Dimensional Stability of Paper

Influence of Fibre-Fibre Joints and Fibre Wall Oxidation

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Abstract

Paper is a very versatile material. Nevertheless, there are several factors limiting its usefulness, and one of the major issues is that cellulosic and lignocellulosic fibres lower their free energy by sorbing water and this water changes the dimensions of the paper. This phenomenon is usually referred to as a lack of dimensional stability and is often evident as misregister during multicolour printing or curl, cockle and wavy edges during printing, copying and storage or, with a wider definition, also as a shortened life-time of boxes during storage due to mechano-sorptive creep.

The work described in this thesis aims to study and quantify the importance of the different mechanisms causing water-induced dimensional changes in a fibre network and to investigate how to improve the dimensional stability of ligno-cellulosic materials. This has been done both by altering the fiber properties such as the moisture sorptivity and by changing the adhesion and degree of contact within the fibre-fibre joints. The properties of the fibre-fibre joints have been varied by drying laboratory sheets both under restraint and freely to minimise the generation of built-in stresses.

Bleached kraft fibres were treated using the polyelectrolyte multilayer (PEM) technique to improve the adhesion between the fibres and to increase the molecular contact within the joints. In contrast, the degree of contact was impaired by hornifying the fibres before sheet preparation. For sheets allowed to dry freely, the PEM-treatment increased the hygroexpansion coefficient, i.e. the dimensional movement normalised with respect to the change in moisture content, when subjected to changes in relative humidity whereas the hornification process resulted in a slightly lowered hygroexpansion coefficient. However, when the sheets were dried under restraint, the different joint and fibre modifications led to no difference in hygroexpansion coefficient. This was interpreted as being a result of an increase in the total contact zone between the fibres when the sheets were dried under restraint, with a greater extension in the out-of-plane direction of the joint resulting in a transfer of a larger part of the transverse swelling to the in-plane expansion.

The sorptivity of the fibres was changed by oxidising the C2-C3 bond of the 1,4-glucans with periodate. This most likely created covalent cross-links in the fibre wall both improved the integrity of the fibre wall by locking adjacent fibril lamellae to each other and also removed possible sites for water sorption onto the cellulose surfaces. Periodate oxidation also led to a decrease in the crystallinity of the cellulose within the fibres, making more cellulose hydroxyl groups available for the adsorption of water molecules. This means that the oxidation both decreased and increased the interaction between the fibre wall and moisture but, on two different structural levels. The crosslinks significantly reduced the sorption rate when the papers was subjected to changes in relative humidity, as long as the fibres were not subjected to humidities close to
saturation. The smaller change in moisture content when the relative humidity was changed between 20 and 85 % RH meant that the dimensional stability of the crosslinked sheets was increased. On the other hand, the hygroexpansion coefficient was increased in the case of papers made from fibres with the highest degree of oxidation, i.e. the sheets became more sensitive to absolute changes in moisture content.