OPTIMAL OPERATING POINTS IN ALKALINE PULPING

VICENTE COSTANZA†, MIGUEL A. ZANUTTINI‡

† Grupo Tecnología de la Madera, INTEC, UNL-CONICET, Güemes 3450, 3000 Santa Fe, Argentina.
Tel +54 342 4559174; Fax 4532965, e-mail: tisinoli@ceride.gov.ar
‡ Instituto de Tecnología Celulósica, FIQ, UNL, Santiago del Estero 2634, 3000 Santa Fe, Argentina. e-mail: mzanutti@fiqus.unl.edu.ar

Abstract— The problem of optimizing the alkaline impregnation of wood chips is posed and solved under usual restrictions. The cost to be optimized balances opposite criteria by taking economics and product quality into account, and is conditioned by the system dynamics. Evolution is modeled from typical transport phenomena equations. Optimization is attacked in the lines of variational calculus, although the final treatment involves numerical methods.

Cost function design is provided for: alkali consumption, thermal energy consumption, product quality, and total production; each one affected by a preference-weighting coefficient. A new parameter, the “Deacetylation Index”, is introduced as an observable quantity for tracking the end of the digestion stage in pulping processes. This index turns out to be significant even at low temperatures. Cost terms depend essentially on three design variables: (i) alkaline bulk concentration, (ii) digester temperature, and (iii) total duration of the process. An algorithm to ascertain the optimal values of these variables is devised. Numerical results provide insight in deciding changes on design variables in case they are allowed within a certain extent to be manipulated.

Keywords— Optimization, Transport processes, Alkaline pulping.

I. INTRODUCTION

A proper penetration and/or diffusion of alkali into wood chips is essential for all alkaline pulping processes, not only in high yield chemimechanical but for chemical or semichemical pulping as well.

The arriving of the alkali produces swelling and softening of the wood. Both effects are necessary in the ultimate defibration stage of a chemimechanical pulping (Heitner and Attack, 1983). On the other hand, the quality of the impregnation stage previous digestion affects the homogeneity of the chemical treatment, which in turn has incidence on the rejects content of the pulp and final paper quality.

Wood impregnation involves not only diffusion but also, in the case of alkaline liquors, chemical reaction. Especially under moderate conditions, such as those found in chemimechanical alkaline processes, any modeling approach must take into account reaction mechanisms since reagent concentration and load are relatively low and the alkali may be totally consumed by these reactions.

The alkali deacetylates the wood and activates carboxylic groups of the hemicellulose. According to previous work (Zanuttini et al., 1999), the quality of chemimechanical pulps after alkaline treatment is more sensitive to deacetylation than to carboxylic group content.

Traditionally, in alkaline chemical pulping impregnation is conducted at temperatures above 100 C. High temperature results in an overall diffusion-controlled process with flat reaction profiles in agreement with classical unreacted-core model results. For short reaction times, this leads to mostly unreacted chips. Ideally, reaction should occur as soon as the alkali reaches acetyl groups. It is therefore desired for the penetration of the alkali into the wood to be reaction-driven, which only happens at high reaction rates. Perhaps one of the reasons why some researchers (Zanuttini et al., 1999, Jimenez et al., 1989a,b, Jimenez et al., 1990) adopted the travelling front model was their familiarity with wood preserving pressure treatments, where diffusion is practically ignored (Costanza and Miyara, 1988, 2000).

At low temperatures alkali diffusion becomes substantial, the process is no longer diffusion-controlled, and there is a reaction gradient inside the chip, so reaction occurs in all parts of the wood, leaving no unreacted core.

Previous experimental work on the pure diffusion mechanism deserved criticism. McKibbins (1960), and Lönnberg and Robertsen (1992) did not distinguish between diffusion alone and diffusion combined with chemical reaction, so they obtained not really pure but combined coefficients. (See Costanza and Costanza, 2002 for an uncoupled treatment). Talton and Cornell (1987) measured diffusion in the reverse direction, i.e. from saturated wood to dilute solution, without commenting on the eventual distortion due to hysteresis effects. A simplified modeling approach studied the uncoupled system which considered a mass balance for the alkali alone (Kazi et al., 1997). The difference observed between predicted and experimentally obtained alkali concentration profiles suggested that the diffusion coefficient is not a constant but a certain function of the

---

1 Author to whom correspondence should be addressed