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D2.80 Investigation regarding the possibility of using mixtures of unbleached softwood and hardwood to reach the desired strength levels.

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PP	Restricted to other programme participants (including the Commission	
RE	Restricted to a group specified by the consortium (including the Commission	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Deliverable D2.80

The potential of using mixtures of hardwood and softwood to decrease MSC in kraftliner.

Stefan Antonsson
and
Mikael E. Lindström

KTH Chemical Science and Engineering

Division of Wood Chemistry and Pulp Technology,
Royal Institute of Technology, KTH

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Abstract

Previous studies have revealed that unbleached birch kraft pulp has excellent mechano-sorptive, hygroexpansion and tensile stiffness properties compared to ordinary softwood kraft liner pulp. Together with chemical additions to the birch pulp most properties can be improved to a level above or in the range of the kraft liner pulp. However, it is not easily achievable to exchange pulp raw material in a mill and hence, it was motivated to investigate if minor additions of birch pulp to the softwood kraft liner pulp would be beneficial for the properties of the kraft liner.

In order to do so, different ratios of birch and kraft liner pulps were mixed and formed to sheets tested with different evaluation methods. Tensile strength properties, short span compression test (SCT), fracture toughness properties, hygroexpansion, brightness and mechano-sorptive creep properties were measured.

The results show approximately linear relations between the characteristics of the pulp mixtures and the ratios of the different pulps in the mixtures. However, some tendencies to non-linear relationships were observed although these where generally not positive when having small additions of birch pulp.

Keywords: *High kappa number pulp, Kraft liner pulp, Birch, Mechano-sorptive creep, Hygroexpansion, Tensile properties, SCT*

Introduction

Kraftliner, the top and bottom layer of corrugated board, one of the main paper products, has many demands on hygromechanical properties. Except high performance in tests evaluating static compression, tensile stiffness and fracture toughness at constant humidity, the creep rate at variations in relative humidity is of major importance. In a previous study (Antonsson *et al.* 2007) it was shown that hardwood kraft pulps, and especially a birch pulp had a better stiffness, hygroexpansion and mechano-sorptive creep behaviour compared to a reference softwood kraftliner pulp. In connection to this study Figure 1 was obtained showing the relationship between tensile stiffness and hygroexpansion coefficient, which are important parameters for predicting isocyclic creep behaviour (Antonsson *et al.* 2008; Antonsson *et al.* Manuscript).

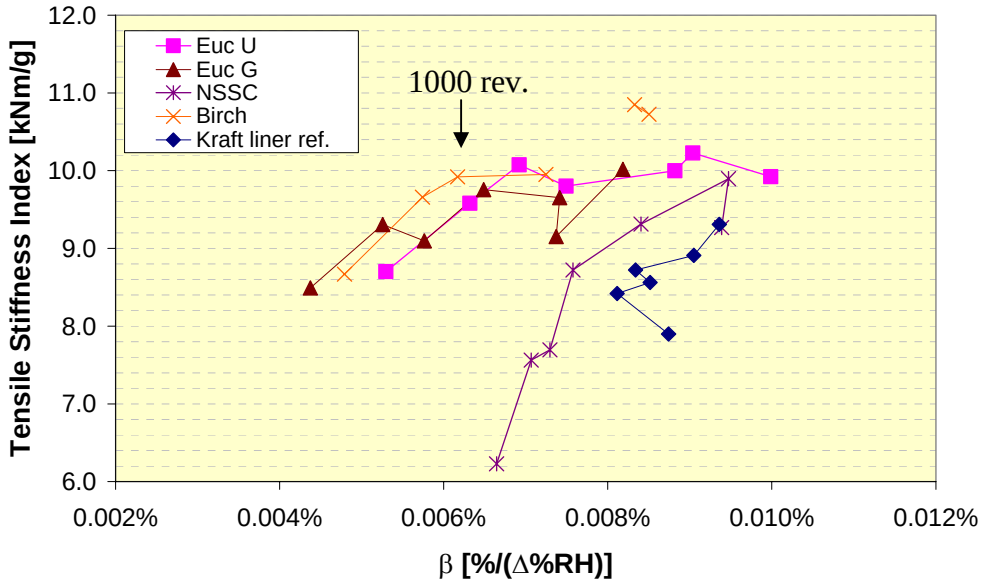

Figure 1: Data obtained in an earlier study (Antonsson *et al.* 2007) showing the relationship between tensile stiffness and hygroexpansion of pulps beaten to different degrees in a PFI-mill.

The drawback with the birch pulp observed was lower values for tensile (except tensile stiffness) and fracture toughness properties. This drawback can be compensated for by additions of different chemical additives as shown in another study (Gimåker *et al.* 2007). On the other hand, in practical life, a mill will not completely change to another type of pulping raw material overnight. Hence, it is interesting to investigate the possibility to exchange only a minor part of the softwood kraftliner pulp with a hardwood kraft pulp, in order to gain enhancement in tensile and mechano-sorptive creep stiffness without lowering the values of fracture toughness and tensile properties.

Hence, the aim of this study was to investigate the properties of pulp mixtures with different ratios of birch kraft and softwood kraft liner pulp. Based on the information in Figure 1, a beating degree of 1000 PFI-revolutions was selected as a suitable beating level for the birch pulp and the softwood reference pulp was Escher-Wyss beated to 30M°SR.

Experimental

Materials
An unbleached (kappa no. 76), never dried, softwood (mainly Pine, *Pinus Sylvestris*, and Spruce, *Picea Abies*) pulp was kindly supplied by Smurfit Kappa Kraftliner, Piteå, Sweden. This pulp will hereafter be denoted SKK. The Birch pulp (*Betula pendula/ B. pubescens*) was kindly supplied by Billerud, Gruvön, Grums, Karlstad, Sweden and had a kappa number of about 13. This pulp will hereafter be denoted BSG.

Methods
The pulps were carefully washed with deionized water and the BSG was screened in a NAF, Nordiska Armatur Fabriken, water jet defibrator prior to further handling. PFI-beating (1000 revolutions according to ISO 5264-2:2002) and Escher-Wyss beating (to 30 M°SR) were performed on the BSG and SKK respectively. SKK and BSG in different mass ratios; 100:0; 95:5; 90:10; 85:15; 75:25: 50:50; 25:75 and 0:100 were mixed. The mixtures were disintegrated in tap water according to ISO 5263:1997 with 30 000 revolutions before sheet forming. Sheets with a grammage of about 120 g/m^2 were made with a Rapid Köthen equipment according to ISO 5269-2:2004. Drying temperature was 93°C and the sheets were dried during 20 minutes.

Grammage was measured according to ISO 536:1995 and thickness according to ISO 534:2005, although the thickness was measured on a stack of eight sheets. Short span compression test (SCT), tensile properties and fracture toughness parameters were measured according to ISO 9895:1989, ISO 1924-3 and SCAN P77:95 respectively, although the fracture toughness was measured on only 6 test pieces.

Hygroexpansion measurements were made with an apparatus developed at STFI in principal built up as a model previously described elsewhere (Salmén *et al.* 1987) consisting of several pairs of rigid and a movable clamps between which the paper samples are fasten. Weights are put on top of the paper strips as the length is recorded. Hygroexpansion of the sheets was measured according to ISO 8226-1:1994. The test pieces were cycled without load between 50%RH and 90%RH three times prior to testing to release dried in stresses. The test span between the clamps was 100 mm, the width of the test piece 15mm and the difference in length was measured between 33%RH and 66%RH at 23°C. Brightness of the different pulps was measured by an Elrepho Brightness Tester on a stack of 8 Rapid Köthen sheets. The average of three measurments was calculated and presented.

Results and Discussion

Densities and brightness

The densities of the pure pulps are somewhat different and as BSG is added to the SKK the density is increased almost linear with regards to the added amount as seen in Figure 1.

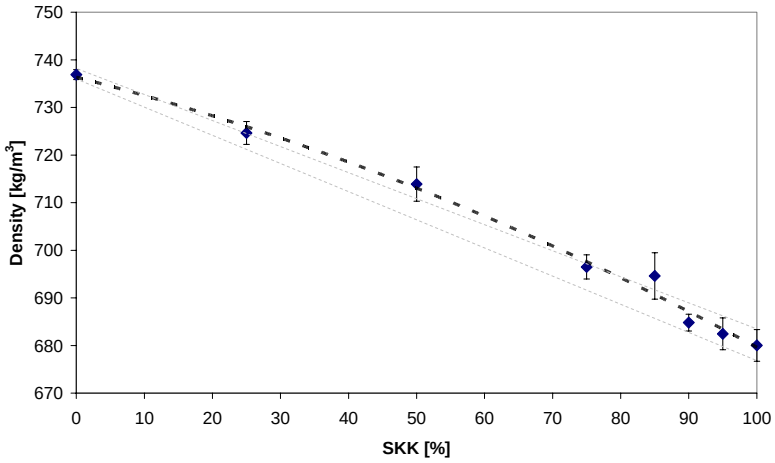

Figure 2: The densities are increased almost linear to the added amount of BSG to the SKK. Error bars indicate a 95% confidence interval.

The light absorption should be linear to the addition of a pulp into another (Harrison 1937), hence the non-linear behaviour seen in Figure 3 is probably due to effects of light scattering.

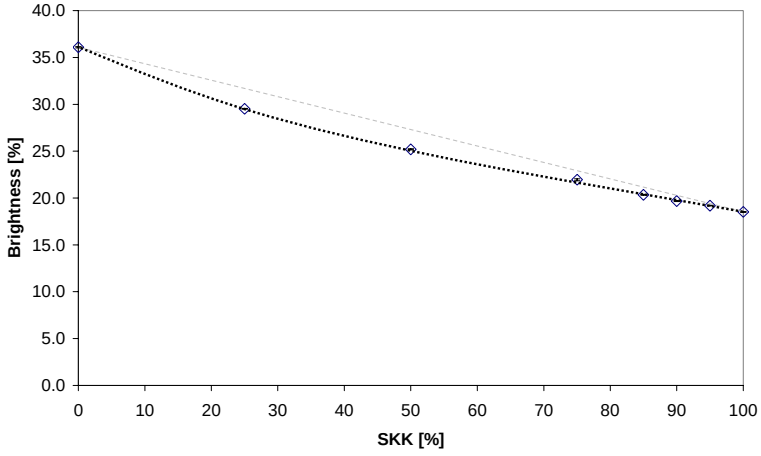

Figure 3: The relationship between brightness and added amount BSG to the pulps is not linear, probably due to differences in the light scattering. Error bars indicate a 95% confidence interval.

Tensile properties and compression strength

As shown in Figure 3, there are indications that none of the tensile properties is affected in a favourable direction compared to a linear change between the pure pulps. However, the departure from a linear relationship is not significant in any of these figures.

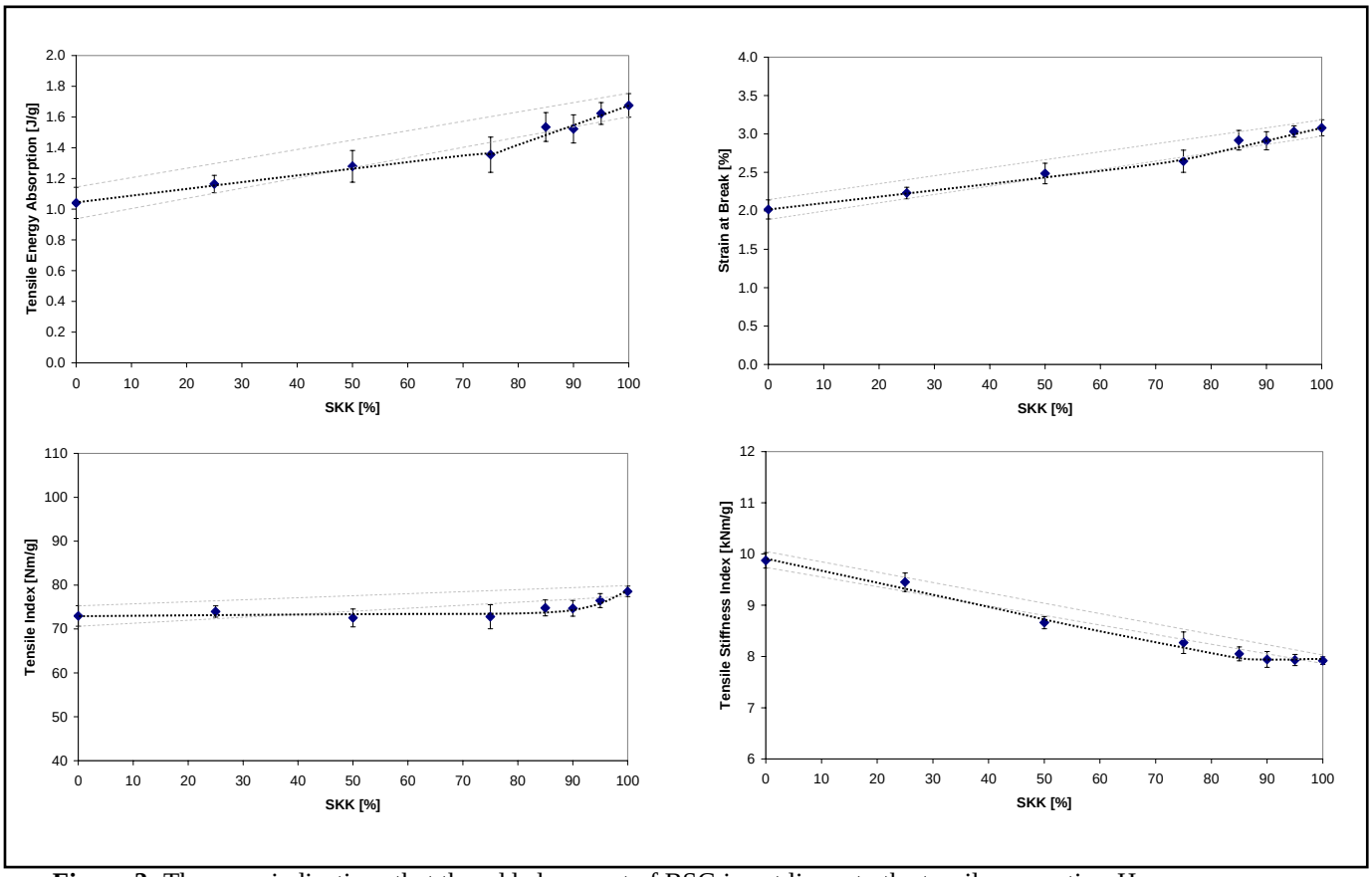

Figure 3: There are indications that the added amount of BSG is not linear to the tensile properties. However, the differences from a linear relationship are small. Error bars indicate a 95% confidence interval.

The SCT index values of the mixtures are presented in Figure 4. Small additions of BSG are enough to result in significant increases of the compression strength.

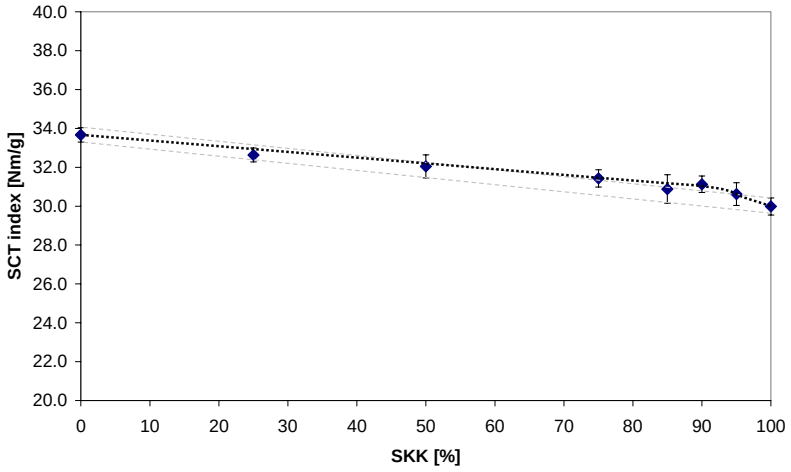

Figure 4: Small additions of BSG are enough to result in significant increases of the compression strength. Error bars indicate a 95% confidence interval.

Fracture toughness properties

Fracture toughness properties for the different pulp mixtures are presented in Figure 5. Small addition of BSG tends to not affect the apparent strength index heavily but on the other hand is apparent strain at break more affected at lower additions of BSG.

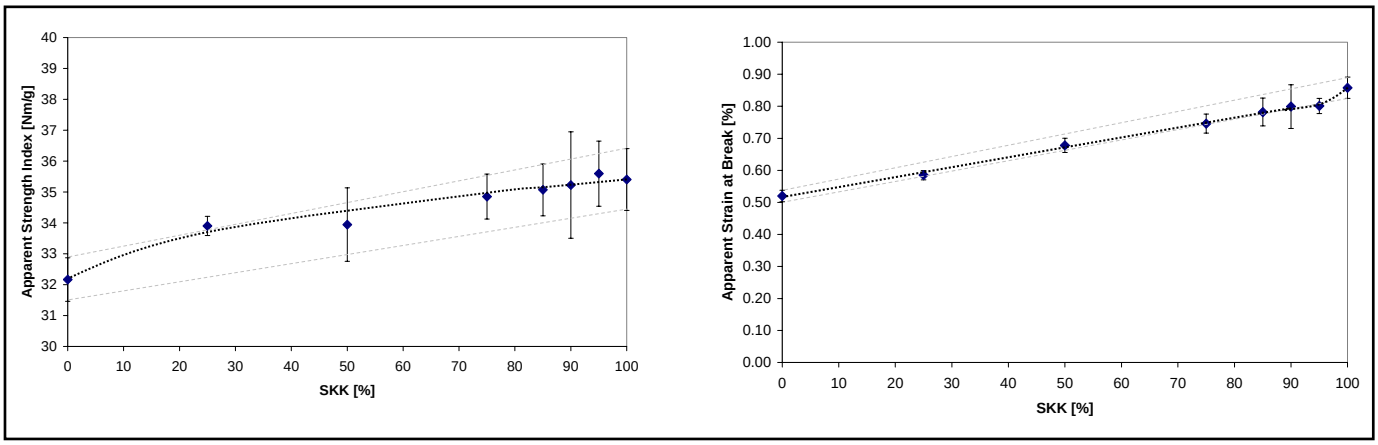

Figure 5: There are indications that the relationship between the pulps is not linear but these indications are not significant. Error bars indicate a 95% confidence interval.

Hygroexpansion properties

The hygroexpansion coefficient is almost linear in relationship to the addition of BSG to SKK as seen in Figure 6. If there is a deviation from this relationship it shows on decreased hygroexpansion for the mixtures and hence, mixing pulp does not harm hygroexpansion properties.

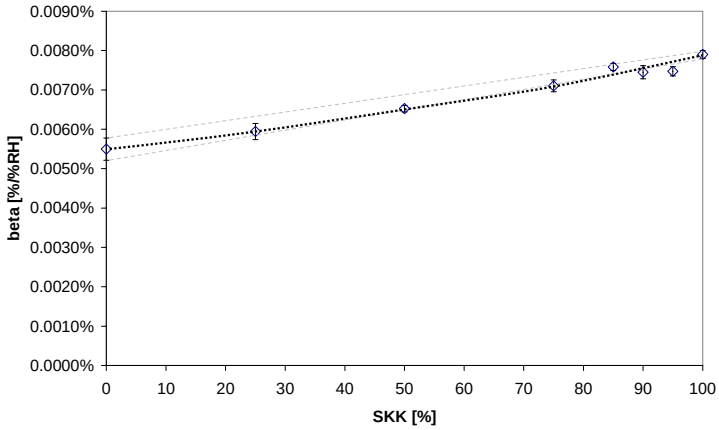

Figure 6: The hygroexpansion coefficient is almost linear in relationship to the addition of BSG to SKK. Error bars indicate a 95% confidence interval.

When comparing the hygroexpansion compared to the tensile stiffness for the mixtures as well as the pure pulps (data obtained from an earlier study (Antonsson *et al.* 2007)), it is evident that there are no additional benefits on the tensile stiffness hygroexpansion ratio of adding a particular amount of BSG to the SKK as seen in Figure 7.

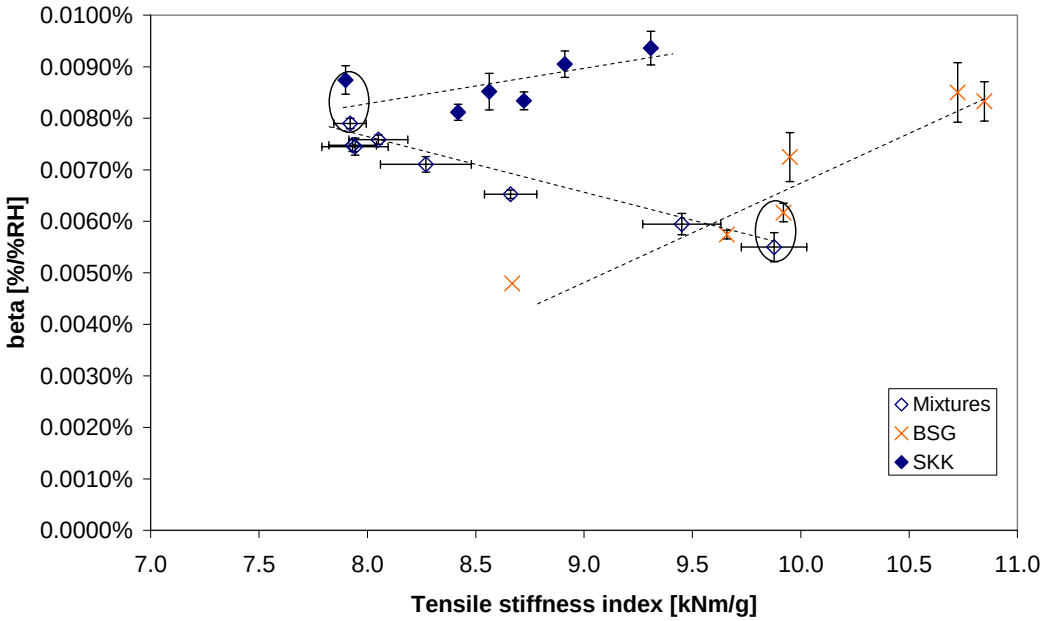

Figure 7: There are indications that the relationship between the pulps is not linear but these indications are not significant. Error bars indicate a 95% confidence interval.

Conclusion

It is possible to enhance essential properties such as hygroexpansion, SCT and tensile stiffness by additions of BSG but, minor additions are unfavourable compared to larger additions per added amount. Hence, small additions of BSG is not a recommended route of enhancing kraft liner properties.

On the other hand, there are no signs that mixtures of pulp degenerate the properties of the resulting sheets as compared to pure pulps.

Acknowledgements

Petri Mäkelä and Christer Fellers at STFI-Packforsk are acknowledged for valuable ideas and comments regarding this study. Access to the testing equipment at STFI-Packforsk; the hygroexpansion tester and the fracture tester with Fracture lab, is gratefully acknowledged. Billerud, Gruvön, and Smurfit Kappa Kraftliner, Piteå, are gratefully acknowledged for supplying the pulps and the SustainPack Program for financially supporting the study.

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