Swelling and dissolution mechanisms of natural cellulose fibres

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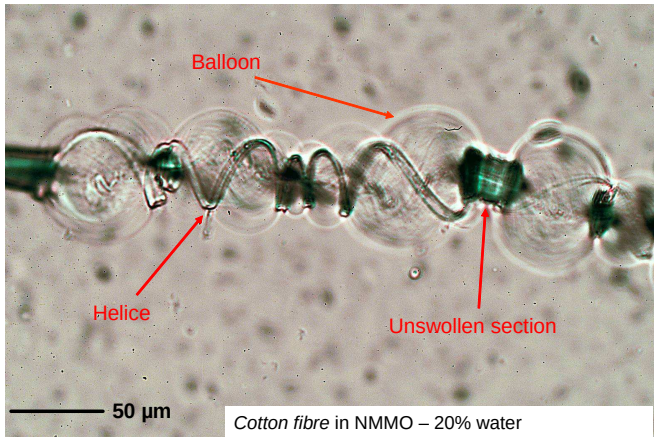
One of the limitations to the use of cellulose is the difficulty involved in the processing and fabrication because of the specific structure of the fibres. In most cases, cellulose cannot be used in its natural form. It has to be dissolved. The focus of this paper is to study the swelling and dissolution mechanisms of cellulose fibres.

The swelling and dissolution mechanisms of cellulose fibres strongly depend on the quality of the solvent. Five dissolution modes can be observed when a free floating cellulose fibre is in a solvent [1]. Several explanations have been proposed for the ballooning phenomenon observed in moderate quality solvent (mode 2 and 3). According to Ott et al. [2], during swelling in a solvent, the primary wall (external wall), considered as poorly soluble, cracks, then slides along the fibre to form protective regions where the fibre cannot swell. In order to highlight this analysis, we have performed high resolution observations by optical microscopy These observations reveal very clearly the presence of three main regions (See figure below).



Cotton fibre in NMMO – 20% water

By studying the dissolution mechanisms of cotton fibres at different development stages (from elongation of the primary wall to the deposit of the secondary wall), we have shown that the dissolution of the primary wall is very difficult to obtain even in good quality solvent. At later stages, the secondary wall deposited (internal wall) dissolves from the inside and swells. The primary wall cracks under pressure to form unswollen sections and helices, and prevents the swelling and the dissolution of the fibre in some zones. The mechanism proposed is illustrated by high resolution microscopy observations and scanning electron microscopy images.

After the removal of the primary wall by enzymatic treatment, the dissolution of wood and cotton fibres occurs with a homogeneous swelling instead of ballooning. Helices and unswollen sections are not visible any more.

This study reveals that natural cellulose fibres do not dissolve easily due to their specific wall structure and shows the potential of new “activation” methods by enzymatic treatment to ease the dissolution.

[1] Cuissinat C., Navard P., *Swelling and dissolution of cellulose Part 1: free floating cotton and wood fibres in N-methylmorpholine-N-oxide – water mixtures*, Macromol.Symp., 244 (1), 1-18, 2006
[2] Ott, E.; Spurlin, H. M.; Grafflin, M.W.; *Cellulose and cellulose derivatives*, Part 1, Interscience publisher, New York, 1954