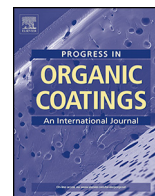




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Progress in Organic Coatings

journal homepage: www.elsevier.com/locate/porgcoat

Short communication

The effects of water soluble polymers on paper coating consolidation

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ARTICLE INFO

Article history:

Received 23 November 2012

Received in revised form 2 December 2013

Accepted 1 January 2014

Available online 31 January 2014

Keywords:

Water soluble polymer

Coating consolidation

First critical concentration

Water evaporation

Gloss

ABSTRACT

The consolidation process of wet paper coating layers has been generally divided into several stages by the definitions of first critical concentration (FCC) and second critical concentration (SCC), however few works have been done on the kinetics of water expelled during drying and its influence on the critical concentrations. In this paper, the effects of three kinds of water soluble polymers, i.e., carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA) and modified coating starch, on the consolidation of model kaolin clay-latex coatings were investigated. On-line water evaporation loss rate, together with the level of FCC and time needed to reach FCC, was characterized. The results showed that water evaporation loss weight increased almost linearly with drying time during the initial wet coating layer consolidation stage. On-line water evaporation rate and the value of FCC decreased with water soluble polymers addition, while the time needed to reach FCC became longer. Among the three polymers studied, CMC was the most effective, then PVA and starch.

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1. Introduction

Coating suspensions, mainly comprised of dispersed colloidal particles such as kaolin clay, calcium carbonate, synthetic latex and other minor functional additives, are widely used in paper, paint, nanocomposite film, and thin layer catalyst industries to improve the surface properties [1–4]. After application, the wet coating layers are dried to form an immobilized structure by liquid absorption to the base substrate and evaporation from the coating surface [5]. It is commonly believed that drying process strongly affects the final coating properties, e.g., void fraction, binder redistribution, ink absorbency and print mottle tendency in offset printing [6–9], therefore many researchers studied the consolidation process and postulated various mechanistic models to better understand it [5,10,11].

The generally accepted mechanism, proposed by Watanabe and Lepoutre [5], divided the pigment coating consolidation process into three phases, i.e., liquid, gel and solid, by the first and second critical concentration (FCC and SCC). Based on the classical mechanism, some other theories have also been postulated. Laudone and co-workers [10] suggested that there should be a third point, i.e., the inter-critical concentration (ICC), between the FCC and SCC. They assumed that at ICC point the coating layer might begin to shrink and void fraction decrease half-way. Recently

Zang et al. [11] proposed a new filter cake formation mechanism for latex-pigment coating structure development during consolidation, which includes four stages, i.e., filter cake formation, cake growth, latex coalescence and solid. The definition of latex coalescence concentration (LCC) was introduced, at which point the front of filter cake reaches the bottom of the wet coating layer, and moisture evaporation afterwards leads the coating capillaries to shrink, latex particles beginning to deform and coalesce.

Whether in the Lepoutre's three-stage consolidation model or the modified four-stage models, the distribution of particles and liquid in the wet coating layer changes according to the various drying phases, which may influence the pigment and binders concentration in the cross section, and therefore the coating structure and performance. It was assumed that the consolidation process was affected by many factors, such as coating composition (pigment type and blend, binder kind and level, and chemical additives), the properties of base stock (absorbency and roughness), and drying conditions [1,5,12–15]. And it was reported that the FCC is always lower for coating layers with water soluble starch binder than that with particulate latex, and low T_g (glass transition temperature) filming latex usually leads to higher FCC of coatings than the non-filming latex [5,16]. However, few works have been done on how to adjust the critical concentrations.

Water soluble polymers, such as carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA) and modified coating starch, are usually applied in paper coatings to obtain performance like rheology regulating, water holding, latex binder migration inhibiting and OBA effect enhancement [16–20], whereas their effects on

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critical concentration and water evaporation behavior during wet coating drying are not clear. The target of this work is to evaluate the influence of water soluble polymers on coating consolidation process, focusing on real time water evaporation rate, the value of FCC, and time needed to reach FCC. Model paper coating layers were prepared by mixing kaolin clay pigment, carboxylated styrene butadiene (SB) latex and water soluble polymers, and then applied on impervious polyester substrate. Wet coating layer on-line gloss and water evaporation loss weight were monitored to determine the FCC point and water evaporation loss rate.

2. Experimental

The mineral pigment was a commercial coating kaolin clay from Maoming Technology, China, with 90–92% by weight of particles finer than 2 μm and an average size of about 1.2 μm . A carboxylated styrene butadiene (SB) latex obtained from BASF Corp. was used as binder, with an average particle size of about 0.15 μm and a glass transition temperature of 20 $^{\circ}\text{C}$. Three kinds of water soluble polymers, i.e., CMC (Hengda, China), PVA (Tianyi, China) and modified coating starch (Roquette, China), were used as co-binders.

The kaolin clay pigment was pre-dispersed at 68% solids content (by weight) in distilled water, using 0.3 parts of sodium polyacrylate dispersant per hundred parts of pigment (pph, on a dry weight basis). Model paper coating colors were prepared by mixing pigment dispersion, latex binder, distilled water and one type of the water soluble polymers each time, as described in previous work [19,20]. Latex dosage was kept constant at 15 pph. The polymers were dissolved in a water bath with the temperature of 60 $^{\circ}\text{C}$ for CMC, and 95 $^{\circ}\text{C}$ for PVA and starch separately, and the adding amount varied from 0 pph to 3 pph. For all coatings, solids content (including pigment, latex and polymer) were consistent at 50% by weight. Sodium hydroxide solution was used to adjust the coating color pH to 8.5.

Model coating layers were prepared by applying the coating colors on non-porous polyester (Mylar) films with a wire wound draw down bar. This can ensure that all the water lost is by evaporation from the coating surface, so that the wet coating gloss change and water loss weight during consolidation can be monitored without interference of water and binder penetration into base sheet. The wet coating layers were dried at ambient conditions with the temperature of about 23 $^{\circ}\text{C}$ and humidity of 40–50% RH. The basis weight of dry coating layers were fixed in the range of $20 \pm 2 \text{ g/m}^2$.

Glossmeter was used to measure the wet coating layers gloss every 10 s after application with an incident angle of 75 $^{\circ}$, thereby the time needed to reach FCC was determined. Electronic balance with a video record accessory was utilized to monitor water evaporation loss weight of coating layers with a specified area [7]. On-line water evaporation rate (in grams per square meter) was calculated from the wet coating layer weight loss during drying period, and the coating solids content was achieved by dividing the final bone dry weight of coating layer by its real time weight.

3. Results and discussion

Surface gloss and water evaporation loss weight of wet coating layers with various water soluble polymers consolidated at room temperature were illustrated in Figs. 1–8, accordingly the solids content and on-line water evaporation rate were inferred.

Fig. 1 shows the property changes of control coating layer during consolidation. As can be seen, coating gloss increased apparently from about 84% after application to 90% at the FCC point, and then dropped sharply to a lower constant value of about 66% after SCC. The time needed to reach FCC was about 230 s, and the value of FCC was about 70.2%. The coating gloss kept high levels during the initial

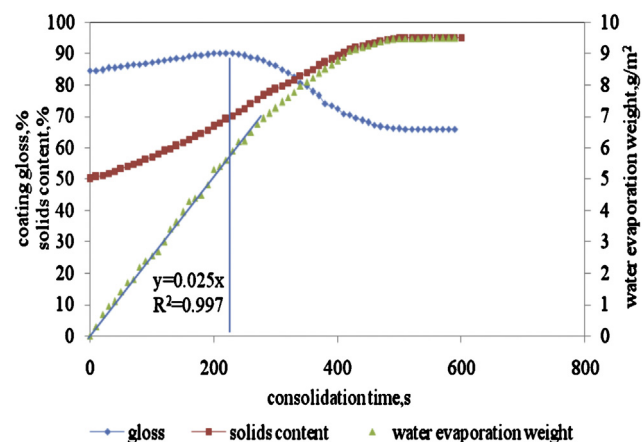


Fig. 1. Gloss and water evaporation weight for the control coating as a function of consolidating time. (t_{FCC} : 230 s, FCC: 70.2%)

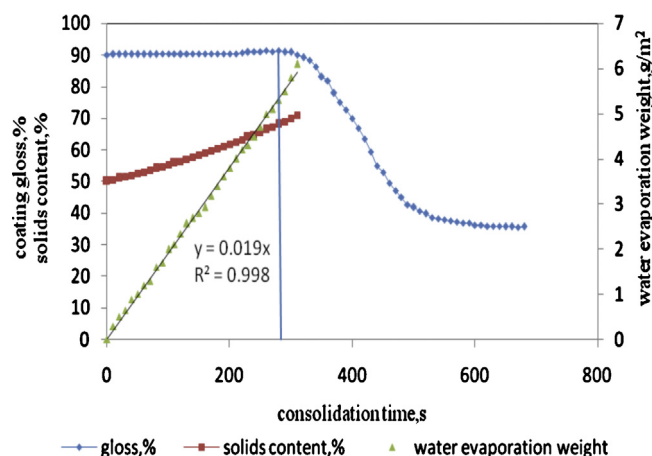


Fig. 2. Gloss and water evaporation weight for the coating containing 0.5 pph CMC vs. consolidating time. (t_{FCC} : 280 s, FCC: 68.0%)

period before FCC because the wet surface was covered with a continuous water film like a mirror, and the slight gloss improvement may be attributed to the leveling of the coating layer, orientation of the pigment particles, and increase of medium refractive index

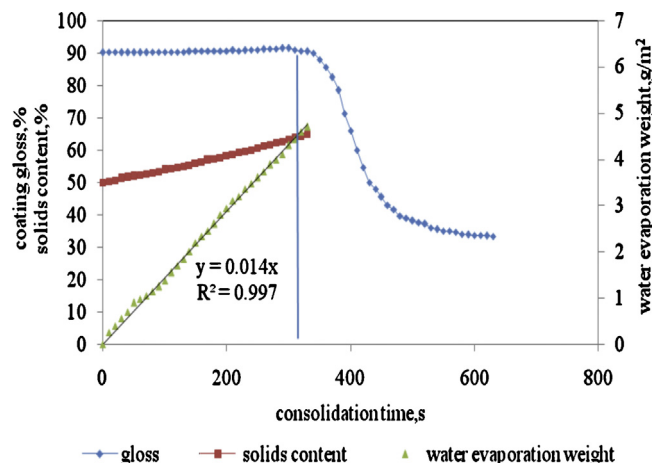


Fig. 3. Gloss and water evaporation weight for the coating containing 1 pph CMC vs. consolidating time. (t_{FCC} : 320 s, FCC: 64.4%)

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