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Extended Oxygen Delignification of Pine Kraft Pulp

Abstract
The research deals with the issue of how the conditions of the oxygen delignification process (that is, the removal of residual lignin from pulp fibres with oxygen in alkaline medium) affect pulp properties. The investigation refers in particular to the effect of the amount of added NaOH, the time and the temperature of the oxygen delignification process of normal pine sulphate pulp (kappa number 31.5) on its kappa number, yield and the strength properties of the pulp. Similarly, we investigated the effect on these indices of the initial and inter-stage pulp treatment with peracetic acid, depending on its amount and the pH of the medium. It has been stated that delignifying pine kraft pulp with oxygen only to the level of kappa number <10 is difficult and results in an excessive decrease in pulp yield. Initial treatment of this pulp with peracetic acid in amounts of 0.33 and 0.66% A.O. prior to pulp treatment with oxygen in alkaline media enables it to be delignified to kappa number 7.5-9, with the yield higher by 0.5-1.4 % than that of pulp delignified with oxygen alone. Pulp delignified with oxygen and using the peracetic acid pre-treatment also restores higher viscosity, tear index, and fibre strength in comparison with pulp delignified with oxygen alone.

Key words: *pine kraft pulp, oxygen delignification, peracetic acid, fibre properties.*

Introduction

Extended oxygen delignification of conventional pine kraft pulp (with a kappa number of around 30) is not a widely used process in the pulp and paper industry. However, it is assumed that treating this kind of pulp prior to the bleaching process should result in the decreased consumption of bleaching agents, a reduced amount of detrimental effluents from the bleaching process, as well as a reduced cost of bleaching. The main reason why this process is not yet widely used is its inability to decrease the residual lignin content in pulp to a level corresponding to kappa number below 14 without deterioration of pulp yield and strength [1]. The reason for that, according to literature, are the changes which take place in residual lignin and reduce its susceptibility to oxygen action, in particular the accumulation of 5,5'-diphenyl, p-hydroxy-phenyl units hard to oxidise with oxygen, as well as the possibility of the existence of main bonds between lignin and carbohydrates [2, 3]. It has been stated that peroxy compounds such as persulphuric, perphosphoric, performic, pernitric and peracetic acid, as well as the salts of some of these acids, could be the compounds that might act on the residual lignin to make it more susceptible to the action of oxygen and hydrogen peroxide [4-10]. Although the production technologies of the above-mentioned compounds have not yet been fully worked out, persulphuric and peracetic acid will most probably be used in practice. In order to use these agents in practice, it is advisable to decrease the cost of production and make it possible to produce them in a pulp mill (e.g. as chlorine dioxide) at a relatively high concentration. Peracetic acid, according to literature, is characterised by a relatively high oxidising potential [11]. After having been mixed with this compound, the pulp is characterised by a highly acid reaction (pH 1.8 - 2.8) [12, 13]. In most research works, during the treatment with peracetic acid the pH increased up to 3.5 - 7 units [14-19]. The treatment was conducted at low (50-60 °C) [13, 18], medium (70 - 80 °C) [12, 16, 18, 19] as well as high (90 °C) [17] temperatures. The time for treating the pulp with peracetic acid was set within a range of 40-180 minutes, and the higher temperatures were accompanied by shorter reaction times.

In the case of peracetic acid, its distilled form is preferred because the distillation decreases the costs of peracetic acid by the decrease of the content of hydrogen peroxide and acetic acid in it [20]. It is given that currently produced peracetic acid is a mixture of about 35-40% of pure peracetic acid, 40% of acetic acid and 5-10% of hydrogen peroxide and water [21].

Aim of Work

The aim of this work was to study how the process of extended oxygen delignification of pine kraft pulp (kappa number 31.5 with and without the application of peracetic acid treatment) affects the degree of delignification, pulp yield and strength indices of pulp and fibres.

Methodology

Pulps

For the experiments, industry-standard pine kraft pulp with a kappa number of 31.5 and a viscosity of 892 cm^3/g was used.

Applied delignification and bleaching chemicals

Oxygen, ethylenediaminetetraacetic acid (EDTA), $MgSO_4$, distilled peracetic acid (CH_3COOOH).

Oxygen delignification

The weighed portion of pulp (50 g oven-dried pulp, hereafter referred to as o.d. pulp) was placed in a polyethylene bag, and then the following substances were added in turn: 0.5% magnesium sulphate relative to o.d. pulp (as 1% solution) followed by the appropriate amount of sodium hydroxide. The content was mixed in a bag by squeezing, and was then transferred in quantity to a Jayme digester. An autoclave was closed, filled with oxygen to 8 MPa, the rotating mechanism was switched on, heated to a temperature of 100 °C within 30 minutes, and then heating was continued at this temperature. The pulps were delignified in a single- or a two-stage process of oxygen delignification. After the preset time lapse, the digester was degassed and emptied. After oxygen delignification, the pulp was pressed to obtain a liquor sample to determine the final pH, and was then washed with distilled water, filtered, and its dryness and yield were determined.

Pulp treatment by peracetic acid

A sample of disintegrated pulp was placed in a polyethylene bag. Heated distilled

water in the amount necessary to ensure the assumed concentration of fibrous slurry, the proper amount of peracetic acid as active oxygen (A.O.) relative to o.d. pulp, and sodium hydroxide for determining pH, were all added to a beaker. After thorough mixing of the ingredients and determining the pH, the solution was poured into a polyethylene bag containing heated pulp. The content was mixed by squeezing and heated in a water bath for 30 minutes at a temperature of 50 °C, and then for 90 minutes in 70 °C. After the preset time lapse, the pulp slurry was squeezed into a Büchner funnel, then washed with distilled water and stored in polyethylene bags in wet conditions in a fridge for further work. Analysis of active oxygen concentration (A.O.) in a solution of peracetic acid was carried out by the titration method described by Amini & Webster [22].

Determination of pulp properties

Standard methods were used to measure the kappa number (PN-70/P50095) and viscosity (SCAN-C 15:62, SCAN-C 16: 62) [23]. To determine the percentage of the lignin content in pulp on the basis of the kappa number, a conversion index 0.152 was assumed. Pulp brightness was determined according to ISO 2470 (ISO brightness). The fibres' strength factor (FS-factor) was determined in a Trouble-Shooter TS-100 tester (Pulmac) [24].

Discussion and results

Pine kraft pulp (kappa number 31.5) underwent a single- and two-stage medium consistency oxygen delignification to decrease the content of residual lignin in it to a level corresponding to the range of extended delignification, i.e. to a kappa number below 14. In the case of such pulps, this kappa value is assumed to be the lowest safe limit, beyond which the yield and strength properties of pulp delignified with oxygen significantly decrease. Thus the amount of residual lignin removed from kappa number 30 pulp does not usually exceed 50%. Finding a safe and efficient method of removing the amount of lignin higher than about 50% from the pulp (with the mentioned pulp indices at a good level) constitutes an important issue which is being investigated by the world's leading research centres.

In this work, the treatment of pine pulp with one of the most available peroxide chemicals, distilled peracetic, was investigated. This chemical may be used for this purpose because it activates residual lignin and increases its susceptibility to the delignification action of oxygen. The treatment of pine kraft pulp with peracetic acid was performed in different variants of the process. Owing to this, it was possible to define the effect of the amount of peracetic acid used, as well as the pH of the medium during the treatment on the results of delignification and pulp quality indices. All the experiments are specified in Table 1, which contains in columns the total amount of added alkali, the process temperature, time, the conditions of the treatment in the Pa stage (i.e. the treatment with peracetic acid) and the pH of liquor after the O_2-stage.

Figure 1 shows the results of the single- and two-stage medium consistency oxygen delignification of pine kraft pulp, kappa number 31.5. The subsequent pulp delignification experiments differed from each other in:

- the amount of sodium hydroxide added at the beginning of the process, which amounted to 1.5%, 3% and 4.5% to o.d. pulp.
- process time - 60 min., 120 min., 180 min.
- temperature. Most of the experiments were carried out at a temperature of 100 °C. In five experiments, in which the initial pulp was delignified only with oxygen, the temperature was increased to 110 °C.
- application of peracetic acid pulp treatment of pulp. To investigate the effect that may be achieved by a preliminary lignin activation, some oxygen delignification experiments were performed with the application of a pre- or inter-stage treatment with peracetic acid which was added as active oxygen (A.O.) to o.d. pulp in amounts of 0.33 and 0.66%.

In this work, the trial was made to delignify normal pine sulphate pulp (kappa number 31.5) to a level of lignin content that would be clearly lower than that which is obtained when this type of pulp is conventionally delignified with oxygen. Considering that in a two-stage oxygen delignification of pine kraft pulp with a kappa number of ~30, we can obtain kappa number 10-12 pulp without any deterioration of pulp yield [25], it seems that a goal of extended oxygen delignification should be to obtain a kappa number lower than 10. This could ensure a significant effect of decreased consumption of chlorine dioxide in the bleaching process.

In the first experiments, we established the conditions in which it is possible to delignify pine kraft pulp, kappa number

***Table 1**. List of the performed experiments and their characteristic parameters.*

Exp. number	Oxygen delignification sequence	Total amount of added NaOH	Temp., °C	Time, min	Conditions of treatment with peracetic acid in stage Pa	pH of liquor after O_2 - stage
1	QO	1.5	100	60	-	9.0
2	QO	3	100	60	-	10.3
3	QO	3	100	120	-	9.5
4	QO	4.5	100	120	-	10.5
5	QO	4.5	100	180	-	10.0
6	QO	1,5	110	60	-	9.4
7	QO	3	110	60	-	10.2
8	QO	3	110	120	-	9.8
9	QO	4.5	110	120	-	9.7
10	QO	4.5	110	180	-	9.2
11	QPaO	1.5	100	60	0.33 % A.O., pH 2.6	8.9
12	QPaO	3	100	60	0.33 % A.O., pH 2.6	10.4
13	QPaO	3	100	120	0.33 % A.O., pH 2.6	9.4
14	QPaO	1.5	100	60	0.66 % A.O., pH 2.6	9.0
15	QPaO	3	100	60	0.66 % A.O., pH 2.6	10.2
16	QPaO	3	100	120	0.66 % A.O., pH 2.6	9.3
17	QPaO	4.5	100	180	0.66 % A.O., pH 2.6	9.7
18	QPaO	1.5	100	60	0.33 % A.O., pH 3.5	9.1
19	QPaO	3	100	60	0.33 % A.O., pH 3.5	10.3
20	QPaO	3	100	120	0.33 % A.O., pH 3.5	9.5
21	QPaO	4.5	100	120	0.33 % A.O., pH 3.5	10.4
22	QPaO	1.5	100	60	0.66 % A.O., pH 3.5	9.2
23	QPaO	3	100	60	0.66 % A.O., pH 3.5	10.2
24	QPaO	3	100	120	0,66 % A.O., pH 3.5	9.4
26	QPaO	4.5	100	120	0.66 % A.O., pH 3.5	10.4
27	QOPaO	2+1	100	60+60	0.33 % A.O., pH 3.5	-
28	QOPaO	3+1.5	100	60+60	0.33 % A.O., pH 3.5	-
29	QOPaO	2+1	100	60+60	0.66 % A.O., pH 3.5	-
30	QOPaO	3+1.5	100	60+60	0.66 % A.O., pH 3.5	-

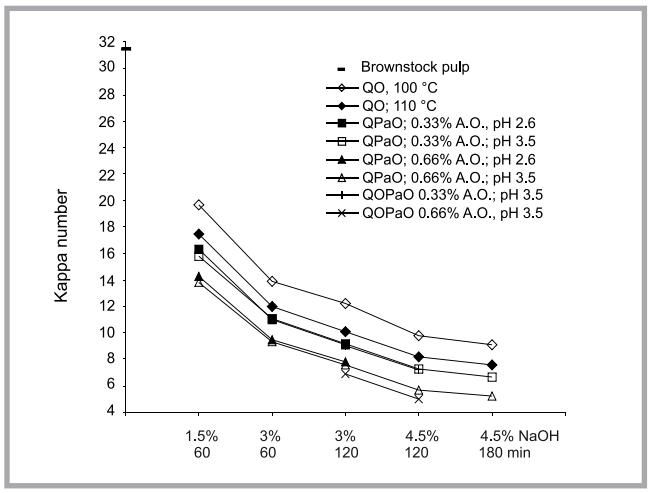

Figure. 1. *Kappa number values obtained in different variants of the oxygen delignification of pine kraft pulp, kappa number 31.5. (Standard deviation of kappa number determination was 0.1).*

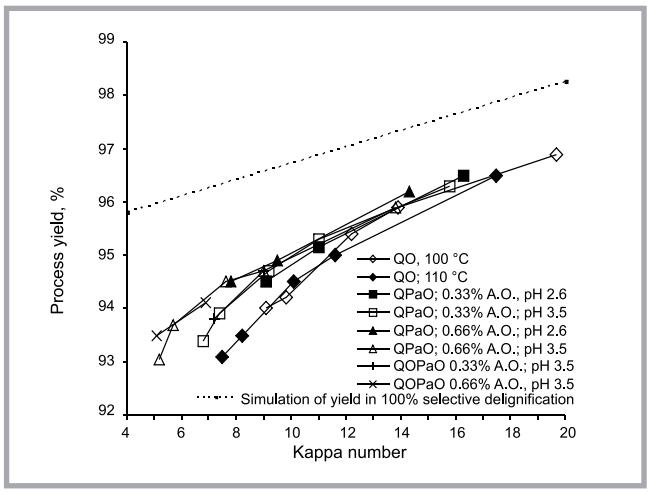

Figure 2. *Yield-to-kappa number relationship in different variants of oxygen delignification of pine kraft pulp, kappa number 31.5. (Standard deviation of yield amounted to 0.14%).*

31.5 to kappa number 14, the level to which this type of pulp is delignified in industry processes. As shown in Figure 1, the delignification of pine pulp to kappa number 14 during 60 minutes (the process time which is most often applied in the industrial process [25]), requires 3% NaOH to o.d. pulp.

As can be seen from the data in Figure 1, although pulp delignification with oxygen alone to kappa number 14 is not a problem, reducing the kappa number to below 10 is only possible after increasing the alkali charge to 4.5% (to o.d. pulp), extending the process time to 120 or 180 minutes, or/and raising the temperature to 110°C. Such process conditions are difficult to attain in industry, mainly due to the very long retention time in an oxygen reactor. In the experiments carried out in the next part of our research, we investigated in what conditions it is possible to obtain pine kraft pulp with a kappa number below 10 with peracetic acid pre-treatment.

Figure 1 shows that using pre-treatment of pulp with peracetic acid in the amount of 0.33 or 0.66% A.O. and 3% of NaOH, it is possible to reach the kappa numbers of 11.1 and 9.2 in O_2-delignification. In the second case, the delignification of pulp already corresponds to the assumed level of extended oxygen delignification < 10.

In order to establish what level of kappa number it is possible to delignify the normal pine pulp without an excessive decrease of pulp yield and strength, a range of experiments was performed using a peracetic acid pre-treatment, an increased amount of NaOH and a longer process time. The condition of individual experiments were chosen so that we could compare the result of experiments performed with and without peracetic acid pre-treatment as well as those in which different amounts of peracetic acid was used. As shown in Figure 1, the pulps obtained in these experiments had very low kappa number, as low as 5 - 7.

The effect of delignification of pine sulphate pulp, i.e. the degree of delignification obtained in the experiments performed, is shown in the data in Table 2 (see page 98). They also enable us to establish how much the amount of lignin removed from pulp as a result of peracetic acid pre-treatment can be increased, and how much more lignin can be removed upon a twofold and threefold increase of the amount of NaOH added in the O_2-process and extending its time to 120 and 180 minutes.

As can be seen from the data in Table 2, the increase in the amount of removed lignin obtained using peracetic acid in the amount of 0.33% A.O. (to o.d. pulp) was 8 - 12 rel. %, while at a twofold dose the amount was 13-19 rel. %, in comparison with those experiments in which pulp was delignified with oxygen alone. There is therefore no proportional relationship between the amount of peracetic acid used and the decrease in kappa number obtained.

As for how much more lignin can be removed upon a twofold and threefold increase of the amount of added NaOH and extending the process time, Table 2 shows that by increasing the amount of added NaOH at the beginning of the process to 3% and simultaneously extending the time up to 120 min., it is possible to remove from the pulp 20 - 24 rel. % more of the lignin than at 1.5% of added NaOH and process time 60 min. By increasing the amount of added NaOH up to 4.5% with a simultaneous extension of the process time to 180 minutes, it is possible to remove from the pulp 27 - 34 rel. % more of the lignin than at 1.5% of NaOH and duration time 60 min., and only 7.5-10 rel. % more of the lignin than at 3% of added NaOH and 120 min.

The results obtained indicate that the residual lignin remaining in conventional pine kraft pulp after removing 37-56 rel. % of this component from it, irrespective of the process variant (with or without peracetic acid), is much less susceptible to oxidation in oxygen delignification conditions. According to literature, this phenomenon probably results from the accumulation of residual lignin structures 5,5'-diphenyl and p-hydroxyphenyl units in pulp, which are relatively hard to oxidise under oxygen delignification conditions. Another reason may be the formation of the 5,5'-diphenyl units as a result of secondary condensation reactions taking place between free phenyl radicals [2, 3].

The experiments performed also proved that changing the pH of the peracetic acid pre-treatment from 2.6 to 3.5 has no significant effect on the amount of residual lignin removed from the pine pulp in the oxygen delignification process. This indicates that it is not necessary to raise

the pH of the medium to 3.5 during the pulp treatment with this chemical at the Pa stage.

In two-stage oxygen delignification experiments, the pulp was treated with peracetic acid after the first oxygen stage; that is, pulp of a much lower lignin content (kappa number 17 and 14) in comparison to a single-stage delignification. It was expected that the decrease in the kappa number would be higher than in a single-stage process. However, as shown in Figure 1, the decrease of the kappa number in this case was comparable to 0.33% when A.O. of peracetic was used, and was higher by only about 0.7 kappa number units when pre-treatment with 0.66% A.O of this chemical was applied.

An alternative method of extending the delignification of pulp in an oxygen process, apart from treating it with peracetic acid, is to raise the temperature of the process. Figure 1 shows that in a single-stage oxygen delignification at 110 °C, it is possible to obtain in the same conditions (amount of NaOH, process time) a decrease of kappa number higher by 5-7.3 rel. % in comparison with the decrease of kappa number obtained at 100 °C. It is 3-5% less than in those experiments in which peracetic acid pre-treatment of pulp in the amount of 0.33% A.O. to o.d. pulp was applied.

Figure 2 shows the relationship between yield and kappa number in different variants of oxygen delignification process of pine kraft pulp with brownstock kappa number 31.5, as well as the simulation of changes in this index in a process of 100% selective delignification of this pulp.

The data of Figure 2 shows that the oxygen delignification of pulp kappa number 31.5 to kappa number 12.5 takes place with almost the same yield, both in the processes with and without peracetic acid (perhaps apart from that performed at 110 °C). At the same time, it can also be seen that the decrease in kappa number of this pulp to 15-12.5 results in almost the same loss of carbohydrates, i.e. 1.4-1.5% in these variants of the oxygen delignification. However, in oxygen delignification to a kappa number of about 7.5, performed only with oxygen, the amount of carbohydrates dissolved increases rapidly from 1.4-1.5 to 3.3%, that is, almost to the amount of the removed lignin (Figure 2, Table 3). Consequently, the yield of pulp delignified only with oxygen decreases rapidly to 93.1%. As for the yield, the experiments of the oxygen delignification process with peracetic acid treatment produced more advantageous results. Figure 2 shows that in experiments in which the pre- or inter-stage treatment of pine kraft pulp with 0.66% of this chemical was applied, the delignification to kappa number 7.5 was the most selective. The amount of dissolved carbohydrates increased from 1.4-1.5% to 1.9%, so in comparison with the delignification of pulp to kappa number 12.5, this meant by only 0.4%. Owing to this, the yield of pulp delignified with oxygen to kappa number 7.5 with pre-treatment of pulp with peracetic acid was 94.5%, i.e. higher by about 1.4% than the yield of pulp delignified with oxygen alone.

Summing up, it can be stated that the normal pine sulphate pulp can be delignified with oxygen alone without any risk of excessive decrease in yield to kappa number 12.5, and with peracetic acid pre-treatment in the amounts of 0.33 and 0.66% A.O., to kappa number 9-10 and 7.5, respectively.

To achieve a better image of the changes taking place in the pulp during the extended oxygen delignification, the tear index, intrinsic viscosity of pulps and the zero-span fibre strength factor (FS) were determined. The results are presented in Figures 3, 4 and 5.

The extent to which different conditions of individual variants of extended oxygen delignification affects the strength properties of the pine pulp can be estimated by determining the tear index at several beating levels. Here this method was used in a simplified variant, i.e. the determination and comparison of tear index of pine pulp beaten in a Jokro mill at only one beating time (to a freeness value of 20 °SR). Figure 3 shows the relationship between the tear index and the kappa number of oxygen-delignified pulp in different variants whose conditions are defined in Table 1.

As shown in Figure 3, the smallest decrease in the tear index was found in those experiments in which initial pine kraft pulp was delignified using pre-treatment with peracetic acid, and the highest decrease when the pulp was delignified only with oxygen in 110 °C. Within the range of kappa number 7.5-10, tear index of pulp delignified with peracetic acid pre-treatment was higher by 5-22 rel. % than the values of this index of pulp delignified only with oxygen, depending on the kappa number and the variant of the process.

The tear index of pine kraft pulp delignified in a two-stage O_2-delignification with inter-stage treatment with peracetic acid was lower than that obtained for pulp delignified with oxygen using pre-treatment with peracetic acid, and higher than that of pulp delignified with oxygen alone.

Figure 4 shows the intrinsic viscosity of pine kraft pulp with a kappa number of 31.5 delignified with oxygen, depending

Table 2. *Comparison of the effectiveness of oxygen delignification of pine kraft pulp kappa number 31.5 in different process conditions.*

Process sequence	Removed lignin, rel. %. at:				
	1.5% NaOH, 60 min.	3% NaOH, 120 min.		4.5% NaOH, 180 min.	
QO (100°C)	37.5	61.3	+23.8	71.1	+33.6
QO (110°C)	44.4	67.9	+23.5	73.9	+31.4
QPaO (0.33% A.O)	49.8	70.7	+20.9	78.9	+28.8
QPaO (0.66% A.O.)	56.2	75.9	+19.7	83.5	+27.3

Table 3. *Share of carbohydrates in yield decrease of pine kraft pulp delignified with oxygen to defined kappa number; ^{X} (31.5- K) · 0.152, where K is kappa number.*

	Share of carbohydrates in decrease of yield, % at:				
Kappa number to which pulp is delignified	15	12.5	10	7.5	5
Approximate amount of removed lignin from pulp, %x)	2.5	2.9	3.3	3.65	4.0
QO (100°C)	1.3	1.5	2.4	-	-
QO (110°C)	1.6	1.8	2.4	3.3	-
QPaO (0.33% A.O.,100°C)	1.3	1.5	1.8	2.4	-
QPaO (0.66% A.O.,100°C)	1.3	1.3-1.4	1.8	1.9	3.0

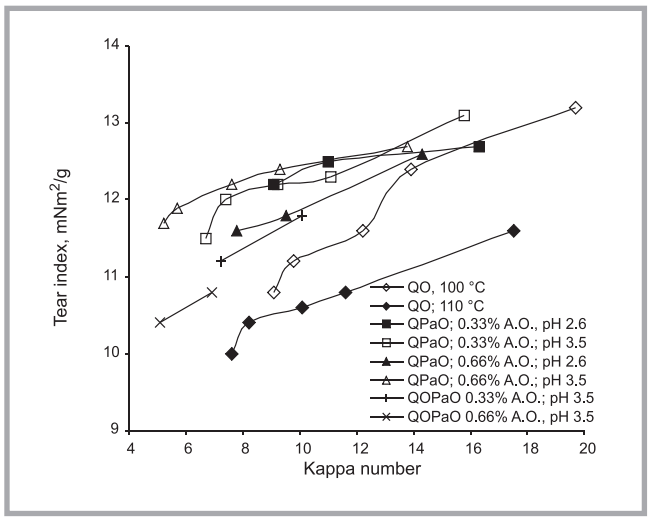

Figure 3. *Relationship between tear index and kappa number of oxygen-delignified pine kraft kappa number 31.5 pulp in different variants of the process. (Standard deviation of tear index measurements was 0.2 mN· m²/g).*

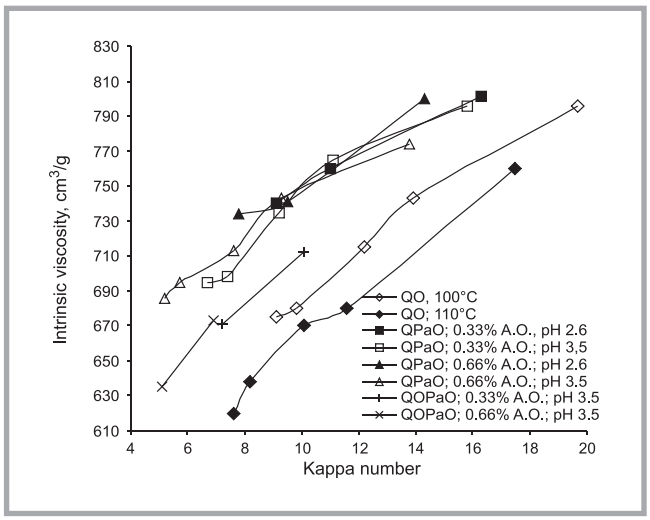

Figure 4. *Relationship between kappa number and intrinsic viscosity of oxygen-delignified pine kraft kappa number 31.5 pulp in different variants of the process. (Standard deviation of viscosity was 8 cm³/g).*

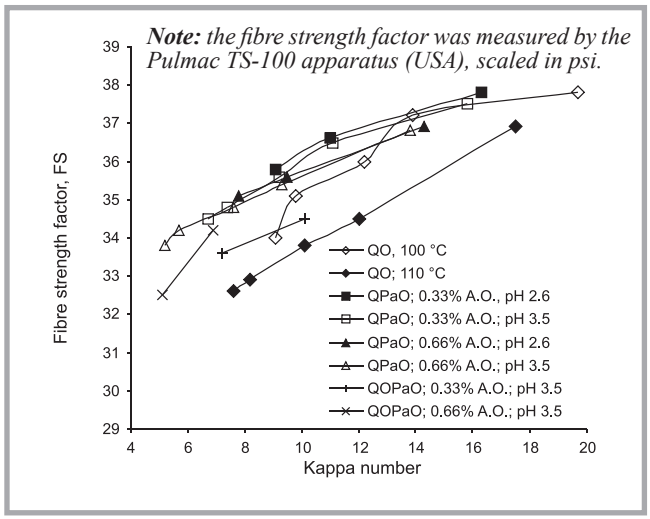

Figure 5. *Relationship between zero-span fibre strength factor and kappa number of oxygen-delignified pine kraft kappa number 31.5 pulp in different variants of the process (after beating the pulp in a Jokro mill to freeness 20°SR, beating time 12 min.); (Standard deviation of FS-factor was 1.1).*

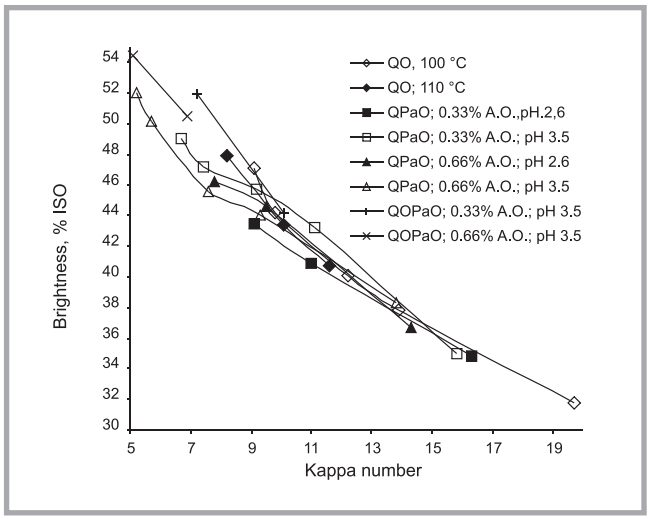

Figure 6. *Relationship between kappa number and ISO brightness in different variants of oxygen delignification pine kraft pulp, kappa number 31.5. (Standard deviation of ISO brightness was 0.2%).*

on the kappa number and the variant of the process. In general, it is known that the reduction of viscosity affects fibre strength, and consequently decreases the strength properties of pulp. This is due, above all, to the action of alkali at elevated temperatures and the reaction of cellulose degradation, in whose mechanism hydroxyl radicals play a significant role [19]. Figure 4 shows that within the amount of removed lignin which corresponds to extended delignification of pulp (kappa number 5-14), in all variants of oxygen delignification the slope of curves showing intrinsic viscosity-to-kappa number relationship is more or less constant (the decrease of pulp kappa number by one unit corresponds to the decrease of viscosity by the constant amount of cm³/g). So we did not, as in the case of yield, observe a threshold of removed residual lignin beyond which the intrinsic viscosity of pulp rapidly decreased. Within the range of kappa number 7.5-10, the viscosity of pulp delignified with peracetic acid pre-treatment was higher by 10-18 rel. % than the values of this index of pulp delignified with oxygen alone.

Apart from that, the analysis of Figure 4 indicates that:

- the values of viscosity of pulp delignified at 110 °C are lower than those of pulp delignified at 100 °C by about 6 rel. %.
- the intrinsic viscosity of oxygen-delignified pulp with peracetic acid pre-treatment at pH 2.6 (i.e. without any addition of NaOH) and pH 3.5 are comparable
- the viscosity of pulp delignified in a two-stage oxygen delignification with inter-stage pre-treatment with peracetic acid, in comparison to that delignified in single-stage oxygen delignification with pre-treatment with peracetic acid was lower by about 5 rel. %.

The direct effect of the extended delignification of pine kraft pulp in different variants of oxygen delignification on fibres' strength was determined by determining the zero-span fibre strength factor

in a Pulmac TS-10 Troubleshooter (Figure 5). The figure shows that extended oxygen delignification of pulp with peracetic acid pre-treatment resulted in the lowest decrease of fibre strength. In the range of kappa number 7.5-10, the fibre strength factor of pulp delignified with peracetic acid pre-treatment was higher by 1-7 rel. % than the values of this index for pulp delignified with oxygen alone, depending on the kappa number and the variant of the process.

As in the case of viscosity, neither the tear index nor the zero-span fibre strength factor of pulp delignified in a two-stage oxygen delignification with inter-stage treatment with peracetic acid were higher than the values of these indices of pulp delignified in a single-stage process and pre-treated with peracetic acid. It can thus be concluded that the division of the amount of added NaOH into two oxygen stages, thus moderating the conditions of the treatment of fibres with alkali, do not bring any effects which could justify the introduction of such a modification.
The amount of chemicals used in the process of bleaching kraft pulps to a brightness level of 88-90% ISO is not only dependent on a lower content of lignin in these pulps. Their higher brightness level before bleaching may also have a significant effect. Figure 6 shows that in a range of kappa number values corresponding to extended delignification, the brightness ISO of conventional pulp delignified with oxygen in one stage is increased in proportion from about 37% to 55%. The brightness of oxygen-delignified pulp without the use of peracetic acid at a definite kappa number level is close to that of oxygen-delignified pulp with a pre-treatment with peracetic acid. Pulp delignified in two-stage oxygen delignification with treatment with peracetic acid between stages has a slightly higher brightness at a definite kappa number.

Conclusions

1. Conventional delignification of pine kraft pulp, kappa number 31.5 to kappa number < 10 with oxygen alone requires an increased amount of added alkali, an extension of the process time and higher temperature, and leads to an excessive decrease of pulp yield. The pre-treatment of pulp with peracetic acid in the amounts of 0.33 and 0.66% A.O. (to o.d. pulp) enables us to delignify it in the oxygen process to a kappa number of 7.5-9 with the yield higher by 0.5-1.4% in comparison with the yield of pulp delignified with oxygen alone.
2. The increase in the amount of removed lignin obtained due to the application of peracetic acid pre-treatment in the amount of 0.33% A.O. (to o.d. pulp) was 8-12 rel. %, while at a twofold dose it was 13-19 rel. % in comparison with pulp delignified with oxygen alone.
3. In the case of delignification of pine pulp with oxygen alone and also using peracetic acid pre-treatment, the most effective way of proceeding is to remove this part of the lignin which accounts for 37-56% of its content in pulp. With a twofold and threefold increase in the amount of NaOH added and an extension of the process time, the amount of lignin removed from the pulp increases by only 20-24% and 27-34 rel. %, respectively.
4. The tear index, intrinsic viscosity and fibre strength factor of oxygen-delignified pine pulp with peracetic acid pre-treatment were higher than that of pulp delignified only with oxygen by 5-23, 10-18 and 1-7 rel. %, respectively.
5. The two-stage oxygen delignification of conventional pine kraft pulp with inter-stage treatment with peracetic acid gives a similar decrease in the kappa number as a single-stage oxygen delignification with pre-treatment with this chemical, and a slightly lower tear index, viscosity and fibre strength.

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TRICOTEXTIL Institute of Knitting Techniques and Technologies Łódź, Poland at the Brussels Eureka 2006 World Exhibition on Innovation, Research and New Technologies

At EUREKA 2006, which took place in Brussels from 23rd to 28th November 2006, two inventions developed in the TRICOTEXTIL Institute and financed by the Polish State Committee for Scientific Research and the Ministry of Science & Higher Education were awarded a **Gold and a Bronze Medal.**

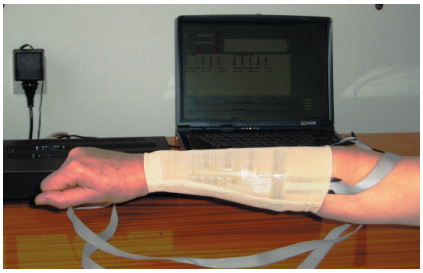
The **Gold Medal** with special distinction was awarded for the

'Method of pressure measurements under garment used in compression therapy'

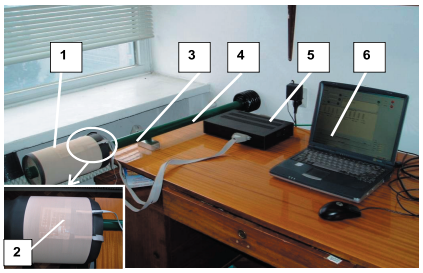
invented by Andrzej Nawrocki, Krzysztof Kowalski, Elżbieta Maklewska, and Władysław Tarnowski.

The device developed, called TEXTILPRESS, allows pressure measurement under garments used in compression therapy, which is known to be the most successful method for healing and preventing hypertrophic (HP) scars by using textile products. Regarding the lack of appropriate devices in hospitals for measuring the pressure exerted by textiles on scars, at present how correctly a garment fits is estimated subjectively. In the case of small children, wrong selection of the pressure can lead to an additional hazard, resulting in bad health conditions. HP scars mainly occur as a result of skin injuries, such as burns or bites, and constitute a problem for the patient not only because of extensive skin deformations and visual effects, but also the probability of causing serious motion disturbances. That is why the invention of the method of pressure measurement and the TEXTILPRESS device, developed by the TRICOTEXTIL Institute and tested in cooperation with the Clinical Hospital for Children's Oncology, Surgery of the Medical University of Łódź, the TRICOMED SA (the manufacture of compressive products), and the ATT Company, both with headquarters in Łódź, is a milestone in the rational treatment of HS healing.

The method and the device have been described in details in Fibres & Textiles in Eastern Europe, vol.14, No. 5/2006 (59), pp. 111 – 113.



Measurement of the pressure exerted by a compression band with the use of the TEXTILPRESS device.



View of the TEXTILPRESS measuring stand during measuring; 1 – textile compression band, 2 – measuring matrix placed under the band, 3 – cylinder, 4 – cylinder holder, 5 – data acquisition system, 6 – computer.

The **Bronze Medal** was awarded for the

'Method for estimating the wale and course density & the surface porosity of knitted fabrics by computer image analysis'

invented by the team of the Research Laboratory for Textile Metrology (TRICOTEXTIL).

The method is based on using a measuring stand equipped with a CCTV camera coupled with a PC. The system software developed by the authors includes two separate applications: the Textil2D, responsible for transmitting the pictures from the video camera, and the Loo2D, which allows the 2D surface pictures of the knitted products to be analysed. This method means that we may better interpret the influence of the surface state and the 3D structure of knitted fabrics on its biophysical properties determined by standard and original test methods, including those developed by the authors.

The stand enables us to quickly determine the knitted fabrics' structural parameters and the surface porosity, which is characterised by the size of clearances interlaced between yarns. The high repeatability of the results and the compatibility with existing test methods confirm the usability of this invention in the laboratory and in industry.

Research concerned with the test stand was carried out in cooperation with the Technical University of Łódź. Articles concerned with the method awarded have been described in Fibres & Textiles in Eastern Europe, vol. 14, No. 3/2006 (57), pp77-80, and vol. 14, No. 5/2006, pp107-110.

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