Hygroexpansion of paperboard by a correlation method of images obtained by ESEM

Jérémie Viguié[1], Pierre J.J. Dumont[1], Sabine Rolland du Roscoat[2], Pierre Vacher[3], Isabelle Desloges[1], Evelyne Mauret[1], Jean Francis Bloch[1]

[1]Laboratoire de Génie des Procédés Papetiers (LGP2), CNRS / Institut Polytechnique de Grenoble (Grenoble INP) BP 65, 38402 Saint Martin d'Hères cedex, France
[2] Laboratoire Sols-Solides-Structures-Risques (3SR), CNRS - Université de Grenoble, BP 53, 38041 Grenoble Cedex 9, France
[3]Laboratoire SYMME, Polytech Savoie, Université de Savoie Domaine Universitaire BP 80439, 74944 Annecy le Vieux, France

8th PAGORA DAYS , July 2nd & 3rd 2009

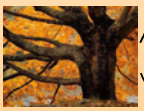
Objective

Assess the hygroexpansion of paperboard in plane and in z-direction at the macroscopic scale. Study, at the mesoscopic scale, the strain mecanisms layer by layer.

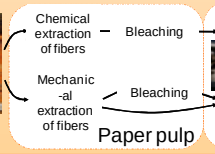
Current work

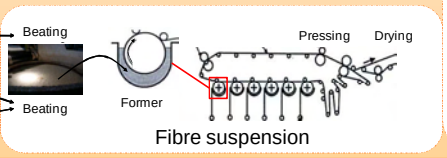
Material

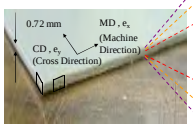
Paperboard [1] ➔ stratified material – layers made up of different paper pulps



Wood







Paperboard

Bleached chemical pulp and pigment layer

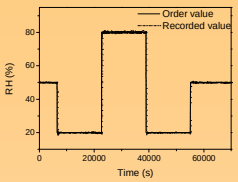
Bleached and unbleached mechanical pulp

Bleached chemical pulp and pigment layer

Measure devices

- Humid air generator
- Chamber with controlled relative humidity and temperature 23 C

- Relative humidity (RH %) cycle: **50 – 20 – 80 – 20 – 50 %**



VARIMASS®

Mass variation Δm of a sample with a dry mass m_s

➔ **Moisture content** $\frac{\Delta m}{m_s}$

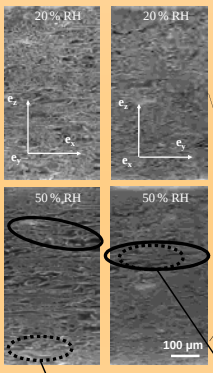
VARIDIM®

Length variation ΔL of samples with L_0 = 150 mm and l = 15 mm

➔ **Hygroexpansive strain in plane** $\varepsilon_h = \frac{\Delta L}{L_0}$

Imaging – Image correlation

Environmental Scanning Electron Microscope (ESEM) (Quanta 200 FEI)



➔ Relative Humidity change 20 ➔ 50 %

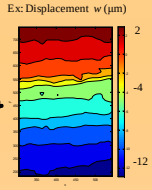


Image correlation software *7D* [2]

Displacement field measurement

$$\underline{\mathbf{u}}(x,y,z) = u\underline{\mathbf{e}}_x + v\underline{\mathbf{e}}_y + w\underline{\mathbf{e}}_z$$

Strain field

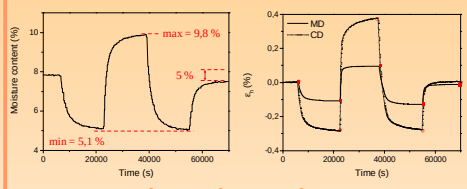
$$\varepsilon_{xx} = \frac{\partial u}{\partial x} \qquad 2\varepsilon_{xz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}$$

$$\varepsilon_{yy} = \frac{\partial v}{\partial y} \qquad 2\varepsilon_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}$$

$$\varepsilon_{zz} = \frac{\partial w}{\partial z}$$

Behaviour at the microscopic scale

Moisture content and hygroexpansive strain evolutions

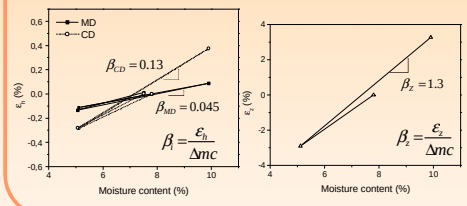


- End of cycle: irreversible loss of water absorption capacity
- Largely anisotropic hygroexpansive strains

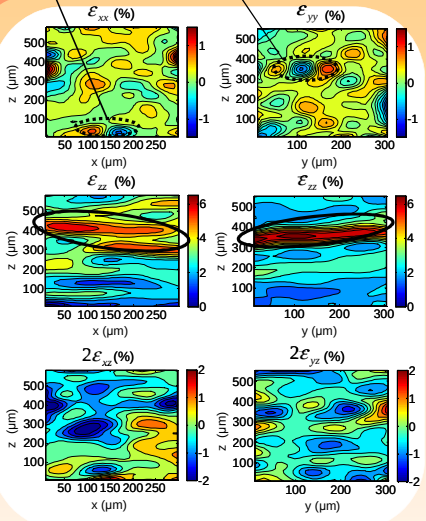
$\varepsilon_z >> \varepsilon_{hCD} > \varepsilon_{hMD}$

- Due to high anisotropic hygroexpansive behaviour of fibers [3]

Hygroexpansive strain vs moisture content



Behaviour at the mesoscopic scale



$\langle \varepsilon_{xx} \rangle = 0.198\%$
$\langle \varepsilon_{yy} \rangle = 0.241\%$
$\approx \varepsilon_h$ in MD and CD

- Largely heterogeneous in z-direction
- Ordered in layers

➔ Expansion of local porous aeras

- Higher hygroexpansion in inner layers

- Effect of mechanical pulp with high fine content?
- Interface between layers?

Conclusion & Perspectives

The hygroexpansion of paperboard was studied at the macroscopic scale using standard methods. The hygroexpansive strain is highly anisotropic. It is more significant in the z-direction than in the cross and machine directions. At the scale of the fiber network, the components of the displacement field were measured by a correlation method of images obtained by ESEM to assess the strain field through the paperboard thickness. The strain field is very heterogeneous and its variations with relative humidity are combined with an evolution of the material porosity. The behaviour variability is significant between the inner and outer layers. This can be certainly related to the different kind of pulp which are used to make these layers.

References

[1] J. Viguié, P.J.J. Dumont, I. Desloges , E. Mauret. « Some experimental aspects of the compression behaviour of boxes made up of G-flute corrugated board ». Submitted to Packaging Technology and Science, 2009.
[2] P. Vacher, S. Dumoulin, F. Morestin, S. Mguil-Touchal, « Bidimensional Strain Measurement using Digital Images ». Instn Mech Engrs Part C ImechE, Vol 213, pp.811-817, 1999.
[3] L. Salmén, C. Fellers. « The nature of volume hydroexpansivity of paper ». J Pulp Paper Sci., Vol 15(2) pp.63-65, 1989.

Contacts: jeremie.viguie@efpg.inpg.fr