Sodium carbonate in alkali extraction during bleaching bamboo (D. strictus) pulp

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SUMMARY

Bamboo fibres being more open require controlled treatment during extraction stage in bleaching. The practice of using Sodium Hydroxide is likely to cause degradation of the pulp if the process parameters are not rigidly controlled. In order to provide milder conditions and bring economics, the use of Sodium Carbonate in its place has been investigated. The limited literature available on the chemistry of extraction stage places Sodium Carbonate practically on the same level as that of Sodium Hydroxide. The Sodium Carbonate extracted pulps on bleaching with Calcium Hypochlorite gave practically equivalent characteristics in terms of brightness, post colour number, alpha cellulose, etc. Bench scale observations were confirmed by plant scale trials.

In recent years, Pulp and Paper Industry in India is also facing the world wide inflation and escalation of cost of chemicals, This makes the Industry to look for alternative cheaper chemicals, wherever possible. In this paper an attempt has been made to study the viability of using sodium carbonate as an extraction chemical to substitute sodium hydroxide.

LITERATURE REVIEW :

Though, the alkaline chemistry of sodium hydroxide and sodium carbonate is almost similar in several respects, the weak basicity of sodium carbonate has limited its use.

Singh *et al*[1] have reported that the extraction stage delignification follows two distinct phases, (i) a rapid initial phase and (ii) a slower second phase. The change in the Kappa number or the rate of delignification during the second phase was found to have a linear relationship with the caustic soda consumption, which is effected by the temperature of the system. They also observed that the caustic soda consumption is a zero order reaction for first twenty minutes and then becomes negligible. The drop in Kappa number in the rapid phase amounted to 65% of the total drop consuming only 13% of sodium hydroxide. The consumption of caustic soda in both phases is around one fifth of its addition, indicating thereby that the amount of alkali utilized in delignification is quite less and the rest is utilized in maintaining the pH of the system so as to avoid lignin redeposition.

Peter Axegard[2] observed the Kappa number to never reach a constant level, but continue to decrease even after a long period. Thus, in the slower reaction phase, the very slow rate of delignification within a defined period of about two hours put the reaction as an independent function of the alkali consumption following a zero order reaction in hydroxyl ion concentration. The initial rapid and the later slower phase reactions are two separate first order reactions with respect to the Kappa number of the pulp. He also opined that the chlorinated lignin upon extraction yields lignin of two types - eliminated easily and with difficulty. It is likely that in the rapid phase, a favoured topographical condition exposes a maximum amount of lignin to chemical attack, accelarating the delignification upto a short period. Afterwords the residual lignin is so difficult to reach, that the reaction slows down considerably. He also believed the rapid phase delignification to be a function of hydroxyl ions following a reaction order between zero and one. Thus this mechanism though different from that of Singh *et al*, indicates the initial rapid phase delignification to depend on the alkalinity, temperature and chlorination of the pulp.

Coniferyl aldehyde, the main constituent of soft wood lignin, being quite resistant to alkaline hydrolysis, a strong alkali may be necessary to

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extract it, but bamboo lignin contains mostly syringyl groups which are not so resistant to alkaline hydrolysis. Further, soft wood hemicelluloses contain 1 : 4 glucan which can undergo isomerisation to 1 : 4 mannan during alkaline hydrolysis to get stability, whereas bamboo hemicelluloses, which contain 1 : 4 xylan do not undergo this change. They get removed during sodium hydroxide extraction. Hence, a milder alkali can possibly reduce the alkaline hydrolysis of bamboo hemicelluloses and preserve them.

Emil Heuser[3] has believed that a certain amount of alkalinity is being maintained during extraction with the same delignification irrespective of the type of alkali used. Chang[4] reports the isolated lignin from unbleached pulp equally soluble in sodium hydroxide as well as sodium carbonote. Arnold *et al*[5] have found sodium carbonate and ammonium hydroxide to be at par in efficiency when compared to sodium hydroxide. All this is of relevance to the present study. As the literature though limited, is confined to temporal soft and hardwoods, authors initiated this study on the possibility of sodium carbonate as a substitute for sodium hydroxide.

EXPERIMENTAL :

After encouraging results were obtained from preliminary studies on the use of sodium carbonate as a substitute for sodium hydroxide in alkali extraction, detailed studies were carried out.

STUDY ON SEQUENTIALLY CHLORINATED (H/C) PULP :

Extraction of sequentially chlorinated pulp (H C) was done at 55°C using sodium carbonate and sodium hydroxide alone, as well as in a 50 : 50 mixture, both expressed as NaOH. Hypo stage bleaching was then carried out, substracting 1.0% chlorine on the weight of unbleached pulp, in form of hypochlorite, added during sequential bleaching, from the total demand of chlorine for achieving $80\pm1°$ Elrepho brightness. The pulps were tested for their chemical and physical properties. The conditions maintained and results obtained are tabulated in Table 1.

STUDY ON CHLORINATED PULP :

Extraction of chlorinated pulp was carried out at 55°C with sodium carbonate and sodium hydroxide as above. The pulps were subsequently bleached with hypochlorite to get a brightness of $80\pm1°$ Elrepho and tested for their chemical and physical properties. The conditions maintained and the results obtained are in Table 1

Effluent characteristics of the filtrate from alkali extraction stage were studied and are in Table 1.

For all tests, Standard Procedures were followed. The pulp was beaten in valley beater to a freeness of 40° SR. A plant trial was taken to confirm the results of bench scale studies. Results are tabulated in Table 2.

RESULTS AND DISCUSSION :

From table 1 it is obvious that the pulp extracted with sodium hydroxide has shown a slightly lower permanganate number than the carbonate extracted pulp, probably for the following reasons.

(i) The carbonate extracted pulp contains more of hemicelluloses which consume permanganate and show a higher number,

(ii) After the removal of rapid phase lignin, the residual lignin content in the pulp is higher in the case of carbonate extracted pulp.

The sequentially chlorinated as well as chlorinated pulps, when extracted with sodium carbonate (or a 50 : 50 Na_2CO_3 & NaOH mixture), show a tendency for less shrinkage as compared to the NaOH extracted pulp. This can probably be attributed to less degradation of hemicelluloses owing to the milder action of sodium carbonate. The extracted pulp on subsequent hypochlorite bleaching, gave practically same brightness, physical and chemical properties as that of NaOH extracted pulps.

The pH of the pulp during the carbonate extraction has a comparatively lower value than during hydroxide extraction (Table 1 & 2). This can be explained since the alkalinity provided by sodium carbonate is weaker than that of NaOH at equivalent concentrations. In the case of carbonate extracted pulp, the addition of buffer during the hypochlorite bleaching is also reduced indicating a better pH stabilization in the system. From the effluent characteristics (Table 1) it is observed that the effluent generated from carbonate extracted pulp at the extraction stage is less polluted in terms of total solids and COD.

Results of the plant scale trials, conducted in an integrated pulp and paper mill, using bamboo and following sequential chlorination confirmed the findings of the bench scale studies (Table 2).

The advantage of using sodium carbonate in terms of cost benefit is two fold, viz. (a) it is substantially cheaper than sodium hydroxide and (b) it is more readily available

TABLE—I BENCH SCALE STUDY BLEACHING OF SEQUENTIAL CHLORINATED AND CHLORINATED PULPS

Particulars	Unit	H/CEH			CEH		
Extraction stage :							
1. Alkali added (as NaOH)	%	2.5	2.5	2.5	2.5	2.5	2.5
2. Ratio of NaOH:Na_2CO_3 as (NaOH)		100:0	50:50	0:100	100:0	50:50	0:100
3. Consistency	%	10	10	10	10	10	10
4. Temperature	°C	55	55	55	55	55	55
5. Retention time	hrs	2.0	2.0	2.0	2.0	2.0	2.0
6. Initial pH		11.2	11.0	9.5	11.2	10.3	9.5
7. Final pH		10.7	10.6	9.3	10.6	10.3	9.2
8. Yield	%	96.8	97.1	97.2	96.5	97.0	97.3
9. K. No.	No.	5.3	5.4	5.6	5.4	5.7	6.0
10. Total solids in effluent	ppm	6900	6500	6238	6600	6396	6108
11. COD in effluent	ppm	3850	3726	3122	3706	3626	3053
HYPOCHLORITE BLEACHING :							
12. Hypo added on O. D. pulp	%	3.0	3.0	3.0	4.0	4.0	5.0
13. Hypo consumed on O. D. pulp	%	2.93	2.99	2.82	3.7	3.9	4.0
14. Consistency	%	10	10	10	10	10	10
15. Temperature	°C	40	40	40	40	40	40
16. Retention time	hrs	4.0	4.0	4.0	4.0	4.0	4.0
17. Initial pH		9.0/9.2	9.0/9.2	9.0/9.2	9.0/9.2	9.0/9.2	9.0/9.2
18. Final pH		8.8/9.0	8.8/9.0	8.8/9.0	7.6/7.7	7.8/7.9	8.0/8.2
19. Buffer added as NaOH on O. D, pulp	%	0.88	0.97	0.66	0.9	0.9	0.9
PROPERTIES OF PULP :							
20. Brightness (Elrepho)	%	80.4	80.3	79.8	80.5	80.1	79.5
21. Post colour number	No.	6.1	6.7	5.9	6.0	6.5	6.0
22. Viscosity (0.5 CED)	cps	5.40	5.45	5.54	6.30	6.53	6.83
23. Copper number	No.	0.97	1.04	0.99	0.50	0.44	0.48
24. Alpha cellulose	%	84.70	85.10	86.10	85.00	84.25	84.25
PHYSICAL PROPERTIES :							
25. Final freeness	°SR±1	40	40	40	40	40	40
26. Basis weight	gsm±1	60	60	60	60	60	60
27. Burst index	N/kg	2.3705	2.6019	2.7735	3.405	3.3147	3.5127
28. Tear Index	Nm^2/kg	5.4578	5.2941	5.7205	6.5189	9.6470	6.5764
29. Breaking length	km	4.8770	4.6510	4.8000	4.6440	4.7310	5.1430
30. Tensile Index	Nm/kg	47.8100	45.6000	47.0500	45.5300	46.3800	50.4200

Note 1 : 1% hypo is added for sequential chlorination
Note 2 : Kappa number of unbleached pulp is around 25.0

TABLE—2 PLANT SCALE TRIAL : PROCESS CONDITIONS AND RESULTS

	Particulars	Unit	Na_2CO_3 Extraction	NaOH Extraction
Unbleached Pulp :				
1.	K. No.	No.	16.2	15.6
2.	Final Freeness	°SR ±1	40	40
3.	Basis weight	gsm ±1	60	60
4.	Burst index	N/Kg	3.84	3.9
5.	Tensile index	Nm/kg	61.45	60.41
6.	Tear index	Nm^2/kg	10.03	10.23
7.	Chlorinated pulp K.No.	No.	8.6	8.4
Alkali Extraction :				
8.	Alkali added as NaOH	%	2.5	2.5
9.	Consistency	%	10	10
10.	Temperature	°C	55	55
11.	Retention time	hrs	2	2
12.	Initial pH		8.54	9.64
13.	Final pH		7.8	8.2
14.	K. No.	No.	6.2	5.6
Hypo bleaching I :				
15.	Hypo added on O.D. pulp	%	3.0	3.0
16.	Hypo consumed on O.D. pulp	%	2.95	2.85
17.	Consistency	%	10.0	10.0
18.	Temperature	°C	36	36
19.	Retention time	hrs	4.0	4.0
20.	Brightness (Elrepho)	%	72.8	71.9
21.	Initial pH		8.06	8.35
22.	Final pH		7.56	8.1
Hypo bleaching II :				
23.	Hypo added on O.D. pulp	%	0.3	0.3
24.	Retention time	hrs	2.0	2.0
25.	Temperature	°C	ambient	ambient
26.	Consistency	%	10	10
27.	Brightness (Elrepho)	°	76.4	76.5
28.	Post colour number	No.	11.6	11.2
29.	1% NaOH solubles	%	9.76	8.91
30.	Alpha cellulose	%	80.2	81.0
31.	Viscosity (0.5 CED)	cps	4.37	4.41
32.	Copper number	No.	2.05	1.93
33.	Burst index	N/kg	3.04	2.8
34.	Tensile index	Nm/kg	52.77	51.09
35.	Tear index	Nm^2/kg	5.91	5.61

N B : Trials have been taken on sequentially chlorinated pulp.

CONCLUSIONS :

The bench scale and plant trials indicate that sodium carbonate as a substitute for sodium hydroxide during alkali extraction stage, can very well serve the purpose without having any adverse effect on the physical or chemical properties of the finally bleached pulp. Indications are that a slightly better pulp could be obtained with sodium carbonate extraction, due to milder extraction conditions. The effluent of the carbonate extracted pulp at the alkali extraction stage shows less contamination in terms of total solids and COD values.

In view of poor availability of sodium hydroxide, difficulty in its handling and high cost when compared to sodium carbonate, the substitution can play a role in our efforts for reduction in cost of production.

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