Trabalho

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ULTRAFINE PARTICLE BINDER TECHNOLOGY FOR LOW COST MANUFACTURE OF COATED PAPER AND BOARD

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ABSTRACT

A new coating binder technology designed to provide high performance in both coated printed and packaging grades has been developed. It is based on novel Ultra-Fine Particle Size Technology (UFPST). The technology provides an environmentally responsible alternative to the current binder systems by allowing for a significant reduction in total binder levels, thereby lowering a mill's carbon footprint and concerns around biochemical oxygen demand (BOD).

The ultrafine particle size allows for significant reductions in binder level without significant reduction in surface strength. Binder level replacement ratios of 2:1 are typical, however higher replacement ratios have been achieved, significantly reducing coating costs. Reducing the overall binder level leads to an increase in the system's Pigment Volume Concentration (PVC). Increasing the PVC yields significant enhancements in coating bulk, fiber coverage, optical properties, and ink set rates. With the application of this technology, ink set rates have been increased without picking or piling.

The increase in PVC created with the UFPST produces a more open coating structure, which can be favorable for digital grade applications. This structure can significantly reduce the after coater drying demand, providing added energy savings.

Keywords: Binder types, coating technology, coating costs, novel composition, pigment volume concentration, ultrafine particles size technology.

INTRODUCTION

Developments in coating technology are continuously being driven by economic and environmental pressures. There is constant pressure on paper manufacturers to lower manufacturing costs without compromising quality. The cost contribution for the principle coating components in the total coating color cost is illustrated in **Figure 1** [1, 2]. This is not a representation of any particular coating, but represents an average of typical ranges across coated board and paper grades, commonly encountered. It shows the contribution from the binder systems, both synthetic and natural, is in the range of 55% of the total formulation cost. The contribution of the pigment system is also significant at



Figure 1. Average cost contribution of coating color components for all grades

approximately 35%. There are a very wide range of binder types and technologies giving the coating formulator a host of strategies to achieve the desired results. In addition to a binder system that allows for a binder reduction, one that also facilitates the use of lower cost pigment systems can provide significant saving in the overall coating color cost.

Coating binders can be divided into two major classifications, natural and synthetic. Styrene butadiene latex (SB/SBR) and polyvinyl acetate (PVAc) are two of the most common synthetic binders. SB is prepared by the polymerization of styrene and butadiene monomers. Similarly, polyvinyl acetates are prepared by the polymerization of vinyl acetate monomer and can include the use of acrylate containing monomers (PVAc-acrylates). For both SB and PVAc, adjusting the styrene/butadiene and acetate/acrylate ratios can affect the final coating sheet properties, respectively. Carboxylation can also be part of the polymerization process which provides stability to the latex products, and also binding power in the case of PVAc [3]. Because of its unique combination of binding strength, rheological benefits, and water retention capacity, starch has been used as a coating binder for many years [4].

Three new binder technologies have recently emerged. The need for more environmentally friendly technologies has fueled developmental efforts in the field of "Bio based binder" systems, often referred to as "Bio-Latex". A second technology strategy has been the movement towards finer particle sized

^{*} Authors' reference:

^{1.} Kemira Chemicals, Inc. - USA



Figure 2. Photomicrograph of UFPST and SB latex

binders. Specific surface area (SSA) increases as particle size decreases. Decreasing the binder particle size increases the total number of particles for a given volume. This will typically increase binding power. Finally, combining more environmentally friendly chemistries with ultrafine particle size morphology is a third choice. This combination has been achieved by using a unique polymerization step process, creating a binder with novel composition and efficacy. It is this novel combination that best describes the technology presented in this paper, which can be described as an ultrafine particle size technology (UFPST).

Figure 2 shows two photomicrographs illustrating the difference in particle size of a standard SB latex with the UFPST. The particle size of the UFPST shown on the left is approximately one half of particle size of the standard SB product shown on the right. The ultrafine particle size allows for significant reductions in binder level without significant reduction in surface strength. Binder replacement ratios of 2 parts SB latex to 1 part UFPST are typical, with levels of 3:1 achievable in some cases at equal pick strength to those achieved with traditional latex chemistries.

THEORY

The UPFST has a number of unique characteristics, imparting important benefits to the finished coating structure. These include the Pigment Volume Concentration (PVC), surface strength and its influence on porosity, coating stability and rheology.

Pigment volume concentration

Reduction in overall binder level leads to an increase in the systems Pigment Volume Concentration (PVC). Pigment Volume Concentration is defined as the ratio of the volume of pigment divided by the total coating volume (pigment + binder).

PVC = (pigment volume/pigment volume + binder volume) x 100. (Eq. 1)

A typical PVC curve is shown in **Figure 3**. The Critical Pigment Volume Concentration (CPVC) is the point shown on the curve where the volume of pigment is exactly equal to the volume of the binder [5,6,7]. It is coating dependant, but generally occurs around 50%. At this point, there is just sufficient binder present to fill the voids between the pigment particles. Coatings to the left of the CPVC (lower pigment volume) are comprised of more binder than pigment on a volumetric basis. Conversely, coatings to the right of the CPVC



Figure 3. General pigment volume concentration (PVC) curve

(higher pigment volume) are comprised of more pigment than binder. Figure 3 shows the PVC for a typical paperboard coating. An exterior house paint formulation is also shown for reference. Exterior house paints have a relatively low pigment volume and consequently have a high binder volume, resulting in a very low void volume. These coatings are designed to withstand the rigors of harsh weather elements. The focus of this paper will be on formulations to the right of the CPVC. As the pigment volume concentration increases, a sharp break occurs in the coating's film properties. Finding ways to increase pigment volume in any coating formulation provides opportunity for optical and printing improvements. However, increasing the pigment volume has to be balanced with the potential for loss in coating strength. The key, is to provide the benefits associated with higher pigment volume without a detrimental impact on coating strength.

Impact of PVC on coating properties/process

The impact of increasing the PVC on coated sheet optical properties, specifically brightness and opacity, is shown in **Figure 4**. Twelve (12) parts of SB latex was systematically replaced by



Figure 4. Impact of increasing PVC on optical properties



Figure 5. PVC change associated with UFPST substitution of SB latex

UFPST at a replacement ratio of 2:1 until 100% replacement of the SB latex is achieved with 6 parts UFPST.

The increase in opacity and brightness can be attributed to the increase in PVC from 74.7% (PVC_i) to 86.5% (PVC_f) when all 12 parts of SB latex were substituted with 6 parts UFPST shown in **Figure 5.** [See Appendix I for calculation of PVC values].

Figure 6 shows the impact of increasing the PVC via binder reduction on sheet porosity. The data illustrates a linear response to the increase in PVC from the substitution of standard SB formulation to partial and then full replacemnt of the SB with the UFPST. With an increase in porosity the more open structure can equate to improved optical properties as shown in Figure 4. This, however, can often decrease the coating surface strength, leading to picking or piling during offset printing. The IGT (Institute von Graphische Tecknologie) dry pick test values in Figure 6 indicate there is only a nominal decrease in surface strength, which is not typically observed with traditional binders.



Figure 6. Impact of increasing PVC on porosity



Figure 7. Impact of increasing PVC on coating drying demand

Figure 7 demonstrates an additional benefit associated with increasing the PVC. Figure 7 shows the steam pressure (drying demand) for a machine evaluation where the total binder level was decreased by 50% by replacing SB Latex with the UFPST. During the pre-trial period with the lower PVC formulation, the steam pressures in both post dryer sections were in the mid to upper 300kPa range. When the higher PVC formulation was introduced to the machine, the steam pressure in both sections began to decrease to the low to mid 200kPa range. The machine was then able to speed up 20m/min.

Coating stability and rheology

The technology of higher surface area binders is not new. However, the high anionic charge of the high SSA latex products often limits their practical application. In short, in order to achieve high SSA with traditional latex binders, high levels of anionic surfactant must be used to stabilize the colloidal suspension [8,9,10]. Traditional coating colors are predominantly anionic; the presence of divalent metal cations can interact with anionic latex materials, impacting the coating stability and rheology. This can translate to handling issues, coater runnability problems, and coated sheet defects. On a blade coater, rheology problems can manifest themselves as coating scratches, blade weeping or whiskering. Excessive cross direction coatweight variation can also occur. In a metered size press coater operation, rheology problems can lead to rod spitting, nip rejection or roll exit misting.

Divalent cations, particularly calcium, are used in high concentration in a number of digital printing applications. The cation acts as a "fixative" for the pigment based ink. One of the most common cations used is calcium, which is often introduced by calcium chloride addition. A major factor limiting the application of calcium chloride and similar technologies into fullly coated grades is the coating stability. In **Figure 8**, the impact of a calcium chloride on high SSA latex *versus* UFPST is illustrated. In both cases, 1% of calcium ion (Ca²⁺) on a volumetric basis was introduced to each binder system via a 10% calcium chloride solution. The treated samples were stirred under low shear. There was an immediate interaction with the high



Figure 8. Photograph of high SSA SB latex and UFPST treated with calcium chloride

SSA SB latex, creating a highly flocculated insoluble precipitate. The addition of calcium chloride did not destabilize the UFPST suspension.

Rheological data for full coating colors containing standard SB latex and UFPST, respectively, is shown in **Figures 9** and **10**. The pigment system was a blend of 75% ultrafine Ground Calcium Carbonate (GCC) and 25% Brazilian clay (kaolin). The control binder system was six (6) parts ethylated starch and 4.4 parts of standard SB latex. The experimental formulation contained the same pigment system as the control. The binder system was modified to contain 6 parts ethylated starch and 2.2 parts of UFPST (no change in starch). The PVC increased from 77.5% to 82.4%. Figure 9 shows the Brookfield Viscosity and Hercules High Shear Viscosity data for the two formulations. The Brookfield and Hercules data were very similar. Nominal decreases in Hercules data are observed with the UFPST. The UFSPT Brookfield viscosity data shows a more discernable difference, with a decrease in the UFPST viscosity.



Figure 9. Brookfield and Hercules viscosities of SB latex coating and UFPST coating



Figure 10.Viscoelastic properties of SB latex coating and UFPST coating

Figure 10 shows the data which illustrates the viscoelastic behavior of coatings containing SB latex and UFPST. This data was generated with an oscillatory viscometer. The coating formulations containing the UFPST exhibited slightly lower elastic and viscous modulus when compared to the respective control formulation (SB), demonstrating the stability of coating formulations containing the UFPST.

PILOT EVALUATION

A pilot evaluation was conducted for a Bleached Board Packaging grade. The fourteen (14) point board was double coated single sided. The focus of the study was on the top coat. The pre-coat was applied at the mill site with a jet applicator blade coater. The pre-coat weight was 13 g/m², consisting of 100 parts GCC and polyvinyl acetate (PVAc) as the synthetic binder system, and was kept constant for all the top coat conditions. The top coat was applied at the pilot facility with a jet applicator blade at a speed of 500 meters/minute (m/min). The top coat target weight was 13 g/m². The top coat pigment system was a blend of 50% GCC and 50% kaolin; it was held constant for all conditions. The control formulation contained 16 parts of a traditional Styrene Acrylate (SA). The SA was progressively reduced and replaced with UFPST at a 2:1 replacement ratio until a 100% replacement of the SB latex was attained. **Table 1** shows the top coat conditions evaluated.

Table 1. Top coat pilot trial conditions

	Control	1	2	3	4
Ultrafine high glossing clay	50	50	50	50	50
Ultrafine GCC	50	50	50	50	50
Replacement level latex	0%	25%	50%	75%	100%
UFPST	0	2	4	6	8
SA latex	16	12	8	4	0
Target solids	65.5%	65.5%	65.5%	65.5%	65.5%



Figure 11. Gloss and brightness results pilot evaluation with UFPST

Figure 11 shows the gloss and brightness values, demonstrating the impact of increasing the PVC. The PVC of the control was 71.3% and that of condition #4 was 82.8%. [See Appendix 2 for calculation]. There was an increase in gloss of about 5 units when comparing trial point #4 with the control. Additionally, there was an increase in brightness of approximately 0.5 when comparing the same conditions.

The increased values were achieved without any sacrifice in printing performance. The basic print performance data is presented in **Figure 12**. This includes a subjective print rating, pass to fail and slope values. The pass to fail and slope values were determined by Nancy Plowman Associates (NPA), using their proprietary methods (NPA Slopes).

All of the trial points (1-4) are comparable to the control. There is a slight increase in the ink set rate as shown in the increased slope value, due to the binder reduction (increase in PVC). All of the board was printed on a commercial offset press, without issue with respect to picking or piling. The printed board was rated in a



Figure 12. NPA slope/passes to fail and printing rating results

Very good		
Average		
Poor		

Table 2: Description of Print Quality Rating Scale



Figure 13. Gurley porosity and glueability results for pilot evaluation

blind study by a third party. The results indicate there was no loss in printing quality. Lower values indicate better quality. A more detailed description is given in **Table 2**.

Finally, the Gurley Porosity values for the trial conditons and glueability are illustrated in **Figure 13**. Increased porosity led to quicker ink set rates (at equal pick), improved optical properties and improved post coater drying efficiency. No loss in glueability was experienced with the more open coating structure associated with the 50% reduction in binder.

CONCLUSIONS

A new ultrafine particle size of UFPST binder allows for significant reductions in binder level without the typical reduction in surface strength. Binder replacement ratios of 2:1 and higher have been achieved routinely, leading to meaningful reductions in coating costs. Reduction in overall binder levels lead to an increase in the systems Pigment Volume Concentration (PVC). Increased PVC yields significant enhancements in optical properties, such as opacity and brightness, and faster ink set rates. Ink set rates have been increased without the detrimental effect of picking or piling.Moreover, higher PVC formulations containing UFPST binder have demonstrated significant decreases in after coating drying demand.

The UFPST provides consistent rheology and coating color stability with and without the presence of divalent cations such as calcium. This, in addition to the more open coating sturcture created by the UFPST, may make it a good candidate for development of digital printing grades.

Appendix I – PVC calculation for Figure 5

A specific gravity value of 2.6 g/cc was used for clay and 2.7 g/ cc was used for calcium carbonate [11]. The pigment system for the coatings referenced in Figure 4 was 70% GCC and 30% Brazilian clay. The specific gravity for the mineral blend was calculated as a weighted average of the two separate minerals

2.7*0.7 + 2.6*0.3 = 2.67g/cc

The contribution from all other coating additives was eliminated from the calculation since they are small relative to the pigment and binder. These additives were kept constant for all conditions.

Control formulation

100 parts of pigment/112 total parts = 89.3% of the formulation by weight

12 parts of binder/112 = 10.7% of the formulation by weight Pigment volume of the contol formulation = 89.3/2.67=33.4Specific gravity of SB latex = 0.95g/cc [12]

Binder volume of the control formulation = 10.7/0.95 = 11.3

PVC = (33.4/33.4+11.3)*100 PVC = 74.7%

Trial condition #4

100 parts of pigment/106 total parts = 94.3% of the formulation by weight

6 parts of binder/106 = 5.7% of the formulation by weight Pigment volume of condition #4 = 94.3/2.67 = 35.3

Sspecific gravity of UFPST = 1.03 g/cc [13]

Binder volume of condition #4 = 5.7/1.03 = 5.5

 $PVC_{f} = (35.3/35.3+5.5)*100 \quad PVC_{f} = 86.5\%$

Appendix II – PVC calculation for Figure 11

A specific gravity value of 2.6 g/cc was used for clay and 2.7 g/cc was used for calcium carbonate [10]. The pigment system for the coatings referenced in Figure 4 was 50% GCC and 50% Brazilian clay. The specific gravity for the mineral blend was calculated as a weighted average of the two separate minerals

2.7*0.5 + 2.6*0.5 = 2.65g/cc

The contribution from all other coating additives was eliminated from the calculation since they are small relative to the pigment and binder. These additives were kept constant for all conditions.

Control formulation

100 parts of pigment/116 total parts = 86.2% of the formulation by weight

16 parts of binder/116 = 13.8% of the formulation by weight Pigment Volume of the Contol Formulation = 86.2/2.65= 32.5 Specific gravity of SA latex = 1.05 g/cc [12]

Binder volume of the control formulation = 13.8/1.05=13.1

Trial condition #4

100 parts of pigment/108 total parts = 92.6% of the formulation by weight

8 parts of binder/108 = 7.4% of the formulation by weight Pigment volume of the contol formulation = 92.6/2.65 = 34.9Binder volume of the control formulation = 7.4/1.03 = 7.2

$$PVC_{f} = (34.9/34.9+7.2)*100$$
 $PVC_{f} = 82.8\%$

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