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The relationship between dispersion stability and print quality on the coated paper

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Abstract

Inkjet printing on the coated paper has been required for many years, but it is known that because of poor penetration ability of the coated paper, residual ink on the coated paper causes bad effects on print performance. To investigate the relationship between dispersion stability of ink and print quality, three types of dispersion were prepared (self-dispersed pigment type, surfactant-dispersed pigment type and polymer-dispersed pigment type). Ink with higher dispersion stability is less likely to aggregate during drying process, which leads to less roughness, high optical density, gloss and good abrasion resistance. When humectant in ink was optimized in terms of penetration into coated paper, polymer-dispersed pigment showed prominent print quality.

Introduction

Recently inkjet print-on-demand for offset coated papers and non-porous media is being required on the field of commercial printing. Inkjet systems are vastly superior to offset printing systems in terms of cost, time and environmental friendliness. Especially offset coated papers played an important role in commercial printing for many years. Since the coated paper can absorb less ink compared with the porous plain paper , when conventional inks are printed on the coated paper, residual ink on the paper surface sometimes causes bad effects on print performance parameters such as gloss, optical density, and rub fastness during drying process. The stability of pigment dispersion during penetrating process and drying process dominates the pigment aggregation on the paper surface influencing the print quality and rub fastness. However, there is less report about the effect of dispersion stability to optical density and gloss on the coated paper. It was reported that abrasion resistance after completely drying is affected by the strength of the ink layer on the paper and adhesion to the media [1]. But the abrasion resistance during drying process has not been studied. In the fields of high-speed commercial and industrial printing, abrasion resistance during drying process is strongly required in terms of productivity.

In this paper, in order to clarify the relationship between stability of pigment dispersion and print quality, various pigment dispersions with different stabilities were prepared. That is, self-dispersed pigment, surfactant-dispersed pigment and polymer-dispersed pigments were prepared and their dispersion stability and print qualities were evaluated. According to the results, utilizing polymer-dispersed pigment led us to propose optimal pigment, dispersant and humectant for the coated paper in the high-speed printing field.

Experimental

Preparation of pigment dispersions

The following dispersions were prepared at 100/45 ratio of pigment to polymer or surfactant. Carbon black (Pigment Black 7) which was used in dispersions has the same specific surface area and dibutyl phthalate absorption number.

Self-dispersed pigment type (SD)

Liquid-phase oxidation method was used to produce self-dispersed carbon black (Pigment Black 7). 153 g of styrene-acrylic polymer (solid content 29.5 wt %, Mw: 10000 g / mol) was added to the pigment dispersion.

Surfactant-dispersed pigment type (Sur-D)

100 g of carbon black and polyethylene glycol alkyl ether (Kao Corporation, Mw: 800 g / mol) 45 g were added to 400 g of ion-exchanged water. The mixture was dispersed by a homogenizer and filtrated to eliminate course particles.

Polymer-dispersed pigment type (PD)

Styrene-acrylic polymer with non-ionic segment 134 g (solid content 32 %, Mw: 50000 g / mol) were added to ion-exchanged water and neutralized. The mixture and 100 g of carbon black were mixed and dispersed by a homogenizer. Then, the dispersion was concentrated by an evaporator and filtrated.

Measurement of print quality

Each ink was produced by the following method. To each dispersion (pigment concentration is 7 %), humectants, 3 wt % of acetylene glycol type surfactant and water were added and the mixture was filtered. Ink was filled in a home inkjet printer and printed on OK top coat plus (Oji Paper Co., LTD).

Optical density and Gloss

Printed coated paper after 1 day was used for evaluation. Optical density was measured by SpectroEye (Gretag Macbeth) and gloss was measured by glossmeter PG-1M (Nippon Denshoku). Gloss at 60 degree was adopted.

Abrasion resistance

Printed coated paper was dried for 1-60 min at room temperature and the coated paper was rubbed 20 times by plain paper at 7840 Pa.

Measurement of hydrated ink viscosity

The inks in vessel were dried at room temperature. When the ink weight decreased to 75, 50 and 43% compared with the initial weight, their rheological properties were measured by rhometer Physica MCR301 (Anton Paar). Weight at 43% indicates water contained in ink is completely evaporated.

Scanning Electron Microscope (SEM) analysis

The surface of printed coated paper was characterized (×100 k) by SEM S-4800 (Hitachi).

Penetration

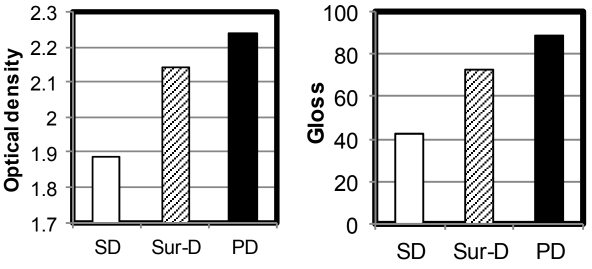
The penetration volume of inks into the coated paper was measured by Automatic Scanning Absorptmeter KM500win (Kumagai Riki Kogyo Co., LTD) [2]. These inks didn't contain solid contents to gain accurate data. Contact time between liquid and paper was set as 200 ms.

The presence of humectants in cross-section surface of the coated paper was qualified using time-of-flight secondary ion mass spectrometry (TOF-SIMS) TOF-SIMS IV (IONTOF). m/z = 118 which means fragmentation of the humectant molecular ion was detected.

Results and Discussion

Influence of dispersion stability on optical density and gloss

Inks which contain self-dispersed pigment (SD) dispersion, surfactant-dispersed pigment (Sur-D) dispersion and polymer-dispersed pigment (PD) dispersion respectively were printed on the coated paper. Their print qualities (optical density and gloss) were evaluated (Figure 1 and 2).



Figures 1 and 2. *Optical density and gloss of printed paper*

Optical density and gloss of PD ink were highest of the three and those of SD ink were lowest. To investigate the influence of dispersion stability during drying on their print performances, ink viscosities under dehydration were measured (Figure 3). When the pigment particles contained in mounted ink are unstable on the coated paper, they are highly aggregated and viscosity of the ink increases immediately. As the water was evaporated, viscosity of the SD ink showed steep rise. It suggested that SD became unstable during the drying process. It was thought that the proportion of humectant increased along with concentration which resulted in weakening electrostatic repulsion between pigments and accelerating aggregation. On the other hand, Sur-D ink and PD ink showed slight viscosity growth during the drying process. This result indicated that their pigment dispersions were stable even in concentration process. Sur-D was supposed to be stabilized by steric repulsion by non-ionic oxide chains of the surfactant-type dispersant. However, at the completely dehydrated condition (43 wt %), its viscosity somewhat increased. On the other hand, polymer dispersant of PD was hardly desorbed from pigment because of its higher molecular weight, thus PD showed a slower aggregation by the stability effect derived from electrostatic and steric repulsion.

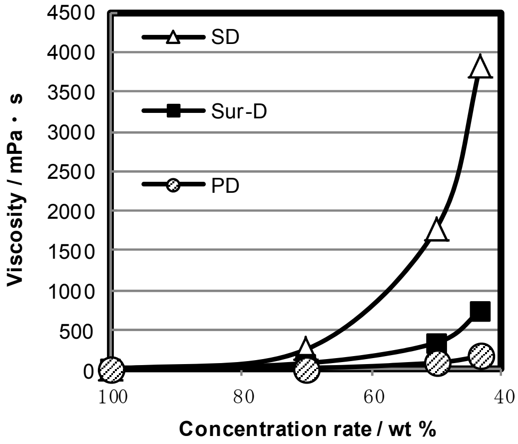


Figure 3. *The viscosity of dehydrated ink with different type dispersion*

The stability of three types of ink is also estimated by observing printed surface through SEM analysis. In Figure 4, printed surface of SD indicated that pigments aggregated together and localized on the coated paper due to lack of dispersion stability during drying process. Microscopic analysis about printed coated paper of Sur-D and PD showed that dispersion stability linked to uniformity of pigment distribution. Lee et al. [3] reported that gloss is associated with surface smoothness affected by colloidal stability in the glossy inkjet coating field. It was suggested that the homogeneity of pigment particles on the printed surface of PD lead to its highest gloss (Figure 2). According to the picture of Sur-D, its printed area was also smooth, but the surface of printed paper looked whitish which made optical density and gloss lower than those of PD ink. The desorbed surfactant was presumed to exist on the right surface. These results suggested that there was a good correlation between dispersion stability and pigment distribution on the printed surface, and smoothness referred from dispersed pigment strongly influenced the optical density and gloss.

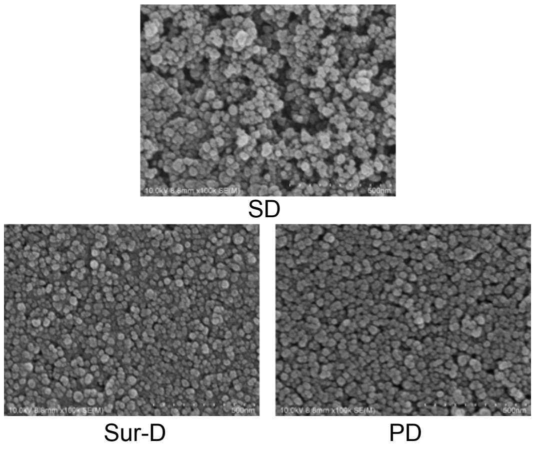


Figure 4. *The SEM analysis of the printed surfaces*

Abrasion resistance during drying process

In the high-speed continuous printing, it is necessary for printed paper to dry as soon as possible while passing through drying equipment before the printed surface makes contact with a roller. To clarify the influence of dispersion stability to abrasion resistance during drying process, each printed paper of three types of ink was rubbed after 30 minutes drying at room temperature (Figure 5).

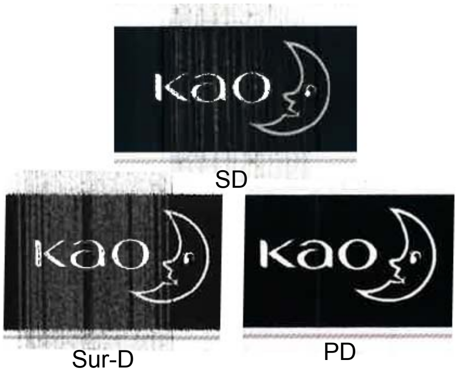


Figure 5. Abrasion resistance after thirty minutes printing

While the resistance of PD ink against abrasion was acceptable, the printed coated paper of SD and Sur-D showed poor performance. According to the SEM analysis of SD ink (Figure 4), the localized aggregation structure of pigment particles was thought to be fragile against stress. Abrasion resistance of Sur-D was not sufficient because surfactant with low molecular weight might not work well as a binder to connect pigments under abrasion. Good resistance in PD was attributed to the pigment uniformity on the coated paper and the effect of polymer dispersant as binder. Our findings indicated that both dispersion stability during drying process and polymer as binder are indispensable for the sufficient resistance against abrasion.

To improve abrasion resistance in shorter time after printing, it would be effective to accelerate penetration of liquid contents in ink into the coated paper. In order to investigate the influence of humectant species to penetration volume, part of humectant (A) used as base solvent was exchanged with humectant (B) whose surface tension is lower than that of A, and penetration volume was measured (Figure 6). Using humectant (B) as a part of ink vehicle, penetration volume into the coated paper increased.

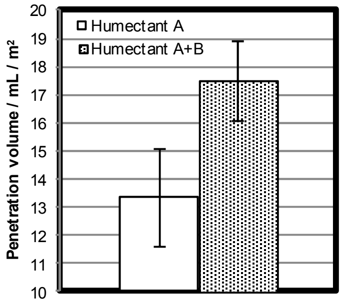


Figure 6. Penetration volume of ink vehicle into the coated paper

Additionally, to visualize the presence of humectant into the coated paper, two humectants in cross-section surface of the coated paper were qualified using TOF-SIMS analysis (Figure 7). Identification of fragmentation of the humectants (A and B) molecular ion at m/z = 118 suggested that PD ink containing B penetrated more deeply into the coated paper compared with using A alone.

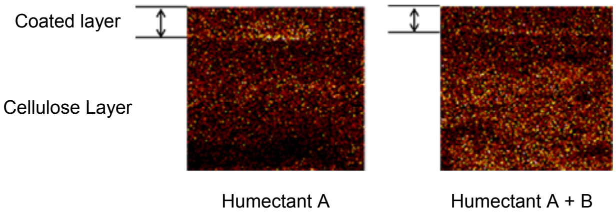


Figure 7. Detection of humectants in the coated paper by TOF-SIMS

On the basis of these results, abrasion resistance of PD ink with penetration formulation was examined. Using humectant B to accelerate penetration, PD ink showed the excellent abrasion resistance only after five minutes of drying (Figure 8). There is a good correlation among the penetration volume of vehicle, the presence of humectant into the coated paper and abrasion resistance, indicating that accelerating ink penetration into the coated paper helps improve the abrasion resistance during drying process.

The abrasion resistance of SD and Sur-D inks after 30 minutes drying didn't change although humectant B was added to two inks (Figure 9). This result suggested that when an ink doesn't possess dispersion stability and contain polymer, its abrasion resistance does not improve even though penetration of vehicle is accelerated.

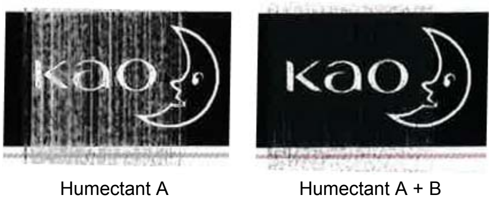


Figure 8. Abrasion resistance after five minutes printing of PD ink with humectant B

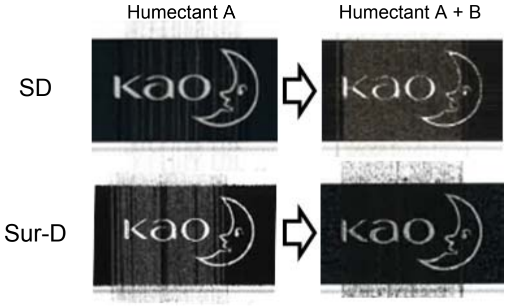


Figure 9. Abrasion resistance after thirty minutes printing of SD and Sur-D ink with humectant B

Adding humectant B changed optical densities of the three inks (Figure 10). While the optical densities of SD and Sur-D ink declined with humectant B , PD ink containing humectant B showed increasing optical density. Depression of the optical density in SD and Sur-D could be explained by their poor stabilities on the coated paper during drying condition. Since low surface tension solvents like humectant B generally show low dielectric constant and hydrophobicity, they tend to weaken electrostatic repulsion and promote desorption of dispersant. Nonetheless, PD ink kept dispersion stability thanks to the polymer dispersant with steric repulsion. Humectant B was thought to act as a plasticizer of dispersant polymer, and the gap between pigments was covered with plasticized polymer which might induce increasing optical density.

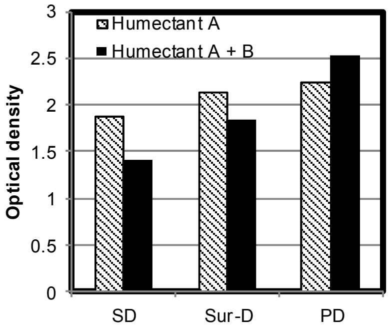


Figure 10. *Optical density of three types of ink with/without humectant B*

Conclusions

Influence of dispersion stability in ink on print performance parameters (optical density, gloss and abrasion resistance during drying process) was examined. Ink with good dispersion stability showed the uniformity of pigment particles on the coated paper and high optical density and gloss. When PD was used for ink, it offered satisfactory abrasion resistance. Polymer dispersant was thought to work as binder. To achieve abrasion resistance in a shorter period of time after printing, a low-surface tension humectant can be added to accelerate penetration of ink vehicle into the coated paper, leading to excellent resistance against abrasion. To achieve higher print quality, both dispersion stability during drying process and polymer as binder are indispensable, and humectant in vehicle affecting permeability into the paper is also important.

When the print speed increases and/or a number of inks are jetted on the coated paper, better abrasion resistance during drying process is demanded. It is our challenge to design polymer dispersants which keep its dispersion stability by preventing desorption from pigment and by making the electrostatic and steric repulsion work even in any circumstance.

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Author Biography

Takayuki Suzuki obtained his BS in chemistry at the Osaka Prefecture University in 2008 and his MS in agriculture at Kyoto University in 2010. In 2010, he joined Kao Corporation and has been engaged in research and development of performance chemicals for inkjet printing technology.