Quality of Indigneous Coated Papers And Ways to Improve it

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Abstract

Coated paper market in India is diversifying rapidly. Some of the Indigenous coated paper samples were compared for different optical, printing and surface characteristics with papers of foreign origin. Except few mills whose quality was found to be at par with foreign papers, most of other Indian mills were lacking in quality parameters like print non uniformity, print gloss and ink demand. Picking velocity of all Indigenous coated papers was higher than foreign samples which are undesirable. To improve the quality of Indigenous coated papers effect of different coating color variables were examined using Plackett- Burman statistical design. The parameters studied were pigment type, its amount, binder amount, total solids, amount of thickner. The effect of these on rheological, optical, surface and printing characteristics was studied.

Keywords: Coating, Picking velocity, Print non-uniformity, Print gloss

INTRODUCTION

Coated paper market in India is diversifying rapidly. At the same time coated paper manufacturing cost needs to be reduced to compete in the international market. Today the requirements of coated grade are expanding to embrace qualities normally seen in uncoated grade such as higher brightness, higher light fastness, lower cost and improved runnability. Also machines are running faster and chemical technology is also evolving rapidly to keep pace with the modern trend. The advancement in printing technology is also posing stringent quality requirements.

To meet this there is a need to assess the quality of indigenous coated papers. In present investigation, the indigenous coated papers were evaluated and compared with papers of foreign origin. The possibilities of improvement were also examined.

RESULTS AND DISCUSSION

Optical Characteristics of Indigenous and Imported coated paper samples

The brightness and whiteness of coated paper of Indian origin are mostly lower than imported samples except for few mills which have comparable values (Fig 1, 2). It has been observed that Indian coated paper have lower brightness (3-5 points), whiteness (3-16 points) and fluorescence (2-7 points) when compared to corresponding base paper (Tables I, II). This indicates that Indian coated paper manufacturers are required to improve these properties. The low value of above properties could probably be due to improper scattering of light by the applied coating layer. The coating layer in such paper has high light absorption. To improve these, an improvement in coating formulation is needed to get coating with high light scattering and low light absorption. Also fluorescence values obtained for Indian

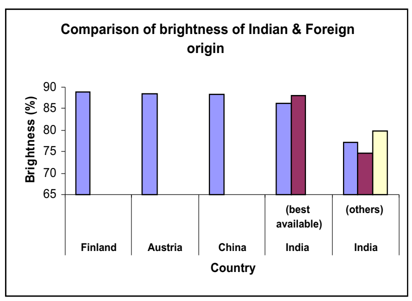

Figure-1

coated papers is lower than that of imported ones (Fig.3). This could probably be due to improper grade of optical whitener being used by Indian manufactures in coating recipe.

The lower brightness and whiteness in the case of indigenous coated papers is probably due to improper coating structure. The primary influence of coating structure on optical characteristics brightness and opacity is through optical scatter. Optical scatter has a linear dependence on coating void volume i.e. if the void volume is doubled

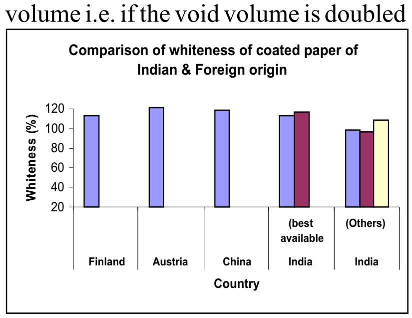

Figure-2

(without affecting void size) [1]. One can expect double in the scattering of light. The dependence of scattering on void size is highly nonlinear. For example, if the void size is doubled then there could be quadruple effect on the light scattering. This is due to the wave nature of light. Conditions used for applying coating also affect depositions, distributions and coverage of the coating layer with a corresponding impact on brightness and opacity values. Particle shape, size and size distribution of pigment influences its dimensional configuration and volume configuration in the final coated layer. The pigment particle dimensions together with the volume and relative size of the inter particle voids determine the scattering and opacifying effect of pigment in coating.

Printing Characteristics of Indigenous and Imported coated paper samples

The indigenous coated papers were compared with imported ones for different printing characteristics.

Print density

Print density is affected by ink setting/ink holdout. For good density the vehicle of printing ink should stay on the top of paper together with ink pigment. The more the dried ink is retained on the outer surface of the paper, the higher will be the ink density; accordingly, the lower will be the ink demand. Paper with large pores in coating will have more penetration of printing ink leading the lower density [2]. This is observed in case of some indigenous coated papers. This indicated that blending of different pigments in coating colour needs to be properly evaluated to get improvement in the quality of indigenous paper.

Print density which is indicative of print

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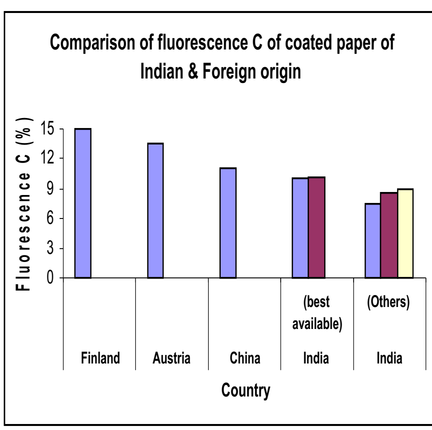
Table I: Base Paper and Coated Paper Characteristics of samples collected from different mills

Properties	Base Paper Mill 1	Coated Mill 1	Base Paper Mill 2	Coated Mill 2
Grammage (g/m^2)	56.0 – 64.0	74.5 – 90.	56.0	73.4 – 90.0
Both side Coat Weight (g/m^2)	-	18.0 – 26.0	-	17.0 – 26.0
Bendtson Smoothness (ml/min)	139 - 397	1 - 82	114	8 - 24
Bendtson Porosity (ml/min)	403 - 823	10.1 – 25.0	398	9.0 – 15.4
Formation (Techpap)	72.3 – 81.1	46.4 – 76.5	69.5	50.5 – 51.6
Brightness(%)	80.0 – 86.2	77.1 – 82.2	80.8	77.6 – 74.5
Whiteness(%)	114.3 – 123.2	98.3 – 120.1	122.4	97.0 – 107.3
Fluroscence C (%)	5.3 – 6.9	3.4 – 14.6	5.3	3.9 – 4.1
Cobb 60	17.0 – 21.3	22.3 – 25.0	20.3 – 22.0	21.0 – 24.5
Ash (%)	7.0 – 10.4	23.0 – 32.2	12.2	23.5 – 36.2

Table II: Base Paper and Coated Paper Characteristics of samples collected from different mills

Properties	Base Paper Mill 3	Coated Mill 3	Base Paper Mill 4	Coated Mill 4
Grammage (g/m^2)	60.0	89.0	54.0 – 67.0	85.0 – 112.0
Both side Coat Weight (g/m^2)	-	19.0	-	17.0 – 22.0
Bendtson Smoothness (ml/min)	233	13	115 - 269	5 - 9
Bendtson Porosity (ml/min)	245	10.6	195 - 342	1.47 – 10.2
Techpap Formation	64.0	65.6	66.1 – 73.1	45.0 – 55.0
Brightness (%)	85.4	80.8	82.6 – 86.6	76.7 – 80.2
Whiteness (%)	142.8	112.6	85.2 – 142.3	83.0 – 113.2
Fluroscence C (%)	7.6	5.1	4.4 – 7.2	3.0 – 4.6
Cobb 60	19.8 - 21.0	22.5 – 25.1	19.0 – 23.0	23.1 – 27.3
Ash (%)	12.4	28.2	12.0 - 18.0	28.6 – 33.0



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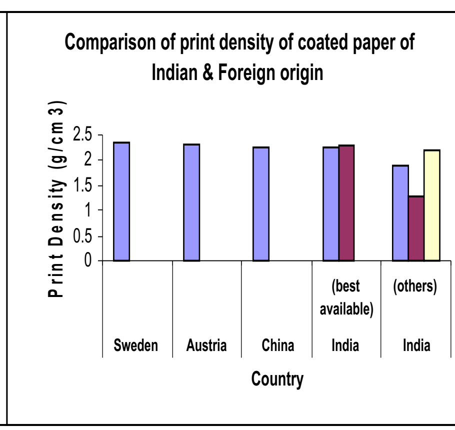

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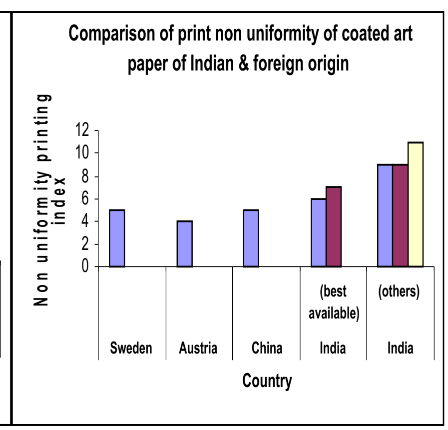


Figure-5

darkness at a particular ink layer for best quality indigenous papers is comparable to that of foreign samples. However it is lower in other samples (Fig.4). This indicates that more ink will be required to print most of Indian coated papers when compared to foreign papers.

Print Mottle (Print Non-Uniformity)

Print non uniformity leads to print mottle which is uneven appearance of color density in a print. This is due to the surface factors to absorb ink evenly due to variation in base paper formation or coat weight. The variation in sheet matrix formation measured as look through of imported coated paper is quite lower than indigenous paper. The base paper formation in case of indigenous papers has shown wide variation (Table I, II). The base paper formation variation can lead to print mottle non uniform compression during calendering, resulting in variation in coating layer densification [3,14]. Sheets that contain binder migration, coat weight variation, inferior coating profile and heterogeneous pigment blends can all cause mottle formation on the printed sheet.

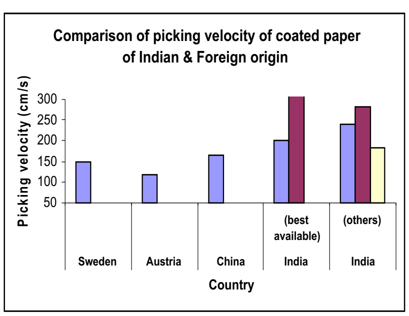
The non uniformity printing index is lower for imported papers as compared to indigenous coated paper (Fig. 5).

Picking velocity

Picking velocity of all indigenous coated paper were found to be quite higher (more than 2000-2800 mm/s) than imported ones (1400-1600 mm/s) (Fig.6). As a guide, for lithographic printing paper should not show any pick up to velocity of 1400 mm/s using low viscosity oil at 27°C, 65% relative humidity. The higher values indicate that excessive binder is being used by Indian paper manufactures without any special advantage. The excess amount of binder always has negative effect on the printing characteristics.

Print Gloss

Print gloss is an important requirement of coated paper. Delta gloss which is indicative of difference in the print gloss and paper gloss was more in case of



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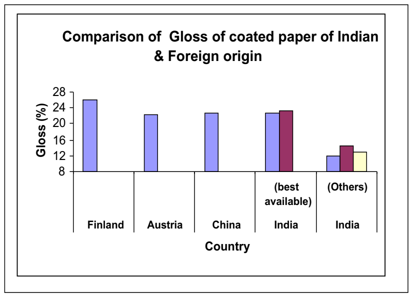

Figure-7

foreign papers (Fig.7). The best available Indigenous coated paper has delta gloss close to imported ones whereas this parameter was quite low in the case of other coated samples.

Print gloss depends not only on the unprinted initial sheet gloss but also on the surface porosity and ink binder interactions [4]. Generally the higher initial sheet gloss is, the higher is print gloss. Print gloss and delta gloss are strongly affected by both surface and bulk structure of coating. Apart from sheet gloss the print gloss is also affected by pore radius and microscopic surface topography. The effect of pore radius on print gloss is possibly through both capillary pressure and phase separation. Smaller pores have higher capillary pressure and thus greater pulling the ink from the paper surface. Inks are typically multiphase system comprised of pigments, resins and solvents. It has been hypothesized that the pores could pull the solvents from the full ink and then set ink more rapidly than large pores [5]. It has also been theorized that surface pores are of greater importance than bulk pores. Sheet gloss is influenced by a broad bandwidth of roughness from the microscopic to the macroscopic [6]. Yet, print gloss and delta gloss are influenced by microscopic topography independently of sheet gloss. The reason for this is that the ink layer is capable of hiding a significant amount of microscopic roughness. The mechanism is independent of the influence of micro topography on sheet gloss.

POSSIBILITIES OF IMPROVEMENT IN COATED PAPER QUALITY

The above investigations indicate that quality of some of the indigenous coated papers is at par with foreign one. These mills are mainly doing double coating i.e. Precoating and Top coating. Most of the other mills are having single coating operation. The possibilities of improving their quality with single coating were examined in this study. In coating color the major component is pigment.. Pigments actually forms 80-95% of the coating by weight. Presently, the Indian mills are using China clay (80 – 90%) and GCC (10 – 20%) as pigment in coating formulation. The effect of different coating pigments was examined.

EFFECT OF DIFFERENT PROCESS VARIABLES ON DIFFERENT CHARACTERISTICS OF COATED PAPER

Coating of paper is a multivariable system and obtaining quantitative estimates of the effect of each of the parameter on the process is quite difficult. Main attention was paid to pigments as pigment is the most abundant component in coating and hence most important factor affecting the properties of coating. Different process variable affects the coating by interacting in different ways. The effect of following seven process variables on the coated paper quality was studied

- China clay dosage
- Talc dosage
- GCC dosage
- PCC dosage
- Binder dosage
- Total solids of coating colour
- Thickner dosage (water retention chemical)

The coated paper properties studies were brightness, surface roughness, gloss, print gloss, printing picking velocity, print contact factor (m) and saturation ink density (D_∞).

The relative effect of seven process variables on coated paper quality has been studies using a Plackett-Brman statistical design [7]. In this type of experiment design, two levels (low and high) of each variable were selected as given in Table III. The high (+) and low (-) levels were chosen far enough apart to expect a significant response in coating, but not so remote from normal conditions. The assumption made was that within the restricted range of each variable, the response is entirely linear.

Tale IV shows the combination of coting conditions used in experimental set up. The coating colour parameters and coated paper characteristics are given in Table V. Different sets of coating colour were separately applied to base sheet using an automatic rod coater. The coating weights were controlled 20-21 g/m^2 range. The coated sheets were calendered and their properties were tested. The main effect of process variable on properties viz viscosity, water retention, brightness, surface roughness, gloss, print gloss, picking velocity, print density parameter (m, D_∞) was evaluated and ranked accordingly (Table VI).

Table VII shows the main influential variable as the % of mean..

OPTICAL CHARACTERISTICS

Brightness:

On the brightness of coated paper, out of the pigments china clay, Talc, GCC and PCC, china clay gave negative effect where as other pigments gave positive effect. The optical characteristics of different pigments are given in Table (VIII) . PCC used has highest brightness and whiteness followed by GCC, Talc and China clay. The average particle size of GCC is lowest and specific surface area is highest as compared to other pigments. In an admixture is coating, GCC gave relatively more positive effect probably due to lower particle size and higher specific surface area. Binder and total solid of coating colour showed negative effect where as the thickner used to improve water retention gave positive effect.

Gloss:

China clay gave positive effect on gloss where as it was negative in the case of Talc, GCC and PCC. GCC gave highest negative effect followed by PCC and Talc indicating that introduction of these pigments with china clay will give coated paper with somewhat matt finish. The higher surface gloss in case of china clay is probably due to relatively lower void volume formation in the coating layer [4,14]. Binder level and total solid of coating colour gave positive effect on gloss.

SURFACE CHARACTERISTICS

Surface Roughness:

China clay gave negative effect on surface roughness i.e. smoother surface is obtained when china clay is used as pigment in coating. The positive effect of Talc and PCC were comparable where as it was higher for GCC indicating the GCC containing coated paper will be comparatively less smoother. Talc was able to enhance the evenness of paper surface, probably because the Talc particles are plate shaped and possess high aspect ratio [8]. Binder level gave positive effect where as total solid and thickner gave negative effect.

PRINTING CHARACTERISTICS

Print Gloss:

Print gloss is improved with the presence of china clay as it has shown positive effect. The highest negative effect is shown by GCC followed by Talc and PCC. Binder level and total solid gave positive effect where as thickner has shown negative effect.

Picking velocity:

Presence of Talc and GCC showed improvement in the picking velocity where as negative effect is shown by china clay and PCC. Binder level, total solid and thickener showed positive effect on the picking velocity.

Print density:

The print density curve i.e. the optical density of print plotted against ink film thickness on the printing form gives indication about the ink requirement of paper in getting particular print density. In in getting particular print density. In print density curve the density D (i.e. the contrast with respect to unprinted paper) is plotted against the ink film thickness. Such density curve generally follows expression [9]

$$D = D_{\infty}(1 - e^{-mx})$$

where D_{∞} is saturation density i.e. the density which is approached by theoretical curves if ink film thickness is increased indefinitely m is the contract factor or density smoothness. It shows how quickly the saturation density is obtained.

x is the ink layer thickness.

GCC pigment has highest effect on contact factor i.e. m followed by Talc, China clay, PCC. This indicated that GCC help in improving print density relatively higher than other pigments studied. Also GCC gave positive effect on D_{∞}. The other pigments like China clay, Talc and PCC had shown negative effect on D_{∞}. Binder level, total solids and thickener had shown positive effect on 'm' where as it is negative for D_{∞}. The introduction of Talc should encouraged in the matt finish or semi matt finish coated papers to be printed by offset printing as the following features of offset process are especially demanding for Talcs.

- Tacky ink emulsified by moisturing solution.
- Hydrophilic moisturizing solution
- Offset blanket materials.

Talc helps to reduce the abrasitivity of matte paper surface and lower the tendency for ink scuff or ink ruboff. Ink scuff occurs when ink paper surface degrades the ink layer. With less abrasive surface, the ink layer better resists [10].

Coarse GCC generally used for matte papers create an abrasive surface against ink that can be controlled by using Talc in the recipe. Compared 100% carbonate recipe, talc improves the ink holdout. Viscosity is positively affected by total solids and thickener. Ink setting/ink hold out especially in offset printing is a function of ink penetration and/or ink absorption into the coating layer. The solvent of printing ink should obviously escape from the ink after printing. The more dried ink is retained on the outer surface of the paper, the higher will be the ink density or, accordingly lower will be the ink demand [11]. If the pores of coating layer are too big, obviously the printing ink will penetrate easily into the paper and print gloss will be low. This is the case observed for GCC. To avoid this GCC and PCC should preferably be used along with platy pigments like Clay or Talc.

EFFECT ON RHEOLOGICAL PROPERTIES OF COATING COLOUR

Talc gave positive effect on coating colour viscosity where as all the other pigment gave negative effect. The highest negative effect was shown by PCC indicating that introduction of excess PCC will change the rheological characteristics of coating color. This is probably due to high aspect ratio and narrow particle size distribution in the case of PCC. This may affect the ability to be pumped and also flow behavior in coating equipment. PCC have lower viscosity than china clay at the same solid content, probably due to that as compared to platy china clay the needle like. PCC particle tend to orient under shear stress along the longer axis [12].

The water retention is negatively affected by China clay and Talc indicating that pigment help in improving the water retained by coating layer where as it is positively affected by presence of GCC and PCC (table V). The positive water retention value i.e. lesser water retained by coating colour on the paper surface.

To get better coating, the pigment should be such that there is good water retention of coating colour. If water is not retained somewhat, it will drawn in to paper instantly during application and a hard cake will build up on the metering device. Water retained in worst with GCC and PCC than China clay probably due to reason that in the case of China clay and Talc water simply has to go a longer way through tortuois platy packing where as in case of PCC and GCC the particle size distribution is narrower so water has a shorter penetration path and tortuosity factor is less.

CONCLUSIONS

The brightness and whiteness of coated paper of Indian origin are mostly lower than imported samples studied except for few mills which have comparable values

- Indian coated paper have lower brightness (3-5 points), whiteness (3-16 points) and fluorescence (2-7 points) when compared to corresponding base

Table III : Process variables used in the experiments

S.No.	Process Variable	Process variable conditions	
		Low Level	High Level
A	China clay (Parts)	25	77
B	Talc (Parts)	3	19
C	GCC (Parts)	6	56
D	PCC (Parts)	1	20
E	Binder (%)	10	18
F	Total Solids (%)	50	65
G	Thickner (%)	0.2	1

Table IV: Plackett-Burman statistical design

Exp No.	Process variable						
	A	B	C	D	E	F	G
1	+	+	+	-	+	-	-
2	-	+	+	+	-	+	-
3	-	-	+	+	+	-	+
4	+	-	-	+	+	+	-
5	-	+	-	-	+	+	+
6	+	-	+	-	-	+	+
7	+	+	-	+	-	-	+
8	-	-	-	-	-	-	-

Table VIII: Particle size and optical characteristics of different pigments used

Property	China clay	GCC	PCC	Talc
5%	<0.542µm	<0.606 µm	<1.55 µm	<3.187 µm
15%	<0.73 µm	<0.725 µm	<1.83 µm	<3.88 µm
35%	<1.13 µm	<0.895 µm	<2.25 µm	<4.81 µm
65%	<1.82 µm	<1.028 µm	<2.57 µm	<5.58 µm
Avg. Particle size (µm)	4.13	1.30	3.26	7.08
Specific surface area (m^2/cm^3)	3.09	5.15	2.05	0.96
Brightness (%)	80.45	90.68	95.54	85.86
Whiteness (%)	70.25	87.50	94.21	76.48

paper.

· The Indian coated paper has low fluorescence values than imported coated paper samples.

· Except few samples indigenous coated paper have lower print density at a particular ink layer as compared to imported coated papers ' Lower print density indicates that these paper will require high ink quantity.

· The non uniformity printing index is lower for imported coated paper as compared to indigenous coated paper. This indicates that indigenous coated paper could have more mottling tendency as compared to imported coated paper.

· Indigenous coated paper have unnecessarily higher picking velocity than imported one indicating that excessive binder is being used in coating formulations.

· Except few samples generally Indigenous coated paper gives low print gloss in printing.

· The coating formulation which is presently containing 80 – 90 parts Of China clay and remaining GCC need modification by either substitution of PCC or talc by at least 10%.

· Binder level needs to be reduced as higher picking velocity is not desirable.

· China clay has negative effect on the brightness of coated papers as compared to other pigments like GCC, PCC and Talc.

· China clay gave positive effect on gloss while talc, GCC & PCC gives negative effect. GCC has highest negative effect on gloss. Binder level and total solids of coating color gave positive effect on gloss.

· Smoother surface is produced when China clay is used as a pigment followed by talc and PCC.

· China clay has more positive effect on print gloss while GCC has negative effect. Binder level and total solids shows positive effect while thickner gave negative effect on print gloss.

· China clay and PCC gave negative effect on picking velocity while talc and GCC shows an improvement in picking velocity.

· GCC helps in improving the print density more than other pigments. It also has positive effect on D_∞ (saturation density). Binder level, total solids and thickner shows positive effect on m (contact factor or density smoothness) whereas negative for D_∞ (saturation density).

· Introduction of Talc should be encouraged in matte finish or semi matte finish coated paper to be printed by offset printing.

· Water retention value (WRV) is negatively affected by China clay and Talc indicating that these pigments help in improving the water retained by coating layer, whereas it is positively affected by GCC and PCC.

EXPERIMENTAL

The base paper and coated paper samples used in this study were collected from the different coated paper manufacturers from India and abroad. The papers were conditioned at temperature of 27±1° C and 65±2% relative humidity prior to testing and tested as per relevant ISO methods for different optical and printing properties. The brightness, opacity and fluorescence of coated samples and base paper were tested using Elrepho spectrophotometer. Gloss was checked at 75° using Zehntner and PPS roughness was measured using PPS roughness tester. The formation of paper samples were tested using TECHPAP formation tester.

The printing tests which include print density, print non-uniformity and picking velocity were carried out using IGT printability tester AIC2-5.

Coating Experiments

The coating base paper used was 60 gsm paper manufactured from mixed hardwood pulp and bamboo pulp in ratio 80:20. All coating chemical i.e. pigment, latex, thickner, dispersant and deformer were procured from the coating plant. The viscosity of coating color prepared was measured using Brookfield viscometer. The water retention of coating slip was masured using AA-GWR Gravimetric water retention meter (DT Paper Science, 1.5 bar, 120s, 5 µm filter).

The coating color prepared was applied to 21.0×29.8 cm base sheet using an automatic bar coater (Zehnter ZAA-2300). The coating amount was adjusted using bar of different numbers. The coated sheets were placed immediately in an oven maintained at 120 ºC for 30s to dry. The sheets were coated one side with the coat weight of 20 gsm. The coated paper was calendered in laboratory calendar (DT Paper Science, Finland) using soft nip. Each paper was calendered at the linear load of 100 kN/m and temperature of 60 ºC. The speed of calendered was kept at 20m/min.

COATING COLOR PREPARATION

The coating color preparation process proceeded in the order of pigments (China clay, GCC, PCC/Talc)'! distilled water (high speed mixing)'! dispersant(high speed mixing) '! defoamer (high speed mixing) '! latex (low speed mixing)'! thickner (low speed mixing)'! NaOH (low speed mixing)'! distilled water. The total solids of coating slip were kept around 60% and pH was 8 to 9/.

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Table V: Coated Paper Characteristics

Property	Brightness (%)	PPS Roughness (μ)	Gloss (%)	Print Gloss (%)	Picking velocity (m/s)	m (μ^{-1})	D	Viscosity	Water Retention
Exp. 1	80.3	1.78	42.4	73.7	223	0.33	2.4	50	2.23
Exp. 2	82.3	1.63	40.4	78.2	89	0.32	2.43	115	1.582
Exp. 3	82.6	1.90	38.0	75.7	237	0.30	2.43	57.5	1.49
Exp. 4	76.4	1.32	55.4	88.4	182	0.32	2.3	135	1.31
Exp. 5	77.8	1.44	41.0	84.4	273	0.31	2.35	450	1.36
Exp. 6	80.0	1.21	50.7	81.1	123	0.30	2.57	325	1.03
Exp. 7	78.8	1.06	44.2	78.8	91	0.23	2.9	400	0.97
Exp. 8	79.4	1.28	62.2	82.3	69	0.20	3.4	455	2.03
Mean	**79.7**	**1.45**	**46.8**	**80.3**	**160.8**	**0.29**	**2.6**	**248.44**	**1.5**

Table VI: Main effects of process variables on properties and relative ranking

Variables	Brightness	PPS roughness	Gloss	Print Gloss	Picking velocity	M (μ^{-1})	D.	Viscocity	Water Retention
China clay	-1.63 (2)	-0.22 (2)	2.8 (6)	0.35 (6)	-12.2 (6)	0.013 (5)	-.011 (5)	-41.9 (6)	-0.23 (4)
Talc	0.2 (6)	0.05 (5)	-9.6 (1)	-3.13 (3)	16..2 (4)	0.02 (4)	-1.6 (4)	106.3 (5)	-0.07 (7)
GCC	3.2 (1)	0.36 (6)	-7.8 (2)	-6.3 (1)	14..2 (5)	0.05 (3)	0.27 (3)	-223..2 (1)	0.17 (6)
PCC	0.65 (5)	0.05 (5)	-4.6 (5)	-0.1 (7)	-22.2 (3)	0.01 (6)	-0.17 (6)	-143.1 (3)	.033 (3)
Binder	-0.85 (4)	0.315 (1)	4.98 (4)	0.5 (5)	135.8 (1)	0.053 (1)	-0.46 (1)	-150.7 (2)	0.20 (5)
Total solids	-1.16 (3)	-0.105 (3)	0.17 (7)	5.4 (2)	11.8 (7)	0.05 (2)	-036 (2)	15.7 (7)	-0.40 (2)
Thickner	0.2 (6)	-0.1 (4)	-6.6 (3)	-0.7 (4)	40..2 (2)	0.01 (7)	-0.07 (6)	119.4 (4)	-0.60 (1)

Table VII: Main effect as percentage of mean

Variables	Brightness	PPS roughness	Gloss	Print Gloss	Picking velocity	m (μ^{-1})	D.	Viscosity	Water retention
China clay	-2.1	-15.2	6.0	0.44	-7.6	4.3	-4.2	-16.9	-15.4
Talc	0.3	3.5	-8.5	-3.9	10.1	6.0	-6.2	42.8	-4.7
GCC	4.0	24.8	-16.7	-7.9	8.8	16.6	10.4	-9.8	11.0
PCC	0.8	3.5	-9.8	-.013	-13.8	2.8	-6.3	-57.6	12.2
Binder	-1.1	21.7	10.6	0.6	84.5	18.3	-17.7	-60.6	13.0
Total solids	-1.5	-7.24	0.4	6.7	7.3	17.2	-13.8	6.3	-24.0
Thickner	0.3	-6.9	-14.1	-0.9	25.0	2.41	-2.7	48.1	-38.4