diffusion coefficients of the different water phases (vapor, free water, bound water) will be determined using tests that isolate the different modes of transport, and with the help of NMR (Nuclear Magnetic Resonance) relaxometry. A unique form of MRI (Magnetic Resonance Imaging) will be used to monitor the time evolution of the spatial distribution of moisture content and temperature. We will then be able to determine the sorption dynamics and validate the model, taking into account the specific structure of the wood.

The results will ultimately be used for the hygrothermal modelling of wood in building. They will also allow to properly model, control and improve the energy needed for the drying processes of timber, an essential stage of wood treatment which adds value to sawn products and protects timber against primary decay, fungal stain and insect attacks. Also, the knowledge developed in this thesis will help predicting the occurrence of deformations and/or cracks in building materials or in woodworking objects.

Desired profile of the candidate : Skills in physics, fluid mechanics or/and material sciences. Prior knowledge in wood science and NMR might be a plus but are not required.

Location: Laboratoire Navier (Ecole des PontsParisTech, Univ. Gustave Eiffel, CNRS), Champs sur Marne (20 min. from Paris center by RER A)

The PhD degree will be awarded by the University Gustave Eiffel

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