Mixed Pulping of Bamboo and Hardwoods

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This study was undertaken to work out the possibility of cooking bamboo and mixed hardwood chips together. These two raw materials are widely different in their physical as well as chemical characteristics. The bamboo chips are readily pulpable whereas the hardwood chips are dense dark contain more extractives and require more drastic pulping conditions. Thus in the pulping of mixed hardwood chips more surface is to be exposed to the pulping chemicals so as to get a clean uniform pulp. This was achieved by suitably controlling the size of the mixed hardwood chips, i.e. rejecting the +22 mm and above fractions. The normal mill size bamboo chips (−37 +3 mm) were used along with mixed hardwood chips of this particular size in 70 : 30 ratio for the mixed pulping experiments.

In the first instence separate pulping studies were carried out to find out the conditions which would be neither too drastic for the bamboo chips nor too mild to the mixed hardwood chips. This pulping condition was utilized for the mixed pulping. It was found that the bamboo and mixed hardwood pulps produced under the similar pulping conditions were at two different Kappa Numbers, the former at a lower and the latter at higher value. This characteristic was actually useful because of the fact that the bleach requirements of the bamboo pulp is higher than that of the mixed hardwood pulp at the same Kappa Number level. Hence a lower Kappa Number bamboo pulp and the higher Kappa Number mixed hardwood pulp suited well for the mixed bleaching. The pulp obtained from the mixed cooking was having a Kappa Number in between that of the bamboo and mixed hardwood pulp Kappa Numbers and showed good response to bleaching. It was also found that in the digester, the bamboo, mixed hardwoods and the mixed pulps were at three different Kappa Number levels similar to those obtained in the separate pulping experiments under identical conditions. The strength properties of the mixed pulps were quite comparable to those of bamboo and mixed hardwood pulps. The granulation characteristics of the black liquor obtained in the mixed cook was slightly shifted to a higher black liquor total solids range compared to the granulation of mixed hardwood black liquor alone.

Introduction

The conventional raw material for the pulp and paper industry in India is chiefly bamboo, belonging to the grass family. As the paper industry progressed more and more, the shortage of this important raw material was felt. Naturally the paper industry had to go for other raw materials like hardwoods, agricultural residues e.g. straws, bagasse etc. along with bamboo to makeup the shortages. There are certain small mills which use agricultural residues, but for a large mill which is mainly based on bamboo, the agricultural residues cannot be a solution because of the process difficulties. The solution was to use the local hardwoods, to the maximum possible extent.

It is not possible to get a single species of hardwood in a particular region of a forest as so many different species of hardwoods are available mixed together. Hence, it is seldom possible to supply purely one variety or the other of the hardwood. Now, the logical way left is to go in for the mixed hardwoods. Even-though these hardwoods vary among themselves in basic densities, physical and chemical

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characteristics, and in the same species depending on age and other conditions, one has to use them in a heterogeneous mixture because of the segregation difficulties. Commercial pulping of these varieties of hardwoods poses some complex problem. Some of these woods are very dense and, hence, are difficult to chip and cook. Some hardwoods give very low pulp yields, while pulp of some varieties are difficult to bleach. Also the strength properties of the pulps of some hardwoods are very poor. On the basis of all these factors some of the readily available hardwoods have been graded into different groups[1]. On a broader classification these can be put into two categories namely aceptable and non-acceptable woods. Leaving aside those which fall under the second category the rest of the hardwoods can be combined and used as acceptable mixed hardwoods. The proportion of the individual woods in the mixture will vary depending on their availability. In the second category fall some of the woods like Jamba *(Xylia xylocarpa)*, Matti *(Terminalia tomentosa)* and Kindal *(Terminalia paniculata)*. These woods are quite dense, require more pulping chemicals, give low yield and the pulps will be very dark, shivy and poor in strength properties[2]. Exclusion of these three local hardwoods seems to be essential to get acceptable quality pulp. The mixed hardwoods used in the present study were the North Kanara hardwoods which consisted of Nandi (*Lagerstroemia lanceolata*) Heddi *(Adina cardifolia)* Kalam *(Mitragyna perviflora)*, Dhaman *(Grewia tiliaefolia)*, Ghoting *(Terminalia belerica)*, Bhendi (*Kydia calycina*), Dindal (*Anogeissus latifolia*), Teak *(Tectona grandis)*.

In the utilization of these hardwoods along with bamboo, the point of immediate consideration would be whether to pulp them separately or mixed pulping would be adopted by using suitable proportion of hardwoods. Because of their inherent difference the usual practice would be pulping bamboo and mixed hardwoods separately and processing them in two different streets. The final pulps could be blended in suitable proportions and mixed bleaching could be adopted. The second alternative would be pulping them together which require only one street for processing right from the chip silo. From an economic point of view the second alternative would be better suited than the first. The present study deals with mixed pulping of bamboo and hardwoods in 70 : 30 ratio which would yield the type of furnish which is being used for making unbleached and bleached varieties of papers.

Experimental

i) Bamboo and mixed hardwood chips were collected from the chip silo taking adequate care to get a representative lot. The chip classification was done in the Williams chip classifier and the results are recorded in Table No. 1.

ii) In order to study the effect of the size of the mixed hardwood chips on rejects percentage some pulping experiments were carried out. These experiments were done in autoclave digesters fitted

Table No. I

Distribution of bamboo and Mixed Hardwood Chips

Sieve size, mm	% Retained Bamboo chips	% Retained Mixed hardwood chips
+32	5.4	12.3
−32+25	19.0	16.2
−25+22	11.7	9.6
−22+19	13.2	11.1
−19+16	18.9	12.2
−16+13	14.7	11.5
−13+ 6	14.2	20.4
− 6+ 3	1.6	4.6
−3	1.3	2.1

horizontally to the vertically rotating cradle, immersed in electrically heated polyglycol bath. In the case of mixed hardwood chips, different chip fractions were used by successively removing the oversized chip fractions and in the case of bamboo chips tbe normal mill size chips were used. The pulping expeiments were carried out using 15.6% chemicals as Na_2O and 'H' factor 594. The cooking employed and the results obtained are recorded in Table No. II.

iii) In order to study the effect of 'H' factor on the pulping of bamboo and mixed hardwood chips, three cooks were carried out in each case, using 15.6% chemicals as Na_2O but using 'H' factors 640, 870 and 1100. For this study, the normal mill size bamboo chips were used but for the mixed hardwood chips size selected was $-22 +3$ mm. The pulping conditions and the results are recorded in Table No. III. These pulps were bleached using CEHH sequence to $80 \pm 1\%$ brightness. The bleaching conditions and results are recorded in Table No. IV.

iv) To optimize the pulping conditions for the mixed cooking of bamboo and mixed hardwood chips, some separate pulping experiments of bamboo and mixed hardwood chips ($-22 +3$ mm size) were carried out in rotary digesters having indirect electrical heating arrangement. The conditions adopted were similar to those used in the pulping experiments in the autoclave rotary digester i.e. 15.6% chemicals as Na_2O and 'H' factor of 1100. Since the hardwood pulp obtained was not satisfactory, further experiments were done using 18.0% chemicals as Na_2O and 1100 'H' factor. Separate coooking of bamboo chips as well as mixed hardwoo dchips ($-22+$ 3 mm size) and mixed cook of these two in 70 : 30 ratio were carried out. The pulping data and the results are recorded in Table No. V. These pulps were found to be suitable for the purpose and were bleached by the conventional bleaching method using CEHH sequence to $80 \pm 1\%$ brightness. The bleaching conditions and the results are recorded in Table No. VI.

v) The bleached pulps of bamboo and mixed hardwoods were beaten in the Laboratory Valley Beater to four different slowness levels and standard handsheets were prepared on the British Sheetmaking Machine. These were tested for the Strength properties and the data are recorded in Table No. VII. The unbleached and bleached pulps obtained from the mixed cooking of 70% bamboo and 30% mixed hardwoods chips were also beaten to four freeness levels and standard handsheets were prepared on the British Sheetmaking Machine. These handsheets were tested for the strength properties and the results are recorded in Table No. VIII.

vi) The unbleached and bleached pulps obtained from bamboo, mixed hardwoods and from the mixture of 70% bamboo and 30% mixed hardwoods were subjected to Bauer McNett Fibre Classification and the results are recorded in Table No. IX.

vii) The black liquors obtained in the separate cooking of bamboo and mixed hardwood chips as well as that obtained from the mixed cooking of 70% bamboo and 30% mixed hardwoods; were utilized to determine the solids content as well as to study their granulation characteristics. These liquors diluted to 17° Tw at 82°C. to simulate the plant conditions. The granulation characteristics were studied in the Rotary Vacuum Flash Evaporator using 0.4 mm Hg vacuum. In order to have comparative study the bamboo and mixed hardwood liquors were mixed in 70 : 30 ratio on the basis of the black liquor solids, and the granulation characteristics of the resultant liquor was also studied. All these data are recorded in Table No. X.

Table No. II

Effect of chip size on pulping

Particulars	Bamboo chips mill size −37+3	Mixed hardwood chip size, mm					
		Mill size −32+3	−32+3	−25+3	−22+3	−19+3	−16+3
Oversize chips removed, %	Nil	Nil	12.3	28.5	38.1	49.2	61.4
Chemicals (as Na_2O), %	15.6	15.6	15.6	15.6	15.6	15.6	15.6
Chips : Liquor* ratio	1:3	1:3	1:3	1:3	1:3	1:3	1:3
Cooking schedule :							
70°C to 120°C., Min.	45	45	45	45	45	45	45
At 120°C., Min.	45	45	45	45	45	45	45
120°C to 165°C., Min.	45	45	45	45	45	45	45
At 165°C., Min.	45	45	45	45	45	45	45
"H" Factor	594	594	594	594	594	594	594
Unbleached screened pulp yield, %	52.3	41.7	43.2	44.6	45.6	46.8	47.4
Rejects, %	1.8	6.0	4.9	3.4	2.3	1.7	0.3
Kappa Number	30.4	46.1	49.2	46.5	46.5	48.3	45.8
Black liquor at 17° Tw at 80°C. pH	10.7	10.4	10.5	10.6	10.5	10.5	10.4
R.A.A. as Na_2O, gpl	10.4	6.5	7.4	7.8	7.6	7.0	7.0

*Water was used as a diluent

Table No. III

Effect of "H" factor on Bamboo and Mixed Hardwood Pulping

Particulars	Cook Nos.	Bamboo chips*			Mixed hardwood chips**		
		1	2	3	1	2	3
Chemicals as Na_2O, %		15.6	15.6	15.6	15.6	15.6	15.6
Chips : Liquor* ratio		1:3	1:3	1:3	1:3	1:3	1:3
Cooking schedule							
70°C to 120°C., Min.		45	45	45	45	45	45
At 120°C., Min.		45	45	45	45	45	45
120°C to 170°C. Min.		45	45	45	45	45	45
At 170°C., Min.		30	45	60	30	45	60
"H" factor		640	870	1100	640	870	1100
Results							
Unbleached pulp yield, %		50.1	49.8	49.7	47.4	45.5	45.0
Rejects, %		2.5	2.1	1.7	1.7	1.5	1.2
Kappa Number		31.3	28.6	26.4	56.8	41.8	36.2
Black Liquor at 17° Tw at 80°C. pH		10.7	10.6	10.5	10.5	10.4	10.4
R.A.A. as Na_2O, gpl		9.5	8.5	8.1	7.4	6.5	5.9

* Chips size −37+3 mm

** ,, ,, −22+3 mm

\+ Water was used as a diluent

Table No. IV Bleaching of Bamboo anp Mixed hardwood Pulps

Particulars	Bamboo pulps			Mixed hardwood pulps		
	1	2	3	1	2	3
Kappa Number	31.3	28.6	26.4	56.8	41.3	36.2
Chlorination Stage						
Chlorine added, %	7.8	7.3	7.0	9.5	7.2	6.3
Chlorine consumed, %	7.3	6.68	6.26	9.46	7.14	6.26
Alkali Extraction Stage						
NaOH added, %	2.0	2.0	2.0	3.0	2.0	2.0
Initial pH	9.5	10.2	10.2	10.0	9.8	10.0
Final pH	8.8	9.6	9.9	9.2	8.8	9.5
Hypochlorite treatmeut Ist Stage						
Hypo added as av. Cl_2, %	2.4	2.0	1.75	4.0	2.5	2.0
Final pH	6.6	6.5	7.0	6.8	6.3	6.5
Hypo consumed, %	2.2	1.8	1.49	3.7	2.34	1.86
Hypochlorite treatment IInd Stage						
Hypo added as av. Cl_2, %	0.5	0.6	0.75	1 0	1.0	1.0
Hypo consumed, %	0.36	0.34	0.46	0.56	0.58	0.56
Final pH	6.9	7.2	7.1	7.3	7.4	7.5
Total chlorine added. %	10.7	9.9	9.5	14.5	10.7	9.3
Total chlorine consumed, %	9.9	8.8	8.2	13.7	10.1	8.7
Shrinkage during bleaching, %	8.0	7.5	7.0	9.6	6.5	5.0
Bleached pulp yield, % (on raw material)	46.1	46.1	46.2	42.8	42.5	42.7
Pulp Brightness, % (Elrepho)	79.0	79.1	80.4	81.1	79.8	79.0
Viscosity, 0.5% CED at 25°C., cp.	15.3	15.8	13.4	14.4	13.9	14.5
Bleaching Conditions						
Stages		C	E	H	H	
Consistency, %		3	5	5	5	
Time, Min.		60	60	60	90	
Temperature, °C.		Ambient	55+2	45	45	
Sulphamic acid on pulp, %		—	—	0.07	0.07	

Table No. V

Pulping conditions and results for Bamboo and Mixed hardwood chips

Particulars	Bamboo chips Normal size		Mixed hardwood chips—22+3 mm size		70% Bamboo +30% Mixed hardwood
	Ro—3	Ro—5	Ro—2	Ro—4	(—22+3) Ro—7
Chemicals as Na_2O, %	15.6	18.0	15.6	18.0	18.0
Chips ; Liquor ratio*	1:2.7	1:2.7	1:2.7	1:2.7	1:2.7
Cooking schedule					
70°C to 120°C., Min.	45	45	45	45	45
At 120°C , Min.	45	45	45	45	45
120°C. to 170°C., Min.	45	45	45	45	45
At 170°C., Min.	60	60	60	60	60
"H" factor	1100	1100	1100	1100	1100
Results :					
Unbleached screened pulp yield, %	50.8	50.0	46.3	43.7	47.1
Rejects, %	1.6	1.0	0.8	0.5	1.0
Kappa Number	27.4	21.1	41.5	31.2	24.9
Black Liquor at 17°Tw at 80°C. pH	10.7	10.9	10.3	10.5	10.7
R.A.A. as Na_2O, gpl	9.5	10.9	5.3	8.4	9.9

*Water was used as a diluent
Ro refer to—Laboratory Rotary Digester Cook Numbers.

Table No. VI

Conventional Bleaching data of pulps of Bamboo, Mixed hardwoods and the Mixed pulps

Particulars / Pulps	Mixed hard-woods Ro—4	Bamboo Ro—5	70% Ro—5 + 30% Ro—4	Mixed cook of 70% Bamboo + 30% Mixed hardwoods Ro—7
Kappa Number of the pulp	31.2	21.1	—	24.9
Chlorination Stage				
Chlorine added, %	5.7	5.7	5.7	5.7
Chlorine consumed, %	5.65	4.7	5.32	5.22
Alkali Extraction Stage				
NaOH added, %	1.5	1.5	1.5	1.5
Initial pH	10.3	10.6	10.7	10.3
Final pH	9.0	9.8	9.7	9.4
Pulp brightness, %	30.1	29.9	29.9	31.8
Kappa Number	8.8	7.2	7.2	6.9
Hypochlorite treatment 1st Stage				
Hypo added as av. Cl_2, %	2.5	2.25	2.5	2.5
Final pH	6.6	6.7	7.3	7.4
Hypo consumed, %	2.24	1.97	2.02	1.90
Pulp brightness, %	73.9	76.3	77.2	75.5
Hypochlorite treatment IInd stage				
Hypo added as av. Cl_2, %	0.75	0.75	0.75	0.75
Final pH	7.6	7.8	7.8	8.0
Hypo consumed, %	0.36	0.33	0.36	0.26
Total chlorine added, %	8.95	8.70	8.95	8.95
Total chlorine consumed, %	8.25	7.00	7.70	7.38
Shrinkage during bleaching, %	8.6	7.0	7.0	6.4
Bleached pulp yield on raw material basis, %	39.9	46.5	—	44.1
Brightness of bleached pulp, %	79.8	79.7	80.0	80.5
Viscosity (CED), cp.	10.3	10.4	9.8	11.5
Bleaching conditions :				
Stages	C	E	H	H
Consistency, %	3	5	5	5
Temperature, °C.	Amb.	55±2	45	45
Time, Min.	60	60	60	90
Sulphamic acid on pulp, %	Nil	Nil	0.07	0.07

TABLE VII

Strength Properties of Bleached Pulp of Bamboo and Mixed hardwoods

Properties	Ro-4 Mixed hardwood Bleached pulp				Ro-5 Bamboo Bleached pulp			
Initial slowness, °SR	16.0	—	—	—	15.0	—	—	—
Beating time, Min.	2.0	12.0	16.0	21.5	3.5	10.0	12.5	16.5
Final slowness, °SR	20.0	30.0	39.0	50.0	20.0	31.0	40.0	50.5
Drainage time, (700 ml) Sec.	8.5	21.9	31.7	57.6	8.5	23.6	35.7	58.7
Basis wt., g/m²	58.1	60.0	59.4	59.5	59.8	59.1	61.5	60.7
Thickness, microns	110	97	93	91	110	98	95	93
Bulk, cm³/g	1.89	1.62	1.56	1.53	1.84	1.66	1.54	1.53
Breaking length, km	4.24	6.29	6.63	7.26	4.66	6.30	6.44	6.85
Stretch, %	1.9	2.6	2.7	3.0	2.0	2.3	2.4	2.5
TEA, J/m²	33.0	70.9	71.3	87.2	33.8	54.3	58.3	71.3
Double folds (MIT)	7	33	56	151	10	43	50	84
Burst factor	28.9	47.2	50.7	57.0	34.8	46.2	47.7	47.9
Tear factor	85.3	80.0	78.2	70.6	93.6	76.5	74.2	65.9
Air Porosity, Bendtsen, ml/min.	73000	940	400	170	73000	1100	640	195
Scattering Coefficient, cm²/g	463	414	379	373	351	349	325	315
Opacity, %	83.3	82.3	81.6	81.8	77.6	76.6	77.6	78.4
Strength Index	1276	1790	1900	2060	1480	1790	1815	1820

Ro refer to—Laboratory Rotary Digester Cook Numbers.

TABLE VIII

Strength Properties of Unbleached & Bleached Pulp of the Mixed Pulp from Bamboo and Mixed hardwoods

Particulars	Ro-7 Mixed Pulp from 70% Bamboo + 30% Mixed hardwoods Unbleached Pulp				Bleached Pulp			
Initial slowness, °SR	14	—	—	—	15	—	—	—
Beating time, Min.	5.5	12.5	16.0	18.5	3.0	12.0	15.5	18.0
Final slowness, °SR	21.0	31.0	40.5	50.0	20.0	32.0	40.0	51.0
Drainage time, (700 ml) Sec.	9.9	22.4	38.5	57.5	8.9	23.8	37.7	57.2
Basis wt., g/m²	58.2	59.5	59.6	59.2	60.9	61.4	59.5	60.4
Thickness, microns	108	102	98	95	107	95	89	88
Bulk, cm³/g	1.82	1.72	1.64	1.60	1.76	1.55	1.50	1.46
Breaking length, km	5.62	6.71	7.56	7.65	5.41	6.82	7.32	7.78
Stretch, %	2.4	2.6	2.9	2.9	2.5	2.5	2.6	2.9
TEA, J/m²	50.6	66.1	82.2	80.6	48.8	63.2	67.4	81.2
Double foldss (MIT)	26	61	101	111	18	91	103	141
Burst factor	42.1	51.7	55.2	58.7	40.8	52.3	53.8	56.5
Tear factor	100	92.8	85.9	83.1	97.9	80.8	72.6	68.2
Air porosity Bendtsen, ml/min.	2850	1100	385	290	73000	435	250	80
Scattering Coefficient, cm²/g	—	—	—	—	362	331	313	313
Opacity, %	—	—	—	—	80.4	78.3	78.0	78.7
Strength Index	1810	2050	2120	2150	1710	2020	1990	2040

Ro refer to—Laboratory Rotary Digester Cook Numbers.

TABLE IX

Bauer McNett Fibre Classification of Unbleached and Bleached Pulps

Cook Nos.	Pulp	°SR	% of fibre retained on				
			Mesh +30	-30+50	-50+100	-100+150	-150
			Sieve opening mm-				
			0.595	0.297	0.149	0.105	—
Ro-4	Unbleached	15	21.8	31.3	11.1	13.4	22.4
	Bleached	16	19.8	31.8	13.0	13.0	22.4
Ro-5	Unbleached	14	52.6	12.9	2.8	4.4	27.3
	Bleached	15	51.4	12.7	2.8	6.3	26.8
Ro-7	Unbleached	14	41.9	17.4	9.7	4.7	26.3
	Bleached	15	43.2	18.4	7.0	7.0	24.4

TABLE X

Black Liquor Characteristics

Cook No.	Raw Material	Black liquor at 17°Tw at 80°C.					Granulation range % solids
		R.A.A. as Na_2O gpl	Black liquor total solids gpl	%	Organics, %	Inorganics, %	
Ro-4	Mixed hardwoods	8.4	208	18.8	66.4	33.6	33 — 36
Ro-5	Bamboo	10.9	197	17.9	63.8	36.2	No granulation upto 50% solids & above
Ro-4	70% Bamboo + 30% Mixed hardwoods	9.9	198	17.9	64.2	35.8	42 — 46
	70% Ro-5 liquor + 30% Ro-4 liquor (on the basis of T. S.)	—	—	—	—	—	40 — 45

Ro refer to—Laboratory Rotary Digester Cook Numbers.

Discussions

The chips classification data reveals that in the case of mixed hardwood chips the +32 mm fraction was 12.3% whereas that for bamboo chips it was 5.4%. This high fraction of the oversize chips suggests that chipping was not proper. Since, mixed hardwoods require severe pulping conditions the more surface area of the chips exposed to the pulping conditions the better would be the pulp quality. Hence, controlling the chip size of the mixed hardwoods is one of the decisive factors in the pulping. This would necessitate suitable modifications in the chippers and rechippers, or the development of new chippers to get the proper size chips from the hardwoods.

In the pulping of mixed hardwood chips more severe pulping conditions were required as compared to the bamboo pulping conditions. In the mixed pulping of bamboo and mixed hardwood chips, the conditions adopted should not be too severe for the bamboo chips to be overcooked resulting in a weak pulp and at the same time should not be too mild for the hardwood chips to be undercooked resulting in considerable amount of rejects. Hence, in the mixed pulping of bamboo and hardwood chips the critical factor was the size of the hardwood chips. This can be seen in the result of the experiments carried out using different chip size fractions of mixed hardwoods along with the normal mill bamboo chips. It is seen from Table No. II, that the rejects varied from 0.3 to 6.0 percent as the mixed hardwoods chip size varied from −16 +3 mm fraction to the normal mill size chips. The rejects obtained using the normal mill size bamboo chips was 1.8 percent. This suggested that to suitably control the rejects content and to get clean in the mixed pulping of bamboo and mixed hardwoods controlling the chip size of the mixed hardwoods was an essential. The results showed that the mixed hardwood chip size of −19 +3 mm compared well with the normal mill size bamboo chips in rejects content. This would mean the removal of around 50 percent of the oversize chips and this cannot be possible unless one can afford to put a battery of rechippers or could suitably modify the chippers or install new ones which would not produce so much oversize chips and at the same time without producing excessive fines and dust. Since, the pulping conditions adopted here, were comparatively milder than the one required for the mixed hardwood pulping, the chip fraction of −22 +3 mm size was selected for further work. This gave a rejects content of 2.3 percent and the selection of this fraction would mean the removal of significant fraction i.e., in this case 38 percent of oversize chips. Selection of still higher size chips would result in more rejects as well as in unclean and shivy pulp.

The results in Table No. II clearly show that the Kappa Numbers of the pulps produced using different chip size fractions of hardwoods under similar pulping conditions, were nearly the same. These pulps were at higher Kappa Number value compared to that of the bamboo pulp Kappa Number, produced under similar pulping conditions.

The pulps produced in the previous experiments were at considerably higher Kappa Number values and resultant pulps were shivy. This necessiated the study of the effect of 'H' factor on the Kappa Number of bamboo mixed hardwood pulps. and The experiments carried out using 15.6 percent active alkali as Na_2O and at three different 'H' factor values of 640, 870 and 1100 using bamboo and mixed hardwood chips separately gave signifact reduction in the Kappa Number of mixed hardwood pulps. The Kappa Number dropped down from 57 to 36 in the case of mixed hardwood pulps whereas it reduced from 31.3 to 26.4 in the case of bamboo pulp under similar pulping conditions (Table No. III). The results clearly indicated that the 'H' factors below 1100 were not suitable as this would result in higher Kappa Number of mixed hardwood pulps and the pulps would be shivy & not clean.

The results of Table No. III indicate that under similar pulping conditions the mixed hardwood pulp was at comparatively higher Kappa Number than that of bamboo pulp. This was a favourable

point because of the fact that the bleach demand of hardwood pulp was comparatively less than that of the same Kappa Number bamboo pulp. It would mean that a higher Kappa Number mixed hardwood pulp would require the same amount of bleaching chemicals as that of the lower Kappa Number bamboo pulp, if properly selected. The total chlorine demand of mixed hardwoods pulp is nearly $\frac{1}{4}$th of its Kappa Number whereas for that of bamboo pulp it is about 1/3rd its Kappa Number as chlorine to get a pulp brightness of about 80% brightness[3]. The above six pulps bleached by using CEHH sequence to $80 \pm 1\%$ pulp brightness showed that the bleach demand for 31.3 Kappa Number bamboo pulp was nearly the same as that for 41.3 Kappa Number mixed hardwood pulp. The bleach demands for 28.6 Kappa Number bamboo pulp and for 36.2 Kappa Number mixed hardwood pulps were nearly the same.

Encourged with the small scale experiments further pulping studies were conducted in the laboratory rotary digester using 2 Kg chips on O.D. basis. The conditions used were the same i.e., 15.6% active alkali as Na_2O and 1100 'H' factor. The bamboo and mixed hardwood pulps produced were having 27.4 and 41.5 Kappa Numbers respectively. These values were slightly higher than those obtained in the autoclave bomb cook experiments. The amount of active alkali used were not sufficient to properly regulate the delignification to yield satisfactory pulps. This problem was overcome by increasing the chemicals to 18 percent as Na_2O and using similar pulping conditions. The bamboo and mixed hardwood chips separately pulped gave pulps of Kappa Numbers 21.1 and 31.2 respectively (Table No. IV). It was found that the bamboo pulp of 21.1 Kappa Number consumed 7% of total chlorine whereas the mixed hardwood pulp of 31.2 Kappa Number consumed 8.3 percent of total chlorine to get a brightness of about 80 percent. It was also found that the Kappa Numbers of bamboo as well as the mixed hardwood pulps after the alkali extraction stage were 7.2 and 8.8 respectively. The total amount of chlorine applied in both the cases was nearly the same in the chlorination stages.

The pulping condition adopted (Table No. V) indicated that the two pulps obtained viz., bamboo and mixed hardwoods were at two different Kappa Numbers and their total bleached consumption was also different. Since, in the bleaching studies, the Kappa Number of the alkali extracted pulp of mixed hardwoods was found to be higher than that of the alkali extracted bamboo pulp it was felt that part of the excess residual chlorine remaining in the chlorination stage of the bamboo pulp would be utilized by the hardwood pulp in the mixed pulp bleaching. This was actually verified when 70 percent bamboo pulp of 21.1 Kappa Number and 30 percent mixed hardwood pulp of 31.2 Kappa Number were blended and bleached under identical conditions (Table No. V). The Kappa Number of the alkali extracted pulp was 7.2 in this case and the bleach consumption was 7.7% out of 8.95% total chlorine applied. The viscosity values of the pulps of bamboo, mixed hardwood and the 70 : 30 blend of these two were 10.4, 10.3 and 9.8 cp (CED) respectively, at 80% brightness which showed that these pulps can be blended together without adverse effects.

The mixed pulp obtained from 70 percent bamboo and 30 percent mixed hardwoods using 18 percent cooking chemicals as Na_2O and 1100 'H' factor had a 24.9 Kappa Number and 47.1 % screened pulp yield. Both these values were in between those of the corresponding values for bamboo and mixed hardwood pulps. This mixed pulp when bleached with CEHH sequence to 80.5 percent brightness consumed 7.4 percent total chlorine out of 8.95 percent applied. The viscosity of this pulp was 11.5 cp (CED). The bleached pulp yields on raw material basis of bamboo, mixed hardwoods and the mixed pulps were 46.5, 39.9 and 44.1 percent respectively.

It was quite logical to think whether in the mixed pulp produced

both the bamboo and mixed hardwood pulp fibres were having 24.9 Kappa Number or they were having 21 and 31 Kappa Numbers respectively, as was obtained under similar pulping conditions in the separate pulping (Table No. V). A pulping experiment was conducted using bamboo and mixed hardwood chips in 70 : 30 ratio and also some bamboo and mixed hardwood chips were kept separately in stainless steel wire cages of cylindrical shape. The Kappa Numbers of the pulps of bamboo, mixed hardwood and mixed pulps were 22.4, 34.5 and 26.4 respectively. This conclusively proved that bamboo and the mixed hardwood pulp fibres were at different Kappa Number values in the mixed pulp.

The beating and drainage properties of the bleached pulps of bamboo, mixed hardwoods and the mixed pulps were quite comparable. The strength properties like breaking length, burst factor and tear factor were also similar in all the three cases. The scattering coefficient and opacity values of the mixed hardwood pulps were higher compared to the bamboo pulp or the mixed pulp values. In the latter two cases these properties were quite comparable. The Strength Index value of the mixed hardwood pulp at the initial slowness was comparatively less than either of the bamboo pulp or the mixed pulp value. At higher slowness values the Strength Index values of all these there pulps were comparable.

The strength properties of the unbleached and bleached mixed pulps were quite comparable except in tear factor. The tear factors of the unbleached pulps were slightly higher than those of the bleached pulps at the same slowness values.

The fibre classification data gave a + 30 fraction of 51.4% for the bleached bamboo pulp and 19.8% for the mixed hardwood bleached pulp. The-150 fractions of these two pulps were 26.8% and 22.4% respectively. The mixed pulp contained a + 30 fraction of 43.2% and - 150 fraction of 24.4% and the overall distribution was normal.

The hardwood black liquor usually shows the granulation tendency in the black liquor at a solids content of about 30-35 percent. This could result in the plugging of the evaporator tubes and difficulties encountered in the Chemical Recovery Plant. The mixed hardwood black liquor obtained showed granules at the solids range of 33 - 36 percent whereas the bamboo black liquor did not show at the solids range of 50% and above. The mixed black liquor obtained of hardwood and bamboo black liquors showed granulation at 42 - 46% solids. A black liquor prepared by mixing 70% of bamboo black liquor and 30% of mixed hardwood black liquor on the basis of the black liquor solids; also granulated at 40 - 45% solids. This showed that there was no difference in the black liquor that was obtained by the mixed cook or the one that was prepared by separate mixing in the same ratio. The results showed that the granulation tendency of the mixed cook liquor shifted to a higher solids range compared to the mixed hardwood black liquor.

Conclusions :

i) For mixed pulping of bamboo and mixed hardwoods, the chip size of the latter should be suitably controlled to get satisfactory pulp with minimum of rejects content. In the present laboratory work the chip size for mixed hardwood selected and found acceptable was -22+3 mm and the bamboo chips size -37+3 mm was accepted.

ii) The two pulps produced from the bamboo and the mixed hardwoods chips, under similar pulping conditions, were at two different Kappa Number values. The hardwood pulp had a higher Kappa Number and the bamboo pulp a lower one. This was also found to be the case in the mixed pulp, obtained from mixed pulping of bamboo and hardwoods.

iii) The chlorine requirement of the bamboo pulp was found to be more than that of the mixed hardwood pulp of the same Kappa Number. Hence,

the higher Kappa Number of the mixed hardwood pulp and the lower Kappa Number of the bamboo pulp (as obtained in the mixed cooking) suited well in the subsequent bleaching operations.

iv) The strength properties of the individual pulps of bamboo, mixed hardwoods and the mixed pulps were comparable and were satisfactory. Moreover, the viscosities of these individual as well as mixed pulps were not much different.

v) The granulation tendency of black liquor obtained in the mixed cook of 70 percent bamboo and 30 percent mixed hardwood had shifted to a comparatively higher total solids range.

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