Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 74, 2011: 156-160
(Ann. WULS-SGGW, Forestry and Wood Technology 74, 2011

The effect of liquor to wood ratio on strength properties of NSSC pulp

K. JOACHIMIAK[1], J. BOCIANOWSKI[2], A. WÓJCIAK[1]
[1]Institute of Chemical Wood Technology, Poznan University of Life Science, ul. Wojska Polskiego 38/42, 60-637 Poznan, Poland
[2]Department of Mathematical and Statistical Methods, Poznan University of Life Science, ul. Wojska Polskiego 28, 60-637 Poznan, Poland

Abstract: *The effect of liquor to wood ratio on strength properties of NSSC pulp.* The aim of this work was to find the optimal liquor to wood ratio which leads to the best strength properties of NSSC pulp. According to technical possibilities of production line, three sets of liquor to wood ratios were carried out: 1.4, 1.8 and 2.2. From each collected sample the hand sheets were formed and SCT, CMT, Tear and Burst were determined. Statistical methods allowed to describe the optimal conditions of birch chips digestion process to rich the best strength properties of NSSC pulp. The results of the studies have shown that low liquor to wood ratio did not influenced negatively the pulp strength properties. Saving the liquor may be beneficial for its further treatment and/or recovery.

Keywords: NSSC, liquid to wood ratio, pulp, statistical methods

INTRODUCTION

Neutral sulphite technology besides the delivery of high quality fibers brings environmental difficulties which need to be solved to keep the production running. The most problematic issue is spent liquor with high inorganic to organic ratio. That is why one of the reasonable way to treat NSSC spent liquor is so called cross recovery with Kraft spent liquor [Area et al. 2001].

Most of the wood and non-wood plants pulping process optimization analysis were based on delignification kinetics. There is still not enough data in literature which describe the influence of process variables on pulp quality [Jiménez et al. 2000].

The aim of this work is to examine the influence of liquid/solid relation, on the strength properties of NSSC pulps paper sheets (CMT, SCT, Burst and Tear strength) obtained, using mathematical and statistical methods.

MATERIAL

Industrial chips obtained from birch trees (*Betula verrucosa*) were used as raw material. The chips included following fractions: >O45 – 1.1%, >II8 – 5.7%, >O7 – 91.0%, >O3 – 2.1%, the rest – 0.1% (O and II mark holes and slots diameter in mm according to Brecht-holl classification) (SCAN–CM–40:94)).

PULPING METHODOLOGY

All cooking experiments were carried out on industrial NSSC production line with controlled capacity and with the 82% average yield of the process.

Starting cooking liquor concentration was the same during all experiments (165g/dm^3 Na_2SO_3; 50g/dm^3 Na_2CO_3). After processing at 179°C for 14,5 min and at different conditions of liquor to wood ratio (l/w), , the chips were defibred by disc refiner with 36% of concentration.

STUDIED PARAMETERS

Pulp samples were collected after cooking with 1.4, 1.8, 2.2 liquid to wood ratio (l/w). For each tested l/w, collected pulp sample were refined in PFI laboratory mill to gain four levels of pulp freeness: 20ºSR (Schopper-Riegler), 25ºSR, 30ºSR, 35ºSR. Four strength properties were examined: SCT (EN/ISO 9895), CMT (EN/ISO 7263), Tear strength (EN 21974) and Burst strength (EN/ISO 2758).

STATISTICAL ANALYSIS

In order to find the interaction between variable l/w and Schopper-Riegler freeness on strength properties, to determine correlations between them and transfer all the data on plots, the set of statistical methods were applied: analysis of variance (ANOVA), scatter–plot, Principal Component Analysis (PCA), Parallel Coordinate Plot (PCP) [Shapiro and Wilk 1965]. Analysis of the data was performed using the statistical package GenStat v. 10.1 (GenStat 2007).

RESULTS AND DISCUSION

The process was optimized mainly for CMT and SCT strength parameters. Burst and Tear strength were used to wider the analysis spectrum.

As the first step of analysis was to research the significant difference between all strength properties results gained with variable l/w ratio. Table 1 shows that each strength property differed significantly regarding to l/w ratio and SR freeness. Also the analysis of variance has proved that l/w ratio and PFI refining has influenced CMT, Burst and Tear.

Table 1 Mean squares from analysis of variance for CMT, SCT, Burst and Tear strength.

Source of variation	CMT		SCT		Burst		Tear	
	df	ms	df	ms	df	ms	df	ms
l/w	2	1556.2***	2	2.514***	2	23369***	2	109944***
SR	3	8905.8***	3	3.484***	3	129701***	3	60617***
l/w × SR	6	783.0***	6	0.420**	6	8414***	6	20634***
Residual	106	122.8	170	0.116	125	1103	28	1548

l/w – liquid to wood ratio, SR – Freeness in °SR (Schopper-Riegler), df – degrees of freedom, ms – mean squares, ** - significant at 0.01 level, *** - significant at 0.001 level

As seen in the Table 2 and scatter plot (Fig. 1) the strength of the correlations among two mechanical factors can be presented as follow with lowering values: CMT/Burst > SCT/Burst > CMT/SCT > CMT/Tear > Burst/Tear > SCT/Tear. The refining process influences fibers shape because of effects occurring during the treatment such as external fibrillation, fibers shortening and fines creation. During the internal fibrillation the cell wall delaminates and the fibers water swelling increases [El-Sharkawy et al. 2008]. The stronger fibers fibrillation cause the higher Schopper–Riegler number and worse dewatering on paper machine wire section [Smook 1992, Lumiainen 2000].

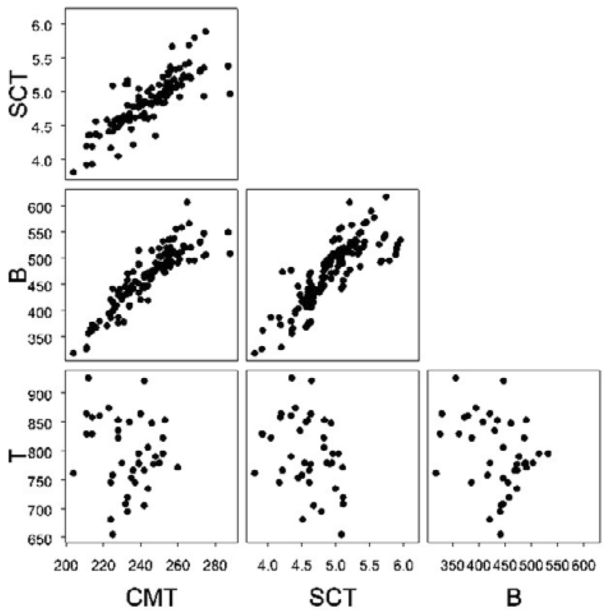

Fig. 1 Scatter plot of CMT, SCT, Burst (B) and Tear (T) strength correlation.

During the whole analysis big impact of freeness on strength properties were observed. That is why in the next step we have analyzed the data gained for three different l/w ratio pulp samples refined to four levels of freeness. Figure 2 shows the visual inspection of the obtained data sets created by the transformation from the four-dimensional space to two-dimensional plane. The Principal Component Analysis (PCA) answers the question which l/w and SR freeness values have formed similar collection (marked space on Fig. 2).

Table 2 Correlation matrix for CMT, SCT, Tear and Burst strength.

Correlation	CMT	SCT	Burst	Tear
CMT	1			
SCT	0.834***	1		
Burst	0.937***	0.847***	1	
Tear	-0.436	-0.787**	-0.544	1

Note: *,** or ***shows increasing significance of correlation between analyzed strength properties (P<0.05, P<0.01 or P<0.001, respectively). Minus before value indicate reverse correlation.

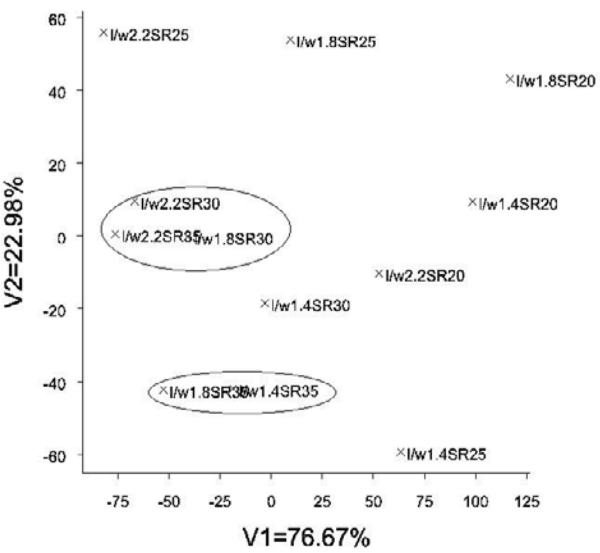

Fig. 2 The Principal Component Analysis of l/w and SR freeness pairs.

The first group of higher l/w and freeness and the second one of lower l/w and the highest freeness do not differ significantly the pulp strength properties. The rest of the l/w and SR freeness pairs, especially pulp refined to 20°SR and 25°SR have differed strongly the mechanical factors. It can be explained by well known phenomenon: the increase of 5°SR freeness at the beginning brings more fiber strength than at the end of refining [Markstrom 1995].

Figure 3 shows PCP for 12 objects (l/w and SR) and 4 traits (CMT, SCT, Burst and Tear). Reciprocal orientation of lines confirm or exclude correlation between neighboring variables.

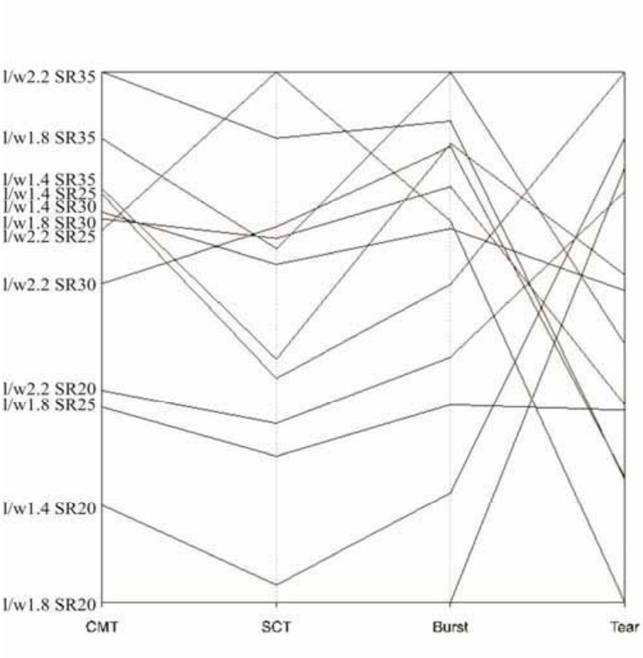

Fig. 3 Parallel coordinate plot for combination of l/w ratio and freeness.

The lines close to parallel and with similar angle of inclination have been marked as “positive”. Nine positive correlations between CMT and SCT for all tested l/w ratio and freeness can be distinguished. The best results (CMT, SCT, Burst) were achieved for combination of variables 2.2 l/w and 35°SR. However two data sets for 2.2 l/w have shown negative correlation with middle freeness: 25°SR and 30°SR.

It suggests that condition 2.2 l/w ratio may be unpredictable, according to strength properties.

Simultaneously the next best mechanical properties were gained from pulp refined up to 35°SR (1.8 and 1.4 l/w). Birch pulp refined above the 30º SR brings less dynamic increase of the strength properties. To reach better tensile stiffness it is necessary to involve to much refining energy [Lumiainen 2000].

CONCLUSIONS

It has been proved that it is possible to obtain NSSC pulp with strength properties comparable to those processed at higher liquor volumes, using liquor to wood ratio 1.4 during cooking. Saving the liquor and consequently limited inorganic to organic ratio in spent liquors may be beneficial for its further treatment and/or recovery. The only way to reach better strength properties is applying more specific energy consumption (SEC) for refining up to 35°SR freeness.

REFERENCES

1. AREA M.C., FELISSIA F.E., VENICA A., VALADE J.L., NSSC process optimization: pulping, pulps and spent liquors, Tappi Journal 84(4): 1-12, 2001
2. JIMÉNEZ L., PÉREZ I., TORRE DE LA M.J., GARCIA J.C., Influence of process variables on the properties of pulp and paper sheets obtained by sulphite pulping of olive tree wood, Wood Science and Technology 34: 135-149, 2000
3. SHAPIRO S. S., WILK M. B., An analysis of variance test for normality (complete samples), Biometrika 52: 591-611, 1965
4. EL-SHARKAWY K., KASKENHOLY K., PAULAPURO H.,: Tailoring softwood kraft pulp properties by fractionation and refining, Tappi Journal 10: 15-32, 2008
5. SMOOK G.A. Handbook for pulp & paper technologists. In: Preparation of papermaking stock. Angus Wilde Publications Inc. Vancouver: 205-206, 1992
6. LUMIAINEN J. Papermaking Part 1, stock preparation and wet end. In: Refining of chemical pulp. Fapet. Jyvaskyla: 13, 18, 35, 2000.
7. MARKSTROM.H.,: Testing methods and instruments for corrugated board, Lorentzen & Wettre, Kista: 35. 1995

Streszczenie: *Wpływ modułu cieczy warzelnej na właściwości wytrzymałościowe masy obojetnosiarczynowej (NSSC).* Celem pracy było określenie optymalnego modułu cieczy prowadzącego do uzyskania najlepszych wskaźników wytrzymałościowych masy NSSC. Analizy prowadzono dla trzech modułów: 1.4, 1.8, 2.2. Z pobieranych próbek masy uformowano arkusiki papieru, dla których po zmieleniu oznaczano parametry wytrzymałościowe SCT, CMT, przedarcie i przepuklenie. Metody analizy statystycznej pozwoliły ocenić zależności pomiędzy modułem cieczy, stopniem zmielenia i właściwościami wytrzymałościowymi masy oraz wskazać optymalne warunki prowadzenia procesu.

The research paper financed by The European Social Fund within the framework of The Integrated Program of the Regional Development Process.

Corresponding author:

Adam Wójciak
Poznan University of Life Science,
Institute of Chemical Wood Technology,
ul. Wojska Polskiego 38/42
60-637 Poznan, Poland
Tel.: +48 61 848 74 53,
e-mail address: adak@up.poznan.pl,