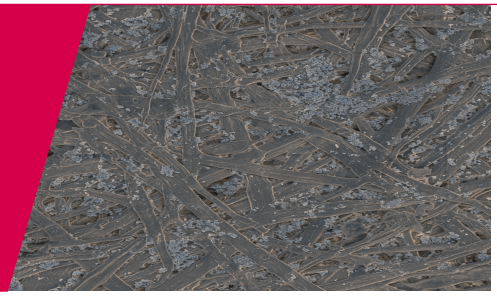
Bridging network properties to the effective paper hygro-mechanics

Bridging network properties to the effective paper hygro-mechanics

E. Bosco, R.H.J. Peerlings and M.G.D. Geers



Project goal

Moisture content variations lead to complex phenomena at the fibrous network level, which govern the macro-scale hygroscopic deformation. This limits the industrial performance and the product development in the field of digital ink-jet printing.

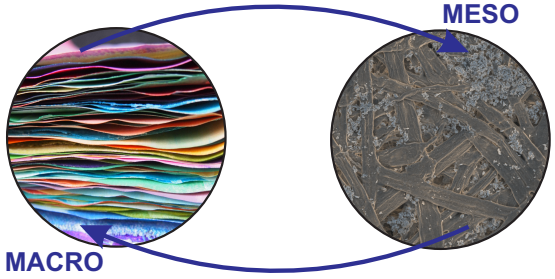


Figure 1: Multi-scale nature of the hygro-expansive phenomena affecting the dimensional stability of paper.

The goal of this project is to develop a consistent predictive model of paper hygro-mechanical behaviour.

Meso-scale model

The meso-structural network is described through a 2D squared unit-cell with diagonal elements. The fibres cross sections reflect the anisotropy of the network via the orientation distribution [1]. The mutual constraint between fibres in hygro-expansion is accounted for by treating the inter-fibre bonds as layered composite plates.

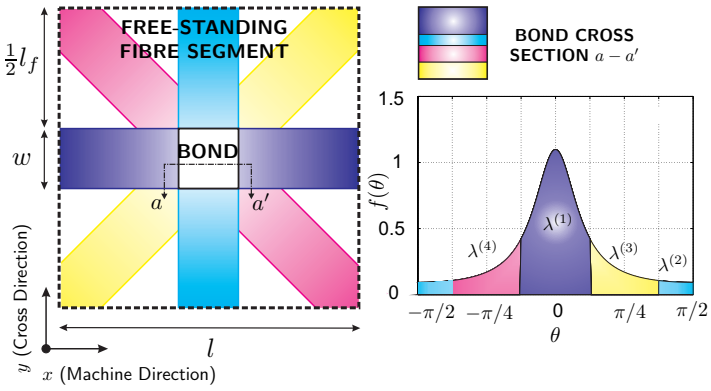


Figure 2: Geometry of the proposed unit-cell.

Constitutive hypotheses

Paper fibres are modelled as transversely isotropic continua with elasto-plastic constitutive behaviour and moisture dependent buckling strength in compression [2]. A dedicated homogenization procedure provides the hygro-mechanical effective properties, depending on the different production history (freely dried or restrained dried paper).

Results

Consistently with experiments [3], the effective hygro-expansive coefficients, shown as a function of the degree of fibre alignment along the machine direction, are smaller in the restrained dried rather than in the freely dried case.

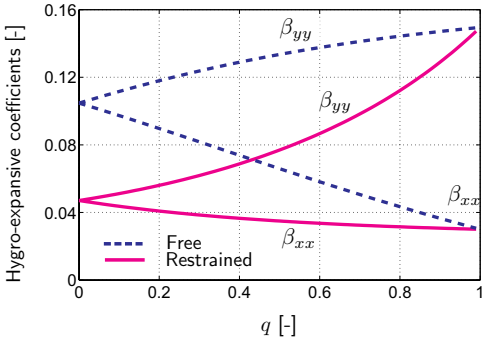


Figure 3: Effective hygro-expansivities as a function of the network anisotropy for freely and restrained dried paper.

The predicted hygro-expansive strains for the different production processes, illustrated with respect to the moisture content, reveal the typical irreversible shrinkage occurring in restrained dried paper and the linear reversible behaviour for the freely dried case. The comparison with experimental results [3] offers a good agreement.

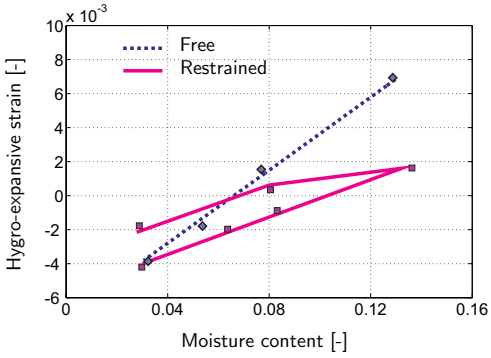


Figure 4: Hygro-expansive strain versus moisture content for freely and restrained dried paper.

Conclusions

The developed model of paper's underlying fibrous network predicts the effective hygro-mechanical behaviour of the material, focussing on the irreversible shrinkage and on the dependence on the production process.

References:

[1] Bosco E., Peerlings R.H.J., Geers M.G.D. Int. Journal Solids Struct. (2014)

[2] Bosco E., Peerlings R.H.J., Geers M.G.D. In preparation

[3] Larsson P.A., Wagberg L. Cellulose 15 (2008) 515-525