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EFFECT OF OPTICAL WHITENING AGENTS IN WET END AND SURFACE SIZING ON RECYCLED FIBRE BASED PAPER WITH DIFFERENT FILLERS

Abstract

The use of fluorescent/ optical whitening/ brightening agent (FWA/OWA/OBA) as shading colorant has become a main tool to eliminate the yellowish hue of bleached pulp and to improve the quality in terms of appearance i.e. brightness, whiteness, fluorescence and tint. Different types of OWAs with different sulphonic groups namely di-sulphonic (DS), tetra-sulphonic (TS) and hexa-sulphonic (HS) were evaluated in the present study using recycled pulp having brightness 83.1 % along with two fillers (GCC and Talc). The optical properties of hand sheets using di-sulphonic (DS) OWAs in wet end showed the best result for both fillers. The highest value of brightness, whiteness and fluorescence attained by wet end addition of di-sulphonic (DS) OWAs with GCC and talc filler are 91.3%, 142.8, 24.38 and 88.2%, 137.6 and 23.32, respectively. Addition of different OWAs was done by adding the slightly lower doses of OWAs at wet end and the rest amount in surface sizing. Moreover in surface sizing, the most promising results were attained in the combinations having hexa-sulphonic (HS) OWAs. Recycled pulp with GCC filler showed the best result with di-sulphonic (DS) OWAs in wet end and hexa-sulphonic (HS) in surface sizing whereas with Talc filler di-sulphonic (DS) OWAs in wet end and tetra-sulphonic (TS) in surface sizing showed the best result. The addition of OWAs in wet end and surface sizing resulted in modified optical properties such that they were improved in some combinations. The range of cost reduction with addition of OWAs in wet end and surface sizing was between 25-33% with GCC and 22-30% with Talc.

Keywords : OWA, Bleached recycled pulp, Brightness, Whiteness, GCC and Talc

INTRODUCTION

The use of fluorescent/ optical whitening/ brightening agent (FWA/OWA/OBA) and shading colorants are the main tools to eliminate the yellowish hue of bleached pulp fibers and to improve paper quality in terms of appearance i.e. brightness, whiteness, fluorescence and tint. They convert invisible ultraviolet radiation at 300-400 nm to visible blue light at 400-500 nm. Using OWAs is a convenient way to increase the reflectance (and thus the lightness) of paper and simultaneously to move the shade from yellow to blue. This subtle tint change makes the paper look even whiter.

The OWAs used in the paper industry are derivatives of diamino-stilbene-sulfonic acids. The number (2, 4 and 6) of sulfonic acid groups (-SO3H) is used to classify these products as di-, tetra- and hexa-sulfonic OWAs respectively. High affinity di-sulphonic OWAs are mainly used in the wet-end. Traditional tetra-sulphonic OWAs are widely used in the wet-end, at the size press and in coating. Hexa-sulphonic OWAs are applied only at the size press or in coating application for high whiteness levels, due to their low affinity to fibers [1].

Disulfo OWAs have high affinity, but are extremely sensitive to alum and cationic auxiliaries. Because of their low compatibility with starch, they can't be used effectively in the size press. Tetrasulfo OWAs have adequate affinity and are compatible with starch and alum, making them suitable for a wide range of applications. As hexasulfo OWAs have low affinity, they are only suitable for surface application, where they are used to obtain maximum whiteness [2].

Roughly one-third of the OWA is added in wet-end and the remaining two-thirds are added on paper surface through size press. The OWA requires good acid and alum stability, compatibility with fillers, and good affinity with fibers, since any unabsorbed OWA is lost in the white water [3, 4].

Some of the critical factors in use of OWAs include retention, quenching, and competition with other UV absorbers. OWA retention can be increased by addition of a coagulant to the pulp stream, either before or after the whitener. It is necessary to note that highly charged cationic polyelectrolytes can easily destroy the fluorescent character of the molecule. The effect is called quenching. The coagulants used for the retention of filler, fines and fibers have a negative effect on efficacy of OWA [5].

OWAs can be considered to be anionic direct dyes. They are substantive, capable of hydrogen bonding, and can bind to cellulosic fibers without assistance from cationic additives to affect retention. However, strongly cationic chemicals (including alum) which act as quenching agents should be avoided since they adversely affect fluorescent properties and reduce brightness. Low pH and presence of trivalent aluminum are unfavorable as far as the efficiency of an OWA is concerned. If the pH is low enough, some of the sulfonic groups can occur in acid form. This lowers the solubility of OWAs. Aluminum salts of OWAs are insoluble and impart a greenish shade to the paper, in addition to reducing the effectiveness of OWAs [6]. In higher white shades, a hexa-sulphonic OWA is additionally applied at the size press to obtain the required whiteness level [1].

Now-a-days alternate OWAs are available in the market in place of sulfonic group based OWA. It is important to study their chemistry and chemical interaction with papermaking fibers and additives, so that the cost of papermaking could be decreased with better usage of OWA for the target brightness and whiteness.

The selection and dosage of OWAs for wet-end and size press applications are generally suggested by the chemical suppliers. The selection and dosage of OWAs for wet-end application are critical. The chemistry of interaction of OWA with cellulosic fibers and wet-end additives, primarily fillers, is not well known to papermakers. This, in turn, makes a gap between knowledge and application part. Paper makers are using the OWAs at wet end as well as at size press. This study was envisaged to select the appropriate OWAs for addition in wet-end and size press for recycled pulp based industries and to understand their effect on brightness and whiteness of paper. The different OWAs will be applied in wet-end and size press and selected based upon their interaction and effect on paper and to reduce the consumption of OWAs for the targeted brightness and whiteness as well as paper making cost

EXPERIMENTAL

Materials

Pulp: The bleached recycled pulp (BRP) was procured from an integrated pulp and paper mill in southeast India. The pulps were used as such without refining/beating.

Wet-end Chemicals:

a) *Optical whitening agents:* Different OWAs di-tetra and hexa sufonated were used in the study collected from different suppliers in India.

b) *Alkyl ketene dimer (AKD):* AKD emulsion for internal sizing of paper was used as sizing agent.

c) *Cationic starch (CS):* Cationic starch of 0.02-0.025 degree of substitution was used as dry strength additive.

d) *Cationic fixing agent (CFA):* Low molecular weight cationic polyamine fixing agent (CFA) was used as fixing agent and medium to high molecular weight cationic polyacrylamide flocculant (CPAM) used as retention aid.

e) *Fillers:* GCC-60 and talc were collected from local suppliers.

Methods

Preparation of wet end chemicals

a) *Cationic starch:* Cationic starch of 1% solids (w/v) was cooked at 90±2°C for 30 minutes with continuous stirring using an agitator.

b) *AKD:* AKD emulsion was diluted to 1% solids before addition to pulp stock. Distilled water was used for the preparation of different chemical solutions.

c) *OWAs*: Various OWAs were characterized in terms of pH, solids and E value. The later was determined through spectrophotometer. The solids content and E-Value of the different OWAs were determined.

E-Value: It is the absorption of a 1% solution of unit path length. The absorbance is directly depending on the nature of the solution, concentration and the path length of the solution.

Principle: The absorbance of UV light in a solution at a characteristic wavelength is used for the quantitative determination of OWA in solution. OWA reacts as a light transformer. Only the absorption bands from 340-370 nm have the ability to transform into and emit visible light of 440-450 nm. The E-value of a product is thus the absorbance of a hypothetical 1% solution by 10 mm path length at a defined wavelength.

Procedure: Absorbance of 1% (w/v) solution of OWA was measured at 350 nm using 10 mm standard quartz cuvette on a UV-VIS Spectrophotometer using distilled water as blank with absorbance zero. The powder OWAs were wetted using 2-3 mL of 5% Na_2CO_3 solution before their dilution using distilled water.

The ionic behavior and charge demand of the OWAs of 0.1% concentration was also determined using the Mutek PCD-03.

Preparation of Di-sulphonated OWA (Powder): The required amount of OWA was weighed on solid basis and was dissolved in hot water at a temperature of 60-65°C as its solubility in water is less.

Preparation of Tetra-sulphonated OWA (Powder): The required amount of OWA was weighed on solid basis and was dissolved in hot water at a temperature of 40-45°C.

d) Low molecular weight cationic polyamine fixing agent (CFA): 0.1% (w/v) solution was prepared in distilled water. 1 g of the liquid CFA was weighed and the volume was made up to 1 L using distilled water. The ionic behavior and charge demand of the CFA of 0.1% concentration was determined using the Mutek PCD 03 pH.

e) Medium to high molecular weight cationic polyacrylamide flocculant (CPAM): 0.1% (w/v) solution of the granular flocculant was prepared in distilled water by gradual addition of the granules in lukewarm water (40-45 °C). Continuous mild stirring of about 400 rpm was given to the solution for 30 min. The ionic behavior and charge demand of the CPAM of 1gpl concentration was determined using the Mutek PCD 03 pH.

Stock Preparation

Different components (chemicals and additives) were added to the pulp slurry in the following order with continuous stirring:

- BRP (1% consistency)
- OWA solution: kg/t of pulp
- CFA: 200 g/t of pulp
- Cationic starch: 5 kg/t of pulp
- AKD: 0.9 kg/t of pulp (without filler); 6 kg/t of pulp (with filler)
- Filler (when required)
- CPAM: 200 g/t of pulp

Handsheets Preparation

Handsheets of 70 gsm were made on sheet former as per TAPPI Test Method T 272 sp-97. They were pressed in hydraulic press and then air dried. The handsheets were conditioned at 27±2 °C and 65±5% relative humidity for at least 24 hours as per IS/ISO: 187.

Surface Sizing

Oxidized starch was dispersed to 10% (w/v) slurry by mixing it with distilled water. The dispersed slurry was taken into a beaker and placed into water bath at 50°C. The temperature of water bath was raised to gelatinize the slurry. Continuous mild stirring was given to the slurry. The slurry was then cooked at 90°C for about 30 minutes. Solid level of cooked oxidized starch was maintained at the concentration of 14% while viscosity was maintained at 45-50 cP at 60°C. After cooking of oxidized starch specific OWAs was added to oxidized starch as per the dose of OWA application. Final solid at the time of application of Oxidized starch and OWA solution is maintained at 10%. All OWAs were used on as such basis in surface sizing For surface sizing of handsheets, starch was applied using an automatic laboratory bar coater (RK print coater). The starch pick up (sizing weight) was controlled by using bars of different numbers and by adjusting speed of the bar coater. All sheets after starch application were air dried at 27±2°C and 65±2% relative humidity for at least 4 hours.

Optical Properties of Handsheets

The following optical properties of paper handsheets were measured with the brightness tester (L&W Elrepho):

- Basic brightness (R457 420)
- ISO brightness (R457 C)
- CIE whiteness (CIE W D65 D65/10)
- Yellowness (Yellowness D65 D65/10)
- L*, a*, b*
- ISO Opacity
- Light scattering coefficient
- Fluorescence (R457 Flour D65)
- The fluorescence using C source i.e. R457 Flour C was also calculated using the following formula: R457 C – R457 420 i.e. brightness - basic brightness.

RESULTS AND DISCUSSION

Characterization of wet-end chemicals

General properties at 0.1% solution namely colloidal charge (µeq/g) and pH of cationic fixing agent were 3050 and 7.4, respectively. Colloidal charge (µeq/g) of 1 % AKD and cationic starch was 111 and 1655, respectively. The pH of 1% solution of AKD and cationic starch was 3.1and 6.4, respectively. Viscosity of cationic starch was 31 cP at 1% solid level at 30°C. Initial solid (%) of AKD and cationic starch, GCC and talc was 16.1, 89.6, 69.7 and 100, respectively. Brightness, %ISO of GCC and talc was 93.0 and 90.0, respectively. Colloidal charge (µeq/g) and pH for recycled pulp at consistency of 0.33% was reported as 3.93 and 8.2, respectively. Brightness, %ISO of recycled pulp was 83.1. Colloidal charge (µeq/g) and pH of 5% solution of GCC and talc were 4.72, 10.5 and 1.72, 10.3, respectively as shown in table 1.

Table 1: Characterization of wet-end chemicals and pulp

Parameters	RCP	CFA	AKD	CS	GCC	Talc
Solids (as such), %	...	...	16.1	89.6	69.7	100
Concentration, %	0.33	0.1	1.0	1.0	-	-
Brookfield viscosity (27°C), cP	--	36	24	31.0	-	-
pH	8.2	7.4	3.1	6.4	10.5	10.3
Charge demand, µeq/g	3.93	3050	111	1655	4.72	1.72
Brightness, ISO %	83.1	...	...	...	93.0	90.0

Characterization of different OWAs

Different OWAs have different e-values. Two disulphonated, three tetra sulphonated and one hexa sulphonated OWAs were included in the study. E- Values of di sulphonated OWAs as DS1 and DS2 were 562 and 493, respectively. E- Values of tetra sulphonated OWAs as TS1, TS2 and TS3 were 496, 327 and 265 whereas for hexa sulphonated like HS1 it was 374 as shown in table 2.

Table 2: Characterization of different OWAs and their cost

Name of OWA (% solids)	Type of OWA (sulphonated)	E-value (1 %/ 1 cm)	Cost, Rs/kg	
			(on as such basis)	(on solid basis)
DS1 (22.4)	Di	562	71.5	320.0
DS2 (99.9)	Di	493	249.0	249.0
TS1 (25.7)	Tetra	496	66.0	256.0
TS2 (22.6)	Tetra	327	49.0	217.0
TS3 (99.4)	Tetra	265	164.0	164.0
HS1 (20.7)	Hexa	374	41.0	198.0

STUDY WITH GCC FILLER

Effect of DS1 addition in wet-end with GCC filler at 21% ash level and surface sizing with TS1, TS2, TS3 and HS1

Optical properties with wet end addition of DS1 showed increasing trend with the increase in dose of OWA up to 11 kg/t. The maximum values of optical properties were obtained at a dose level of 11 kg/t of DS1 as shown in table 3.

Table 3: Effect of DS1 in wet end with GCC filler at 21% ash level

DS1 , kg/t	Nil	4	7	11	13
Brightness, %ISO	86.0	88.1	89.7	91.3	90.9
B. Brightness, %ISO	76.9	78.1	78.6	78.5	78.4
CIE Whiteness	114.8	134.5	137.8	142.8	140.1
Fluorescence	14.36	20.12	24.68	24.38	24.21
Yellowness	-11.59	-19.96	-22.51	-22.84	-22.62
L*	93.77	94.10	94.25	94.39	94.31
a*	2.22	2.46	2.52	2.61	2.56
b*	-8.60	-10.63	-11.83	-12.03	-11.92
Opacity, %ISO	87.6	87.1	87.3	87.5	87.4
S. Coeff., m²/kg	69.2	69.2	69.5	69.4	69.1

Further the dose of DS1 was reduced to 7 kg/t in wet end along with addition of other OWAs in surface sizing of the handsheets at doses ranging from 1-4 kg/t. It was observed that maximum values of optical properties were obtained with addition of HS1 at a dose level of 3 kg/t in surface sizing along with DS1 addition of 7 kg/t at wet end which was the best combination among all. On comparing with control, it was observed that the brightness and whiteness was comparable whereas the gain in fluorescence was increased from 24.38 to 26.85 along with 32.8% reduction in cost of OWA per tonne of paper as shown in table 4.

Table 4: Best combinations of DS1in wet end with 21% ash level of GCC

DS1wet-end, kg/t	11 (control)	7			
OWA at size press, kg/t	nil	3 TS3	3 TS1	4 TS2	3 HS1
Brightness, %ISO	91.3	91.8	90.4	90.7	91.0
Basic Brightness, %ISO	78.5	78.5	79.1	78.5	79.1
CIE Whiteness	142.8	142.9	140.7	142.9	143.1
Fluorescence	24.38	26.13	25.14	25.63	26.85
Yellowness	-22.84	-24.10	-23.28	-23.64	-24.10
L*	94.39	94.78	94.69	93.79	94.62
a*	2.61	2.72	2.68	2.62	2.71
b*	-12.03	-12.39	-12.15	-12.43	-13.11
Cost, Rs./t paper	3620	2732	2438	2436	2363

Effect of DS2 addition in wet-end with GCC filler at 21% ash level and surface sizing with TS1, TS2, TS3 and HS1

Optical properties with wet end addition of DS2 showed increasing trend with the increase in dose of OWA up to 8 kg/t. The maximum values of optical properties were obtained at a dose level of 8 kg/t of DS2 as shown in table 5. Further the DS2 dose was reduced to 5 kg/t in wet end along with addition of other OWAs in surface sizing of the handsheets at doses ranging from 1-4 kg/t. It was observed that maximum values of optical properties were obtained with addition of HS1 at a

dose level of 4 kg/t in surface sizing along with DS2 addition of 5 kg/t at wet end which was the best combination among all. On comparing with control, it was observed that the brightness value were comparable whereas the gain in whiteness was observed by 4.5 units, and fluorescence were increased from 21.6 to 26.2 along with 29.3% reduction in cost of OWA per tonne of paper as shown in table 6.

Table 5: Effect of DS 2 in wet end with GCC filler at 21% ash level

DS2, kg/t	nil	3	5	8	10
Brightness, %ISO	86.0	87.6	89.2	91.0	90.9
B. Brightness, %ISO	78.9	78.2	79.5	79.6	79.2
CIE Whiteness	114.8	128.2	137.2	139.2	137.3
Fluorescence	14.36	19.36	21.45	21.55	21.50
Yellowness	-11.59	-16.14	-21.30	-21.35	-21.31
L*	93.77	93.95	94.16	94.20	94.18
a*	2.22	2.45	2.93	2.98	2.94
b*	-6.60	-8.90	-11.42	-11.49	-11.42
Opacity, %ISO	87.6	87.2	87.1	87.3	87.2
S. Coeff., m^2/kg	69.2	68.9	68.9	68.8	68.9

Table 6: Best combinations of DS2 in wet end with 21% ash level of GCC

DS2 wet-end, kg/t	8 (control)	5			
OWA at size press, kg/t	nil	3 TS3	3 TS1	4 TS2	4 HS1
Brightness, %ISO	91.0	90.7	90.5	89.9	90.8
Basic Brightness, %ISO	79.6	78.7	78.9	79.1	79.3
CIE Whiteness	139.2	141.2	141.2	140.3	143.7
Fluorescence	21.60	24.98	24.71	24.85	26.2
Yellowness	-21.35	-23.91	-23.43	-23.66	-25.09
L*	94.20	94.90	94.20	93.54	93.69
a*	2.98	3.14	2.64	2.69	2.83
b*	-11.49	-12.69	-12.47	-12.34	-13.05
Cost, Rs./t paper	1992	1737	1443	1441	1409

Effect of TS3 addition in wet-end with GCC filler at 21% ash level and surface sizing with TS1, TS2, TS3 and HS1

Optical properties with wet end addition of TS3 showed increasing trend with the increase in dose of OWA up to 8 kg/t. The maximum values of optical properties were obtained at a dose level of 8 kg/t of TS3 as shown in table 7. Further the dose of TS3 was reduced to 5 kg/t in wet end along with addition of other OWAs in surface sizing of the handsheets at doses ranging from 1-4 kg/t. It was observed that maximum values of optical properties were obtained with addition of HS1 at a dose level of 4 kg/t in surface sizing along with TS3 addition of 5 kg/t at wet end which was the best combination among all. On comparing with control, it was observed that the gain in brightness was from 89.9 to 90.6 whereas the gain in whiteness was observed by 5.9 units, and fluorescence was increased from 20.67 to 26.24 along with 25% reduction in cost of OWA per tonne of paper as shown in table 8.

Table 7: Effect of TS3 in wet end with GCC filler at 21% ash level

TS3 extra, kg/t	nil	3	5	8	10
Brightness, %ISO	86.0	87.2	88.9	89.9	89.4
B. Brightness, %ISO	78.9	79.1	79.2	79.5	79.4
CIE Whiteness	114.8	130.1	133.5	139.5	138.2
Fluorescence	14.36	17.11	19.67	20.67	19.85
Yellowness	-11.59	-16.18	-19.65	-19.85	-19.71
L*	93.77	93.90	94.30	95.20	95.90
a*	2.22	2.46	3.05	3.11	3.07
b*	-6.60	-8.90	-10.69	-11.10	-11.01
Opacity, %ISO	87.6	87.7	87.9	87.8	87.2
S. Coeff., m^2/kg	69.2	68.3	67.9	68.1	68.2

Table 8: Best combinations of TS3 in wet end with 21% ash level of GCC

TS3 wet-end, kg/t	8 (control)	5			
OWA at size press, kg/t	nil	3 TS3	4 TS1	4 TS2	4 HS1
Brightness, %ISO	89.9	89.5	89.2	89.9	90.6
Basic Brightness, %ISO	79.5	79.2	78.8	79.3	78.6
CIE Whiteness	139.5	139.5	139.3	141.4	145.4
Fluorescence	20.67	23.62	24.26	26.64	26.24
Yellowness	-19.85	-22.94	-23.29	-24.05	-25.84
L*	95.2	94.42	94.59	94.51	94.51
a*	3.11	3.31	2.98	2.94	3.24
b*	-11.10	-12.32	-12.19	-12.60	-13.51
Cost, Rs./t paper	1312	1312	1084	1016	984

STUDY WITH TALC FILLER

Effect of DS1 addition in wet-end with TALC filler at 21% ash level and surface sizing with TS1, TS2, TS3 and HS1

Optical properties with wet end addition of DS1 showed increasing trend with the increase in dose of OWA up to 11 kg/t. The maximum values of optical properties were obtained at a dose level of 11 kg/t of DS1 as shown in table 9. Further the

Table 9: Effect of DS1in wet end with TALC filler at 21% ash level

DS1, kg/t	Nil	4	7	11	13
Brightness, %ISO	83.5	86.8	87.5	88.2	87.4
B. Brightness, %ISO	76.6	76.4	76.7	76.9	76.4
CIE Whiteness	110.2	130.1	134.5	137.6	133.9
Fluorescence	13.49	19.12	23.25	23.32	23.20
Yellowness	-10.49	-18.12	-21.48	-21.68	-21.42
L*	92.93	93.10	93.26	93.66	93.19
a*	2.02	2.18	2.26	2.35	2.24
b*	-5.96	-9.11	-11.18	-11.65	-11.01
Opacity, %ISO	82.5	82.6	82.6	82.4	82.3
S. Coeff., m^2/kg	46.5	46.5	46.8	46.2	46.4

dose of DS1 was reduced to 7 kg/t in wet end along with addition of other OWAs in surface sizing of the handsheets at doses ranging from 1-4 kg/t. It was observed that maximum values of optical properties were obtained with addition of TS3 at a dose level of 3 kg/t in surface sizing along with DS1 addition of 7 kg/t at wet end which was the best combination among all. On comparing with control, it was observed that the brightness and whiteness was comparable whereas the gain in fluorescence was increased from 23.32 to 24.15 along with 22.3% reduction in cost of OWA per tonne of paper as shown in table 10.

Table 10: Best combinations of DS1 in wet end with 21% ash level of TALC

DS1wet-end, kg/t	11 (control)	7			
OWA at size press, kg/t	nil	3 TS3	3 TS1	2 TS2	3 HS1
Brightness, %ISO	88.2	88.1	88.0	87.9	87.7
Basic Brightness, %ISO	76.9	76.8	76.8	76.8	76.4
CIE Whiteness	137.6	137.2	136.5	134.2	136.24
Fluorescence	23.32	24.15	24.12	24.66	25.36
Yellowness	-21.68	-21.65	-21.68	-22.65	-23.03
L*	93.66	93.51	93.61	92.54	92.78
a*	2.35	2.34	2.32	2.34	2.32
b*	-11.65	-11.50	-11.60	-11.60	-11.74
Cost, Rs./t paper	3520	2732	2438	2338	2363

Effect of DS2 addition in wet-end with TALC filler at 21% ash level and surface sizing with TS1, TS2, TS3 and HS1

Optical properties with wet end addition of DS2 showed increasing trend with the increase in dose of OWA up to 9 kg/t. The maximum values of optical properties were obtained at a dose level of 9 kg/t of DS2 as shown in table 11. Further the

Table 11: Effect of DS2 in wet end with TALC filler at 21% ash level

DS2, kg/t	nil	4	6	9	12
Brightness, %ISO	83.5	85.9	86.5	87.3	86.8
B. Brightness, %ISO	76.6	76.5	76.4	76.5	76.4
CIE Whiteness	110.2	130.1	132.9	138.8	136.1
Fluorescence	13.49	20.12	21.73	21.94	21.82
Yellowness	-10.49	-18.12	-20.57	-20.68	-20.62
L*	92.93	92.94	92.96	93.21	93.10
a*	2.02	2.62	2.82	2.92	2.95
b*	-5.96	-9.12	-10.94	-11.41	-11.20
Opacity, %ISO	82.5	82.3	82.4	82.3	82.7
S. Coeff., m^2/kg	46.5	47.1	47.2	46.9	46.8

DS2 dose was reduced to 6 kg/t in wet end along with addition of other OWAs in surface sizing of the handsheets at doses ranging from 1-4 kg/t. It was observed that maximum values of optical properties were obtained with addition of HS1 at a dose level of 2 kg/t in surface sizing along with DS2 addition of 6 kg/t at wet end which was the best combination among all. On comparing with control, it was observed that the brightness and whiteness value were comparable whereas the gain in fluorescence were increased from 21.94 to 24.69 along with 29.7% reduction in cost of OWA per tonne of paper as shown in table 12.

Table 12: Best combinations of DS2 in wet end with 21% ash level of TALC

DS2 wet-end, kg/t	9 (control)	6			
OWA at size press, kg/t	nil	3 TS3	4 TS1	2 TS2	2 HS1
Brightness, %ISO	87.3	87.1	87.1	86.9	87.3
Basic Brightness, %ISO	76.5	76.4	76.4	76.2	74.6
CIE Whiteness	138.8	137.9	138.6	138.2	137.5
Fluorescence	21.94	24.4	24.12	24.89	24.69
Yellowness	-20.68	-22.90	-22.12	-22.24	-23.02
L*	93.21	93.61	93.21	93.20	92.74
a*	2.92	2.75	3.12	3.16	2.90
b*	-11.41	-12.01	-11.25	-11.62	-12.05
Cost, Rs./t paper	2241	1986	1758	1592	1576

Effect of TS3 addition in wet-end with TALC filler at 21% ash level and surface sizing with TS1, TS2, TS3 and HS1

Optical properties with wet end addition of TS3 showed increasing trend with the increase in dose of OWA up to 9 kg/t. The maximum values of optical properties were obtained at a dose level of 9 kg/t of TS3 as shown in table 13. Further the

Table 13: Effect of TS3 in wet end with TALC filler at 21% ash level

TS3, kg/t	nil	4	6	9	12
Brightness, %ISO	83.5	85.9	86.3	86.8	86.5
B. Brightness, %ISO	76.6	76.1	76.7	76.5	76.4
CIE Whiteness	110.2	128.1	128.69	138.6	137.1
Fluorescence	13.49	18.4	19.14	20.11	20.05
Yellowness	-10.49	-15.12	-18.64	-18.94	18.75
L*	92.93	92.96	93.23	93.42	93.33
a*	2.02	2.42	2.89	2.95	2.92
b*	-5.96	-8.42	-10.07	-10.17	-10.12
Opacity, %ISO	82.5	82.4	82.6	82.7	82.4
S. Coeff., m^2/kg	46.5	46.1	46.3	46.5	46.7

dose of TS3 was reduced to 6 kg/t in wet end along with addition of other OWAs in surface sizing of the handsheets at doses ranging from 1-4 kg/t. It was observed that maximum values of optical properties were obtained with addition of HS1 at a dose level of 4 kg/t in surface sizing along with TS3 addition of 6 kg/t at wet end which was the best combination among all. On comparing with control, it was observed that the gain in brightness was from 86.8 to 87.3 whereas the gain in whiteness was observed by 1.3 units, and fluorescence was increased from 20.11 to 25.17 along with 22.2% reduction in cost of OWA per tonne of paper as shown in table 14.

Table 14: Best combinations of TS3 in wet end with 21% ash level of TALC

TS3 wet-end, kg/t	9 (control)	6			
OWA at size press, kg/t	nil	2 TS3	4 TS1	3 TS2	4 HS1
Brightness, %ISO	86.8	86.9	86.7	86.7	87.3
Basic Brightness, %ISO	76.5	76.2	76.8	76.5	77.2
CIE Whiteness	138.6	138.9	137.9	138.2	139.9
Fluorescence	20.11	23.54	23.38	23.36	25.17
Yellowness	-18.94	-22.86	-22.12	-22.58	-24.45
L*	93.02	93.10	93.12	93.54	93.47
a*	2.95	2.99	2.97	2.95	3.11
b*	-10.17	-11.94	-11.49	-11.85	-12.70
Cost, Rs./t paper	1476	1312	1248	1131	1148

CONCLUSION

Using GCC filler the maximum values of optical properties for DS1, DS2 and TS3 was obtained at a dose level of 11 kg/t, 8 kg/t and 8 kg/t, respectively at wet end. The best combination of OWAs at wet end + surface sizing was DS1 @ 7kg/t + HS1 @ 3 kg/t, DS2 @ 5 kg/t + HS1 @ 4 kg/t and TS3 @ 5 kg/t + HS1 @ 4 kg/t where reduction in cost was up to 32.8%, 29.3% and 25.0%, respectively without compromising the optical properties.

Using talc filler the maximum values of optical properties for DS1, DS2 and TS3 was obtained at a dose level of 11 kg/t, 9 kg/t and 9 kg/t, respectively at wet end. The best combination of OWAs at wet end +in surface sizing was DS1 @ 7 kg/t + TS3 @ 3 kg/t, DS2 @ 6 kg/t + HS1 @ 2 kg/t and TS3 @ 6 kg/t + HS1 @ 4kg/t where reduction in cost was up to 22.3% , 29.7% and 22.2%, respectively without compromising the optical properties.

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