Effect of Increased Proportion of Ultra Fine Ground Calcium Carbonate in Coating Pigments on Surface, Optical and Printing Properties

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The effect of blending two grades of ground calcium carbonate pigments, namely, GCC-90 and GCC-95, with no.1 Brazilian clay on surface, optical and printing properties of coated paper was studied. The coating mixtures were prepared with five combinations of clay and GCC keeping the proportions of binder and other additives constant. Different coat weights (11-40g/m^2) on a 121-g/m^2 base paper were applied by means of laboratory K-Coater. The coated sheets were calendered on a laboratory supercalender. It was observed that the addition of GCC to the clay pigment reduced the viscosity of the coating mixture and increased the brightness, whiteness, and surface strength of the coated sheets. On the other hand, coating formulation having higher proportion of clay gave reduced oil penetration and increased gloss of unprinted and printed sheets.

Keywords: GCC, Coating pigments, Particle size, Viscosity, Brightness, Pick resistance, Stain length, Gloss, Print density, Print gloss.

INTRODUCTION

The demand for pigment-coated papers is increasing faster than the total paper demand. This trend is driven largely by the printers and converters who are continuously enhancing quality standards of their products to meet the ever rising end-user expectations.

A paper **coating** is a composite film consisting of **pigment particles**, binder, additives, and air voids. Pigments comprise about 80% of the total weight of the coating and greatly impact the cost, operational parameters, and end use performance of **coated** papers. Desirable properties of coated paper such as brightness, light scattering, ink holdout, sheet **gloss, and print gloss** can be related to **coating** pore structure. Sheet gloss is affected by surface roughness and print gloss is affected by both surface roughness and porosity (1). The porosity controls the ink holdout and the ink setting rate. For highly porous paper the ink travels deep into the paper leading to a low print gloss. On the other hand, a closed surface reduces ink setting rate that in turn causes problems like set-off. There is no unanimity among the printers and end users about the desired gloss of coated paper. The trend today appears to be towards producing a matt surface that can achieve high print gloss and good print quality. The benefits would be easy to read, low glare background combined with high print gloss and striking contrast between the matt base paper and glossy print (1).

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Many approaches to achieve the desired coating structure are being tried (2, 3); some of them are to engineer the shape and size of the pigment particles (4), to develop new pigments, to apply multiple layers of coating using different pigments (1,2), and to blend several types of pigments in a single coating layer (5).

Traditionally the clay is the major pigment used for coating on paper surfaces. The use of calcium carbonate, both ground (Gcc) and precipitated (Pcc), is increasing for technological and economic reasons (6,7). The other pigments like talc, titanium dioxide, and synthetic (plastic) **pigments are used in relatively smaller quantities (8).**

The GCC pigments introduced for paper coating in early 1960s were rather coarse (about 35% less than 2 µm) and were used primarily in precoat with the purpose of reducing the tendency of blade streaks in the topcoat (9). The grinding technology has greatly improved since then, and today it is possible to produce GCC to fineness where 98% of the pigment particles are smaller than 2 µm. Of course, the control of particle size and shape is much easier in PCC.

Table-1 highlights the major differences in the characteristics of clay and calcium carbonate coating pigments. Whether a particular characteristic of a pigment is advantageous or disadvantageous depends on the requirement of the finished product. .

More than one pigment may be combined in coating formulations to achieve the desired coating structure (12). Santos et al. (13) analyzed the potentialities of using blends of GCC and PCC in **coated** paper and concluded that GCC **pigment** was very effective in improving printability,

Table-1 Comparison of clay and calcium carbonate coating pigments

In general, clay coatings are glossy while $CaCO_3$ coatings have matt finish. However, particle size distribution of pigments has an important effect on gloss (10); the finer the pigment, the more readily it will gloss. Grinding GCC to a suitable fineness can give a coated gloss equivalent to that of a clay coating.
Clay produces smooth coated surface that helps in achieving greater image detail, good ink holdout, and high printed gloss (11).
Clay is stable under all papermaking conditions, while $CaCO_3$ is reactive in an acidic environment, which may cause trouble in the reuse of coated broke.
Clay coatings are less abrasive than $CaCO_3$ coatings.
$CaCO_3$ is more abundantly found in nature than the clay. The $CaCO_3$ resources are practically inexhaustible
GCC coating colors have lower viscosity (6) that allows coating at high solids. GCC coating colors exhibit pseudoplastic rheology (9) while clay coating colors show dilatancy at high shear rates. Coating at high solids results in lower demand for binder and drying energy.
$CaCO_3$ coatings have higher brightness, porosity, and ink absorbency.

Table-2 Pigments used

	Clay	GCC-90	GCC-95
Brand name	Amazon Premium SD	Hydrocarb-90	Carbital-95
Brightness (ISO), %	88.81	93.51	94.29
Weight percent < 2 m	99.78	90.56	97.1
Weight percent < 1 m	98.93	73.21	78.5
Residue on 325-mesh sieve, %	0.003	0.003	0.0017

Table-3 Binder and other additives in coating color (Parts per 100 parts pigment (by weight)

Latex (Styronal D-718)	12.00
Starch (Emcoat K-40)	2.00
CMC (Finnfix-10)	0.50
Insolubilizer (MF-50)	0.50
Lubricant (Sapcote C-104)	0.50
Dispersing agent (PA-40)	0.05
% Solids	66-66.5

Table-4 Properties of base paper

Grammage, g/m^2	121
Brightness	90.1
Bulk, cm^3/g	1.37
Porosity (Gurley), s/100ml	40
$Cobb_{60}$, g/m^2	21
Ash, %	10.5
Surface strength by Wax Pick	No pick at 14 A
Smoothness (Bendtsen), ml/min	140 – 180

print gloss and gloss, PCC **pigment** was efficient in improving optical properties, and there was a possibility to find the best combination. Maillard et al. (14) observed that **GCC** and/or **clay could be** combined with a softer pigment like talc to lower the abrasivity of the paper surface at the same time maintaining the matt or semi-matt finish.

In the present work, we have studied the effect of blending GCC with clay on the coating structure and printability characteristics. The pigments used in this study were a fine no.1 Brazilian Clay (99% < 2 µm and two ultra fine GCC pigments, namely, GCC-90 (90% < 2 µm) and GCC-95 (95% < 2 µm).

Experimental methodology

Preparation of Coating Color

Table-2 shows the important characteristics of pigments used in this study. The clay and GCC-90 pigments were available as dry powders and GCC-95 as predispersed slurry. For different pigments and pigment combinations, the amounts of binder and other additives were kept constant at the level given in Table-3. Measured quantities were added in the following sequence: pigment CMC starch latex insolubilizer and lubricant. Each coating color was prepared for 400 g pigment (dry basis) and the concentration of the coating color was targeted at 66.5% solids. The pH of the color was adjusted to 8.5-9.0 by adding 1N sodium hydroxide solution in the required quantity. The dispersant (PA-40) was used in the preparation of slurries of clay and GCC-90 pigments only. It was found by trial and error that a dispersant dose of 0.05% gave minimum viscosity of the pigment slurries. The viscosity of the coating mixture was measured using a Brookfield viscometer (Model LV DV-II+ Version 3.0).

APPLICATION OF COATING

The coating was applied to the top side of a 121 g/m^2 base paper by means of laboratory K-coater. Some important properties of the base paper used are given in Table-4. The coat weights were varied between 11 and 40 g/m^2 using different coating bars available with the laboratory K-coater. The coated sheets were air dried in the laboratory and calendered in a laboratory supercalender.

EVALUATION OF COATED SHEETS

The coated sheets were tested for thickness, brightness, gloss, surface strength, print penetration, and ink transfer characteristics.

Surface Strength: The surface strength of coated sheets was determined from the measurements of pick velocity in an IGT printability tester (Model AIC2-5) following the method described in IGT information leaflet W31 (15). The surface strength was calculated as product of pick velocity in m/s and viscosity in Pa.s of the pick test oil used. The conditions used for the test printing were: Printing disc aluminum 10 mm, Backing material paper 55 mm, Pick test oil medium viscosity oil, Oil film thickness 8.0 µm, Printing force 350 N, Temperature 23°C (viscosity of the pick test oil at 23 °C = 52 Pa.s), Printing speed accelerating speed with end speed 3 m/s.

The print was observed to locate the point of first picking and the corresponding pick velocity was calculated with the formula: *Vp = 0.005 * Ve * d;* where Vp = velocity at point d (m/s), Ve = end speed (m/s), and d = distance from beginning of the print to beginning of picking (mm). The velocity viscosity product (VVP) was calculated by: VVP = Vp * ; where is the viscosity of the pick test oil.

Print Penetration: The print penetration values of the coated sheets were determined using the same IGT printability tester according to the method described in IGT information leaflet W24 (15). This test provides a combined measure of the ink absorbed by the surface of the paper at the moment of printing due to the absorption of liquid in the surface recesses (roughness) and the absorption into the paper pores at the surface.

In this method, a drop of specified volume of a standard testing oil is spread between the printing disc and a paper strip on the sector of an IGT printability tester. The length of the stain produced by the test liquid on the paper strip is measured. The stain length increases when the roughness and/or absorption of the paper decrease. The stain length in mm is used to represent the varnishability of paper. Print penetration is defined as the reciprocal value of the stain length multiplied by 1,000 (i.e. 1,000/stain length in mm). The conditions used were: Printing disc aluminium, 50 mm, Test liquid Dibutylphthalate with 1% sudan red, Packing rubber, 55 mm, Printing force 1000 N, Printing speed accelerating with end speed 1.2 m/s, Quantity of test liquid 1 drop of 5.8 mg ± 0.3 mg.

Ink Transfer Characteristics: For evaluation of ink transfer characteristics, 10 test strips for each set of coated and supercalendered sheets (different pigment combinations and coat weights) were printed in the IGT printability tester with varying amount of ink on the printing disc. The following printing conditions were used: Printing disc Rubber covered offset discs 20 mm, Backing material none, Ink magenta colored commercial sheet fed offset ink (SICPA), Ink film thickness variable, Inking time 150 s (Sufficient to uniformly distribute the ink), Printing force 625 N, Printing speed constant 0.2 m/sec.

The amounts of ink on the printing disc before and after printing were determined gravimetrically using an analytical balance with a least count of 0.1 mg. After each printing, the remaining ink on the printing disc was cleaned using a solvent (petroleum spirit) and soft cloth. The inking unit was not replenished with fresh supply of ink between the printings. The strips printed by the IGT printability tester were evaluated for print gloss and print density. The print density, PD, is the optical contrast between the unprinted and printed areas on paper surface. The numerical values of print density were calculated from the reflectance values by the following formula (16).

$$PD \quad \log R \big/ R_{,p}$$

Where R = reflectance of a thick pile of paper sheets, and $R_{,p}$ = reflectance of the printed sheet backed by a pile of unprinted sheets of the same paper.

DISCUSSION OF RESULTS

Figure-1 shows that a substitution of GCC for clay in coating mixture lowered its viscosity as reported in other works (17). The lowering in viscosity was proportional to the percentage of GCC in the formulation. Among the two GCC pigments used, the coarser pigment (GCC-90) has a greater viscosity lowering effect than the finer pigment GCC-95. Addition of ultra fine GCC pigments to clay pigment offers the advantage of applying coatings at higher solids and consequently reduced binder demand and drying energy. The coarser GCC pigment is more beneficial in this respect.

Figure-2 shows the brightness of coated sheets at different coat weights and clay/GCC ratios in the pigment. The coated sheets had lower brightness than the uncoated base paper. The brightness decreased further with increase in coat weight. Interestingly, the brightness reduction occurred even when the pigments used were brighter than the base paper. This must have been caused by the increased absorption of light and reduced scattering coefficient due to the presence of binder and other additives in the coating formulation. For a given coat weight, the brightness of the coated sheet increased as the proportion of GCC in the pigment was increased as shown in Figure-2b for sheets having 17 g/m^2 coating. The coating brightness showed little sensitivity to the particle size of carbonate pigments, as both GCC-90 and GCC-95 had nearly the same effect on the brightness.

An important advantage of pigment coating is the significant improvement in the gloss of the paper. Clay pigment

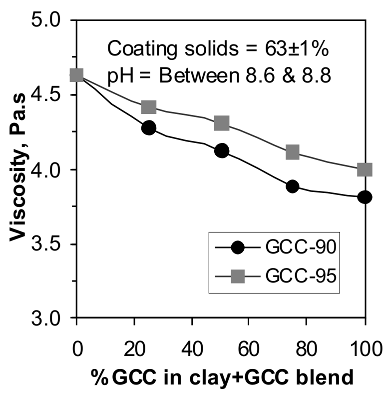

Figure-1 Effect of GCC on Brookfield viscosity of coating color.

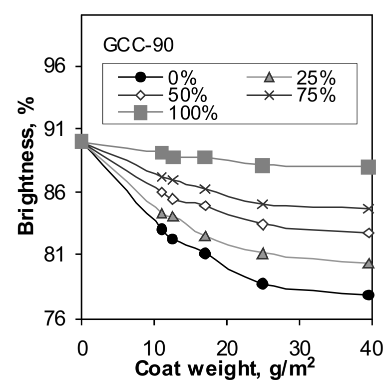

Fig.-2a Effect of substitution of clay with GCC-90 and coat weight on brightness.

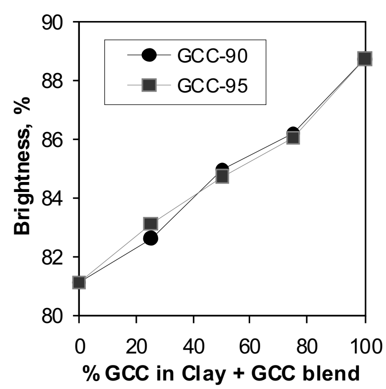

Fig.-2b Effect of substitution of clay with GCC on the brightness.

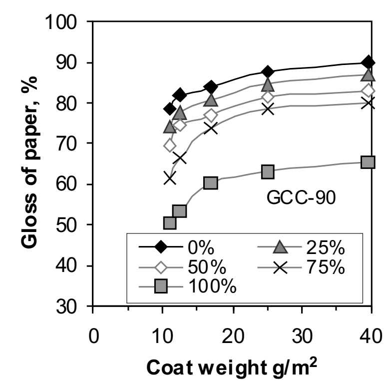

Fig.-3a Effect of substitution of clay with GCC-90 and coat weight on gloss of coated paper.

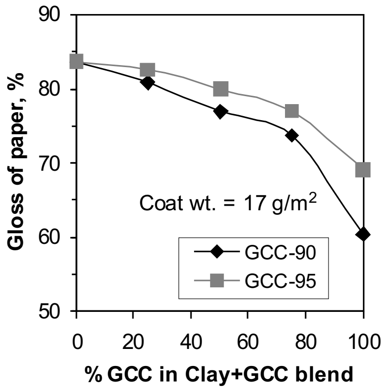

Fig.-3b Effect of substitution of clay with GCC on gloss of the coated paper

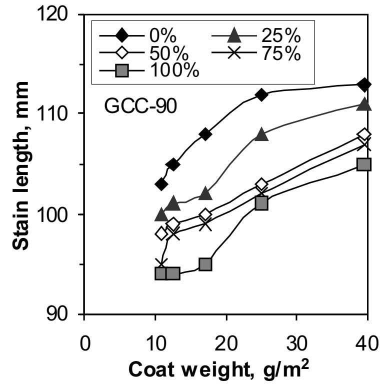

Fig.-4a Effect of substitution of clay with GCC-90 and coat weight on stain length

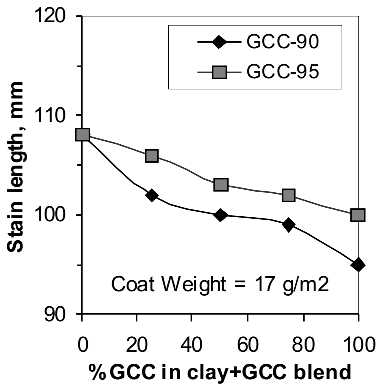

Fig.-4b Effect of substitution of clay with GCC on stain length

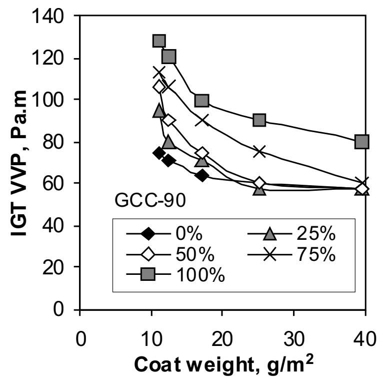

Fig.-5a Effect of substitution of clay with GCC-90 and coat weight on IGT velocity viscosity product.

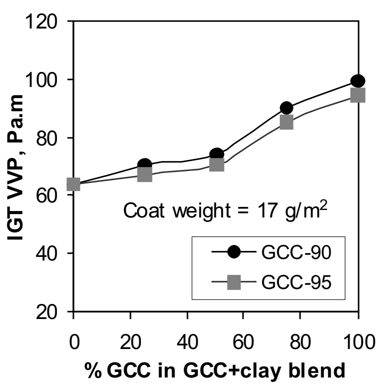

Fig.-5b Effect of substitution of clay with GCC on surface strength (Constant binder content).

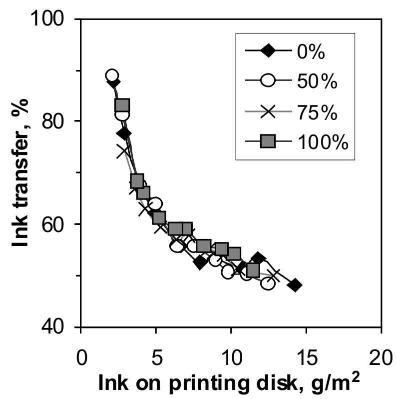

Fig.-6 Ink transferred to the coated paper having 17 g/m^2 coating.

produced the maximum gloss development (Figure-3). Increasing coat weight increased the gloss but increasing the proportion of GCC in the pigment reduced the gloss. For a comparison between the two types of GCC pigments used, the gloss reduction was less for the finer pigment GCC-95 than for the coarser pigment GCC-90 (Figure-3b).

Figures 4a & 4b show the effect of pigment composition and coat weight on print penetration properties of the coated paper as expressed by IGT stain length. A long stain indicates that the paper will have low ink absorption and high ink holdout on printing. The IGT stain length increased as the coat weight was increased. Also, the stain length was greatest for coatings with clay pigments that decreased on increasing percentage of GCC in coating color. Coatings containing GCC-95 pigments showed greater stain length than coatings with GCC-90 pigments (Figure-4b). Stain length increased with the fineness of the particle size of carbonate pigment.

Figure-5 shows the effect of coat weight and pigment composition on pick resistance of the coated paper expressed as IGT velocity viscosity product. The velocity viscosity product decreased with increase in coat weight but increased gradually when the clay pigment was replaced with GCC in the coating color. For equal coat weight of 17 g/m^2, the pick resistance was slightly lower for the finer pigment GCC-95 than for coarser pigment GCC-90 (Figure-5b). Fineman et al. (18) observed as high as 40% saving in binder when using calcium carbonate pigment in place of clay.

Strips of paper having 17 g/m^2 coat weight using different clay and GCC-95 combinations were printed in an IGT printability tester for varying amounts of ink on the printing disk. Figure-6 shows that the percentage ink transferred to the paper was nearly same for all the pigment combinations used in coating. However, for the same amount of ink transferred to the paper, the print density was greater for the GCC coated sheets than for the clay coated sheets.

An important printability parameter is the requirement of ink to attain a given print density (19). The amount of ink required on the printing disc and the ink transferred to the paper surface to achieve print density of 0.94 is given in Table-5. The ink requirement was lowest for sheets coated with 100% GCC.

Just as the gloss of clay coated paper was greater than the gloss of GCC coated paper, the print gloss was also greater for the clay coated sheets than for GCC coated sheets (Figure-7). The increasing percentage of GCC in the coating pigment lowered the print gloss; the coarser pigment GCC-90 was more significant in this behavior. In a mixture of clay and GCC, up to 75% GCC could be incorporated without much loss in print gloss.

Properties of paper, coating, and the printing ink affect printed gloss. A high print gloss is achieved for printings on glossy papers with high ink holdout. As shown in Figure-7a, with low amount of ink transferred to the paper, the print gloss fell below the unprinted paper gloss due to formation of discontinuous

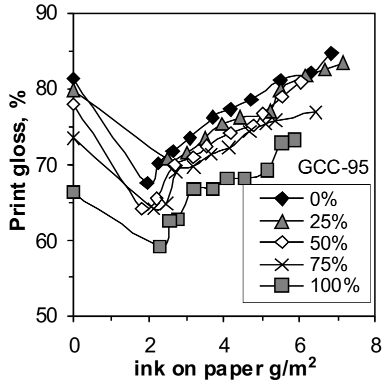

Fig.-7a Print gloss as function of ink transferred to the paper at various GCC-95/ clay ratios (17 g/m^2 coating).

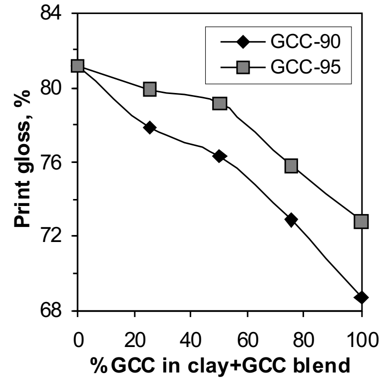

Fig.-7b Print gloss for nearly equal ink transferred to the paper (5.5 g/m^2 for paper coated at 17 g/m^2)

Table-5 Ink requirement at 0.94 print density (Magenta ink)

% GCC-95 in clay + GCC mixture	Ink on printing disc g/m^2	Ink on paper g/m^2
0	14.26	6.84
50	12.53	6.06
75	10.47	5.36
100	10.21	5.53

ink film. As the amount of ink transferred to the paper was increased, the discontinuity in the ink film decreased and consequently the print gloss increased. A similar trend was observed by earlier workers (20). The print density reached a near saturated value for ink on paper > 6 g/m^2, and under such conditions, the delta-gloss (the difference between print gloss and unprinted gloss), was greater for the GCC coated paper than for the clay coated paper.

CONCLUSIONS

1. Substitution of clay with ground calcium carbonate in coating pigment decreases the coating color viscosity. Alternatively, pigment containing GCC can be dispersed at higher solids than the clay pigment.
2. Increasing substitution of clay with GCC in coating pigment increases brightness, surface strength, ink penetration tendency, ink transfer, and the print density, but reduces unprinted and printed gloss.
3. Among the two GCC pigments used in this study, the finer pigment, i.e. GCC-95, gave higher unprinted and printed gloss. Both GCC pigments resulted in greater delta gloss than the clay pigment.

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