WASHING OF SODA RAPESEED PULP

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Abstract

The aim of this work was to investigate the displacement washing process of soda pulp cooked from rapeseed straw. Displacement washing process was described by displacement washing curves recorded for alkali lignin like a tracer. The preliminary results obtained showed that, similarly as for kraft softwood and hardwood fibres, the wash yield determined for soda rapeseed pulp was found to be lower than that for non-porous incompressible particles. Comparing our results for soda pulp with those reported for softwood and hardwood pulps earlier, the displacement front becomes irregular owing to the heterogeneity of soda pulp fibre bed having much greater hydraulic resistance.

Keywords: *displacement washing, soda rapeseed pulp, wash yield, Péclet number.*

Introduction

The objective of washing is to separate cellulose fibres from black liquor while using a minimal amount of wash water. Very often, pulp washing is a compromise between the cleanness of the pulp and the amount of wash water to be used. Pulp washing can be carried out by dilution/drainage or by displacement of the liquor, and most of the industrial washers combine both principles. A substantial amount of filtrate is trapped inside the fibre walls and between the fibre bundles, and is therefore not relevant to the drainage process. Displacement washing is based on the idea of replacing the liquor in the pulp web with wash liquor rather than mixing these two liquors [1]. Appropriate displacement washing is of primary importance in obtaining good washing efficiencies with all types of washing equipment.

Experimental

Rapeseed straw (*Brassica napus* L. convar. *napus*, in our case winter hybrid genotype Rohan) collected from the field in Bohemian-Moravian Highlands was used for the pulping process. The degree of delignification of pulp cooked by the batch soda process expressed by the kappa number was 33.9.

Displacement washing experiments simulated under the laboratory conditions were performed in a cylindrical glass cell with inside diameter of 35 mm under constant pulp bed height of 30 mm. The fibre pulp bed occupied the volume between the permeable septum and a piston, covered with 45 mesh screens to prevent fibre losses from the bed.

Pulp beds were formed from a dilute suspension of unbeaten unbleached soda pulp in black liquor. After compressing to desire thickness of 30 mm, the consistency, i. e., mass concentration of moisture-free pulp fibres in the bed varied within the limits from 68 to 88 kg m^{-3}. The pulp beds were not mechanically conditioned and were used as formed.

To investigate the displacement washing process, the stimulus-response method was chosen. Distilled water at the temperature of 22 °C employed as wash liquid was distributed uniformly through the piston to the top of bed at the start of the washing experiment, approximating a step change in alkali lignin concentration. At the same time the displaced liquor was collected from the bottom of the bed through the septum. The washing effluent was sampled at different time intervals until the effluent was colourless. Samples of the washing effluent leaving the pulp bed were analysed for alkali lignin using an ultraviolet spectrophotometer operating at a wavelength of 280 nm. Displacement washing experiments with pulp fibres including washing equipment were described in detail in the preceding paper [2].

After completing the washing run, the volumetric flow rate of wash liquid was measured gravimetrically at the pressure drop of 7 kPa to determine a permeability and average porosity of the pulp bed. Analogous measurements at various consistencies of the bed were focused on the determination of the effective specific volume and surface of pulp fibres according to [3].

Results and Discussion

For a better and more detailed description of the washing operation, a microscopic model has to be used. The dispersed plug flow model [4] can be chosen to characterize the displacement of the black liquor from the pulp fibre bed. The response to the step input signal can be recorded as a time dependence of the solute (e. g., alkali lignin) concentration in the output stream of effluent. Breakthrough curves obtained experimentally were normalized by plotting them on coordinates of the ratio of the instantaneous outlet to the initial mother liquor concentration in the bed versus the wash liquor ratio defined as the ratio of the mass of the wash liquor passed through the bed and the mass of the mother liquor present in the packed bed. A typical example of washing curves measured for alkali lignin is illustrated in Fig. 1, which shows also the logical limits of plug flow without diffusion and of infinite diffusion as with a fully stirred vessel.

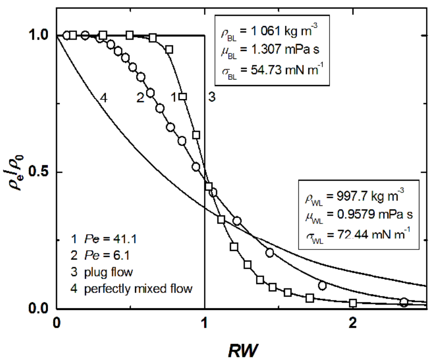

Figure 1. Typical breakthrough washing curves for soda pulp: *Pe* = 41.1 (line 1), *Pe* = 6.1 (line 2), plug flow (line 3), perfectly mixed flow (line4)

Intrinsic properties of effluent stream leaving the bed are changed during displacement process. In Fig. 1, the density, ρ, viscosity, μ, and surface tension, σ, measured at a temperature of 22 °C for the black liquor (BL) and wash liquid (WL) are mentioned. At the beginning of a displacement, the first portions discharged from the bed are fully as concentrated as was the mother liquor. As soon as the first portion of wash liquid passes through the bed, the concentration of lignin drops very rapidly. The major part of mother liquor in interparticle voids is removed and replaced by wash liquid. In the last period, only remains of black liquor are removed from inside narrow pores and fibre walls. In contrast to the first two periods, in which the displacement operation is a dominant one, the leaching referring to the desorption and diffusion of solute from within the fibres prevails. The shape of washing curve including its tail is strongly influenced by a highly complex network of pores and by leaching of solute from within fibre walls into the wash liquid. It is necessary to note that the shorter time contact between the wash liquid and fibres the longer the tail on the washing curve can be achieved. Under our laboratory conditions, the average interstitial velocity of the wash liquid in the bed was quite low in the range from 0.039 to 0.18 mm s^{-1}.

The area below breakthrough curve expressed as the dependence of the dimensionless concentration of solute upon the wash liquor ratio, *RW*, is directly proportional to the amount of a solute removed from the pulp bed. Then, the quality of the displacement washing process can be characterized by the wash yield, $WY_{\mathrm{RW=1}}$, evaluated at the wash liquor ratio equal to unity as follows

$$WY_{RW=1} = \frac{\int_{RW=0}^{RW=1} \frac{\rho_e}{\rho_0}\,\mathrm{d}(RW)}{\int_{RW=0}^{RW\to\infty} \frac{\rho_e}{\rho_0}\,\mathrm{d}(RW)} \tag{1}$$

A measure of lignin dispersion in the bed is indicated by the dimensionless Péclet number defined as

$$Pe = \frac{hu}{D\varepsilon} \tag{2}$$

This dimensionless parameter based on the height of the bed also signifies a ratio of the convective to the diffusive transport mechanisms. Details of the evaluation of the Péclet number can be found elsewhere [2].

Wash yield data are illustrated as a function of the Péclet number in Fig. 2. The experimental points measured for pulp fibres are located below the curve which was derived for the packed bed of non-porous particles by Brenner [5]. In contrast to the packed bed of non-porous particles, when the washing process is reduced to the displacement mechanism and interfacial mixing between the displaced and displacing fluid, the leaching can play a significant role in the case of compressible porous fibres in the swollen state.

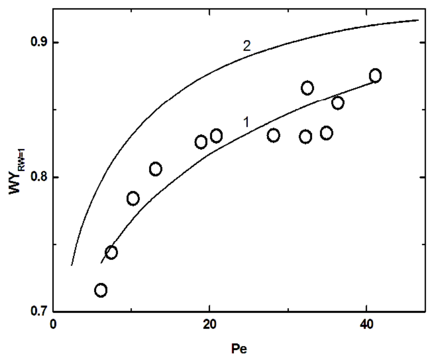

Figure 2. Displacement wash yield as a function of the Péclet number for soda pulp from rapeseed straw (○). Equation (3) (line 1), non-porous particles according to Brenner [5] (line 2)

For the data illustrated in Fig. 2, the influence of the Péclet number on the wash yield can be correlated by the following equation

$$WY_{RW=1} = 0.63\,Pe^{0,087} \qquad (3)$$

valid in the range of the Péclet number of 6 to 41. The equation (3) fitted the data with a mean relative quadratic deviation of 1.9%. Since the values of regression coefficients, which were evaluated by the least square method, represent an estimate of the real values, the 95% confidence intervals were also calculated. They are for the coefficient 0.63 ± 0.012, and for the power of the Péclet number 0.087 ± 0.0063.

These correlations confirmed again the wash yield depends upon the Péclet number in a small degree. The dependence between the Péclet number and the wash yield is in good agreement with those obtained earlier for kraft softwood pulp [2, 6, 7] and kraft hardwood pulp [8].

Conclusion

The hydraulic resistance of the soda rapeseed pulp to the delignification degree expressed for kappa number of 34 was much greater than that for kraft softwood or hardwood pulp fibres.

The displacement wash yield for soda pulp fibres showed an increasing trend with increaseing the Péclet number in agreement with the results obtained for softwood and hardwood fibres.

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Abstrakt

Cílem práce bylo vyšetřit průběh vytěsňovacího praní natronové buničiny uvařené z řepkové slámy. Vytěsňovací praní bylo popsáno pracími křivkami vyjadřujícími koncentraci alkalického ligninu ve vystupujícím proudu výluhu. Předběžné výsledky ukázaly, že podobně jako pro vlákna buničiny z listnáčů a jehličnanů je prací výtěžek menší, než při vytěsňování černého louhu z vrstvy složené z nestlačitelných a neporézních částic. V porovnání s praním sulfátové buničiny z listnáčů a jehličnanů je rozhraní mezi vytěsňovanou a prací kapalinou nepravidelné s ohledem na různé lokální charakteristiky vrstvy natronové buničiny, která projevuje větší hydraulický odpor.