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HANDSHEET PROPERTIES OF RECOVERED AND VIRGIN FIBRE BLENDS

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ABSTRACT

Recovered paper is a valuable raw material for paper industry and its significance has been increasing steadily over the last years. Unbleached spruce kraft pulp was used as virgin fibres and influence of beating on strength properties was investigated. The best properties of unbleached virgin spruce kraft pulp were achieved at 20 °SR. Handsheet properties from recovered fibres from old corrugated containers (OCC) and unbleached spruce kraft pulp blended at different weight ratio were determined. Tensile index, tensile energy absorption index, tear index, burst index and elongation increased with increasing content of unbleached spruce kraft pulp in blend while handsheet porosity decreased. Brightness, opacity, light scattering coefficient s, light absorption coefficient k, ERIC number, light scattering coefficient (s_{950}) and light absorption coefficient (k_{950}) decreased with increasing of unbleached spruce kraft pulp in blend. Blends of OCC with unbleached spruce kraft pulp content of 30 % or higher can also be suitable for production of wrapping papers with high mechanical resistance such as sack papers or shopping bags. Handsheets porosity was high enough for this grade of paper.

KEYWORDS: Recovered fibres, OCC, unbleached spruce kraft pulp, blended handsheets, strength properties, optical properties, porosity.

INTRODUCTION

Maximising the use of recovered fibres versus virgin fibres in appropriate paper grades and under appropriate circumstances can be economically beneficial and can reduce environmental impacts. Maximising recycled content for its own sake can be achieved without regard for product type, mill performance or mill location. However the production will not have a negative environmental impacts and it will be economically rational.

Recovered fibres begin its life period as virgin fibres produced from woods or non-wood plants. Much of the virgin fibres that enter the paper fibres system are used repeatedly before they are finally discarded. However, the use of recovered fibres produces paper with poorer strength properties due to decrease of interfibre bonding (Rushdan 1998).

It is very difficult to directly compare the environmental impact of recovered and virgin fibres in paper production. Both are important and can have an equally strong environmental argument. Forests are a part of the cycle that helps to remove CO_2 from atmosphere. This cycle continues from trees to wood and paper products, which continue to store the carbon through their lifetime and helps to ease the climate change. The fact, that paper products are recyclable and renewable means that their lifecycle can be extended, prolonging this benefit and reducing waste generation.

Constant addition of virgin fibres into papermaking stock is needed because wood fibres cannot be recycled indefinitely. Fibre length as well as fibre bonding ability determines pulp strength. Recovered fibres are usually shorter than virgin fibres and lose strength with each reuse cycle. Depending on the origin of the virgin fibres and type of products, fibres are degraded and become unusable after five to seven cycles. Recovered kraft fibres tend to be stiff and deficient in bonding ability. Therefore it is reasonable to blend them with a proportion of well-fibrillated kraft fibres (Hubbe et al. 2007). Cellulosic fines that are freshly prepared as a result of refining tend to be especially effective for promoting bonding within paper (Hawes and Doshi 1993, Fjerdingen and Houen 1997). Microscopic observations suggest that virgin fines can help fill in spaces within and adjacent to fibre crossings, thus increasing the effective area of bonding between fibres (Somvang et al. 2001).

Kraft pulps tend to be more flexible than fibres produced by purely mechanical fiberizing of wood. The superior bonding potential of kraft pulps becomes evident when they are refined sufficiently to allow collapse of the lumen, delamination of the cell wall, and partial fibrillation of the surfaces. Kraft fibres tend to be more porous compared to mechanical fibres. The optimum percentage of recovered fibres content is not the same for all type paper products. The highest amount of recovered fibre is used in packaging materials and newspaper. Bag and wrapping paper grades are made from highly refined pulp in a variety of basis weights and percentages of recovered fibre content.

Wrapping paper must have good resistance to rupture by tensile and tearing forces. Basis weight and thickness of wrapping paper are usually of secondary importance except that these properties may influence other properties such as density, porosity, strength, stiffness and similar characteristics of paper (Willets et al. 1963).

Determining the best use of recovered and virgin fibre for any paper type requires a life cycle perspective with evaluation of the environmental, economic and technical considerations along the entire supply chain.

The influence of unbleached spruce kraft pulp addition to recovered fibres on handsheet properties was studied for purpose of effective utilization of unbleached spruce kraft pulp strength potential for production of high quality wrapping papers.

MATERIAL AND METHODS

Materials

Unbleached spruce kraft pulp (Kappa number 50, Limiting viscosity number 1190 $cm^3.g^{-1}$), produced in Mondi Štěti, used for sack kraft paper manufacturing, was used as a source of virgin fibres. Recovered fibres from OCC, quality grade 1.05 according to EN 643 2001 were used for preparing blends with virgin fibres. The beating degree of recovered fibres was 26 °SR and of unbleached spruce kraft pulp was 20 °SR.

Methods

Kappa number of unbleached spruce kraft pulp was determined according to ISO 302

2004 and limiting viscosity number according to ISO 5351/1 2010 standards. Unbleached spruce kraft pulp was beaten in a laboratory Jokro mill according to ISO 5264-3 1979 method. Beating degree was determined according to ISO 5267-1 1999 standard. OCC were slushed for 10 minutes in a laboratory Escher Wyss pulper at 4 % consistency. Handsheets (80 $g.m^{-2}$) were prepared according to ISO 5269-2 2004 method and tested according to ISO standards for brightness (ISO 2470-1 2009), opacity (ISO 2471 2008), light scattering coefficient s (ISO 9416 2009), light absorption coefficient k (ISO 9416 2009), effective residual ink concentration ERIC number at 950 nm (ISO 22754 2008), light scattering coefficient (s_{950}) (ISO 22754 2008), light absorption coefficient (k_{950}) (ISO 22754 2008), tensile index and tensile energy absorption index (ISO 1924-2 2008), burst index (ISO 2758 2001), elongation (ISO 1924-2 2008), tear index (ISO 1974 2012) and air permeation resistance – Gurley method (ISO 5636-5 2003).

RESULTS AND DISCUSSION

Unbleached spruce kraft pulp properties

For purpose of optimal utilization of unbleached spruce kraft pulp strength potential, the dependence of strength properties on beating degree was evaluated because the pulp beating has a significant effect on the strength properties.

Strength properties of unbeaten unbleached spruce kraft pulp (12 °SR) and pulp beaten to 16 °SR, 20 °SR and 30 °SR were tested. Fig. 1 shows tensile index, tear index and burst index dependence on the beating degree of unbleached spruce kraft pulp. With increasing beating degree the tensile index and burst index increased to beating degree 20 °SR. These properties are a function of interfibre bonding strength which increased with beating degree. Beating is a process of internal and external fibrillation which increases the area of contact between the fibres by increasing their surface and making them more flexible (Raymond and Rowell 1986).

Tear index decreased with increasing beating degree up to 20 °SR (Fig. 1). Tear index depends on total number of fibres participating in handsheet rupture, fibre length as well as on number and strength of fibre-to-fibre bonds.

Strength properties remain constant with further increasing of beating degree. Evaluation of strength properties shows that the optimal beating degree of unbleached spruce kraft pulp was 20 °SR. Therefore unbleached spruce kraft pulp used for preparation of handsheets from blends with recovered fibres was beaten to this degree.

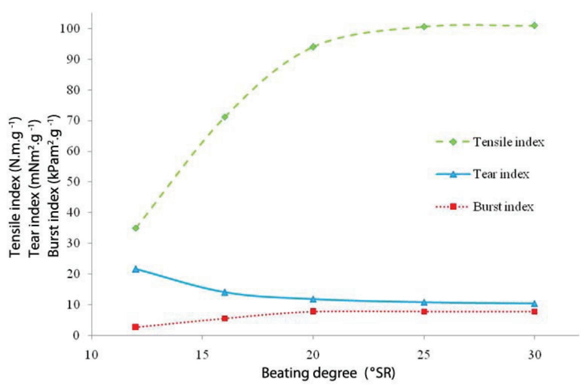

Fig. 1: Tensile index, tear index and burst index versus beating degree of unbleached spruce kraft pulp.

Handsheet properties of recovered and virgin fibre blends

The strength properties of recovered fibres are lower than of virgin fibres. The ability of to upgrade and improve strength properties of recovered fibres is blending with good quality virgin fibres. The strength potential of recovered and virgin fibres blends is not simply the average of the strength potential of their components. This deviation depends on the nature of the components and the specific property of interest (Minor et al. 1993).

Fig. 2 shows the dependence of tensile index and tensile energy absorption index of recovered fibres and unbleached spruce kraft pulp blends. With increasing content of kraft pulp, tensile index increased. Tensile index of recovered fibres increased from 30.8 to 93.0 $Nm.g^{-1}$ (by as much as 66.9 %) at increasing of kraft pulp content in blends from 0 to 100 %. The presence of virgin fibres in blend with recovered fibres increased the interfibre bonding because the virgin fibres formed greater contact area for bonding between fibres. The greater flexibility in virgin fibres increases conformability and eventually enhances interfibre bonding, which corresponds with results of another study (Peh et al. 1976).

In Fig. 2 the influence of kraft pulp addition to recovered fibres on tensile absorption energy index of blended handsheets is shown. Tensile energy absorption index increased from 0.409 to 1.874 $J.g^{-1}$ (by as much as 78 %) at increasing of kraft pulp content in blends from 0 to 100 %. Critical properties of paper for sack grades are high tensile energy absorption and relatively low air permeation resistance (high porosity). This makes a tough paper resisting impact stress during handling of the sack and a paper that lends itself to easy filling of the sack (Shallhorn and Gurnagul 2010).

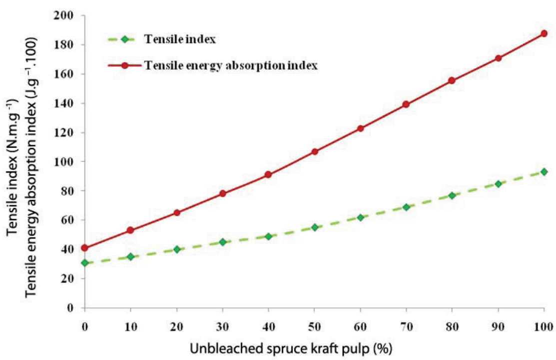

Fig. 2: Tensile index and tensile energy absorption index versus unbleached spruce kraft pulp content in blends with recovered fibres.

Dependence of tear index, burst index and elongation on blend composition prepared from recovered fibres and kraft pulp is shown on Fig. 3. With increased content of kraft pulp in blends from 0 to 100 % the burst index increased from 1.7 to 7.0 $kPam^2.g^{-1}$ (by as much as 75.7 %). Burst strength is an important strength property which indicates resistance of the handsheets to external and internal mechanical strengths. It is highly affected by the level of interfibre bonding and individual fibre strength.

All the same, with increasing of kraft pulp in blends with recovered fibres elongation (Fig. 3) increased from 2.1 to 3.5 % (by as much as 40 %). Elongation can be related to the paper's ability to conform and maintain conformance to a particular contour. It is an important property of sack kraft papers.

Tear index of recovered fibres (Fig. 3) increased from 7.3 to 12.0 $mNm^2.g^{-1}$ (by as much as 39.1 %) with increase of kraft pulp content from 0 to 100 % in blend. Tear index is characterizing toughness of packaging papers for which the ability to absorb shocks is essential.

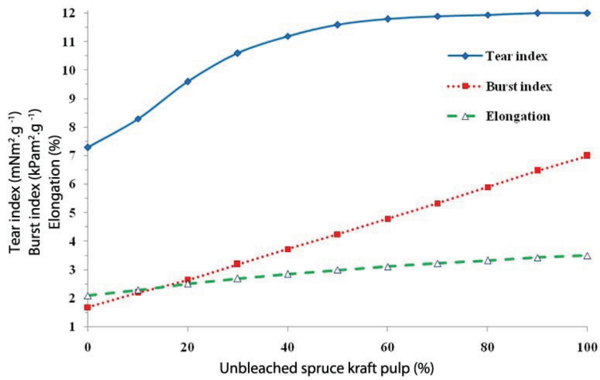

Fig. 3: Tear index, burst index and elongation versus unbleached spruce kraft pulp content in blends with recovered fibres.

Fig. 4 shows air permeation resistance of handsheets depending on blend composition prepared from recovered fibres and kraft pulp. Increasing content of kraft pulp in blend slightly increased air permeation resistance of handsheets from 7 to 8 s (by as much as 11.1 %) at increase of kraft pulp in blend from 0 to 100 %. It means that porosity of blended handsheets slightly decreased with addition of kraft pulp. However, usually the air permeation resistance of handsheets from OCC is higher than air permeation resistance of OCC used in this study. Air permeation resistance of kraft pulp in this study was almost the same as that of recovered fibres. Air permeation resistance is influenced by the internal structure and also the surface finish of the paper. Internal structure is controlled largely by the type and length of fibres, degree of hydration, orientation and compaction of the fibres (Walkinshaw 2006).

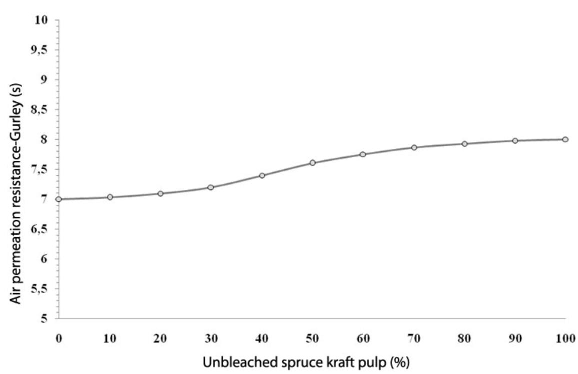

Fig. 4: Air permeation resistance versus unbleached spruce kraft pulp content in blends with recovered fibres.

Brightness, opacity, light scattering coefficient s, light absorption coefficient k, light scattering coefficient (s_{950}), light absorption coefficient (k_{950}) and ERIC number of handsheets prepared from recovered fibres and unbleached spruce kraft pulp blends were determined. The strength properties with increasing content of kraft pulp optical properties of blended handsheets decreased. This is probably related to the decreased amount of bleached pulp contained in OCC.

Fig. 5 shows the dependence of brightness and opacity on composition of recovered fibres and kraft pulp blends. The brightness is determined by the relative amount of absorbed and scattered light and its spectral distribution. Light absorption is caused by chromophoric groups in pulp while scattering is caused by solid-air interfaces of the individual fibres. With increasing content of kraft pulp in blend, brightness decreased. The brightness of recovered fibre handsheets decreased from 30.2 to 18.2 %ISO (by as much as 39.7 %) at increase of kraft pulp content from 0 to 100 %.

Fig. 5 also shows the influence of kraft pulp addition on opacity of blended handsheets. Opacity is influenced by the fibre properties, namely length, wall thickness and number of fibres/mass (Castanheira et al. 2007). Opacity of blended handsheets decreased with increasing content of kraft pulp in blends with recovered fibres. In comparison with brightness, opacity decreased only slightly from 99.7 to 98.7 % (by as much as 1 %) with increasing of kraft pulp content in blends from 0 to 100 %.

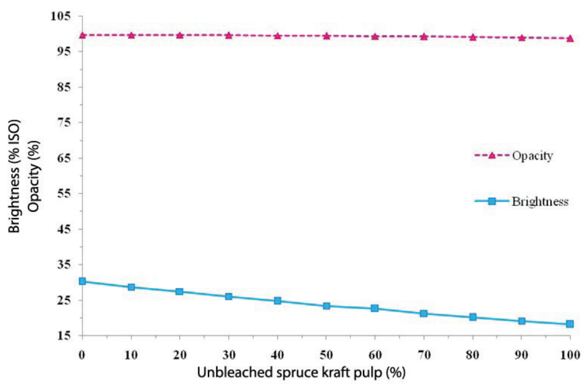

Fig. 5: Brightness and opacity versus unbleached spruce kraft pulp content in blends with recovered fibres.

The optical properties of paper are a function of the specific light scattering coefficient s - reflecting the physical structure, and of the specific light absorption coefficient k - reflecting the chemical composition of the paper (Hanus et al. 1988). It is important to know the dependence of light absorption coefficient k and light scattering coefficient s of handsheets on composition of blends prepared from recovered fibres and kraft pulp (Fig. 6). With increasing addition of kraft pulp to recovered fibres the light scattering coefficient s and the light absorption coefficient k decreased. The light scattering coefficient s of handsheets decreased from 34.1 to 15.7 $m^2.kg^{-1}$ (by as much as 53.6 %), but the light absorption coefficient k decreased only slightly from 16.9 to 14.6 $m^2.kg^{-1}$ (by as much as 13.6 %) with increasing of kraft pulp content from 0 to 100 % in blends with recovered fibres. Handsheets from recovered fibres had a higher light scattering coefficient s than those from kraft pulp, indicating smaller bonding areas in recovered fibres. The obtained results correspond to findings of another study (Rushdan 1998).

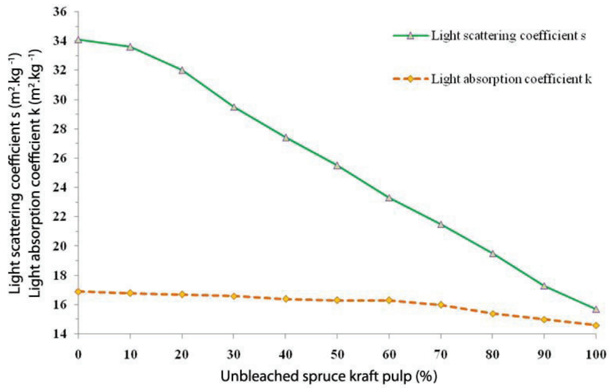

Fig. 6: Light scattering coefficient (s) and light absorption coefficient (k) versus unbleached spruce kraft pulp content in blends with recovered fibres.

Decreasing trend showed the dependence of ERIC number, light scattering coefficient (s_{950}) and light absorption coefficient (k_{950}) of blended handsheets on composition of blends prepared from recovered fibres and kraft pulp (Fig. 7). Increasing of kraft pulp content in blended handsheets from 0 to 100 % resulted in decrease of ERIC number from 431 to 139 (by as much as 67.7 %). At the same time the light scattering coefficient (s_{950}) decreased from 38.4 to 18.2 $m^2.kg^{-1}$ (by as much as 52.6 %) and the light absorption coefficient (k_{950}) decreased from 4.31 to 1.39 $m^2.kg^{-1}$ (by as much as 67.7 %). All of these declining properties are related to the decreasing content of recovered fibres in blends with kraft pulp because the decreasing content of residual ink particles.

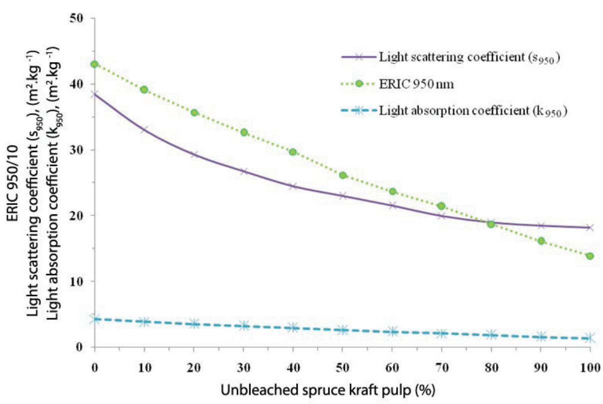

Fig. 7: Light scattering coefficient (s_{950}), light absorption coefficient (k_{950}) and ERIC number versus unbleached spruce kraft pulp content in blends with recovered fibres.

CONCLUSIONS

The unbleached spruce kraft pulp of 20 °SR beating degree was used for the study of handsheet properties blended with recovered fibres. The changes of properties varied depending on the blend composition.

The addition of unbleached spruce kraft pulp up to 100 % can increase the tensile index of recovered fibres by as much as 66.9 %, tensile energy absorption index by as much as 78 %, tear index by as much as 39.1 %, burst index by as much as 75.7 %, elongation by as much as 40 % and air permeation resistance by as much as 11.1 %. On the other hand, brightness decreased by as much as 39.7 %, opacity by as much as 1 %, light scattering coefficient s by as much as 53.6 %, light absorption coefficient k by as much as 13.6 %, ERIC number by as much as 67.7 %, light scattering coefficient (s_{950}) by as much as 52.6 % and light absorption coefficient (k_{950}) by as much as 67.7 %.

Unbleached spruce pulp can be used to enhance properties of recovered fibres whereas strength properties increased with increasing content of kraft pulp, optical properties of blended handsheets decreased. It was related to the decreasing amount of bleached pulp contained in OCC.

A paper made from a blend of recovered fibres (OCC) with the content of 30 % unbleached spruce kraft pulp or higher would be also suitable for the production of wrapping papers with high strength properties such as sack papers or shopping bags.

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