RELATIONSHIP BETWEEN FIBRE CHARACTERISTICS AND TENSILE STRENGTH OF HARDWOOD AND SOFTWOOD KRAFT PULPS

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Fibre characteristics of kraft softwood and hardwood unbleached and bleached pulps, namely FS number – indicating fibre strength, L number – indicating fibre length and B number – indicating fibre bonding ability, were determined by the PULMAC zero-span tester. A higher tensile index of softwood pulp and unbleached pulps is related to a higher FS and L number and, consequently, to higher strength and length of fibres. On the contrary, hardwood pulps have, at an equal tensile index, a higher B number than softwood pulps. At an equal tensile index, the B number of bleached pulp is higher than that of unbleached pulp.

Keywords: hardwood kraft pulp, softwood kraft pulp, bleaching, beating, fibre strength, fibre length, fibre bonding, tensile index

INTRODUCTION

The evaluation of pulp strength properties by conventional methods is not suitable for detailed specifications of pulp properties or fibre line optimisation, as fibre strength and fibre bonding strength are not determined separately and the measured tensile strength is a combination of tensile strength of fibres and fibre-to-fibre bond strength.[1] For an exact evaluation of pulp properties, the determination of tensile properties of fibres is necessary. Tensile strength measurement of individual fibres requires cumbersome drying and fixing of fibres with epoxy adhesive on a metal surface.[2,3] A large number of tests is necessary to get statistically reliable data.

Nowadays, the so-called zero-span tensile test is a widely used method for fibre strength characterisation, in which the tested paper strips and, consequently, a given fibre is clamped at zero span of the tester jaws. This test was already described and analysed by several authors.[4-9] Usually, a Pulmac tensile tester is used in such investigations. Fibre strength in N/cm (FS number), determined by the zero-span test, is not a fundamental measure of fibre strength, but it is an indicator. It was observed that FS number is influenced, to a certain degree, by the bonding strength of fibres in a dry sheet. Cowan[8-10] found out that the effect of bonding can be eliminated by sheet rewetting, while Seth and Chan[11] observed that FS number increases by mild beating. This observation is based on the fact that, by swelling and mild low consistency beating to about 20-22 °SR, the curled fibres are straightened, more fibres are clamped and thus FS number increases.

A Pulmac zero-span apparatus also offers the possibility to measure the additional fibre characteristics,[12] by short-span tensile strength measurements at a 0.4 mm distance between the jaws. L number, determined by comparison of wet short-span to wet zero-span tensile strength, is a measure of fibre length, while B number the ratio of dry short-span to wet short-span tensile strength measure the degree of fibre bonding.

The objective of this work is to evaluate the relationships between fibre characteristics and tensile strength of unbleached

and bleached softwood and hardwood laboratory beaten kraft pulps.

EXPERIMENTAL

Materials

Kraft pulps produced in a mill were used in this investigation. The softwood kraft pulp was produced from a mixture of 90% spruce and 10% pine chips. Kappa number of unbleached softwood kraft pulp (UBSKP) was 25 and intrinsic viscosity – 840 dm^3/kg. The brightness of bleached softwood pulp (BSKP) was of 88.5% ISO and intrinsic viscosity – 590 dm^3/kg.

The hardwood kraft pulp was produced from a mixture containing mainly beech, oak, hornbeam, turkey oak and acacia. Kappa number of unbleached hardwood kraft pulp (UBHKP) was 16 and intrinsic viscosity – 865 dm^3/kg. The brightness of bleached hardwood kraft pulp (BHKP) was of 88% ISO and intrinsic viscosity – 720 dm^3/kg.

Methods

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 ISO 5267-1 Standard. The test sheets (80 g/m^2 and 60 g/m^2, respectively) were prepared according to ISO 5269-2 and tensile index determined according to ISO 1924-2 Standard.

The zero-span tensile strength of unbleached and bleached kraft pulps was measured with a PULMAC INC ZERO-SPAN 1000 apparatus, according to ISO 15361:2000 Standard. The results were expressed as 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 rewet short-span (0.40 mm) tensile tests/Avg. > 10 rewet zero-span tensile tests;

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

RESULTS AND DISCUSSION

Figures 1, 2 and 3 show the differences in FS number, L number and B number between hardwood and softwood kraft pulps, and also the differences caused by beating and bleaching of pulps. Increasing the beating degree over 30 °SR has only a minor influence on the FS number and L number of all pulps, as these parameters slightly decrease by beating (Figs. 1 and 2). The FS number and L number of softwood pulps are significantly higher over the entire range of beating than in the case of hardwood pulps, which is a consequence of the longer softwood fibres, compared with the hardwood fibres.

Figure 3 plots the dependence of B number on the beating degree of unbleached and bleached softwood and hardwood kraft pulps. With increasing the beating degree, B number increased over the whole range of beating, contrary to FS number and L number (Figs. 1 and 2). The bonding strength of hardwood pulps, expressed as B number, strongly increases by beating, while the B number of softwood pulps increases only moderate beating. The B number of unbleached and bleached softwood kraft pulps was approximately 50% lower than that of unbleached and bleached hardwood kraft pulps.

Figure 4 shows the dependence of tensile index on the beating degree of unbleached and bleached hardwood and softwood kraft pulps. With increasing the beating degree, the tensile index of all pulps increased. The tensile index of softwood kraft pulps was higher than that of hardwood kraft pulp over the whole range. At 30 °SR, the tensile index of unbleached softwood pulp was of 84.7 $N \cdot m/g$ and that of bleached softwood pulp – 75.6 $N \cdot m/g$, which means a difference of 10.7%. The tensile index of unbleached hardwood pulp at 30 °SR was of 69.7 $N \cdot m/g$ and that of bleached pulp was of 60.6 $N \cdot m/g$, which is by 13% lower than that of unbleached pulp.

Bleaching significantly reduces the FS number and L number of both hardwood and softwood kraft pulps, while it increases B number (Figs. 1-3). The FS number of unbleached softwood pulp at 30 °SR was the highest – of 96.8 N/cm –, while the FS number of bleached softwood pulp was just 83.0 N/cm, representing a 14.3% decrease of FS number in bleaching. The FS number of unbleached hardwood pulp at a 30 °SR beating degree was 89.0 N/cm, while that of bleached hardwood pulp was just 72.0 N/cm; this represents a 19.1% decrease of FS number in bleaching. The L number of unbleached softwood kraft pulp at 30 °SR was 0.695, and that of bleached softwood pulp was 0.55, representing a 20.9% decrease in bleaching. The L number of unbleached hardwood pulp at 30 °SR was 0.295, and that of bleached hardwood pulp was 0.25, representing a 15.3% decrease in

bleaching. The B number of bleached hardwood kraft pulp at 30 °SR was the highest (4.2), while that of unbleached hardwood kraft pulp was just 3.49. This represents an increase of B number in bleaching by 16.9%. The B number of bleached softwood pulp at 30 °SR was 2.12, while that of unbleached softwood pulp was just 1.76. This represents a 17% increase of B number in bleaching.

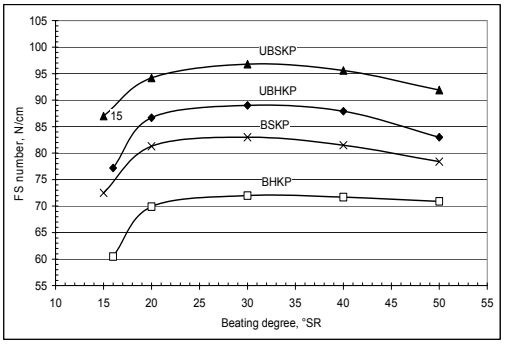

Figure 1: Influence of laboratory beating on FS number of unbleached and bleached hardwood and softwood kraft pulps

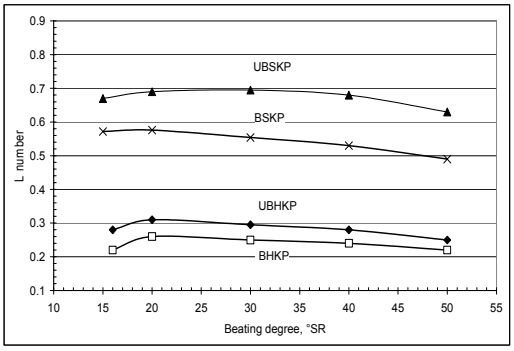

Figure 2: Influence of laboratory beating and bleaching on L number of hardwood and softwood kraft pulps

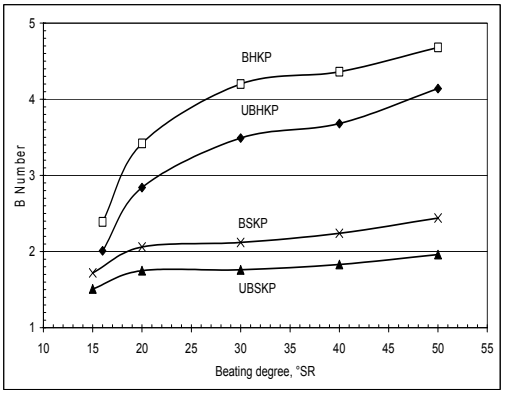

Figure 3: Influence of laboratory refining and bleaching on B number of hardwood and softwood kraft pulps

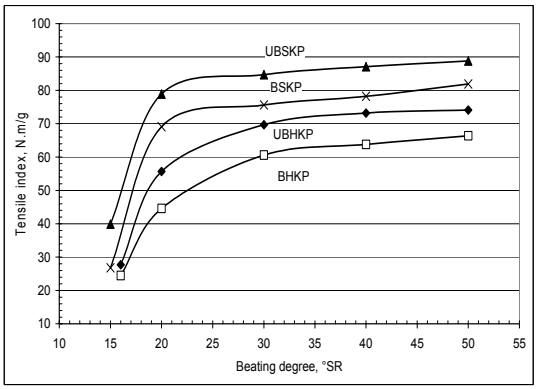

Figure 4: Dependence of tensile index of unbleached and bleached hardwood and softwood kraft pulps on beating degree

Obviously, the lower strength of bleached pulps is mainly caused by the decrease of FS number and L number through bleaching. From the perspective of pulp tensile strength, the significantly lower FS number and L number – *i.e.* much lower fibre strength and fibre length of hardwood pulps – is partly compensated by the strong increase of the B number of hardwood pulps by beating (Fig. 3). This explains the comparatively low differences of tensile index between hardwood and softwood pulps (Fig. 4). Bleaching reduced the tensile index of softwood kraft pulp at 30 °SR by 10.7%, and the tensile index of hardwood kraft pulp by 13%.

Figure 5 shows the dependence of tensile index on the B number of unbleached and bleached kraft softwood and hardwood pulps at various beating degrees (15, 20, 30, 40 and 50 °SR). With increasing the beating degree, B number and tensile index simultaneously increase. An equal tensile index of the tested pulps was achieved at different B numbers, *e.g.* at a tensile index of 60 Nm/g, the B number of unbleached softwood pulp was 1.6, of bleached softwood pulp – 1.95, of unbleached hardwood pulp – 2.995 and of bleached hardwood pulp – 4.2. The B number of unbleached pulps at equal tensile index was lower than that of

bleached pulps. The FS number and L number of softwood kraft pulps fibres are higher and, therefore, even at a low B number, the tensile index is high.

The relationships shown of Figures 1-5 indicate that the tensile index, which is changing with the beating degree, depends on fibre properties. Fibre characteristics depend on the wood species, cooking and bleaching conditions. The compared pulps were prepared by a basically equal cooking and bleaching process, with only minor modifications. Differences in the fibre characteristics of the evaluated pulps are the result of the different properties of the wood species used for pulp production.

Figure 6 provides an overall evaluation of the influence of fibre characteristics on the tensile index of various kraft pulps at 30 °SR. The tensile index of pulps decreases in the same sequence as FS number and L number decrease. The decrease of these fibre characteristics is to some extent compensated by the increase of B number through bleaching, and also by the higher B number of hardwood pulps.

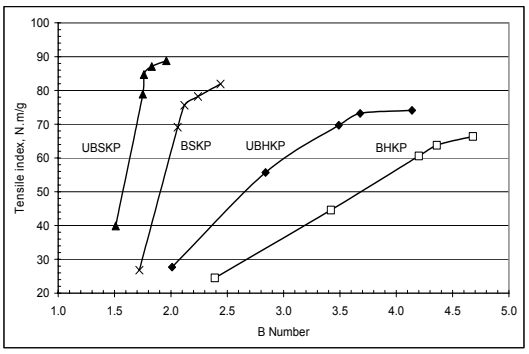

Figure 5: Dependence of tensile index on B number of unbleached and bleached hardwood and softwood kraft pulps

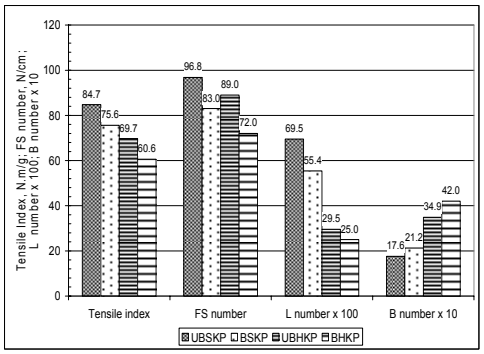

Figure 6: Tensile index, FS number, L number and B number of unbleached and bleached hardwood and softwood kraft pulps at 30 °SR

CONCLUSIONS

The tensile index depends on fibre strength and length characteristics and on fibre bonding ability, as well. The results obtained show that a higher tensile index is related with a higher FS number and L number, characterising fibre strength and length. The softwood kraft pulps have a higher tensile index than the hardwood kraft ones. Also, the unbleached softwood and hardwood kraft pulps have a higher tensile index than the bleached kraft pulps. The decrease in FS number and L number is to some extent compensated by the increase of B number by bleaching and by the higher B number of hardwood pulps.

The influence of laboratory beating on the FS number and L number of unbleached and bleached hardwood and softwood kraft pulps is analogous; increasing the beating degree over 30 °SR reduces only slightly these fibre characteristics. With increasing the beating degree, B number increased over the whole range of beating degree, contrary to FS number and L number.

The FS number of unbleached hardwood and softwood kraft pulps was higher than that of bleached pulps, at an equal beating degree. The FS number of softwood kraft pulps was higher than that of hardwood kraft pulps. The L number of softwood kraft pulps was by 45% higher than that of hardwood kraft pulps, while the L number of unbleached kraft pulps was higher than that of bleached kraft pulps. The B number of hardwood kraft pulps was approximately 50% higher than that of softwood kraft pulps, while the B number of bleached kraft pulps was higher than that of unbleached kraft pulps.

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