Effect Of Pigment Morphology On Coated Paper Optics And Print Performance

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ABSTRACT

Packing of the pigment particles is dependent upon particle shape, size and size distribution of pigment. In this study precipitated calcium carbonate (PCC) pigments of calcite and aragonite crystalline polymorph having rhombhohedral, orthorhombic and scalenohedral habits were used either alone or in combination with finer grade ground calcium carbonate (GCC) pigment to see their impact on paper optics and printing characteristics. It was found that the particle size distribution has an immense effect on optics of coated paper. The effect of base optics on coated paper was found less with narrow particle size distributed pigment and higher with broad particle size distributed pigment. Calcite PCC of scalenohedral habit attribute to highest pick strength and lowest print gloss as compared to rest of the pigments. Aragonite PCC of orthorhombic habit and calcite PCC of rhombhohedral habit improve the print gloss. The ink setting rate becomes slow with introduction of PCC in coating formulation.

***Keywords**: Aspect ratio, Brightness, Ink setoff, Print gloss, Whiteness*

Introduction:

As the precipitated calcium carbonate (PCC) pigment can be manufactured via a series of controlled parameters of different shape, size and size distribution, the choice of the papermakers has been broadened from conventional ground calcium carbonate (GCC) in paper coating application. PCC can be produced by three different processes: a lime soda process, a calcium chloride process and a carbonation process. Carbonation process is most widely used for making PCC due to use of cheaper raw material. The crushed limestone is burnt in a lime kiln at about 1000 °C, where it is decomposed into calcium oxide and carbon dioxide (CO_2). The dry calcium oxide is hydrated or slaked with water at temperature of 3050 °C, producing a calcium hydroxide slurry. The slurry is then fed to a three phase stirred tank reactor, either at atmospheric pressure or pressurized, where calcium hydroxide reacts with CO_2 gas. The particle size, size distribution, shape and surface properties of the calcium carbonate particles can be controlled through reaction temperature, CO_2 partial pressure, flow rate of CO_2, lime slurry concentration and agitator speed (1-3). Thus PCC can be synthesized in well defined size distributions and shapes that overcome several limitations of mined minerals.

The morphology of a pigment plays the most important role in change in coated paper quality. GCC and PCC differ in many aspects. GCC shows broad particle size distribution (BPSD) while PCC exhibits narrow particle size distribution (NPSD) (Fig.1). The packing of pigment particles has immense effect on paper coating structure and results in a significant change in optics and print performance of paper. In the present study the role of particle shape, size and size distribution of calcite and aragonite crystalline polymorph PCC pigments (either used as sole pigment or in combination with calcite GCC pigment) on optical and printing properties of coated paper has been evaluated.

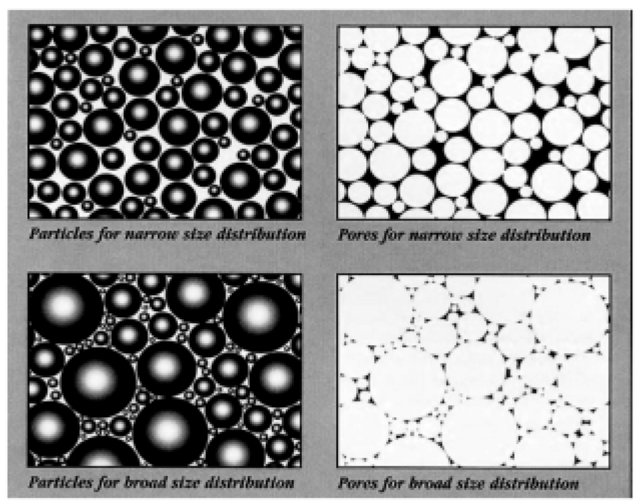

Fig. 1: Particle packing (4)

Exprimental Materials

Commercial grades of calcite and aragonite crystalline polymorph PCCs exhibiting rhombhohedral, orthorhombic and scalenohedral habits were used as pigments in various combinations with rhombhohedral habit calcite GCC. The pigment properties and combinations, and coating formulation used in the study are given in table 1, 2 and 3 respectively.

Table 1: Characteristics of mineral pigments

Particular	GCC	PCC 1	PCC 2	PCC 3
Crystalline polymorph	Calcite	Calcite	Aragonite	Calcite
Crystal habit	Rhombhohedral	Rhombhohedral	Orthorhombic	Scalenohedral
Particle size distribution				
<2μm, %	96	98	100	97
<1μm, %	76	95	98	78
<0.5μm, %	50	76	76	55
Optical characteristics				
Brightness (% ISO)	93.32	97.87	96.2	97.8
CIE Whiteness (%)	90.19	97.2	94.3	97.2

Table 2: Combination of pigments used in the study

Pigment	Parts				
GCC	80	60	40	20	-
PCC*	-	20	40	60	80
Clay	20	20	20	20	20

**For all three PCC pigments*

Table 3 : Coating color formulation

Ingredient	Parts
Pigment	100
Latex	11
CMC	0.5
Lubricant	1.0
Insolubilizer	0.5
OBA	0.5

Coating base paper with a basis weight of 123 g/m^2, having hardwood (80%) and softwood (20%) was used for coating application. The ISO brightness and CIE whiteness of base paper was 89.9 % and 130 respectively. Finer grade coating clay having platelet structure was used as a supplementary pigment in coating formulation. Styrene butadiene based polymer emulsion (Tg: 17^{0}C), polyacrylate based compound and calcium stearate based emulsion were used as binder, dispersant and lubricant respectively. Ammonium zirconium carbonate based compound was added as an insolubilizer. Carboxy methyl cellulose (CMC) based rheology modifier was used as a thickening agent and hexa sulpho stilbene compound was used as an optical brightening agent (OBA).

Methods

Coating color preparation

Calcium carbonate slurry (GCC/PCC) of required amount was taken in dry plastic beaker and kept under agitation. Clay slurry and calculated amount of water were added to it to get targeted solid concentration. The speed of the agitator was adjusted to avoid any foam formation during addition of binder. Cooked CMC paste was added slowly in pigment slurry. The slurry was then agitated at high speed for complete dispersion of CMC. Lubricant, insolubilizer and OBA were added at the vortex of pigment slurry. The pH of the color was adjusted to 8.5 - 9.0. The total solids of coating slip were kept around 67%.

Paper coating application

The coating color was applied on preconditioned (24 h at 23°C and 50% relative humidity) base paper sheets (21.0×29.7 cm^2) with an automatic bar coater (RK-Print Coat Instruments Ltd., U.K., model K 101). The amount of coating was adjusted with bars of different numbers. The coat weight was maintained at 10 g/m^2. The coated paper was immediately placed into an oven at 105 °C for 60 seconds to dry. Subsequently the coated paper was supercalendered in plant scale supercalander applying a linear nip pressure of 76 bar at 50 °C. All the coated papers were passed through two nips.

Analytical techniques

Particle size and size distribution were measured with Horiba make Laser Scattering Particle Size Analyzer, (model no. LA920). Scanning Electron Micrograph (SEM), (model no. JSM6510 LV, JEOL) was used for micro picture of pigments. Brightness and whiteness of coated paper were determined with Data Color Brightness Tester (model Spectraflash 300). L&W Gloss Meter, model no. SE224 was used for the measurement of gloss of coated sheets. Printing properties like IGT (Institute for Graphic Technique) pick velocity, ink setoff and print gloss were measured on IGT Printability Tester, (model no. AIC25).

Results and Discussion

The pigments of different particle size, size distribution and shape were selected for the study (Table 1). Calcite PCC of rhombhohedral habit (PCC 1) and aragonite PCC of orthorhombic habit (PCC 2) show narrow particle size distribution, while calcite PCC of scalenohedral habit (PCC 3) and GCC pigment show broad particle size distribution. The particles shape of all the pigments are illustrated in micro pictures taken through SEM (Fig. 2-5). GCC pigment is blocky or roundish in shape with the lowest aspect ratio

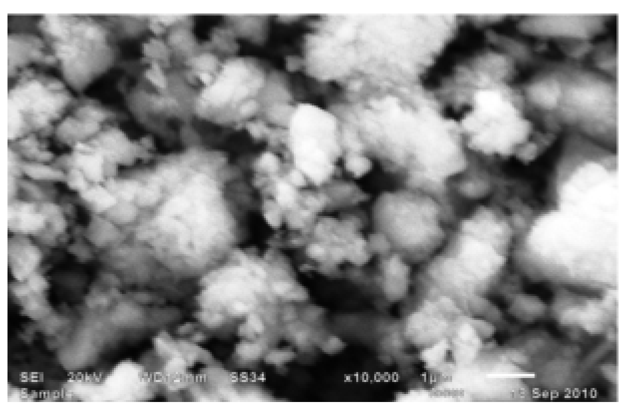

Fig. 2: SEM image of ground calcium carbonate (GCC)

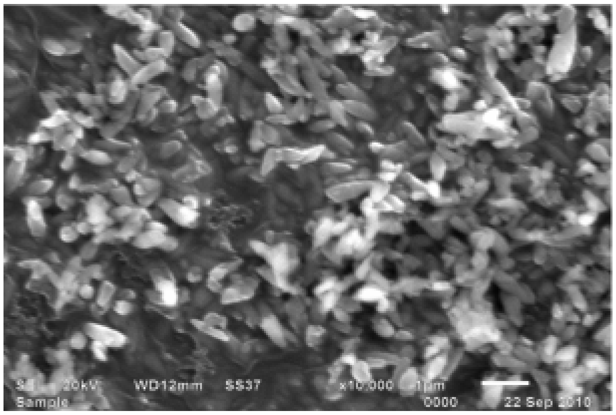

Fig. 3: SEM image of rhombohedral habit calcite PCC (PCC 1)

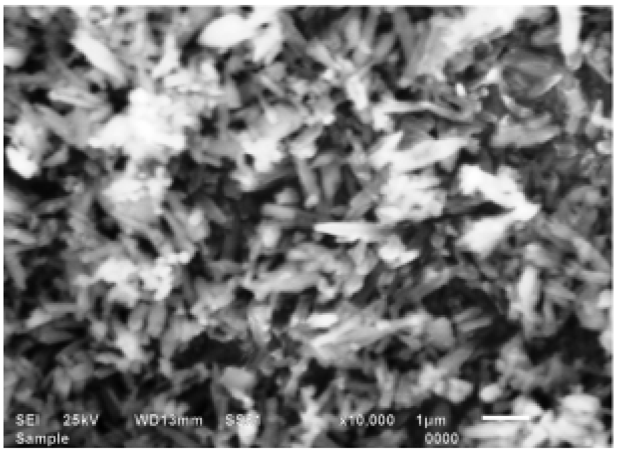

Fig. 4: SEM image of orthorhombic habit aragonite PCC (PCC 2)

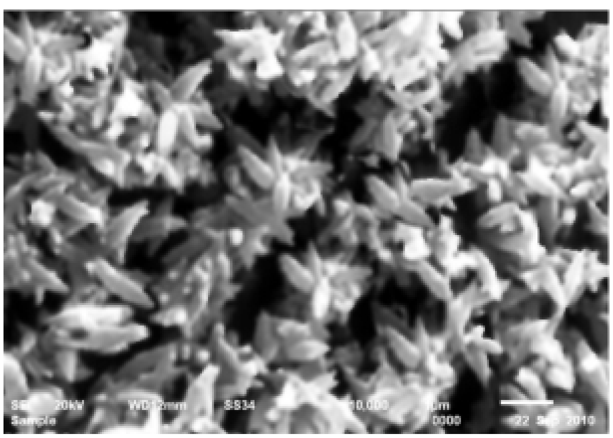

Fig. 5: SEM image of scalenohedral habit calcite PCC (PCC 3)

(particle length to width ratio) near to unity, whereas it is much higher for PCC pigments. PCC 2 shows needle like structure with the highest aspect ratio. PCC 3 exhibits clusters (rosettes) of triangular shaped crystals emanating from a central core.

Brightness

Brightness of paper is measured by comparing the amount of reflected light, of a prescribed wavelength (457 nm) in the blue region of the spectrum. The brightness of all PCC pigments is superior than that of GCC pigment (Table 1).

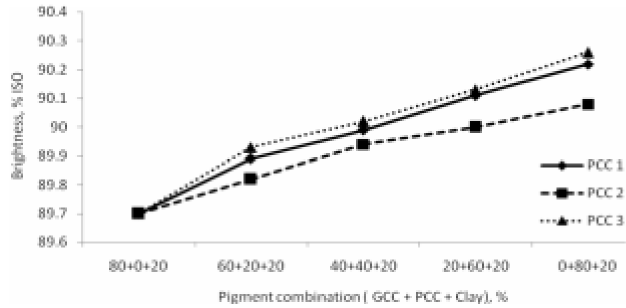

Fig. 6: Effect of pigment blends on brightness of coated paper

Brightness of the coated sheets is directly linked with that of the pigment. The brightness of the coated sheets with PCC 1 and PCC 3 pigment are almost similar and increases with the increment of PCC in the pigment blend (Fig. 6).

Whiteness

Whiteness of paper is measured by the reflectance of a paper surface for all wavelengths of the visible spectrum. The whiteness of a printing paper is considered as an important quality parameter. High paper whiteness improves the contrast to printed areas providing a more distinct appearance of printed text and colors. The whiteness of all the PCC pigments was higher than that of GCC pigment (Table 1), but the drop in whiteness was observed with introduction of PCC in coating formulation (Fig. 7). The NPSD of PCC results in change in geometry of pores which affect the optics of coated sheet. The overall scattering from the coated sheet depends upon the light scattering from base paper as well as coated layer. The geometry of the pores in the coated structure influences the overall light scattering of the coated paper. The high scattering through coated layer exhibiting the effect of the base paper is minimal, but the whiteness of base paper will be decisive in case of poor scattering through coated layer. As the base paper CE whiteness level was much higher (130) as compared with those of all the pigments, the effect of base paper optics on final coated paper was found to be lower in case of NPSD PCC pigments where the light scattering through the coated layer is predominant and higher in case of BPSD GCC pigment where the light scattering through the coated layer is not so much important. The drop in whiteness level of coated paper was more in case of PCC 2, due to the combined effect of lower whiteness and NPSD of particles. PCC 3 showed similar results as observed with PCC 1 with respect to whiteness. Though PCC 3 has relatively larger particle size distribution as compared to that of PCC1 and PCC 2 the drop in whiteness is not that sharp, which may be due to its rosette like structure.

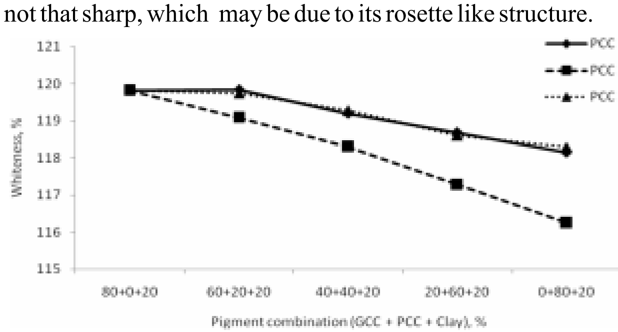

Fig. 7: Effect of pigment blends on whiteness of coated paper

Surface strength

Adequate surface strength is required during printing of coated paper. IGT pick velocity gives an indication of surface strength. The higher the value of pick velocity, higher will be the surface strength. Marginal improvement in IGT pick velocity was observed with PCC 3 whereas reduction was observed in case of PCC 1 and PCC 2 (Fig. 8). The higher void volume arising out of narrow particle size distribution has a

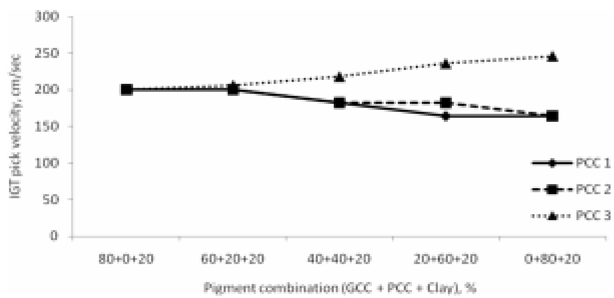

Fig. 8: Effect of pigment blends on IGT pick velocity of coated paper

negative effect on binder coverage and efficiency (4). The NPSD PCC creates larger void volume throughout the coating structure and thus demands more binder as compared to BPSD GCC pigment. The binder demand in case of PCC 3 was either adequate or lower in comparison to that of PCC 1 and PCC 2 as it is having relatively broad particle size distribution.

Ink setoff

Ink setoff gives an indication of setting of ink during printing operation (lower values indicate faster ink setting rate). Various printing defects may occur if ink setting rate is not properly optimized. It depends upon pore size and volume of the coated layer. Smaller pores have high capillary pressure and thus exert greater pulling of the ink from the paper surface.

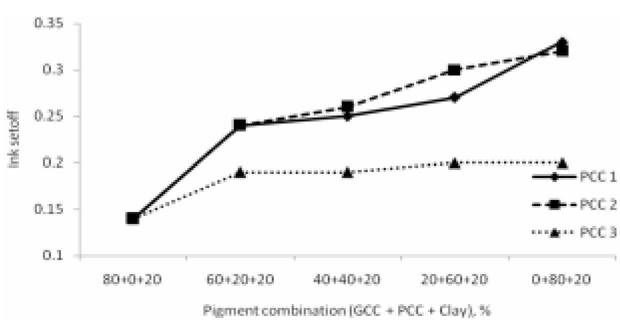

Fig. 9: Effect of pigment blends on ink setoff value of coated paper

The larger pores are not much effective to pull the ink rapidly from the setting ink film because of low capillary pressure (5-7). The results indicate that ink setting rate becomes slow after addition of PCC in color formulation (Fig. 9). PCC pigments have NPSD thus results in larger coating pores as compared to GCC pigment. GCC pigment creates fine pore structure throughout coated layer, which allows faster ink setting rate. The PCC 3 shows higher ink setting rate as compared to PCC 1 and PCC 2 due to its BPSD which results in comparatively finer pore structure (Fig.1).

Print gloss

Print gloss is an important property of printed coated sheet. Print gloss depends not only on the unprinted initial sheet gloss but also on the ink setting rate during printing operation. Generally, the higher the initial sheet gloss, the higher will be the print gloss. Apart from the sheet gloss the print gloss is also affected by pore radius and microscopic surface topography (8). Fig. 10 clearly indicates an improvement in print gloss of coated paper with PCC 1 and PCC 2. The same trend was observed in case of paper gloss (Fig. 11). The particle orientation during coating consolidation affects gloss because tilted surface facets reflect light to different directions. Pigments with high aspect ratio aligned properly during consolidation produce better gloss to coated paper (Fig. 12) (9). PCC 3 showed reduction in print gloss even after having high aspect ratio. The lower gloss with scalenohedral habit PCC 3 pigment is due to irregular particle arrangement as it shows clustered rosette shape resulting in reflection of light in different directions (10).

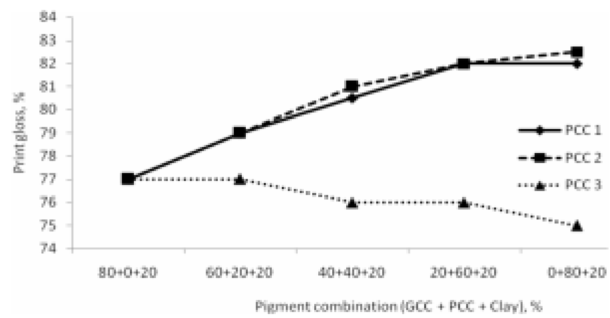

Fig. 10: Effect of pigment blends on print gloss of coated paper

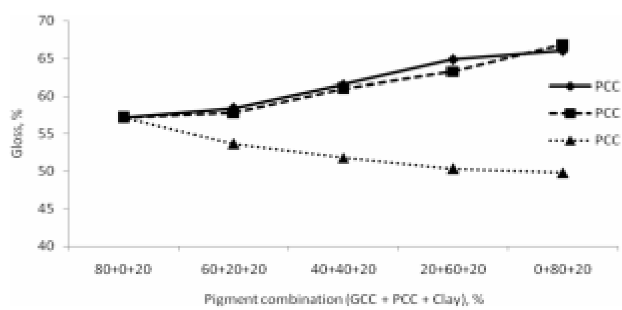

Fig. 11: Effect of pigment blends on gloss of coated paper

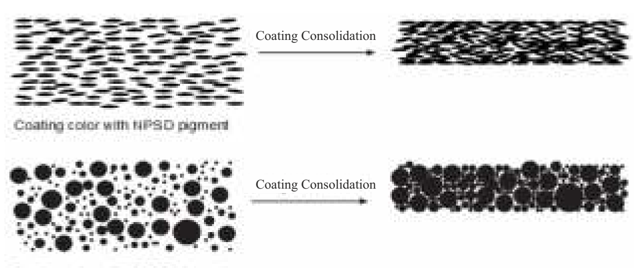

Fig.12: Coating color consolidation with NPSD and BPSD pigments during coating application (9)

Conclusion

The final paper optics and print performance are dependent on pigment particle shape, size and size distribution. The effect of base paper optics on final coated paper was found lower in case of NPSD PCC pigments; the reduction in coated paper whiteness was observed with NPSD PCCs as the base paper whiteness exerts little effect in final coated paper. Surface strength of coated paper was found low in case of calcite PCC of rhombhohedral habit and aragonite PCC of orthorhombic habit, while improvement was observed with scalenohedral habit calcite PCC. The ink setting rate becomes slow with introduction of PCCs in coating formulation. The scalenohedral habit calcite PCC shows higher ink setting rate as compared to other grades of PCCs due to its broad particle size distribution which results in comparatively finer pore structure. The improvement was observed in print gloss in case of calcite PCC of rhombhohedral habit and aragonite PCC of orthorhombic habit whereas reduction was observed in case of scalenohedral habit calcite PCC due to low paper gloss and faster ink setoff.

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