High yield semi-chemical pulping of mixture of bamboo and mixed hardwoods

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SUMMARY

The solution to the increasing cost of fibrous raw material and increasing demand of papet is the semi-chemical pulping methods for obtaining higher yields with suitable quality of pulps. In the present paper the semi-chemical pulping has been tried using kraft liquor, green liquor and neutral sulphite liquors. The unbleached pulps were evaluated and their bleaching characteristics have been studied. These pulps have been bleached by multi-stage bleaching and evaluated at different beatings intervals. Blends of these bleached pulps with bleached mill pulps have been prepared in different proportions and evaluated for strength properties. It can be concluded that the strength properties and brightness of the mixed furnish can yield paper for common cultural purposes like school copies and cheap grade magazines.

Paper industry have tremendously increased in India in the last 20-30 years. At present the total paper production capacity in India is about 12.35 lakhs tonnes as against the installed capacity of 18-16 lakhs tonnes which will be increased to 22 lakh tonnes by 1986, 28 lakhs tonnes by 1991 aad 42.5 lakhs tonnes[1] at the end of this century. To fulfil this requirement lot of cellulosic raw material will be required whereas our forest (the main resources of raw material) is limited and it is decreasing day by day. The paper maker's are aware of this from longback and hence efforts have been made from time to time to develop some new sources of fibrous raw material as well as new methods of pulping so that more paper may be obtained from the same amount of raw material.

Bamboo is the main raw material for Indian Paper Industry. New Bamboo areas even at high cost are being trapped. Looking the future shortage of this valuable raw material more and more of hardwoods and many short rotation plants like agricultural residues, some variety of grasses and Bagasse, Gunny bags, Jute stick etc. are being used these days to meet the growing demand.

The semi-chemical process, which was first developed by United States Forest Product Laboratory, Madison in 1926[2], is now being gradually adopted in other countries in order to conserve the fibrous resources, to bring down the cost of production and to make the paper product more competitive with other materials.

The primary objective in the development of semi-chemical process was not only to utilise hardwoods to obtain higher yield of usable pulp than could be obtained by the conventional pulping process, but also to counteract the steadily increasing raw material cost. Semi-chemical pulping is a two stage process involving chemical treatment of wood chips to obtain a softening and partial removal of ligni-cellulosic bonding material followed by mechanical treatment to complete the fiber separation.

This process is attractive economically because of the high yield attainable, low chemical consumption and because the process lends itself to small units and a minimum of plant investment[2]. In this case because the action of cooking liquor and bleaching agents is directly selectively on the lignin,

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bleached hardwood pulp could be obtained in higher yields also. It also produces a stronger pulp than could be obtained by fully chemical cooking, when the hardwoods species are used. Unbleached semi-chemical pulps at present are used for making corrugating board, speciality board. Newsprint and wrapping papers and may have possibilities of being used as liner and towelling[3,4]. The bleached semi-chemical pulps at present are being used for making Books, Magazines (coated and uncoated) Bond, Writing, Glassine, Grease-proof paper, Food board, Speciality and may have possibilities of being used as waxing carbonizing and towelling tissue etc.[3,4].

Literature survey revealed that some valuable work has been done on high yield pulping. Jauhri, Jaspal and Bhargava[5] used Sulphate Semi-chemical process to produce high yield pulp from Dendrocalmus strictus. Nicolas[6] used the cold soda pulping for Phillippine Bamboo to obtain high yield pulp. Beckker and Caldwell[7] used neutral sulphite-semi-chemical pulping for corrugating medium. A comparative study of neutral sulphite and green liquor semi-chemical pulping for corrugating medium has been done by Raymond[8]. Michael[9] conducted N.S.S.C. pulping of young European black alder, Yuichiro and Yuiko[10] prepared high yield pulp containing no fiber bundles. Worster and Mc Candless[11] prepared semi-chemical pulp using kraft green liquor. Agrawal and Singh[12] prepared semi-chemical pulp from a mixture of hardwoods using neutral sulphite semi-chemical process and sulphate semi-chemical process. Guha, Singh, and Grover[3] used sulphate and neutral sulphite semi-chemical process to produce high yield pulp from a mixture of Maharastra hardwoods.

With these ends in view and to increae the yield, investigation were undertaken to find the suitability of mill chips (comprising of 60-70% Bamboo and 30-40% mixed hardwooods) for the production of semi-chemical pulp using sulphate semi-chemical, green liquor semi-chemical and nentral sulphite semi-chemical processes. The study also includes to find out the suitability of bleached semi-chemical pulp for the production of bleached grade writing and printing paper after blending with bleached chemical mill pulp.

RAW MATERIAL :

Chips were collected from the Silo conveyor belt of the chipper house section of our mill. Chips comprised of 60-70% bamboo and 30-40% mixed hardwoods like sal, salai tec. These were air dried before starting the pulping experiments.

EXPERIMENTAL AND RESULTS

The chips were processed by sulphate semi-chemical process, kraft green liquor process and neutral sulphite semi-chemical process.

A. Sulphate Semi-Chemical Process :

Trials were carried out by the sulphate process in a stationary forced circulation type electrically heated autoclave of 30 liter capacity. 2.5 Kg O.D. chips were taken in each digestion. The material to liquor ratio was kept as 1 : 4. The chemical percentage was kept as 5, 8 & 11% as Na_2O. The time of the digestion was 3½ hrs. (including 3 hrs. to rise to 170°C). The softened chips were washed and refined in the Sprout Waldron disc refiner using plate no. D_2 A-501. The power consumption during refining was determined. The unbleached pulp yield and permanganate number of the pulp were also determined. The spent liquor was collected and analysed for R.A.A. Tweddle, pH and calorific value of the liquor was also determined. The digestion and refining condition, pulp yield, permanganate number and black liquor analysis are recorded in Table-1A.

The pulp obtained (of cook No. 3) was beaten in laboratory valley beater to a freeness of 25, 35, 45 and 55°SR and standard sheets were made and tested for their strength properties according to Tappi standards. The results are recorded in Table-2A.

The pulp of the cook no 3 was bleached by conventional multi-stage bleaching under C/E/C/E H sequence. Bleached yield of the pulp, brightness, copper number, viscosity, post color number of the pulp were determined. Bleaching condition, bleached yield, brightness, copper number, viscosity and post colour number are recorded in Table-3.

The fiber classification of bleached pulp was carried out in Bauer Mc Nett fiber classifier. Results are recorded in Table 4.

The bleached pulp was beaten in laboratory valley beater to a freeness of 25, 35, 45 and 55°SR and evaluated for strength properties. Results are recorded in Table-5.

Bleached semi-chemical pulp (beaten to 45°SR) was blended in different proportions with mill bleached chemical pulp (beaten to 45°SR) and the blends were evaluated for strength properties. The strength value of the blends are given in Table-6.

B. Kraft Green Liquor—Semi-chemical Process :

Pulping trials were also carried out using kraft green liquor in similar manner as in A. The total

TABLE – 1 A. SULPHATE SEMI-CHEMICAL PULPING OF MILL CHIPS.

S No.	Particulars	Cook No. 1	Cook No. 2	Cook No. 3
1.	Wt. of chips taken in Kg (OD basis)	2.5	2.5	2.5
2.	Chemical applied* (% as Na_2O)	5	8	11
3.	Bath Ratio	1:4	1:4	1:4
4.	Cooking schedule			
	(i) to raise 170°C	180 mts.	180 mts.	180 mts.
	(ii) at 170°C	30 ,,	30 ,,	30 ,,
5.	Refiner Clearance (micron)			
	(i)	2540	2540	2540
	(ii)	762	762	762
	(iii)	127	127	—
	(iv)	0	—	0
	(v)	0	—	—
6.	Power consumption during refining (Kwh/tonne)	380	240	100
7.	K. No. (40ml)	36.08	35.58	34.08
8.	Total yield (%)	75.44	65.71	55.13
9.	Black liquor analysis			
	(i) °TW at 60°C	7.0	9.0	12.5
	(ii) R.A.A. as Na_2O g/l	6.20	7.75	9.30
	(iii) pH	8 4	8.95	9.65
	(iv) Calorific value Cal/g	3330	3245	3390

*(i) T.A.A.– 86.18 g/l
(ii) Sulphidity—14.14%

TABLE—1 B. GREEN LIQUOR SEMI-CHEMICAL PULPING OF MILL CHIPS

S. No.	Particulars	Cook No. 4	Cook No. 5	Cook No. 6
1.	Wt. of chips taken in Kg. (O.D. basis)	2.5	2.5	2.5
2.	Chemicals applied* (% as Na_2O)	5	8	11
3.	Bath ratio	1:4	1:4	1:4
4.	Cooking schedule			
	(i) To raise 170°C	180 mts	180 mts	180 mts
	(ii) at 170°C	30 mts	30 mts	30 mts
5.	Refiner clearance (micron)			
	(i)	2540	2540	2540
	(ii)	762	762	762
	(iii)	0	0	0
6.	Power consumption during refining (Kwh/Tonne)	240	200	120
7.	K. No. (40 ml)	36.48	36.08	34.78
8.	Total yield (%)	70.0	63.6	58.8
9.	Black-liquor analysis			
	(i) °TW	12.0	13.0	15.5
	(ii) R.A.A. as Na_2O g/l	9.30	10.85	13.95
	(iii) pH	9.35	9.70	10.0
	(iv) Calorific value, Cal/g	2800	2858	2940

*(i) T.A.A. 39.68 g/l as Na_2O

TABLE—1 C. NEUTRAL SULPHITE SEMI-CHEMICAL PULPING OF MILL CHIPS

S. No.	Particulars	Cook No. 7	Cook No. 8	Cook No. 9
1.	Wt. of chips taken in Kg (OD basis)	2.5	2.5	2.5
2.	Chemicals applied*			
	(i) as Na_2O	5	8	11
	(ii) as Na_2SO_3	10.165	16.264	22.333
3.	Bath ratio	1:4	1:4	1:4
4.	Cooking schedule			
	(i) To raise 170°C	180 mts	180 mts	180 mts
	(ii) at 170°C	30 mts	30 mts	30 mts
5.	Refiner clearance (micron)			
	(i)	2540	2540	2540
	(ii)	762	762	762
	(iii)	0	0	0
6.	Power consumption during refining (Kwh/tonne)	180	140	120
7.	K. No. (40 ml)	36.64	36.04	35.58
8.	Total yield (%)	77.60	72.08	68.60
9.	Spent liquor analysis			
	(i) °TW at 60°C	6.5	8.5	12.5
	(ii) R.A.A. as Na_2O	4.65	7.75	10.85
	(iii) pH	7.5	7.8	8.5
	(iv) Calorific value Cal/g	3470	3498	3600

*(i) Ratio of the Na_2SO_3 and Na_2CO_3 kept 7 : 1 during all experiments.
(ii) Strength of soln. 80.0 g/l as Na_2SO_3

TABLE—2 PHYSICAL STRENGTH PROPERTIES OF UNBLEACHED, SULPHATE SEMI CHEMICAL, GREEN LIQUOR SEMI CHEMICAL AND NEUTRAL SULPHITE SEMI CHEMICAL PULP BEATEN IN LABORATORY VALLEY BEATER.

Sl. No.	Particulars	Cook No. A-3				Cook No. B-6				Cook No. C-9			
1.	Initial freeness °SR	10				9				15			
2.	Final freeness, °SR	25	35	45	55	25	35	45	55	25	35	45	55
3.	Beating period, mts	22	42	50	59	15	22	28	34	11	19	24	29
4.	Caliper (micron)	97	92	87	90	99	101	101	102	110	113	115	105
5.	Bulk (cc/g)	1.58	1.52	1.45	1.46	1.69	1.65	1.64	1.64	1.78	1.75	1.72	1.68
6.	Breaking length (KM)	3.60	4.00	4.55	4.90	3.43	3.64	4.23	4.30	3.00	3.10	3.60	3 84
7.	Stretch, %	0.60	0.65	0.70	0.95	1.10	1.15	1.50	1.20	0.75	0.80	0 80	0.75
8.	Burst factor	25.9	27.3	32.8	37.3	25.6	29.7	32.5	33.8	19.5	21.6	23.9	24.8
9.	Tear factor	58.4	56.2	49.3	45.5	66.7	56.1	48.7	45.1	46.4	43.3	41.9	40.0
10.	Double fold (Nos)	45	80	160	2:0	30	55	160	170	30	35	45	55
11.	Tensile index (Nm/g)	35.29	39.21	44.61	48.03	33.62	35.68	41.47	42.15	29.41	30.39	35.29	37.64
12.	Burst index (K. pam²/g)	2.53	2.67	3.21	3.65	2.50	2.91	3.18	3.31	1.91	2.11	2.34	2 43
13.	Tear Index (m N m²/g)	5.72	5.50	4.83	4.46	6.53	5.50	4.77	4.42	4.55	4.24	4.10	3.92

TABLE—3. MULTI—STAGE BLEACHING OF SEMI-CHEMICAL PULPS IN C/E/C/E/H SEQUENCE.

S. No.	Particulars	Sulphate Semichemical pulp (Cook No. A-3)	Green liquor semi-chemical pulp (Cook No. B-5)	Neutral sulphite semichemical pulp (Cook No. C-9)
1.	**Ist Stage**			
	(i) Chlorine added (%)*	11.0	12.0	12.0
	(ii) Chlorine consumed (%)	11.0	11.94	11.95
	(iii) Consistency, %	3	3	3
	(iv) Temperature, °C	29	29	29
	(v) Retention time (mts.)	60	60	60
2.	**IInd Stage**			
	(i) NaoH added % **	2.5	2.5	2.5
	(ii) Consistency, %	5	5	5
	(iii) Temperature, °C	55	55	55
	(iv) Retention time (mts)	60	60	60
	(v) Final pH	8.1	8.2	8.2
3.	**IIIrd Stage**			
	(i) Chlorine added %*	11.0	8.0	8.0
	(ii) Chlorine consumed, %	10.91	7.74	7.93
	(iii) Consistency, %	3	3	3
	(iv) Retention time (mts.)	60	60	60
	(v) Temperature, °C	29	29	29
4.	**IVth Stage**			
	(i) NaOH added**	2.5	2.5	2.5
	(ii) Consistency	5	5	5
	(iii) Temperature, °C	55	55	55
	(iv) Retention time (mts)	60	60	60
	(v) Final pH	8.5	8.7	8 60
5.	**Vth Stage**			
	(i) Chlorine applied %***	5.0	4.0	5.0
	(ii) Chlorine consumed, %	4.67	3.82	4 83
	(iii) Consistency	5	5	5
	(iv) Temperature, °C	40	40	40
	(v) NaOH added, %	1.60	1.65	1.35
	(vi) Final pH	9.0	9.1	9 05
	(vii) Retention time (mts)	120	120	120
6.	**VIth Stage**			
	(i) Total Cl_2 Added (%)	27.0	24·0	25.0
	(ii) Total Cl_2 consumed (%)	26.58	23.50	24.71
	(iii) NaOH consumed (%)	6.60	6.65	6.35
	(iv) Brightness, % Pv	73.0	72.0	70.5
	(v) Copper No.	1.71	1.84	1.46
	(vi) Viscosity (0.5%) Cps CED	7.08	6.53	8.49
	(vii) P.C. Number	6.35	7.99	5.47
	(viii) Shrinkage, %	20.0	17.7	20.8
	(x) Yield of bleached pulp on chips, %	44.10	48.39	54.33

* Chlorine water, % expressed as available chlorine on oven dry basis of pulp.

** Caustic soda, % expressed on oven dry pulp.

*** Calcium hypochlorite, % expressed as available chlorine on oven dry pulp.

chemicals applied were as Na_2O% on total active alkali basis. As in sulphate semi-chemical process pulp obtained with 11% alkali was proceeded further. The results are recorded in table 1B, 2B, 3, 4, 5 and 7.

C. **Neutral Sulphite Semi-chemical Process** :

Pulping trials were also carried out by the N. S. S. C. process in a similar manner as in A. The ratio of sodium sulphite to sodium carbonate was kept as 7 : 1. The percentage of chemicals was calculated as Na_2O. As in sulphate semi-chemical process pulp obtained with 11% alkali was proceeded further The results are recorded in Table 1C, 2C 3, 4, 5 and 8.

DISCUSSION

Sulphate Semi-chemical Process :

It is observed in Table 1-A that power consumption decreases from 380 KWh/Tonne to 100 KWh/Tonne and the yield of the pulp decreases from 75.4 to 55.13 when the percentage of alkali is increased from 5 to 11%. With this increase in alkali, the permanganate number decreases from 36.1 to34.1 and R.A.A. increases from 6 20 to 9.30g/l. This indicates that the softening of the chips is more as the percentage of chemicals is increased as expected. The calorific value is satisfactory. Table 2 A indicates that unbleached pulp of cook no. 3 can be readily beaten upto 55°SR freeness in 59 mts. The physical strength properties of the unbleached pulp are encouraging. The tear factor of the pulp decreases with increase in °SR whereas other strength properties increase in °SR freeness. Table 3-A shows that the total chlorine requirement is 26.6% and caustic demand is 6.6% to obtain a brightness of 73% PV. The total shrinkage of the pulp during bleaching is 20%. This pulp has a satisfactory viscosity post colour number and copper number indicating that it is not degraded and has a satisfactory keeping quality.

The fiber classification of bleached pulp recorded in Table-4 A shows that the fiber percent retention on 70 mesh is maximum. From Table 5-A, it is observed that on bleaching the beating time is reduced and the physical strength properties improved considerably, this improvement in strength is due partly to the removal of lignin from the fibers and partly to the increase in specific surface which tends to increase inter fiber bonding.

The results recorded in Table-6 indicates that bleached sulphate semi-chemical pulp is of superior quality in comparision to the mill bleached chemical pulp in respect of strength properties, hence with the increase in proportions of semi-chemical pulps, the properties of blends are better than the mill pulp. The brightness of the blends decreases from 78 to 69% PV with the increase amount of bleached

TABLE—4. FIBER CLASSIFICATION OF BLEACHED SEMI-CHEMICAL PULPS.

S.No.	Mesh size	% Reten ion Sulphate semichemical bleached pulp* (A-3)	Green lipuor** semichemical bleached pulp (B-6)	Neutral*** sulphite semichemical bleached pulp (C-9)
1.	+20	29 08	30.27	50.27
2.	—20 + 40	6 63	6.54	8.87
3.	—40 + 70	41.43	36.71	25.14
4.	—70 + 100	7.42	9.73	8.68
5.	—100+ 140	2.76	2.38	3.22
6.	—140	12 68	14.37	7.82
	TOTAL =	100.00	100.00	100.00

* Cook No. 3
** Cook No. 6
*** Cook No. 9

TABLE—5 PHYSICAL STRENGTH PROPERTIES OF BLEACHED SULPHATE SEMI-CHEMICAL, GREEN LIQUOR SEMI-CHEMICAL AND NEUTRAL SULPHITE SEMI-CHEMICAL PULP, BEATING IN LABORATORY VALLEY BEATER

Sl. No.	Particulars	Bleached sulphate semi-chemical pulp (Cook A-3)				Bleached green liquor semi-chemical pulp (Cook No. B-6)				Bleached Neutral Sulphite semi-chemical pulp Cook No. C-9)			
1.	Initial freeness, °SR	21				21				19			
2.	Final freeness, °SR	25	35	45	55	25	35	45	55	25	35	45	55
3.	Beating period (mts)	5	11	19	24	4	10	17	21	6	11	15	18
4.	Bulk (cc/g)	1.55	1.49	1.46	1.31	1.53	1.41	1.33	1.30	2.12	1.67	1.83	1.61
5.	Breaking length (KM)	3.64	4.17	4.86	5.06	3.30	4.25	5 10	4.56	3.82	4.62	5.12	5.20
6.	Stretch, %	1.20	1.30	1.32	1 37	1.40	1.25	1.52	1.65	1.05	1.25	1.30	1.35
7.	Burst factor	29.7	33.8	42.3	44.8	29.8	36.13	40.32	39.50	32.01	40.61	43.41	45.01
8.	Tear factor	66.1	57.6	47.7	44.7	68.80	64.22	60.20	56.66	79.20	60.97	58 91	54.66
9.	Double folds (No)	55	80	490	880	50	560	2000	945	230	550	2000	1550
10.	Tensile Index (Nm/g)	35.68	40.88	47.64	49,61	32.36	41.66	50.98	44.71	37.45	45 29	50.19	50.98
11.	Burst index ($K.Pam^2/g$)	2.91	3.31	4.14	4,39	2.92	3.54	3.95	3.87	3.19	3.98	4.25	4.42
12.	Tear index ($m\ N\ m^2/g$)	6.48	5.64	4.64	4.38	6.74	6.30	6.01	5.56	7.76	5.98	5.77	4.41

TABLE—6. STRENGTH PROPERTIES OF SULPHATE SEMI-CHEMICAL PULP A—3 AND BLENDS WITH MILL BLD. CHEMICAL PULP.

S. No.	Particulars	100% pulpA	80% pulp A+20% pulp B	60% pulp A+40% pulp B	40% pulp A+60% pulp B	20% pulp A+80% pulp B	100% pulp B
1.	Initial freeness, °SR	21	—	—	—	—	18
2.	Final freeness, °SR	45	—	—	—	—	45
3.	Beating period (mts)	19	—	—	—	—	27
4.	Brightness of standard sheets, % Pv	72.0	69.0	70.5	72.5	74.5	78.0
5.	Bulk cc/g	1.46	1.46	1.45	1.45	1.41	1.35
6.	Breaking length (Km)	4.86	4.45	4.41	4.28	4.09	42.10
7.	Stretch, %	1.32	1.30	1.30	1.25	1.05	1.0
8.	Burst factor	42.3	34.1	33.8	32.9	32.2	30.7
9.	Tear factor	47.4	52.0	50.0	47.2	41.9	35.0
10.	Double fold	490	170	90	80	50	40
11.	Tensile Index (Nm/g)	47.64	43.62	43.23	41.96	40.88	41.27
12.	Burst Index (K. Pa m^2/g	4.14	3.34	3.31	3.22	3.15	3.00
13	Tear Index (mNm^2/g)	4.64	5.09	4.90	4.62	4.10	3.43

Note : Pulp A is bleached semi-chemical sulphate pulp from Cook No. 3 brightness is=73.0
Pulp B is bleached chemical Mill pulp, Brightness is 78.0

TABLE—7 PHYSICAL STRENGTH PROPERTIES OF GREEN LIQUOR SEMI-CHEMICAL BLEACHED PULP (B-6) AND BLENDS WITH MILL BLEACHED PULP.

Sl. No.	Particulars	100% Pulp A	80% Pulp A + 20% Pulp B	60% Pulp A + 40% Pulp B	40% Pulp A + 60% Pulp B	200%,Pulp A + 80% Pulp B	100% Pulp 8
1.	Initial freeness, °SR	21	—	—	—	—	18
2.	Final freeness, °SR	45	—	—	—	—	45
3.	Beating period (mts)	17	—	—	—	—	27
4.	Brightness of sheets % Pv	71.0	68.0	69.5	72.5	74.0	78.0
5.	Bulk cc/g	1.33	1.34	1.53	1.37	1.35	1.35
6.	Breaking length (KM)	5.20	4.91	4.56	4.45	4.25	4 21
7.	Stretch, %	1.52	1.42	1.45	1.30	1.35	1.0
8.	Burst factor	40.32	40.02	40.00	36.60	35.02	30.7
9.	Tear factor	60.20	52.28	55.40	45.53	41.40	35.0
10.	Double fold	2000	760	305	165	120	40
11.	Tensile index (N m/g)	50.98	48.13	44.71	43.62	41.66	41.27
12.	Burst Index (K. Pa m^2/g)	3.95	3.92	3.92	3.58	3.43	3.00
13.	Tear Index (mN m^2/g)	5.90	5.12	5.43	4.46	4.06	3.43

Note:— i) Pulp A is bleached Green liquor semi-chemical pulp from cook no. 6, brightness is=72.0
ii) Pulp B is bleached chemical pulp, brightness is 78.0.

TABLE—8. PHYSICAL STRENGTH PROPERTIES OF NEUTRAL SULPHITE SEMI-CHEMICAL BLEACHED PULP AND BLENDS WITH MILL BLEACHED PULP.

S. No.	Particulars	100% pulp A	80% pulp A+20% pulp B	60% pulp A+40% pulp B	40% pulp A +60% pulp B	20% pulp A+80% pulp B	100% pulp B
1.	Initial freenes. °SR	19	—	—	—	—	18
2.	Final freeness, °SR	45	—	—	—	—	45
3.	Beating period (mts)	15	—	—	—	—	27
4.	Brightness of sheet, % pv	70 00	67.5	69.5	71.0	73.0	78.0
5.	Bulk (cc/g)	1.83	1.40	1.41	1.42	1.39	1.35
6.	Breaking length (Km)	5.15	4.66	4.22	4.00	3.84	4.21
7.	Stretch, %	1.30	1.25	1.10	1.10	1.05	1,0
8.	Burst factor	43.41	34.92	32.69	30.50	29.83	30.7
9.	Tear factor	58.91	63.50	55,17	50.55	45.15	35 0
10.	Double fold	2000	250	425	125	75	40
11.	Tensile index (nm/g)	50.19	45.68	41.37	39.21	37.25	41.27
12.	Burst index (K. Pa m^2/g)	4.25	3.43	3.21	3.08	2.92	3.00
13.	Tear Index (m.N.m^2/g)	5.77	6.22	5.41	4.95	4.43	3.43

NOTE—Pulp A is bleached neutral sulphite semichemical pulp from Cook no. 9
Pulp B is bleached chemical pulp, brightness is 78.0

semi-chemical pulp in the blends, however, the brightness is sufficient for writing and printing grade paper where too high brightness is not required.

Green Liquor Semi-Chemical Process :

It is observed in Table 1-B that power consumption decreases from 240 KWh/Tonne to 120 KWh/Tonne and the yield of the pulp decreases from 70 percent to 58.8 percent when the percentage of alkali is increased from 5 to 11%. With this increase in alkali the permanganate number decreased from 36.48 to 34.78 and R.A A. increases from 9.30 to 13.95 g/l. This again indicates that the softening of the chips is more as the percentage of chemical is increased. The calorific value is normal. In Table 2-A, it can also be seen that unbleached pulp of cook no. 6 can be readily beaten upto 55°SR freeness in 28 mts. The strength properties increases with increase in °SR freeness except in case of tear factor.

From table 3-B it is observed that total chlorine requirement is 23.5 percent and caustic demand is 6.65 percent to obtain a brightness of 72 percent PV. The total shrinkage of pulp during bleaching is 17.7 percent. This pulp has satisfactory viscosity copper number, post colour number indicating that it is not degraded and has a satisfactory keeping quality. The fiber classification of bleached pulp recorded in Table 4-B indicates that maximum fibre percent retention is on 70 mesh. From Table 5-B it is observed that after bleaching, the beating time is reduced and physical strength properties improve considerably.

The results recorded in Table-7 indicates that bleached green liquor semi-chemical pulp is superior in comparision to the mill bleached chemical pulp in respect of strength properties, hence with the increase in proportions of semi-chemical pulps, the properties of blends are better than the mill pulp and the brightness of the blends decreases from 78 to 68 percent PV with the increase amount of semi-chemical pulp in the blends, however, this brightness is sufficient for writing and printing grade paper where higher brightness is not needed.

Neutral Sulphite Semi-Chemical Process :

From Table 1-C it is observed that power consumption decreases from 180 KWh/Tonne to 120 KWh/Tonne and the yield of the pulp decreases from 77.60 to 68.60 when the percent of alkali is increased from 5 to 11% as Na_2O (10.16 to 22.33% as Na_2SO_3 respectively). With this increase in alkali the permanganate number decreases from 26.64 to 35.58 and R.A.A. increases from 4.65 to 10.85 g/l as Na_2O. This indicates that the softening of the chips is more as the percentage of the chemicals is increased as expected. The pH of the spent liquor remains around 7.5 to 8.5 and the calorific value is normal.

In Table 2-C it can also be seen that unbleached pulp of cook no. 9 can readily be beaten upto 55 SR freeness in 29 minutes only. The physical strength properties of the pulp decreases with increase in °SR freeness whereas other strength properties increases with increase in °SR freeness. The pulp has very good bulk (1.7 to 1.68).

From Table 3-C, it is evident that the total chlorine requirement is 24.71% and caustic demand Is 6.35% to obtain a brightness of 70.5% PV. Total pulp shringake duriug bleaching is 20.8%. This. pulp has satisfactory viscosity, copper number and post colour number indicating that it is not degraded and has a satisfactory keeping quality.

The fiber classification of bleached pulp recorded in Table 4C shows that fiber percent retention on 20 mesh is maximum. From Table 5-C it is observed that on bleaching the beating time is reduced and the strength properties are improved considerably N S.S.C bleached semi-chemical pulp has very good bulk (2.12 to 1 61). From Table-8, it is observed that bleached neutral sulphite semi-chemical pulp is superior in comparision to the mill bleached pulp, as the bleached semi-chemical pulp has better breaking length stretch and burst factor, hence with the increase in proportions of bleached semi-chemical pulps, the properties of the blends are better than the mill pulp (Except when 20% and 40% bleached semi-chemical pulp are mixed in the blends in this case strength properties of these blends are camparable with the mill pulp).

Brightness of these blends decreased from 78 to 67 5% PV, with the increase amount of bleached semi-chemical pulp in the blends; however, these brightness are satisfactory for printing and writing grade paper where too high brightness is not needed.

On the whole it can be observed that when the same amount of chemicals as Na_2O are used, the yield by the sulphate semi-chemical process are lower than that of neutral sulphite semi-chemical process but the strength properties are better. The pulps obtained by neutral sulphite semi-chemical process are bulkier than the pulp obtained by the sulphate process. The physical strength properties of sulphate semi-chemical unbleached pulp are also superior in comparison to the green liquor semi-chemical unbleached pulp, however, the physical strength properties of green liquor semi-chemical unbleached pulp are equivalent to neutral sulphite semi-chemical unbleached pulp. Power consumption during refining is towards higher side in sulphate semi-chemical in comparison, to the neutral sulphite and green semi-chemical process. Similar trends is observed during beating of unbleached pulp as beating time is more in sulphate semi-chemical process comparatively. Sulphate semi-chemical and green liquor semi-chemical unbleached pulps are darker as compared to the neutral sulphite semi-chemical unbleached pulp. As recorded in Table-3 sulphate semi-chemical green liquor, semi-chemical, and neutral sulphite semi-chemical pulp could be bleached upto a brightness of 70% in multi-stage bleaching following C,E/C/E/H sequence. In case of green liquor semi-chemical process total chemical requirement for bleaching is 23 5% which is lower in comparison to the sulphate semi-chemical process (26 6%) and neutral sulphite semi chemical process (24.71%). The bulk and strength properties of sulphate semi-chemical bleached pulp are lower than that of neutral sulphite semi-chemical and green liquor semi-chemical bleached pulp. After bleaching beating time is reduced in all pulps. In case of sulphate semi-chemical unbleached pulp beating time is higher as compared to other pulps.

It is also observed that green liquor semi-chemical pulp are equivalent to neutral sulphite semi-chemical pulp in strength characteristics, however, they may result in denser sheets.

The physical strength properties of all the blends of sulphate semi-chemical, green liquor semi-chemical and neutral sulphite semi-chemical pulps are satisfactory. However, the exact quantity of the pulp to be blended depends upon the strength values and brightness of the finished sheet. The brightness can be improved further by the addition of suitable fillers.

CONCLUSION

i) Unbleached pulps can be prepared from the mill chips by sulphate semi-chemical process in yield of 55.13 to 75.44%. The pulps have

good strength properties for the production of brown wrapping papers.

ii) When the sulphate semi-chemical pulp is bleached, the pulp has yield falls to 44.10%. Strength properties and brightness are satisfactory for the production of writing and printing papers.

iii) Unbleached pulp can also be prepared from mill chip by green liquor semi-chemical process in yield of 58.8 to 70%. The pulp has good strength properties for the production of brown wrapping papers.

iv) When green liquor semi-chemical pulp is bleached the pulp has a yield of 48.39% and possess a satisfactory strength properties and brightness for the production of writing and printing papers.

v) Unbleached pulp can also be prepared from mill chips by neutral sulphite semi-chemical process in yield of 68.60 to 77.60. The pulp has good strength properties for production of brown wrapping papers.

vi) When neutral sulphite semi-chemical unbleached pulp is bleached the pulp has yield of 54.33% and possess satisfactory strength properties and brightness for the production of writing and printing papers. The bulk and strength properties of neutral sulphite semi-chemical bleached pulps are better than that of sulphate semi-chemical bleached pulp.

vii) Green liquor semi-chemical pulp is equivalent to N.S.S.C. pulp in desired strength properties however, green liquor semi-chemical pulp may result in denser sheets. The bulk and physical strength properties of bleached green liquor semi-chemical pulp are better than sulphate semi-chemical bleached pulp.

viii) When the same amount of chemicals as Na_2O are used the yield by the sulphate semi-chemical process is lower than that of the sulphite semi-chemical process but the strength properties are better.

ix) Power consumption during refining is on the higher side in case of sulphate semi-chemical pulp, whereas in case of green liquor semi-chemical and neutral sulphite semi-chemical process it is almost equal.

x) Green liquor semi-chemical unbleached pulp is equivalent to neutral sulphite semi-chemical unbleached pulp. However, the yield of the green liquor semi-chemical unbleached pulp is lower in comparison to neutral sulphite semi-chemical pulp.

xi) The pulps obtained by neutral sulphite semi-chemical process are bulkier than the pulp obtained by green liquor semi-chemical or sulphate semi-chemical process.

xii) The physical strength properties of sulphate semi-chemical green liquor semi-chemical and neutral sulphite semi-chemical bleached pulps are superior in comparison to the mill bleached chemical pulp in respect of physical strength properties hence with the increase in proportion of semi-chemical bleached pulps in the blends the strength properties are better than mill pulp. The exact quantity of the pulp to be blended depends upon the strength values and brightness required of the sheet.

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