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INFLUENCE OF FIBRE CHARACTERISTICS ON RHEOSEDIMENTATION PROPERTIES OF KRAFT PULP SUSPENSIONS

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ABSTRACT

The influence of beating on rheosedimentation properties and on fibre characteristics of unbleached and bleached hardwood and softwood kraft pulps was investigated. Standard rheosedimentation velocity and final concentration of sediment decreased with increasing beating degree of pulps. FS number and L number of kraft pulps slightly increased with increasing beating degree up to 30°SR while B number increased up to 50°SR. Standard rheosedimentation velocity and final concentration of sediment of hardwood kraft pulps at equal beating degree was higher than of softwoods pulps. This is related to higher B number and lower L number of hardwood pulps. The standard rheosedimentation velocity and final concentration of sediment as well as FS number and L number of unbleached pulps was higher than of bleached pulps.

KEYWORDS: standard rheosedimentation velocity, final concentration of sediment, fibre strength, fibre length, fibre bonding, hardwood kraft pulp, softwood kraft pulp

INTRODUCTION

The control of papermaking process is possible by measurement of strength and bonding properties of pulp fibres. These properties are possible to estimate by rheosedimentation method. This method is based on sedimentation of fibre network. This network is formed from pulp fibres, in case if fibre suspension is approximately 1 kg.m^{-3}. Standard velocity of rheosedimentation (v_s) and final concentration of sediment (c_k) are characteristic parameters of pulp fibres depending on their geometry, structure and mechanical properties in wet state and bonding ability (Milichovský and Češek 2004, Češek and Milichovský 2005). The final concentration is more sensitive to interbonding ability of fibre components creating a fibre suspension. It appears that with increasing this ability the final concentration of sediment decreases. The sedimentation velocity is more depend upon shape and structure of fibres. Both parameters, i.e. sedimentation velocity and final concentration are strongly dependent upon hydratation ability of fibre components – with increasing hydratation ability both parameters decrease.

The movement of rheosedimentating fibre network continuum is very well described by the general equation of continuity (Milichovský and Šestauber 1987) and is similar to the equation applied for description of subsidence of uraniferous phosphate slime (Smellie and La Mer 1956). The detailed method of rheosedimentation parameters estimation was described by Češek and Milichovský (Češek and Milichovský 2005).

Single fibre testing is cumbersome and requires a large number of tests in order to reach statistical precision and is therefore not considered as being practical as a routine testing method. Fibre properties can be measured directly using an alternative method – Pulmac fibre-quality testing. Direct measurement of fibre properties provides information that helps explain the response of handsheet tensile and tear strength to various level of refining. The explanatory power of this approach provides evidence that the fibre-quality testing is a reliable method of evaluating pulp quality.

During cooking and bleaching, the alkaline conditions along these processes favour the structural disorganization of the microfibril chains in the cell wall. The removal of wood constituents during pulping and bleaching creates macropores in the cell wall. The wall becomes more fragile and damaged in relation to its original organization in the wood. This cell wall fragility enables the fibres to suffer more and to deform when mechanical forces are applied to them. Deformations and lumen collapse become more frequent. The more the fibre is damaged during pulping and bleaching, the more sensitive is the fibre wall to be deformed and collapsed.

The objective of this work is to evaluate influence of fibre characteristics on rheosedimentation properties of kraft pulp suspensions, as are standard rheosedimentation velocity and final concentration of sediment.

MATERIAL AND METHODS

Material

Kraft pulps produced in a mill were used in this investigation. The hardwood kraft pulp was produced from a mixture containing mainly beech, oak, hornbeam, turkey oak and acacia. The Kappa number of unbleached hardwood kraft pulp (UBHKP) was 16 and intrinsic viscosity 865 $dm^3.kg^{-1}$. The brightness of the bleached hardwood kraft pulp (BHKP) was 88 % ISO and intrinsic viscosity 720 $dm^3.kg^{-1}$.

The softwood kraft pulp was produced from a mixture of 90 % spruce and 10 % pine chips. The Kappa number of unbleached softwood kraft pulp (UBSKP) was 25 and intrinsic viscosity 840 $dm^3.kg^{-1}$. The brightness of the bleached softwood pulp (BSKP) was 88.5 % ISO and intrinsic viscosity 590 $dm^3.kg^{-1}$.

The unbleached and bleached hardwood and softwood kraft pulps were beaten in a laboratory Valley hollander to 20, 30, 40 and 50 °SR, according to ISO 5264-1. The beating degree was determined according to the ISO 5267-1 standard. The test sheets (60 $g.m^{-2}$) were prepared according to the ISO 5269-2.

Methods

The zero-span tensile strength of unbleached and bleached kraft pulps were measured with a PULMAC INC ZERO-SPAN 1000 apparatus according to the ISO 15361:2000 standard. The results were expressed as a FS number, L number and B number:

FS number (N/cm) = Avg. > 10 wet zero-span tensile tests normalized to 60 $g.m^{-2}$.

L number (%) = Avg. > 10 re-wet shot (0.40 mm) span tensile tests/ Avg. > 10 re-wet zero span tensile tests.

B number (%) = Avg. 10 dry shot (0.40 mm) span tensile tests/ Avg. 10 re-wet short span (0.40 mm) tensile tests.

The standard rheosedimentation velocity (v_s) and the final concentration of sediment (c_k) were evaluated by a simple rheosedimentation method by monitoring the height of the fibre network in a cylindrical vessel. To assure a good reproducibility the amount of air in the pulp suspension must be anxiously controlled. To secure this in preparation of the fibre suspension and in all experiments the diluting water was prepared by de-aeration of distilled water by occasionally gentle agitation with a glass rod during at least 24 hours at temperature of 22 °C. Before every rheosedimentation experiment, the diluting water was further cooled to a temperature of 15 °C by dosing pieces of ice followed by dilution of the pulp slurry to a concentration of approximately 1 $kg.m^{-3}$ with diluting water and carefully agitation of this pulp suspension. The suspension in a 2 L graduated cylindrical vessels with an inner diameter of 10 cm was agitated by up and down movement of a special agitator made by connection of a rod and a disc of 8 cm diameter with 1 cm holes. During up and down movement with agitator we must avoid to any pulling out disc part of agitator from pulp suspension. By this method of agitation we were able to ensure a full initial homogeneity of the pulp suspension. Dependence of the rheosedimentating fibre network height on time can be calculated with a satisfactory correlation coefficient of at least 0.95 from an equation describing the movement of the rheosedimenting fibre network continuum for given boundary condition (Češek and Milichovský 2005). From this relationship the rheosedimentation parameters v_s a c_k were determined for all unbleached and bleached (beaten and unbeaten) hardwood and softwood kraft pulps.

RESULTS AND DISCUSION

The influence of beating on rheosedimentation characteristics (v_s a c_k) of unbleached and bleached hardwood and softwood kraft pulps was compared. With increasing beating degree v_s of pulps decreased (Fig. 1). The beating process influenced more significantly decrease of v_s of hardwood pulps; decrease was up to 70 %. The decrease of v_s in case of softwood pulps beating to 50°SR was 60 %. At equal beating degree v_s of hardwood pulps was three times higher than of softwood pulps. At equal beating degree v_s of bleached pulp was three times lower than of unbleached pulps.

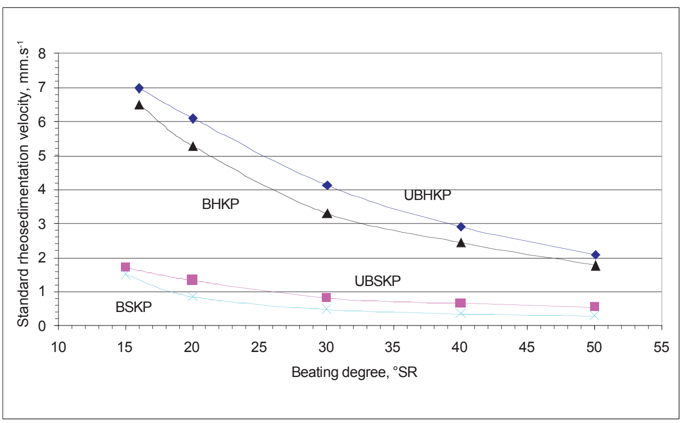

Fig. 1: Dependence of standard rheosedimentation velocity on beating degree of unbleached and bleached hardwood and softwood kraft pulps

Fig. 2 shows dependence of c_k on beating degree of unbleached and bleached hardwood and softwood kraft pulps. With increasing beating degree c_k of hardwood pulps decreased more significantly than of softwood pulps. At equal beating degree c_k of hardwood pulps was higher than of softwood pulps. The final concentration of sediment c_k of unbleached pulps was higher than of bleached pulps. Rheosedimentation characteristics depend more on wood species and less on beating degree. Bleaching process of both hardwood and softwood pulps has influence on morphology of fibres resulting in decrease of v_s a c_k .

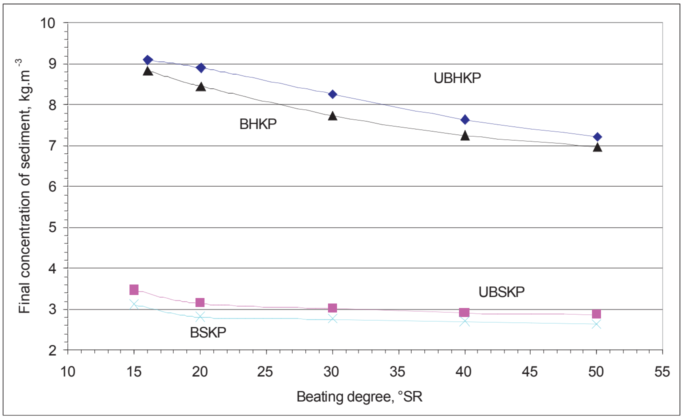

Fig. 2: Dependence of final concentration of sediment on beating degree of unbleached and bleached hardwood and softwood kraft pulps

With increasing beating degree of unbleached and bleached hardwood and softwood pulps up to 30°SR FS number a L number (Figs. 3 and 4) increased. FS number of unbleached pulps was higher than of bleached pulps and FS number of softwood pulps was higher than of hardwood pulps (Fig. 3). L number of softwood pulps was more than twice higher than of hardwood pulps (Fig. 4). L number of unbleached pulps was higher than of bleached pulps.

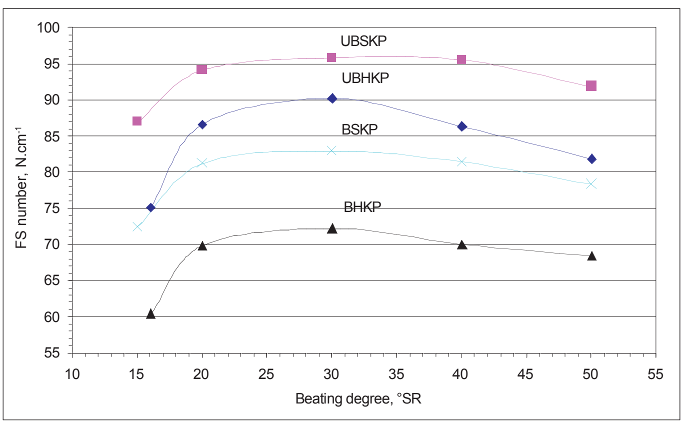

Fig. 3: Dependence of FS number on beating degree of unbleached and bleached hardwood and softwood kraft pulps

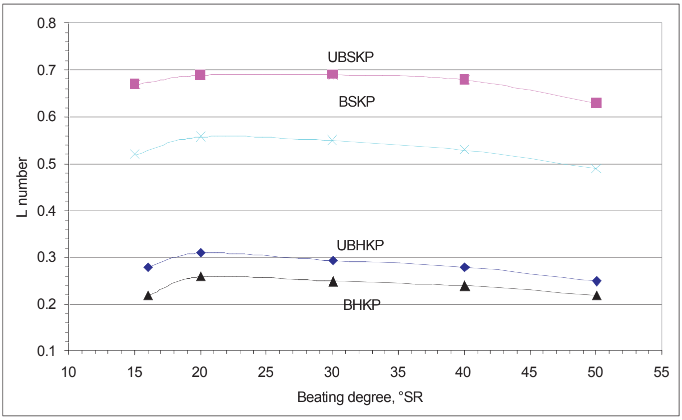

Fig. 4: Dependence of L number on beating degree of unbleached and bleached hardwood and softwood kraft pulps

B number of unbleached and bleached hardwood and softwood kraft pulps increased with increasing beating degree (Fig. 5). B number of hardwood pulps was more than two times higher than of softwood pulps at equal beating degree; at same conditions B number of bleached pulps was higher.

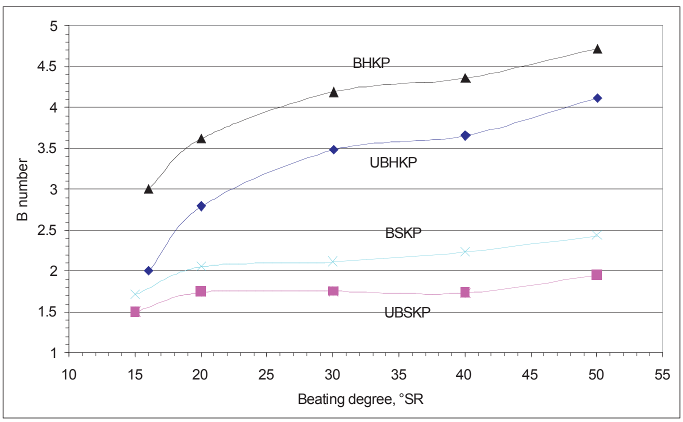

Fig. 5: Dependence of B number on beating degree of unbleached and bleached hardwood and softwood kraft pulps

FS, L and B number of unbleached and bleached softwood and hardwood kraft pulps increased with increasing beating degree (FS number and L number only up to 30 °SR) while rheosedimentation characteristics of kraft pulp suspensions (v_s and $c_{k)}$ decreased with increasing beating degree.

Fig. 6 shows standard rheosedimentation velocity v_s of unbleached and bleached hardwood compared with final concentration of sediment v_s of softwood kraft pulps beaten to 30° SR with corresponding characteristics of fibres expressed as FS number, L number and B number.

Standard rheosedimentation velocity v_s of hardwood pulps were 5 to 6 times higher than of softwood pulps. The difference in v_s between unbleached and bleached hardwood pulps was 19.8 % while in case of softwood pulps the difference is was as high as 41 %.

High v_s values of hardwood pulps are first of all a result of high B number, that is of high bonding potential and low L number that is short length of fibres. On the contrary low v_s values of softwood pulps are a result of a high L number and low B number that is a result of longer fibres with a lower bonding potential. Standard rheosedimentation velocity v_s of bleached hardwood kraft pulps was lower when compared with unbleached pulps due to higher B number and lower FS number and L number. Lower v_s of bleached softwood pulp is a result of higher B number and lower FS number and L number when compared with bleached pulp.

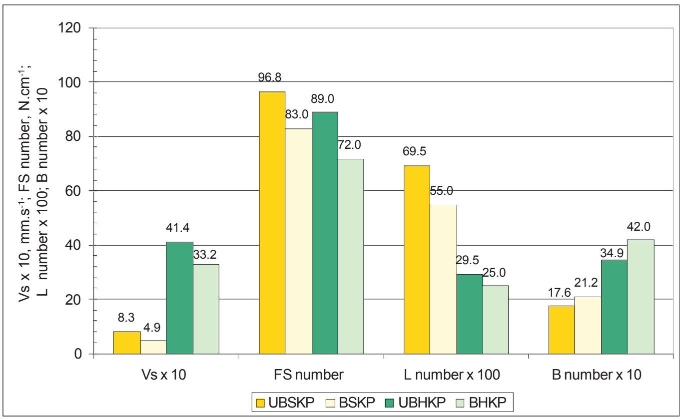

Fig. 6: Standard rheosedimentation velocity, FS number, L number and B number of unbleached and bleached hardwood and softwood kraft pulps at 30 °SR

On Fig. 7 the final concentration of sediment c_k, FS number, L number a B number of unbleached and bleached hardwood and softwood kraft pulps beaten to 30 °SR are compared. Final concentration of sediment c_k of hardwood pulps was 2.8 times higher than of softwood pulps. Final concentration of sediment c_k of bleached hardwood kraft pulp was by 6.3 % lower than of unbleached pulps. The difference between c_k of unbleached and bleached softwood kraft pulps was 8.6 %.

The high c_k values of hardwood pulps is above all a result of high bonding potential (B number) and low L number as hardwood fibres are short. On the contrary low c_k values of softwood pulps are a result of low B number and high L number that is of lower bonding potential and higher length of fibres similarly as in case of v_s. Bleached hardwood pulps are characterised by a lower v_s as B number is higher, but FS number and L number is lower when compared with unbleached pulp. Lower c_k values of bleached softwood pulps are a result of higher B number, but lower FS number and L number when compared with unbleached pulp.

Differences in FS, L and B number between hardwood and softwood pulps were more significantly expressed in the level of v_s. Similarly changes of fibre characteristics caused by bleaching process are more significantly expressed in decrease of v_s level.

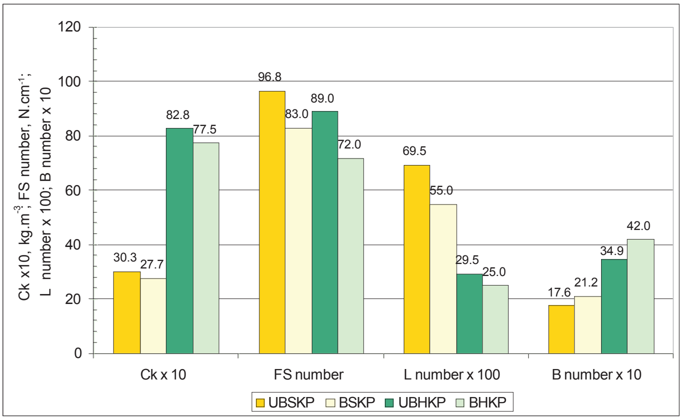

Fig. 7: Final concentration of sediment, FS number, L number and B number of unbleached and bleached hardwood and softwood kraft pulps at 30 °SR

CONCLUSIONS

Wood raw material species has a significant influence on fibre characteristics and rheosedimentation properties of kraft pulps. FS and L number of softwood pulps was higher than of hardwood pulps but v_s and c_k was lower. Standard rheosedimentation velocity v_s and final concentration of sediment c_k of hardwood pulps was higher than of softwood pulps as hardwood pulps B number is higher and L number lower when compared with softwood pulps.

FS number and L number of unbleached hardwood and softwood kraft pulps was higher and B number lower than of bleached pulps; v_s and c_k of unbleached pulps was higher than of bleached pulps.

Beating of pulp has influence on FS number, L number and B number of fibres; influence is highest on B number which expresses bonding capacity of fibres. With increasing beating degree v_s and c_k of unbleached and bleached hardwood and softwood pulps decreased.

From the results follows that properties of pulp suspension depend on fibre characteristics such as fibre strength (FS number), fibre length (L number) and bonding capacity (B number) but also on shape and geometry of fibres as well as on supramolecular structure and chemical composition of fibres.

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