Improvement of Hardwood Pulp Quality : Optimisation of Process and Automisation

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Systematic identification of bottlenecks in hardwood pulping and measures taken to eliminate them are discussed in this paper. The major modifications, like, digester automation, on line Brightness sensor in chlorination stage were carried at the plant, which resulted in substantial improvement in yield and quality of the hardwood pulp. Other process problems, such as blow delay, reblow, effect of chlorination and cooking variables such as cooking temperature, wood chips charge, cooking time and its impact on pulp properties with respect to quality improvement are discussed.

INTRODUCTION

Tamil Nadu Newsprint Papers Limited (TNPL) had three 80 cubic meter capacity stationary digesters, three brown stock washers, screening and bleaching section in Hardwood pulp street. Later, two more digesters of similar capacity were added during July 2000 and February 2003 along with DCS system, on-line weightometer and on-line moisture analyzer.

Bottlenecks in hardwood pulping

Uniform Kappa Number of the pulp plays an important role in the final quality of the pulp. Hardwood pulp Kappa Number was maintained between 18 and 20 with the following cooking conditions.

Chemical applied as Na_2O	:	15-17 %
Cooking temperature	:	170 °C
Steaming time	:	90 minutes
Cooking time	:	90 minutes
Bath Ratio	:	1: 3
H Factor	:	1600

Due to variation in cooking conditions, achieving uniform pulp quality was a major problem. Since Hardwood pulp being used as a supporting fibre component, quality variation affected machine runnability. Despite the shortfall in fibre is met with imported pulps, the paper properties like dimensional stability is affected due to the fact that the most of the imported hardwood pulps are from mixed hardwoods

With these deficiencies importance is given to improve the productivity and quality of home Eucalyptus hardwood pulp by systematic de-bottlenecking.

The following factors were identified as a major contribution to the quality variation.

(1) Blow delay

(2) Reblows

(3) High alkali losses

(4) Variation in chlorination

(1) Blow delay

Cook time at particular temperature is the most important factor in the plant. For example, delay in blow can occur due to space constriants in blow tank, forward system high level and maintenance problem associated with further processing. In such cases, the cooked pulp is left out in the digester for long time till the blow is completed leading to increase in cook time. During this period, residual chemical in the digester react further and degrade the cellulose. Therefore to understand the impact of blow delay laboratory studies were undertaken by stimulating plant conditions.

(2) Reblow

By using isolated automated steam valves, direct and indirect steam was given in the same header. Failure of three way valves in white liquor line resulted in passing of white liquor to other digester kept in low pressure. White liquor contamination in condensate due to pre heater tube leakage results in low quantity of liquor addition to the digester. Due to tight packing with high moisture, liquor penetration throughout the digester was not uniform. The scale formation in the digester strainer prevents uniform liquor flow. This problem

Table 1 : Quality of Pulp due to delay in blow

Particular	Unit	Control Blow Normal	Experiment-1 Blow delay by 30 minutes	Experiment-2 Blow delay by 60 minutes	Experiment-3 After depressuring @ 12°C hold 120 minutes
Total Yield	%	46.	46	44.7	45.7
Secreened Yield	%	45.9	46	44.7	45.7
Kappa No.		24.9	23.5	21.2	24.1
Viscosity of Unbleached Pulp	cps	16.1	13.4	10.2	14.7
RAA of WBL	gpl	6.2	4.2	3.2	4.3
H Factor		1250	1712	2172	1260

Pulping Conditions
Temperature : 170 °C
pressure : 7.5 Kg/cm^2
Chemical % (as Na_2O) : 17
Steaming Time : 120 minutes
Cooking Time : 60 minutes

increased the reblow in the digesters as well as higher knots generation. Reblown pulps affect the quality of pulp. To overcome this problem direct steam and indirect steam headers were separated. For indirect steam header motorised valves were installed. After steaming time, steam will be cut off without passing to avoid excess pressure development in the digester and white liquor going out through vent line was arrested. Keeping the low bath ratio of 1:3 during cooking was also one among the reason for reblow and knots generation. By increasing the bath ratio to 1:4 to 1:4.5, knots generation and reblow were reduced considerably. It also helps to improve the quality of pulp to a greater extent.

(3) Alkali Losses

To handle additional throughput of pulp in Brown Stock Washing area the following modifications were done to reduce the alkali carried over by washed pulp.

(i) In brown stock washer III vacuum pump was installed.

(ii) Bottom shredder in repulper of brown stock washer I & II was reintroduced

(iii) Spray water header size was increased.

Due to the above modification with pulp throughput of 6 T/hour, consistency has increased from 11% to 14%. To further reduce alkali losses and increase the consistency of washed pulp, two Dewatering Screw Presses were installed at the last stage.

(4) Improper Chlorination

Improper chlorination was due to wide Kappa Number variation, more alkali losses carried over to decker pulp, bleach plant supply pulp consistency variation, chlorine pressure variation etc.

Due to the above mentioned reasons, chlorination either goes as under chlorination or over chlorination. To study the effect of improper chlorination on pulp quality Laboratory study was taken with different Kappa pulp (low and high)

Experimental

(I) Effect of blow delay on pulp quality

For the study, 100 % Eucalyptus hybrid wood was chosen as a raw material. The normal pulping condition selected was one that is used in TNPL regularly for pulping of Eucalyptus hybrid chips. Apart from the normal cooking schedule the delay in cooking was stimulated to plant conditions at maximum cooking temperature of 170°C in the range of 30 minutes to 60

Table 2 : Streangth Properties @ 300 ml csf

Particular	Unit	Control Blow Normal	Experiment-1 Blow delay by 30 minutes	Experiment-2 Blow delay by 60 minutes	Experiment-3 After depressuring @ 120°C hold 120 minutes
Breaking length	(m)	6975	6500	5200	6700
Tear Factor		72.9	68	58.1	70
Burst Factor		44	37	33	40.2

Table 3 : Yield Loss & Stength loss due to delay in blow

Particular	Unit	Experiment-1 Blow delay by 30 minutes	Experiment-2 Blow delay by 60 minutes	Experiment-3 After depressuring @ 12°C hold 120 minutes
Yield Loss	%	0.3	3.1	0.95
Strength Loss	%	6.72	20.3	4

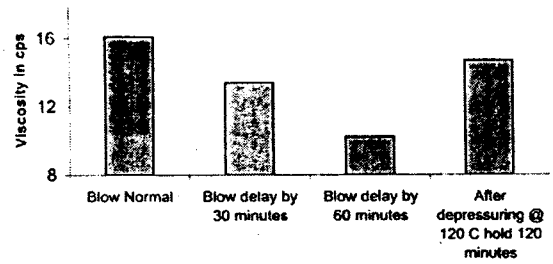

Fig. 1 : Viscosity of Unbleached pulp due to blow delay

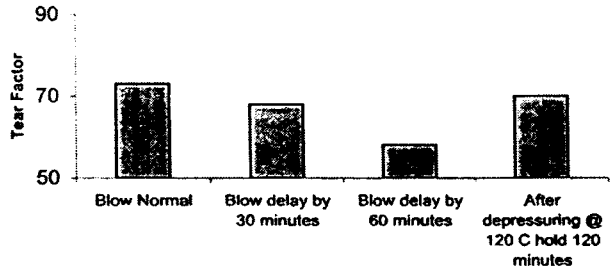

Fig. 2 : Strength Properties (Tear Factor) @ 300 ml csf due to blow delay

minutes. Effect of delay on the quality and strength properties was studied.

Adequate quantities of digester feed chips were collected, after uniform air drying and used for pulping studies. One set of experiment was carried out using 17% Active alkali as Na_2O. The sulphidity of white liquor was 20%. Experiments were carried out by maintaining the temperature 170°C for periods varying from 30 minutes to 60 minutes for Experiment 1 & 2 considering the normal cooking period of 60 minutes at 170°C. In Experiments Number 3 after depressuring the digester to 120°C cook was held up to 120 minutes. In each experiment pulp yield, screened yield, Kappa number. Viscosities of Unbleached pulp, RAA of Weak black liquor and H factor were determined. The unbleached pulp was beaten in PFI mill to 300 ml csf and hand sheets were made. The following cooking conditions were maintained.

Chemical as Na_2O on chips % : 17.0

Bath ratio : 1:3

White liquor sulphidity % : 20

Steaming time : 120 minutes

Cooking time : 60 minutes

Results were given in Table 1, 2 & 3.Effect of blow delay on pulp properties were shown in fig. 1, 2, 3 & 4.

(II) Effect of chlorination on pulp quality

For chlorination studies different Kappa Number (low and high) samples were collected from plant and thoroughly washed to remove the residual alkali.

(a) Chlorination

By fixing the chlorinated pulp brightness as 30%, 40%, 50% (under chlorination, optimum chlorination, over chlorination) suitable chlorine dosage were given and optimization studies were carried using standard bleaching conditions

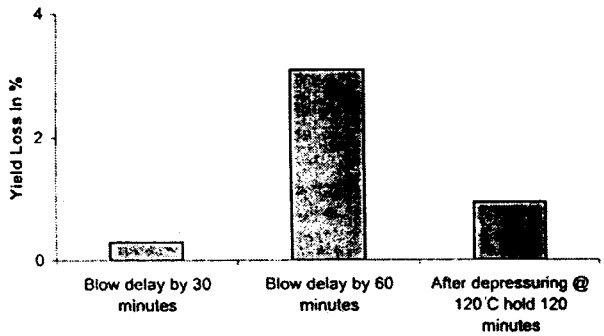

Fig. 3 : Yield Loss % due to blow delay

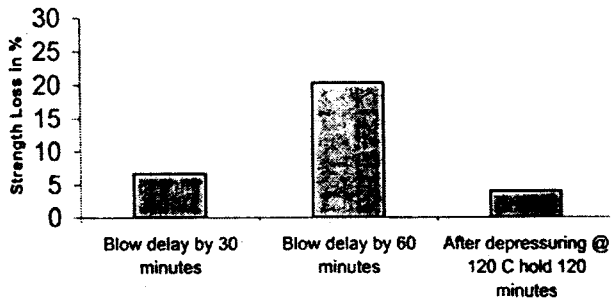

Fig. 4 : Strength loss (Tear Factor) % due to blow delay

Cy : 3%

Time : 30 minutes

Temperature : Ambient

For kappa number 21.3

Parameter	Under chlorination	Optimum chlorination	Over chlorination
Chlorine Charge	K * 0.1	K * 0.17	K * 0.24
Kappa Number * Chlorine mat	29.1	38.5	47.5
Brightness % ISO			

For kappa number 16.5

Parameter	Under chlorination	Optimum chlorination	Over chlorination
Chlorine Charge	K * 0.1	K * 0.17	K * 0.24
Kappa Number * Chlorine mat	31.1	39.5	48.5
Brightness % ISO			

Cy : 3%

Time : 30 minutes

Temperature : Ambient

For kappa number 21.3

(b)Extraction

All the chlorinated pulp of 21.3 & 16.5 Kappa Number were extracted by adding 0.5% H_2O_2 and required amount of NaOH. Extraction was carried out using standard bleaching conditions

Cy : 8%

Time : 60 minutes

Temperature : 60°C

(c) Hypo bleaching

Hypo I & II bleaching was carried out by giving sulfamic acid addition at 10% of hypo and bleaching was carried using standard bleaching conditions.

Cy : 8%

Time : 120 minutes

Temperature : 40°C

Pulp evaluation

All the pulps of Kappa number 21.3 & 16.5 unbleached. Under chlorinated extracted pulp, optimum chlorinated extracted pulp, over chlorinated extracted pulp were evaluated for 300 ml csf using PFI mill. Results are shown Tables-4, 5 & 6 and in Fig. 5, 6, 7 & 8.

(III) Cooking conditions optimisation trials in plant scale:

Before optimistion of cooking conditions:

The following cooking condition were followed for long time

Wood : 100 % Eucalyptus hybrid

Chemical as Na_2O on chips %:15-17

Temperature : 170°C

Pressure : 7.5 kg/cm²

Steaming time : 90 minutes

Cooking time : 90 minutes

H Factor : 1600

Samples of unbleached pulp (Decker) and Hypo II bleached pulps were collected. Testing of Kappa number Brightness, Viscosity was done for Decker pulp. For bleached pulp viscosity and Brightness were measured. Both unbleached and bleached pulps were evaluated for strength properties at 300 ml csf using PFI mill.

Particular	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Wood (Euca)%	100	100	100	100	100
Chemical applied %	15-17	15-17	15-17	15-17	15-17
Temperature °C	165	165	165	165	165
Pressure kg/cm²	7.0	7.0	7.0	7.0	7.0
Steaming time min	120	120	105	90	90
Cooking time min	45	60	75	90	105
H factor	790	940	1100	1245	1400
Trial duration days	15	15	15	15	15

Table 4 : Addition & Consumption of Bleaching Chemicals

	Kapp Number : 21.3 Viscosity : 11.9 cps Brightness : 23.5 % ISO			Kappa Number : 16.5 Viscosity : 8 cps Brightness : 26.5 % ISO		
	Under Chlorination	Optimum Chlorination	Over Chlorination	Under Chlorination	Optimum Chlorination	Over Chlorination
Cl_2 consumption %	0.1	0.17	0.24	0.1	0.16	0.24
Chlorine as Cl_2 % applied	2.5/2.45	3.6/3.5	5.1/4.1	1.65/1.65	2.64/2.64	3.9/3.62
Peroxide applied %	0.5	0.5	0.5	0.5	0.5	0.5
NaOH applied/consumed %	1.65/1.35	1.95/1.57	1.92/1.71	1.52/1.06	1.51/1.27	1.59/1.46
Hypo I stage Hypo applied/con%	3.8/2.85	2.6/1.48	1.7/1.1	3.5/2.57	2.2/1.88	1.5/1.07
Hypo II stage Hypo applied/con%	1.0/0.6	0.75/0.44	0.3/0.15	1.2/0.6	0.75/0.38	0.2/0.12
Total chlorine applied %	7.3	6.95	7.1	6.4	5.59	5.6

Results are shown in Fig. 9, 10, 11, 12 &13

Optimisation trials in plant scale

In the plant digester with DCS control system, keeping chips charging, chemicals charge, temperature as constant, by varying cooking time and steaming time, various trials were taken as given below

During the trial, samples of unbleached pulp (Decker) and Hypo II bleached pulps were collected. Testing of Kappa number, Brightness, Viscosity was done for Decker pulp. For bleached pulp, viscosity and Brightness were measured. Both unbleached and bleached pulps were evaluated for strength properties at 300 ml csf using PFI mill Results are shown in Figures-9, 10, 11, 12 &13.

RESULTS AND DISCUSSION

(1) Impact of blow delay on pulp quality:

The results of blow delay i.e. 30 minutes, 60 minutes, 120 minutes (after depressurizing the digester to 120°C) when compared to normal cook are presented in Table-1 (pulping data), Table-2 (strength properties),Table-3 (yield & strength loss). The Table-1 clearly indicates that blow delay more than 30 minutes is harmful to the pulp. Holding for 120 minutes after depressuring the digester to 120°C does not affect much when compared to blow delay i.e. 30 minutes, 60 minutes with the same cooking conditions.

Contribution of the heating time (H Factor) is very small when compared to the contribution to the cooking time at high temperature. During normal cooking, delignification takes place in cooking stage itself and the reactive white liquor is attacking the lignin and then dissolves. Hemicelluloses and cellulose are preserved

Table 5 : Pulp Properties

	Pulp Properties for Kappa Number 21.3			Pulp Properties for Kappa Number 16.5		
	Under Chlorination	Optimum Chlorination	Over Chlorination	Under Chlorination	Optimum Chlorination	Over Chlorination
Cl_2 mat consumption %	29.1	38.5	47.5	31.1	39.5	48.5
Viscosity, cps	11.3	10.1	7.9	8.0	7.0	5.0
Viscosity reduction %	5.1	15.1	39.5	5.9	17.6	41.2
Extraction mat brightness %	38.2	45.0	51.4	36.5	48.5	55.0
Viscosity, cps	10.1	9.6	7.4	7.5	6.2	4.3
Hypo I mat brightness %	74.1	75.5	77.0	74.5	76.1	78.5
Viscosity, cps	7.7	7.1	6.0	6.0	5.0	3.4
Hypo II mat brithtness %	80.0	81.3	81.0	80.5	81.0	81.3
Viscosity, cps	6.9	6.1	5.0	5.0	4.1	2.8

Table 6 : Strength Properties @ 300 ml csf

	Pulp Evaluation @ 300 ml csf for Kappa Nno. 21.3				Pulp Evalution @ 300 ml csf			
	Unbleached Pulp	Under Chlorinated Extracted Pulp	Optimum Chlorinated Extracted Pulp	Over Chlorinated Extracted Pulp	Unbleached Pulp	Under Chlorinated Extracted Pulp	Optimum Chlorinated Extracted Pulp	Over Chlorinated Extracted Pulp
Breaking length, M	7850	7300	7650	7400	7400	7400	7300	6450
Tear Factor	78.5	77.5	74	70.4	66	64.2	60	50.5
Burst Factor	50.2	48.2	45.9	46.4	46.5	44.8	40.8	35.5
% Stength Reduction (Tear Factor)		1.3	5.7	10.3		2.7	9.1	23.5

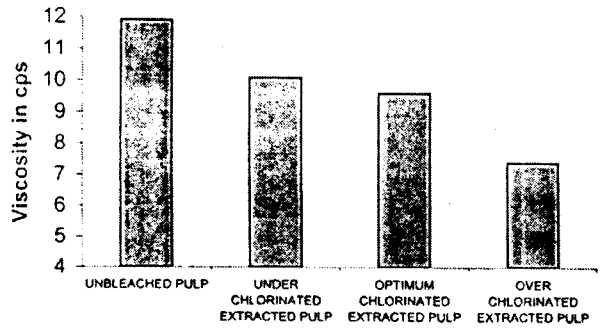

Fig. 5 : Viscosity of Extracted pulp of Kappa No. 2.3

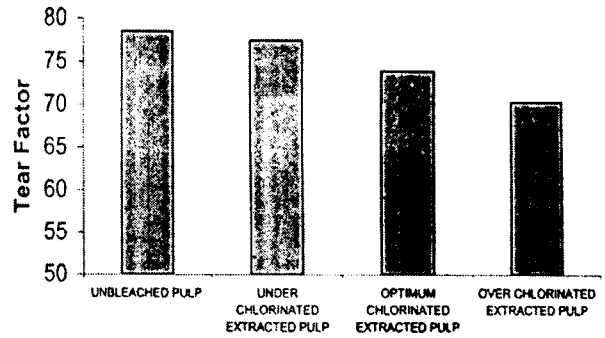

Fig. 6 : Strength Properties (Tear Factor) of Pulp of Kappa No. 21.3

without much degradation resulting in higher yield and strength properties

During blow delay at cooking temperature of 170°C, unreacted residual chemical is entering the crystalline region of cellulose via amorphous region and starts degrading crystalline region cellulose (1). It reduces the -cellulose content of fibre; thereby fibre strength is drastically reduced besides yield loss. Degraded cellulose consisting less degree of polymerization (shorter cellulose chains) having low viscosity of pulp, Sioholm(2) et al suggested that carboxyl groups may increase fibre strength by increasing hydrogen bonding within the fibre. Delayed blow at cooking temperature (170°C) reduces the Kappa Number of the pulp and cooked chips are separated into fibres (4). The residual chemical inside the digester becomes less selective for lignin and more cellulose is degraded i.e. damaging more carboxyl groups leading to the formation of sugar acids

Residual alkali left out is neutralized during this period until residual chemical concentration is reduced to minimum. This degradation of cellulose can't be accounted for peeling reaction alone. Holding blow at cooking temperature of 170°C alkaline hydrolysis by cleavage within the cellulose chain occurs producing new reducing end groups than can participating in the peeling reaction. If the delay exceeds 30 minutes depressurizing the digester to 120°C and holding for longer time is not affecting the carboxyl groups in the cellulose. Carboxyl groups in the cellulose are helping to sustain the fibre strength by way of strong hydrogen bonding within the fibre. It is observed that with high cooking temperature (i.e.,170°C), holding the blow after completion would degrade residual lignin in a way that free phenolic hydroxyl groups were created. In contrast, depressurizing the digester holding at low temperature like 120°C in spite of its residual active chemical would preserve the residual lignin structure to some extent because of its lower free phenolic hydroxyl groups and increase in the guaiacyl groups(3)

(II) Effect of improper chlorination on pulp quality

Amount of residual lignin content of unbleached pulp play an important role in the subsequent chlorination stage since it influences chlorine demand, the amount of substance dissolved in the chlorination stage and ultimately the pulp yield and viscosity (5) ·

By fixing the chlorinated pulp brightness as 30%, 40%, 50% (under chlorination, chlorination, over

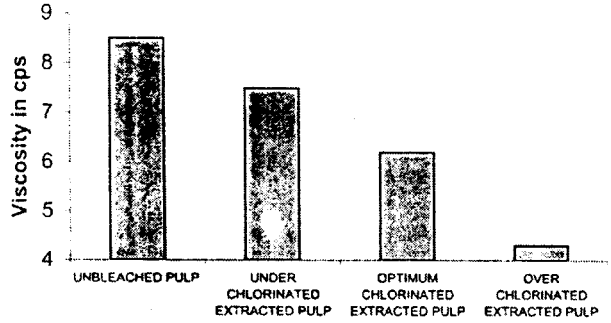

Fig. 7 : Viscosity of Extracted Pulp of Kappa No. 16.5

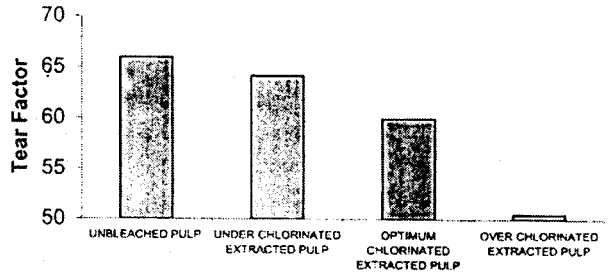

Fig. 8 : Strength Properties (Tear Factor) of Pulp of Kappa No. 16.5

chlorination respectively) suitable chlorine dosage were given and optimization studies were carried out for high kappa (21.3) and low kappa (16.5) decker pulp using standard bleaching conditions. Results were shown in Tables-4, 5 & 6 and in Fig. 5, 6, 7 & 8.

The results show that under chlorinated and optimum chlorinated pulp of high and low kappa consumes all the applied chlorine leaving not excess residual chlorine. Properties of pulp (under & optimum chlorinated) were not affected in the chlorination stage irrespective of low and high kappa number. But in the case of over chlorinated pulp, drop in viscosity was found 33.5%, 41.2 % respectively for high kappa (21.3) and low kappa (16.5). When screened pulp (kappa number 24-26) or (20-23) is subjected to chlorination due to the presence of more lignin consumed all the chlorine, even if excess chlorine is present it goes to the bleach plant effluent only. Excess chlorine is not attacking the cellulose content of hard cook or normal cook pulp because of its high crystalline nature. During over chlorination strength loss is only 10% (Table-6). Whereas in the case of soft cook pulp (low kappa number 16.5) it was already degraded in the cooking stage itself. Over chlorination of soft cook pulp and more retention (more than 60 minutes) of pulp in chlorine tower due to low throughput leads to severe carbohydrate degradation, which resulted in strength (Tear Factor) losses upto 23.5% (Table-6). Optimum chlorination is best for preserving the properties of pulp for subsequent bleaching. In the plant due to kappa variation, chlorine flow variation, more alkali losses (poor pulp washing) lead to either under chlorination or over chlorination. To have good strength of pulp, the strength properties need to be preserved in the cooking stage to withstand cooking conditions. However, soft cooked pulp, which lost the strength properties, will further degrade in the drastic bleaching conditions

III Optimisation cooking condition by various plant trials

Before optimization trial cooking was done for 90 minutes with H factor of 1600 @ 170°C cooking temperature. Cooking with excess effective alkali has been shown to cause extensive degradation and dissolution of hemicelluloses particularly by Xylan. Pulping condition that increase dissolution of hemicelluloses, have a significant impact on pulp yield. Pulps cooked at a higher alkali with 170°C cooking temperature produces low yield and low viscosity

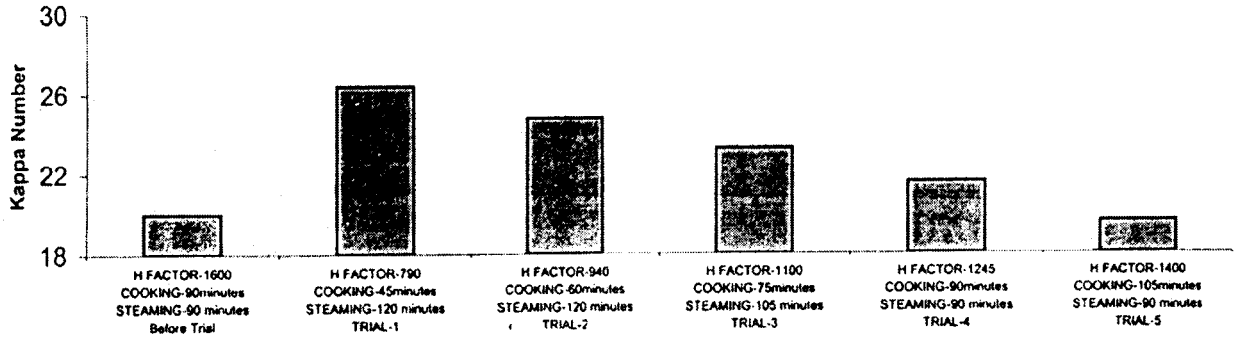

Fig. 9 : Effect of H Factor on Kappa Number

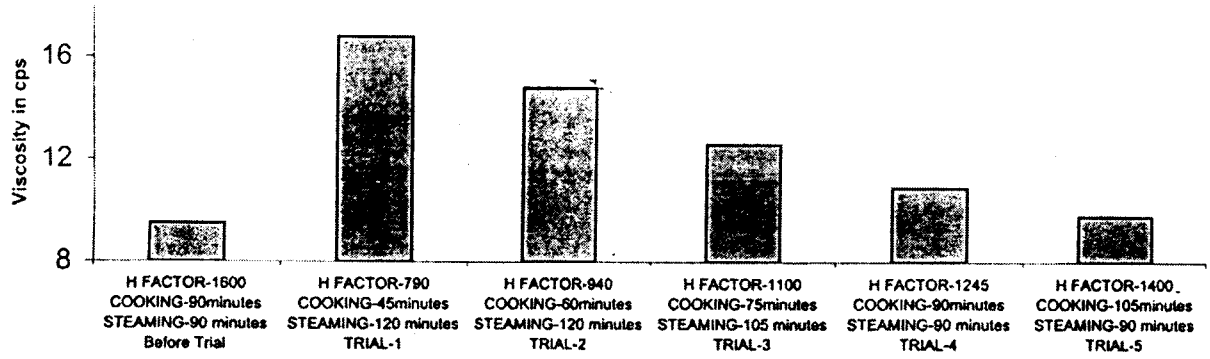

Fig. 10: Effect of H Factor on Viscosity of Unbleached pulp

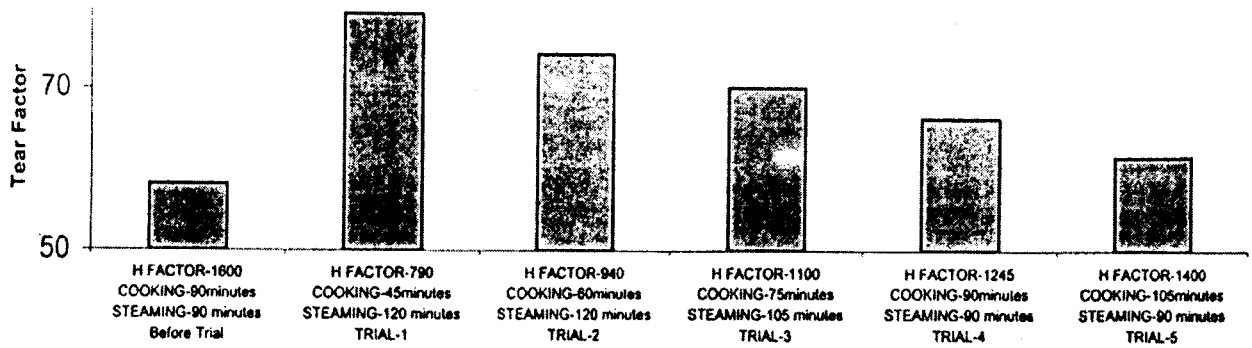

Fig. 11: Effect of H Factor on Strength properties (Tear Factor) of unbleached pulp

having non uniformity in quality of pulp. To overcome these problems cooking conditions were optimized and plant trials were taken

Selection of temperature

Cooking temperature of165°C Hardwood contains more hemicellulose and less lignin compared to softwood. High lignin content of hardwood is located in middle lamella and the remaining lignin is deposited in the secondary cell wall. Since cell wall having large volume, during cooking, lignin is removed first in the cell wall. After 50% dissolution is over, delignification starts in middle lamella due to the greater accessibility and higher concentration. Milder cooking conditions alkali resistance of hardwood hemicellulose like Xylan is not removed during cooking contributing to pulp yield and strength.

Plant cooking trials

By fixing temperature at 165°C, chips charging as constant and varying cooking time from 45 minutes to 105 minutes plant trials were taken. During these trials wood charge and chemical charge were kept constant. Duration of each trials were 15 days. Results are given in Fig. 9, 10, 11, 12 &13.

Results show that Trial II, cooking at temperature of 165°C with steaming time of 120 minutes, cooking time of 60 minutes and H Factor 940 produces pulp of high yield and best strength properties. It is due to that pulps produced at milder cooking conditions like165°C can easily form bonds, present better conformability. Higher viscosity and strength properties of these pulp are due to presence of high hemicelluloses content increase inter fibre bonding ability and good tearing strength. At higher temperature like 170°C removal of these hemicelluloses penalizes inter fibre bonding that has negative effect on tearing strength.

CONCLUSION

Optimisation of process variables and introduction of process automisation resulted in substantial improvement in hardwood pulp quality

(1) Blow delay at cooking temperature 170°C beyond 30 minutes reduces pulp yield and strength properties.

(2) Depressurizing the digester to 120°C and holding it for even 120 minutes doesn't degrade pulp and

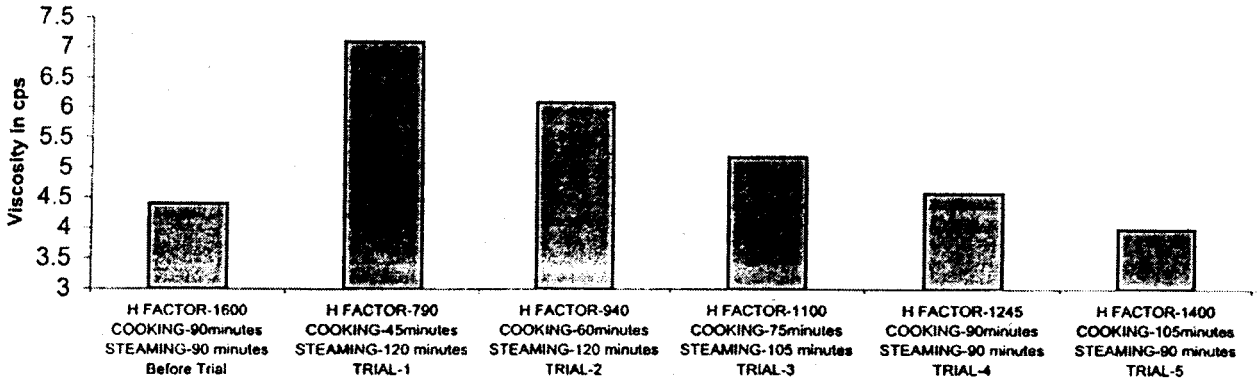

Fig. 12 : Viscosity of Bleached pulp

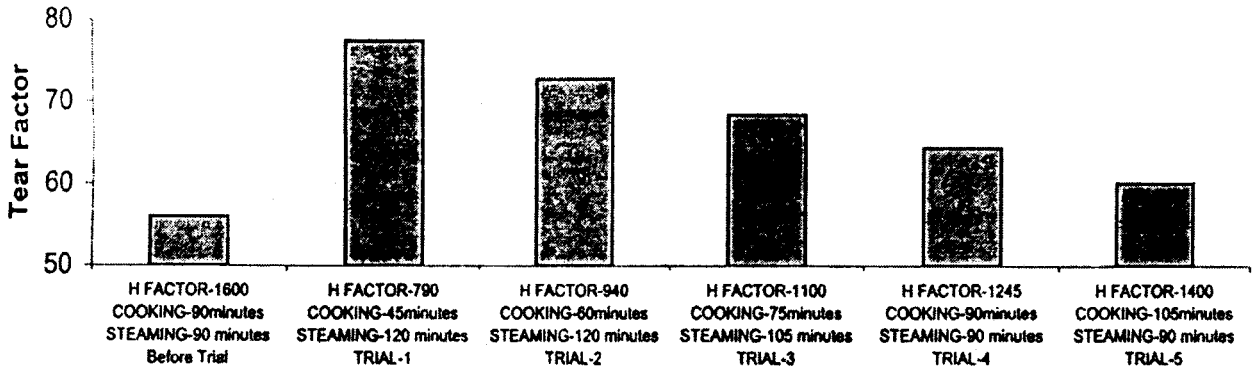

Fig. 13 : Strength properties of Bleached pulp

preserve Yield as well as strength properties.

(3) Introduction of online brightness tester in the chlorination stage, helps to improve the quality of chlorinated pulp due to controlled chlorination

(4) Among the various trials, Trial II, cooking at 165°C with steaming time of 120 minutes, cook time of 60 minutes and H Factor 940 produces pulp of high yield, good strength properties and satisfactory cleanliness. Followed by Trial III cooking at temperature of 165°C with steaming time of 105 minutes, cooking time of 75 minutes and H Factor 1100 also produces pulp of high yield, good strength properties and better cleanliness.

Restrict of the constraints like reblow, blow delays in the hardwood street have improved the plant performance on a continuous basis. Capacity of hardwood street has been stepped up from 72 Tonnes per day to 120 Tonnes per day by introduction of process automation. In spite of conventional CEPHH bleaching, the pulp quality improved substantially to meet the paper machine demand.

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