Journal of Scientific & Industrial Research
Vol. 63, March 2004, pp 265-275

Cost reduction in ivory base paper — Bleaching process

Dharm Dutt*, J S Upadhyaya, R S Malik and C H Tyagi

Department of Paper Technology, Indian Institute of Technology, Roorkee, Saharanpur Campus, Saharanpur 247 001

Received: 30 June 2003; accepted: 02 December 2003

Globalization has compelled the Indian pulp and paper industry to improve the product quality with cost reduction keeping the same profit level to survive in a globally competitive market. With this background, the cost reduction aspect of ivory base paper used as top layer in decorative laminates was studied. In present practice, generally a pulp of brightness of 85 per cent (ISO) was selected for manufacturing of ivory base paper by most of the Indian pulp and paper industries. A pulp of brightness 76.6 per cent was used to develop ivory base paper. Experiments were also conducted to replace caustic with soda ash partially in alkali extraction and O_2 and H_2O_2 reinforced alkali extraction stages. 30 kg caustic and 5 kg soda ash/t of pulp in alkali extraction and O_2 and H_2O_2 reinforced alkali extraction stages gave the similar results to that of 35 kg caustic/t of pulp in alkali extraction. It is observed that the optical and other important properties resemble to that of ivory base paper made from pulp of brightness 85 per cent (ISO). This will help not only in chemical savings but will preserve pulp biomass due to less pulp shrinkage also. Finally, 25 per cent TiO_2 and 7 per cent soapstone to get 99 per cent opacity and 8 per cent ATH (Aluminum tri-hydroxide) to entrap fine particles of TiO_2 without flocculation were mixed into the pulp brightness of 76.6 per cent (ISO) beaten at 30 ^{0}SR. Further, 1.0 per cent melamine formaldehyde resin for wet strength and, 0.039 per cent pigment red dye and 0.1785 per cent pigment yellow dye were added to develop ivory colour. In order to control blemishes of paper and to entrap the dyes on to fibre surface 0.200 kg of Sapco K. F. and sodium aluminates, respectively, per tonne of pulp and 0.03 per cent sodium hexa meta phosphate were added. The laboratory made Ivory base paper shows cost reduction of US $ 6.33 /t of pulp than the normal practice.

Keywords: Ivory base paper, Bleaching process, Cost reduction

IPC: Int Cl.^{7}: D 21 H 19/04

Introduction

In the global market place, in which the price of pulp and paper products tend to decline marginally in real terms, while the costs rise inexorably. The Indian paper industries are facing very tough time for their survival. The Indian paper industries could not match their final products vis-a-vis to the finished products produced by leading paper manufacturers in the developed nations due to reasons like, soaring environmental costs, constant strain to modify air and water emissions high manufacturing costs, obsolete technology, and minimum profit level due to less selling price of end products. One of the possible alternatives for their survival is to minimize the cost of production by augmenting the activities through in-house research and development.

A major problem in the realization of a titanium dioxide filled sheet is the tendency of the very small titanium dioxide particles to pass between the cellulosic fibres and drain into the white water system due to its poor retention. The economics of this situation forces the paper makers to add any of the numerous well-known retention aids. With such retention aids, it is feasible to retain in the sheet as much as 90 per cent of the filler material. Unfortunately, this also causes flocculation or aggregation of the titanium dioxide particles and reduction of the scattering efficiency[1].

This problem is especially acute in the case of print sheets for use in decorative laminates. Ivory base paper, which is opaque and loaded with TiO_2 to give high opacity, is being used as top layer for the manufacture of sun-mica sheets and it must be able to hide the colour of resin-saturated absorbent kraft and barrier paper layers. For the manufacture of sun-mica sheet (decorative laminates), 4 to 5 layers of unbleached kraft absorbent paper are first applied on each other to make a base of sun-mica sheet. Prior to lamination the base sheet is saturated with a resin such as melamine formaldehyde or urea formaldehyde in an amount of 32 per cent based on the total weight of the finished sheet. Then 4 to 5 penultimate layers of barrier paper are applied on the base of sun-mica sheet. For such paper, it is usual to apply a fancy pattern to the sheet and then to saturate it prior to lamination with resins. Finally, a top layer of ivory base paper is applied in the similar manner. During the saturation step the air in the sheet is replaced by resin and refractive index of the sheet becomes approximately the same as that of cellulose. As a result thereof, the sheet becomes transparent and poses 'see through' problems and the reflectance in the blue end of the visible spectrum decreases to 50 per cent which indicates that TiO_2 is absorbing this light without reflecting it [2]. The other methods for increasing the retention of titanium dioxide filler in the sheet are the use of crystalline colloidal materials. In this paper hydrous crystalline aluminum hydroxide known as α-alumina tri-hydrate (gibbsite or hydrargillite) a common crystalline colloid material, was studied for increasing the opacity of flocculated TiO_2 filled sheet. Aluminum tri-hydroxide (ATH) is as fine as a gel, having a stable positive surface and spherical particle configuration with a diam ranging from about 10 mμ to about 30 mμ, which remain positive [3] to a pH level as high as 9. The dispersed aqueous slurry of hydrous aluminum hydroxide forms fine gel that entraps titanium dioxide particles in the wet web and prevents removal of fines and fillers in the Fourdrinier part of the paper machine. Besides it, aluminum tri-hydroxide contributes to brightness, ink receptivity, flame retardancy of paper, high whiteness, better smoothness and anchoring fillers in the wet web[4].

The most important property for ivory base paper is opacity, which controls 'see through` during lamination. Other important properties of ivory base paper are water klemn, castor oil absorbency (COP), and wet strength[5].

Attempts have been made to reduce the cost of ivory base paper during extraction stage by replacing NaOH partially with Na_2CO_3. The other alternative alkali sources for partial replacement, of sodium hydroxide are sodium sulphide[6-9], oxidized and unoxidised white liquor[10] sodium silicate[11-12]. None of these alkali sources is as efficient as sodium hydroxide on a weight basis, but by increasing the charge, time, and temperature of the reaction it can be made to give comparable results[13-14]. In caustic extraction stage, the filtrate containing sodium carbonate can be recycled back and used as an extractant which is popularly known as 'papricycle process'[14-19]. Although the alternative alkali source poses the problem of scaling of process equipment but the problem can be overcome with the addition of 'oxidants'. Authors have successfully tried to replace sodium hydroxide with low cost sodium silicate partially in 'extraction stage' without sacrificing the quality of product. In present practice a pulp of 85 per cent (ISO) brightness is used for manufacturing of ivory base paper by most of the paper manufacturers. A pulp of brightness 76.6 per cent (ISO) is used to develop ivory base paper without affecting the quality of paper. This will not only help in saving the bleach chemicals but preserve the biomass also.

Experimental Procedure

Raw Material Preparation and Pulping Studies — The mixed and screened wood chips of *Eucalyptus treticornis, Bambusa arundacea, Populus ciliata* and saw mill waste of *Pinus roxumberghi* in the ratio of 71:13:10:02 were collected from Star Paper Mills Ltd., Saharanpur located in the foot hills of Shivalik in Northern India. The screened wood chips were digested in electrically heated rotary digester of 0.02 m^3 capacity kraft pulping process. The pulp was screened through a laboratory vibratory flat WEVERK screen with 0.15 mm slits. The pulp yield, screening rejects and kappa number was determined. The results are reported in Table 1.

Bleaching Studies — The unbleached pulp of kappa number 25.90 was bleached by CEpHH bleaching sequence to get pulp of different brightness levels, i.e., 76.6, 78.0, 80.0, 82.0 and 85.0 per cent, (ISO) at different chemical doses. The results are reported in Table 2. The partial replacement of NaOH with Na_2CO_3 during alkali extraction, extraction with H_2O_2 and extraction with O_2 stages of bleaching was carried out without affecting quality. The results are reported in Table 3.

Stock Preparation — Imported softwood pulp of 88 per cent brightness, imported hardwood pulp of 87 per cent brightness and mill pulp of 82 per cent brightness were beaten to 35 °SR in a WEVERK laboratory valley beater separately and then blended in the ratio 40 : 30 : 30. To the combined furnish various non-

Table 1 — Shows cooking results and conditions for Kraft pulping having mixed wood chips of *Eucalyptus treticornis, Bambusa arundacea, Populus ciliata*and saw mill waste *Pinus roxumberghi* in the ratio of 71:13:10:02

Particulars	Active alkali, per cent (as Na_2O)			
	14	15	16	17
Screened pulp yield, per cent	41.50	44.65	47.90	46.50
Screening rejects, per cent	9.10	5.50	1.85	0.65
Unscreened pulp yield, per cent	50.60	50.15	49.75	47.15
Kappa number	30.30	28.70	25.90	24.40
Lignin, per cent	4.54	4.30	3.88	3.66
Residual alkali, g/L	1.57	1.24	0.23	0.11
Fixed cooking parameters:				
Time from room temperature to 105 ^{0}C	= 60 min			
Time from 105 ^{0}C to 165 ^{0}C	= 60 min			
Time at 165 ^{0}C	= 75 min			
Sulphidity of cooking liquor, per cent	= 20.4			
Liquor to wood ratio	= 3.0:1			
Pressure in digester, kg/cm^2	= 6.75			

Table 2 — Bleaching conditions and results of kraft pulp of mixed chips of *Eucalyptus tetrecornis, Bambusa arundacea, Populus ciliata* and saw mill waste *Pinus roxumberghi* in the ratio of 71:13:10:02

Sl No.	Parameters	Kraft pulp				
		Set $_1$	Set $_2$	Set $_3$	Set $_4$	Set $_5$
1	Chlorination stage					
	[1]Amount of Cl_2 applied, per cent	3.25	3.75	4.00	4.25	4.60
	[1]Amount of Cl_2 consumed, per cent	3.22	3.70	3.90	4.15	4.50
	Initial pH	2.60	2.55	2.62	2.58	2.56
	Total per cent of Cl_2 consumed	99.07	98.66	97.50	97.64	97.82
2	Extraction with H_2O_2					
	[1]Amount of NaOH applied, per cent	3.0	3.0	3.0	3.0	3.0
	[1]Amount of Na_2CO_3 applied, per cent	0.5	0.5	0.5	0.5	0.5
	[1]Amount of H_2O_2 applied, per cent	0.5	0.5	0.5	0.5	0.5
	Initial pH	11.62	11.65	11.60	11.62	11.64
	End pH	9.56	9.50	9.52	9.54	9.54
3	Hypochlorite stage (H_1)					
	[1]Amount of Ca $(OCl)_2$ applied, per cent	2.28	2.63	2.80	2.98	3.22
	Initial pH	11.55	11.56	11.55	11.54	11.53
	End pH	9.51	9.50	9.52	9.52	9.53
4	Hypochlorite stage (H_2)					
	[1]Amount of Ca $(OCl)_2$ applied, per cent	0.98	1.13	1.2	1.28	1.38
	Initial pH	11.50	11.50	11.51	11.52	11.54
	End pH	9.50	9.52	9.52	9.50	9.51
5	Total Cl_2 demand, per cent	6.5	7.5	8.0	8.5	9.2
6	Pulp shrinkage, per cent	9.0	9.5	9.7	10.0	10.5
7	[1]Total bleached pulp yield, per cent	43.59	43.35	43.25	43.11	42.87
8	Pulp viscosity, cps (Cuprammonium)	10.8	10.2	9.8	9.5	9.2
9	Pulp brightness, per cent (ISO)	76.6	78.0	80.0	82.0	85.0

Bleaching Conditions

Bleaching sequence	C	E_p	H_1	H_2
Consistency of pulp, per cent	3	11	12	12
Temperature, ^{0}C	ambient	70$\pm$ 2	45$\pm$ 2	45$\pm$ 2
Retention time, min	45	90	120	120

[1]= Kappa number 25.90

[2] = All are expressed on o.d. pulp basis

Table 3 — Partial replacement of NaOH with Na_2CO_3 during alkali extraction, H_2O_2 reinforced extraction, and O_2 reinforced extraction

Parameters	Extraction stages during bleaching							
	E_1	Ep_1	Ep_2	Ep_3	EO_1	EO_2	EO_3	EO_4
Unbleached pulp kappa No.	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
[1]Amount of Cl_2 applied in Chlorination stage, per cent	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
[2]Extraction stage								
[1]Amount of NaOH applied, per cent	3.5	3.5	3.0	2.5	3.5	3.5	3.0	2.5
[1]Amount of H_2O_2 applied, per cent	-	0.5	0.5	0.5	-	-	-	-
[1]Amount of Na_2CO_3 applied, per cent	-	-	0.5	1.0	-	-	0.5	1.0
O_2 pressure, kg/cm^2	-	-	-	-	3.0	5.0	3.0	3.0
Initial pH	11.8	11.8	11.7	11.8	11.9	11.7	11.7	11.8
End pH	9.5	9.4	9.2	9.1	9.3	9.1	9.3	9.2
Kappa number	18.9	11.5	11.7	15.0	9.9	8.2	10.2	11.4

[1]= all are expressed on o.d. pulp basis. [2]= Conditions during extraction stages, temp 70 ^{0}C, reaction time 90 min and consistency 11 per cent.

fibrous additives, as stated in Table 4 and 5 in various blend ratios were added. Thereafter the beater was emptied into a bucket and adjusted to a pH 6.5 with non-ferric alum. For wet strength, 1.0 per cent melamine formaldehyde resin and to develop ivory colour, 0.039 per cent pigment red dye and 0.1785 per cent pigment yellow dye (all based on the weight of total furnish) were added. 0.200 kg Sapco K F and sodium aluminates per tonne of pulp respectively and 0.03 per cent sodium hexa meta-phosphate were added to control blemishes of paper and to entrap the dyes on to fibre surface. Following this the laboratory hand sheets of 70 g/m^2 were prepared on a Mesmer automatic sheet former. Finally the hand sheets were tested for brightness, opacity and ash the results are reported in Tables 4-6. Laboratory made ivory base paper was compared with mill made ivory base paper in terms of brightness, opacity, ash content, water klemn, COP and opacity after saturation with melamine formaldehyde. The results are reported in Table 6.

Cost Reduction Studies — The cost of ivory base paper during normal and modified bleaching processes was determined. The results are reported in Appendix A.

Results and Discussion

Table1 shows the effect of alkali dose on kappa number and pulp yield during kraft pulping of mixed wood chips of *Eucalyptus ttreticornis, Bambusa arundacea, Populus ciliata* and saw mill waste of *Pinus roxumberghi* in the ratio of 75:13:10:02 while keeping all other parameters constant like sulphidity 20 per cent, maximum pulping temperature 165$\pm$2 ^{0}C, maximum pulping time 75 min, liquor to wood ratio of 3.0:1 and digester pressure 7.5 kg/cm^2. On increasing alkali dose from 14 to 16 per cent (as Na_2O), the screened pulp yield improves from 41.50 to 47.90 per cent. While both kappa number and screening rejects decline sharply from 30.30 to 25.90 and 1.85 per cent respectively. Further, on increasing alkali dose to 18 per cent (as Na_2O), the kappa number remains practically constant, whereas screened pulp yield drops to 47.15 per cent. It is evident that the increased alkali dose is not only utilized to solubilize lignin but degrade carbohydrate contents also. Based on above results, 16 per cent alkali (as Na_2O) may be taken as optimum alkali dose.

Table 2 shows the effect of partial replacement of NaOH with Na_2CO_3 during alkali extraction and H_2O_2 and O_2 reinforced extraction stages of bleaching on kappa number without affecting quality. The unbleached pulp of kappa number 25.9 treated with 3.2 per cent molecular Cl_2 at 3 per cent consistency and temperature 27 ^{0}C for 45 min. The CE kappa number reduces by 27 per cent when 35 kg NaOH/t of pulp applied in extraction stage. On the other hand when chlorinated pulp was extracted with 3.5 per cent NaOH, and 0.5 per cent H_2O_2 with 0.1 per cent $MgSO_4$ Cep_1 kappa number reduces by 55.60 per cent. Further, NaOH was partially replaced with Na_2CO_3 by 0.5 and 0.1 per cent, respectively, in Ep_2 and Ep_3 stages while keeping other gradients constant

Table 4 — Optical properties of ivory base paper made from mill pulp of different brightness level and loaded with 40 per cent TiO_2 filler

Sl No.	Furnish composition[1]	Brightness, per cent (ISO)	Ash, per cent	Opacity, per cent
1	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (Brigntness 76.6 per cent ISO) = 100	68.7	22.56	99.4
2	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brigntness 78 per cent ISO) = 100	69.2	22.21	99.0
3	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brigntness 80 per cent ISO) = 100	69.8	22.54	99.3
4	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brigntness 82 per cent ISO) = 100	70.7	22.98	98.63
5	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brigntness 87 per cent ISO) = 100	70.8	23.22	98.80
6	Imported softwood pulp = 10 Imported hardwood pulp = 10 Own mill pulp (brigntness 76.6 per cent ISO) = 80	71.3	22.46	99.02
7	Imported softwood pulp = 10 Imported hardwood pulp = 10 Own mill pulp (brigntness 80 per cent ISO) = 80	71.8	22.78	98.6

[1] = Pulp stock having 0.03 per cent sodium hexa meta phosphate, 0.1 per cent melamine formaldehyde, 0.1785 per cent pigment yellow dye and 0.039 per cent pigment red dye pH in each set is adjusted to 6.5 with non-ferric alum; imported softwood pulp brightness 88 per cent (ISO) and imported hardwood brightness 87 per cent (ISO)

as in Ep_1 stage kappa number increases by 0.80 and 13.52 per cent, respectively, compared to Ep_1 stage. There is very slight difference between kappa numbers of Ep_1 and Ep_2 stages. Therefore the cost of bleach chemicals can be saved without affecting the quality of pulp by replacing 5 kg NaOH with/t of pulp.

In oxygen reinforced extraction stage, kappa number reduces by 61.78 and 68.30 per cent, respectively, on increasing O_2 pressure from 3 to 5 kg/cm^2 while keeping alkali dose constant to 35 kg NaOH/t pulp. Further, kappa number reduces to 61.6 and 56 per cent, respectively, of the unbleached pulp kappa number in EO_3 and EO_4 stages. In EO_3 and EO_4 stages NaOH was partially replaced with Na_2CO_3 by 5 and 10 kg/t of pulp, respectively, while keeping O_2 pressure constant at 3.0 kg/cm^2.

Table 3 shows the bleaching conditions and results of kraft pulp of mixed chips of *Eucalyptus treticornis, Bambusa arundacea, Populus ciliate,* and saw mill of waste *Pinus roxumberghi* in the ratio of 71:13:10:02 having kappa number 25.9. In order to observe the effect of pulp brightness on ivory base paper the pulp was bleached by CEpHH bleaching

Table 5 - Optical properties of ivory base paper made from mill pulp of different brightness level and loaded with 32 per cent TiO_2 filler

Sl No.	Furnish composition[1]	Brightness, per cent (ISO)	Ash, per cent	Opacity, per cent
1	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (Brigntness 76.6 per cent ISO) = 100	65.1	18.54	99.10
2	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brigntness 78 per cent ISO) = 100	65.1	18.21	98.80
3	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brigntness 80 per cent ISO) = 100	66.2	17.81	98.80
4	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brightness 82 per cent ISO) = 100	69.8	17.98	98.44
5	Imported softwood pulp = 0.0 Imported hardwood pulp = 0.0 Own mill pulp (brightness 87 per cent ISO) = 100	67.0	18.26	98.60
6	Imported softwood pulp = 10 Imported hardwood pulp = 10 Own mill pulp (brightness 76.6 per cent ISO) = 80	67.80	18.60	98.80
7	Imported softwood pulp = 10 Imported hardwood pulp = 10 Own mill pulp (brightness 80 per cent ISO) = 80	68.7	18.67	98.2

[1] = Pulp stock having 0.03 per cent sodium hexa meta phosphate, 0.1 per cent melamine formaldehyde, 0.015 per cent pigments yellow dye and 0.0017 per cent pigment red dye pH in each set is adjusted to 6.5 with non-ferric alum. Imported softwood pulp brightness 88 per cent (ISO) and Imported hardwood brightness 87 per cent (ISO)

sequence to get pulp brightness 76.6, 78.0, 80.0, 82.0, and 85.0 per cent (ISO) by using total Cl_2 demand 6.5, 7.5, 8.0, 8.5, and 9.2 per cent (on od pulp basis) respectively. In all the sets, 30 kg NaOH, 5 kg Na_2CO_3 and 5 kg H_2O_2/t of pulp was used in extraction stage.

Table 4 shows the optical properties of ivory base paper made from mill pulp of different brightness, and loaded with 40 per cent TiO_2 with other non-fibrous additives, as stated in Table 4. It is important to note that pH was maintained at 6.5 with iron-free alum. The brightness of ivory base paper increases from 68.7 to 70.8 per cent (ISO), whereas opacity and ash content remains practically constant. Ivory base paper having 10 per cent softwood pulp of brightness 88 per cent (ISO), 70 per cent imported hardwood pulp of brightness 87 per cent (ISO) and 20 per cent mill pulp of brightness 76.6 per cent (ISO) while keeping non-fibrous additives constant as, in Table 4, shows slight increase in brightness by 0.5 per cent. Whereas all other properties like, ash content and opacity remain practically constant. Further, ivory base paper having 10 per cent softwood pulp of brightness 88 per cent (ISO), 80 per cent imported hardwood pulp of

Table 6 — Comparison between laboratory made and mill made ivory base paper

Sl No.	Parameters	Ivory base paper	
		Laboratory made[1]	Mill made[2]
1	TiO_2 loading, per cent	25	50
2	Soap stone powder loading, per cent	7	12
3	ATH loading, per cent	8	0.0
4	PH of stock	6.5	6.5
5	Substance, g/m^2	70	71.5
6	Brightness, per cent ISO	72.00	70.2
7	Opacity, per cent ISO	98.90	98.8
8	Ash in paper, per cent	26.04	27
9	Wet strength, g/cm	136	126
10	Water kelmn (4 minutes), mm	26.5	
	$^{MD}/_{CD}$		30/25
11	Castor oil penetration at 35 ^{0}C, sec $^{TS}/_{WS}$	8/11	10/12
12	[3]Opacity after saturation with melamine formaldehyde (40 per cent M F resin of the weight of paper), per cent ISO	95.2	91.2

Furnish composition:

[1] Mill Pulp = 80 per cent of brightness 76.6 per cent (ISO), Imported softwood pulp = 10 per cent of brightness 87 per cent (ISO), Imported hardwood pulp = 10 per cent of brightness 87 per cent (ISO)

[2] Mill pulp = 60 per cent, Imported soft wood pulp = 40 per cent

[3] = Mill made Ivory base paper showed 'see through' problem

brightness 87 per cent (ISO) and 20 per cent mill pulp of brightness 80.0 per cent (ISO) while keeping non-fibrous additives constant as, in Table 4 shows slight increase in brightness by 0.5 and very little change in ash content and opacity.

Table 5 shows the optical properties of ivory base paper made from mill pulp of different brightness and loaded with 32 per cent TiO_2 and other non-fibrous additives as stated in Table 5. The brightness of ivory base paper increases from 65.1 to 67.0 per cent (ISO), whereas opacity and ash content remains almost constant. Ivory base paper having 20 per cent mill pulp of different brightness, i.e., 76.6 and 80.0 per cent (ISO), respectively, while keeping other furnish and non-fibrous additives components constant shows slight increase in brightness by 1.7 per cent and ash content by 0.41 per cent.

Evidently, sun-mica manufacturers require ivory base paper of 98-99 per cent opacity, 71 per cent (ISO) brightness and 25 per cent ash in paper. It was observed that during manufacturing of ivory base paper the retention of TiO_2 filler is very poor due to its smaller size. However the retention of TiO_2 can be improved by using retention aids such as, melamine formaldehyde. Unfortunately, this causes agglomeration of the TiO_2 particles and reduction in their scattering efficiency. However the desired opacity can be achieved in ivory base paper even after agglomeration, yet during the saturation step the air in the sheet is replaced by melamine formaldehyde resin having the same refractive index as that of cellulose. After saturation the sheet opacity drops by 6-7 units and the 'sun-mica' sheet evidences the 'see through problem'. In order to combat the 'see through problem' in sun-mica, TiO_2 is partially replaced with 'ATH' during the manufacturing process. Table 6 shows a comparison between laboratory made hand sheet and mill made ivory base paper. Laboratory made ivory base paper having mill pulp, imported hardwood pulp and imported softwood pulp in the ratio 80:10:10 and other non-fibrous additives, as stated in Table 6, gives 72.00 per cent ISO brightness, 98.90 per cent opacity and 26.04 per cent ash in paper. This paper, when saturated with M F resin does not show 'see through problem'. On the other hand mill made ivory base paper shows 70.2 per cent (ISO) brightness, 98.80 per cent (ISO) opacity and 27.00 per cent ash content. The mill made ivory base paper during saturation step with MF resin shows 'see through problem'. The reason is that ATH forms gel like structure during sheet formation and it entraps fines and filler particles without aggregation. On the other hand, TiO_2 particles agglomerate to form macro particle in the presence of retention aids. However, higher opacity and ash content can be obtained in the finished paper but during saturation step air present in the voids escapes out side and it acts like simple filler. It results a sharp drop in opacity and poses 'see through problem' in sun mica sheet. It is also observed that mill made ivory base paper having 60 per cent mill pulp of brightness 85 per cent (ISO) and softwood pulp of brightness 88 per cent (ISO) resembles with laboratory made ivory base paper.

Conclusions

(i) Mixed wood chips of *Eucalyptus treticornis, Bambusa arundacea, Populus ciliate,* and saw mill waste of *Pinus roxumberghi* in the ratio of 75:13:10:02 at active alkali 16 per cent (as Na_2O), sulphidity 20 per cent, maximum pulping temperature 165$\pm$2 ^{0}C, maximum pulping time 75 min, liquor to wood ratio of 3.0:1 and digester pressure 7.5 kg/cm^2 gives, 47.90 per cent screened pulp yield of kappa number 25.90.

(ii) There is difference of 0.80 per cent between kappa number of Ep_1 and Ep_2 stages. Therefore, 35 kg NaOH and 5 kg H_2O_2/t of pulp may be taken in hydrogen peroxide reinforced extraction stage.. On the other hand, there is difference of 1.09 between the kappa number of EO_2 and EO_3 stages. There fore, 35 kg NaOH, and 5 kg Na_2CO_3/t of pulp with oxygen pressure 3 kg/cm^2 may be taken in oxygen reinforced extraction stage.

(iii) The brightness of pulp was observed to 76.6, 78.0, 80.0, 82.0, and 85.0 per cent (ISO) when bleached with CEpHH bleaching sequence using total Cl_2 demand 6.5, 7.5, 8.0, 8.5, and 9.2 per cent on o.d. pulp basis respectively. In all the sets 30 kg NaOH, 5 kg Na_2CO_3 and 5 kg H_2O_2/t pulp was used in extraction stage.

(iv) There is little difference in brightness of ivory base papers when mill pulp of different brightness, i.e., 76.6, 78.0, 80.0, 82.0, and 85.0, respectively, loaded with 40 per cent TiO_2 with other non-fibrous additives. It is important to note that iron-free alum is used to maintain the pH because iron forms coloured complexes with catechol. Thus, it smears the brightness of the pulp. While ivory base paper having 80 per cent mill pulp of brightness 76.6 per cent (ISO), 10 per cent imported hardwood pulp of brightness 87 per cent (ISO) and 10 per cent imported softwood pulp of brightness 88 per cent (ISO) loaded with 40 per cent TiO_2 and other non-fibrous additives, as stated above, shows a brightness gain up to 71.3 per cent (ISO).

(v) Mill pulp of different brightness as stated above, loaded with 32 per cent TiO_2 and other non-fibrous additives, as in Table 5, shows a brightness change from 65.1 to 67.0. On the other hand, ivory base paper having 80 per cent mill pulp of brightness 76.6 per cent (ISO), 10 per cent imported hardwood pulp of brightness 87 per cent (ISO) and 10 per cent imported softwood pulp of brightness 88 per cent (ISO) loaded with 40 per cent TiO_2 and other non-fibrous additives, as stated above shows a brightness gain up to 67.80 per cent (ISO).

(vi) The other important properties for laboratory made ivory base paper such as water klemn (4 min) 26.5 mm, castor oil penetration value (COP) $^{TS}/_{WS}$ 8/11 s, and wet strength 136 g/cm are comparable with mill made ivory base paper. The mill made ivory base paper shows 'see through problem' due to aggregation of filler particles in the presence of retention aids. The opacity of ivory base paper drops by 7.6 units during saturation step. On the other hand, laboratory made ivory base paper does not show 'see through problem' because ATH forms gel like structure which entraps fillers and fines without aggregation.

(vii) It is also observed that mill made ivory base paper having 60 per cent mill pulp of brightness 85 per cent (ISO) and softwood pulp of brightness 88 per cent (ISO) resembles with laboratory made ivory base paper.

(viii) The cost reduction per tonne of ivory base paper is estimated to around US \$6.33/t of paper when mill pulp of brightness 76.6 per cent (ISO) is utilized and NaOH is partially replaced with Na_2CO_3 during peroxide reinforced extraction stage.

Recommendations

There may be a problem of specks in the pulp while using mill pulp of brightness 76.6 per cent (ISO). Checking the efficiency of centricleaners can combat this problem. Further, use of surfactants is essential in order to avoid blemishes of the sheet and foam spots.

Reference

1 David V Healy; *Alumna tri-hydrate: a filler for wet end application* (Pluess-Staufer International Inc; 655 Washington Boulevard, suite 900-Slamford, CT 06901).

2 Blazer S M & Lane W C, *U S Pat 3,737, 371* (to Noyes Data Corporation, New Jersey) 05 June 1973, Paper manufacture by H G Halpern*,* 1975, 303.

3 Kirk – Othmer; *Encyclopedia of chemical technology*, **2nd ed**, **I,** A, to Aluminum (Inter Science Publisher, London) 1963.

4 Koeing J J, *Tappi Monog Ser,* **38**, Chapt 2, 1976.

5 William Scot E, *The barrier and resistance properties of paper*, (Tappi Press, Atlanta) 1989, 101.

6 Gill R A & Hagemeyer R W, *Filler for pulp manufacture*, edited by M J Kocurek, **3rd ed 6**, Chap 2, 1992.

7 *Tappi Standard Test Methods no. T-452 om-92*, 1999.

8 Allen T, *Particles size measurement,* **3rd ed** (Chapman & Hall Ltd) 1981.

9 Pryke D & Brown C T, Chlorine Dioxide substitution and pulp mill chemical balances, *CPPA Pacific Western Branch Meeting Proc*, Tech Sect CPPA, Montreal, 1989.

10 Lewko l & Van Donkekelaar A, The new reality –Softwood bleaching: chemical balances, costs, and environmental impacts, *CPPA Pacific and Western Branch Meet Proc*, The Tech Sect CPPA Montreal, 1990.

11 Fleming B I, Chlorine and caustic in pulp bleaching: Future Trends, *Second world Chloro Alkali Symp* (Chlorine Institute, Washington, D C) 1990.

12 Ritcher C T A., *Tappi J,* **38**(3) (1955) 129.

13 Rabson W H, *Pulp Pap Can*, **81** (!) (1980) 24.

14 Kress O & Davis R L, *Paper Trade J,* **94**(11) (1932) 34.

15 Assarson A, Stockman L & Theander D, *Svensk Papperstidn,* **62** (1959) 865

16 Liebergott N, Van Lierop B & Bolker H I, *J Pulp Pap Sci,* **8** (1) (1982) TR5.

17 Berry R M & Flemming B I, *J Pulp Paper Sci*, **14**(5) (1988) 121.

18 Berry R M & Flemming B I J, *APPITA J*, **43**(6) (1990) 426.

19 Berry R M & Flemming B I J., *Pulp PP Sci*, **15**(5) (1989) 165.

Author for correspondence

Email:dharm_dutt@yahoo.com

Appendix – A

(A) The costs of bleach chemicals in present practice at mill A

1.0 Chlorination stage

Chlorine applied in chlorination stage	= 4.6 per cent
(on o.d. pulp basis)	
Chlorine applied/t of pulp	
in chlorination stage	= 46 kg
Cost of chlorine	= US $ 109.50/t
	= 46 x 0.1
	= US $ 4.6/t of pulp

2.0 Extraction stage (Ep stage)

(i) NaOH applied in extraction stage	= 3.5 per cent
	= 35 kg/t of pulp
cost of NaOH	= US $ 328.52 /t
	= 35 x .33
	= US $ 11.55/t of pulp
(ii) H_2O_2 applied in extraction stage	= 0.5 per cent
	= 5 kg/t of pulp
cost of H_2O_2	= US $ 919.84 /t
	= 42 x 0.92
	= US $ 38.64 /t of pulp
Total of (i) and (ii)	= 11.55+ 38.64
	= US $ 50.19/t of pulp

3.0 Hypochlorite stage (H_1 & H_2 stages)

[1]Calcium hypochlorite applied in H_1 and H_2 stages	
as available Cl_2 on od pulp basis	= 4.6 per cent
	= 46 kg/t of pulp
Cost of Calcium hypochlorite	= Rs. 197.11/t
	= 46 x 0.20
	= US $ 9.20/t of pulp
Total of 1.0, 2.0 and 3.0	= 4.6 + 50.19 + 9.20
	= US $ 63.99/t of pulp

[1]Calcium hypochlorite is prepared in plant/t of calcium hypochlorite utilizes 1.0 tonne of Cl_2 and 1.2 tonne of product lime of purity 80 per cent. The cost of Cl_2 is US \$ 109.50 /t, cost of lime US \$ 65.70/t and cost of labour and power US \$ 8.76 per tone of Calcium hypochlorite on 20.10.2001 in mill site.

— Contd

Appendix – A — (Contd)

(B) The cost of bleach chemicals using cost reduction parametres (taking pulp brightness 76.6 per cent during manufacturing of Ivory base paper)

1.0 Chlorination stage

Chlorine applied in chlorination stage (on od pulp basis)	= 3.25 per cent
Chlorine applied /t of pulp in chlorination stage	= 32.5 kg
Cost of chlorine	= US \$ 109.50/t
	= 32.5 x 0.1
	= US \$ 3.25/t of pulp

Extraction stage (Ep stage)

(i) NaOH applied in extraction stage	= 3.0 per cent
	= 30 kg/t of pulp
Cost of NaOH	= US \$ 328.52/t
	= 30 x .33
	= US \$ 9.9/t of pulp
(ii) Na_2CO_3 applied in extraction stage	
	= 0.5 per cent
	= 5 kg/t of pulp
Cost of Na_2CO_3	= US \$ 262.81/t
	= 5 x .26
	= US \$ 1.3/t of pulp
(iii) H_2O_2 applied in extraction stage	= 0.5 per cent
	= 5 kg stage of pulp
Cost of H_2O_2	= US \$ 919.84/t
	= 42 x .91
	= US \$ 38.22/t of pulp
Total of (i), (ii) and (iii)	= 9.9+1.3+38.22
	= US \$ 49.42 /t of pulp

3.0 Hypochlorite stage (H_1 and H_2 stages)

Calcium hypochlorite applied in H_1 & H_2 stages as available Cl_2 on o.d. pulp basis	= 3.25 per cent
	= 32.50 kg/t of pulp
cost of calcium hypochlorite	= US \$ 197.11/t
	= 32.50 x 0.2
	= US \$ 6.5/t of pulp
Total of 1.0, 2.0 and 3.0	= 3.25+49.42+6.5
	= US \$ 59.17 /t of pulp

Particulars	Normal bleaching	Modified bleaching
Cost of bleach chemicals /t of pulp	US \$ 63.99	US \$ 59.17

Conserved biomass	0.71 per cent
Saving in biomass	US $ 1.51
Net saving	US $ 6.33

NOTE: US 1 $ = RS 45.66 ON 20.10.2001 IN INDIA