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A model for paper-water interaction and the resulting swelling

Nik Dave[1,2*], Ron Peerlings[1], Thierry Massart[2], and Marc Geers[1]

[1] Eindhoven University of Technology, 5600 MB, Eindhoven, The Netherlands
N.Dave@tue.nl, R.H.J.Peerlings@tue.nl, M.G.D.Geers@tue.nl
[2] Université Libre de Bruxelles, Avenue F.D. Roosevelt, 50 B-1050, Brussels, Belgium
thmassar@ulb.ac.be

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Paper is vulnerable to moisture-induced deformations developing over time [1]. To be able to predict the time-varying mechanical response of a paper sheet, understanding the liquid transport through the thickness of a paper sheet is key [2,3].

In this work, the time-dependent factors involved in the deformation of a paper strip that is fully or partially wetted from one side and subjected to different boundary conditions is studied with a one-dimensional numerical model. We provide a phenomenological model here to describe the dynamic water flow through the thickness of the paper strip, via the pores, using the unsaturated flow theory. The pore-fibre water exchange is modelled as a diffusion process dependent on the wetted pore surface area. The resulting moisture-induced displacements are characterised through a hygro-elastic material model. The different time scales involved, in the process of imbibition in the inter-fibre pores, absorption (or water uptake) by the fibres and the resulting hygro-expansion, are analysed.

The numerical analysis shows a fair agreement with experimental observations. An independent immersion test provides us with an estimate of the time scales involved in the liquid transport, which is then used to characterise the out-of-plane bending response of the paper strip.

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