Understanding the moisture transport and swelling in paper by using a multi-phase flow approach

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Abstract

Paper is a natural material mainly composed of fibers and pores. This porous hygrophillic structure is highly sensitive to fluctuations in moisture content because of the swelling of the fibers. In this work, we implement a finite element-based computational model to study moisture transport and swelling in paper. The material is modeled using a multiphase flow approach known as hybrid mixture theory (1). This methodology incorporates some features of mixture theory and averaging procedures. The balance equations are presented at the microscale level and, by an averaging procedure, the corresponding macroscale balances are obtained. By using this methodology we can take into account the moisture transport through the diferent phases and constituents of the material in a thermodinamically consistent framework. An application of this theory to porous cellulose networks can be found in (2). We adapted this model to study the moisture transport and swelling in paper. The novelty of our work is that the constitutive relations are derived from physical principles and assumptions at the microscale level. The moisture transport in pores and fibers is modeled using unsaturated flow theory. To establish the local constitutive relations for moisture transport we assumed that pores are tubular structures with different radii, according to the pore size distribution of our material. Water fills first the smaller pores and then the larger ones. With these assumptions we can derive an expression for the permeability of the porous structure. Furthermore, a simple constitutive relationship is proposed to study moisture transport from the pores into the fibers. By studying a single fiber problem, we find an expression for mass exchange between fibers and pores. Swelling and mechanical deformations are introduced by means of a linear elastic law.

References

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