Colorant design for high printing quality on both treated and non-treated papers

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Abstract

The pigment dispersion encapsulated by the polymer with electrostatic and steric repulsion group was known to provide high stability so that the dispersions do not aggregate soon after impacting on the paper. So, polymer dispersed pigment dispersion showed higher jetting stability and good performance of rub fastness on treated paper, but lower optical density on non-treated paper. On the other hand, a pigment with highly oxidized surface showed contrary performance. Thus, to provide higher print quality on both treated and non-treated paper by one ink, a different system needed to be considered. Two pigments with different surface characteristic dispersed together with polymer were found to provide higher jetting stability and higher print quality (optical density and rub fastness) on both treated and non-treated papers. It was concluded that higher optical density could be achieved by adjusting the ratio of two pigments to control the ink penetration into various papers.

Introduction

Recently, inkjet systems have been used in the field of commercial printing because of their reasonable cost, environmental friendliness, and adaptation to print-on-demand. However, the commercial printing market has been dominated mainly by offset printing systems that have been providing higher image qualities on various papers. It is important for inkjet systems to be applied to all the field of commercial printings. But it is actually difficult for one inkjet ink to provide high optical density on a variety of papers. This is because the penetration rates of an ink into various papers are different and mechanisms for improving the optical density could be different. For example, on a high absorptive paper, the ink needs to aggregate as soon as impacting on the paper to provide higher optical density. On the other hand, on a lower absorptive paper, the ink doesn't need to aggregate as fast as the ink droplet needs to spread to provide enough dot size and color homogeneity. Some improvement methods of the image quality on one paper were previously studied [1,2,3]. In this paper, a new improvement method which can provide good print quality on both treated and non-treated papers was studied.

Experimental

Ink Preparation

To prepare the pigment dispersion, the water-insoluble acrylic polymer was adopted. First of all, 25g of the neutralized polymer and 75g of 2 pigment blacks (a) and (b) were mixed with solvent and water. These pigments (a) and (b) had different acidic amount. That amount of (a) was less than 200umol/g and that of (b) was more than 200umol/g. This mixture was dispersed with a homogenizer and was concentrated with an evaporator removing the large size particles.

Then the inks were made with this dispersion, organic solvents, surfactant and water. The initial viscosities and surface tensions of those inks were adjusted to align the jetting performance.

Measurement

Image quality

Image quality was evaluated by the optical density. Optical density was measured by SpectroEye (Gretag Macbeth: GMB).

Color heterogeneity of the printed area and dot size was observed by DDC micro camera (PIAS-2). This color heterogeneity was analyzed by Image-J software.

Physical properties

Inks having various solid contents were prepared by drying at room temperature as dehydrated inks. Those dehydrated inks were the models to simulate ink viscosity behavior during drying process on the paper surface. The rheological properties of the dehydrated inks were measured by rheometer Physica MCR301 (Anton Paal).

Static surface tensions were measured by Wilhemy type surface densitometer FACE CBUP-Z (Kyowa Interface Science Co. Ltd.).

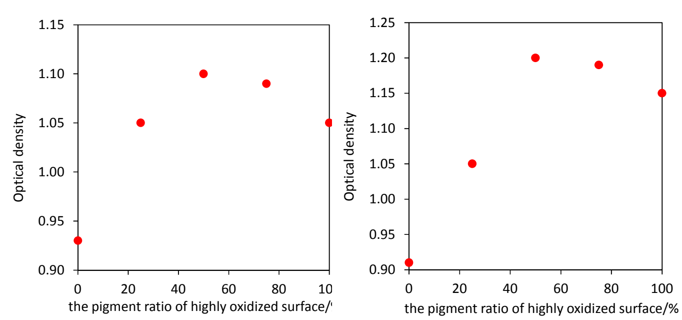
Penetration

The penetration of inks into various papers was measured by automatic scanning absorptometer KM500win (Kumagai Riki Kogyo Co.,LTD).

Results and Discussions

The optical density for the ratio of two pigments

The printed papers were made with a printing pattern of a home inkjet printer. The optical density of the inks with different ratios of two pigments (with highly and lowly oxidized surface) on 2 non-treated papers and 1 treated paper were measured. The results are shown in Figure 1, 2 and 3.



Figures 1 and 2. *The optical density on non-treated paper 1(left) and 2(right)*

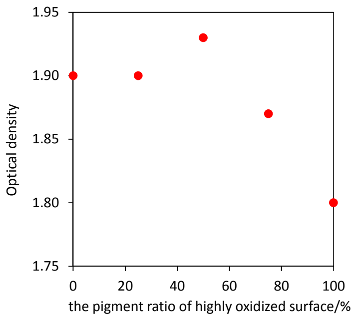


***Figure 3.** The optical density on treated paper*

When the ratio of two pigments was 50/50, the optical densities on both non-treated and treated paper became highest. The mechanism and the way to provide higher print quality on various papers were studied.

The relationship between the optical density and the viscosity of dehydrated inks

The higher optical density was known to be provided by the ink having higher viscosity of dehydrated ink. So, the relationship between the loss of water in the ink during drying process at room temperature and the viscosity of dehydrated ink was measured. Figure 4 shows the viscosity behavior during drying process with different oxidized pigment ratios.

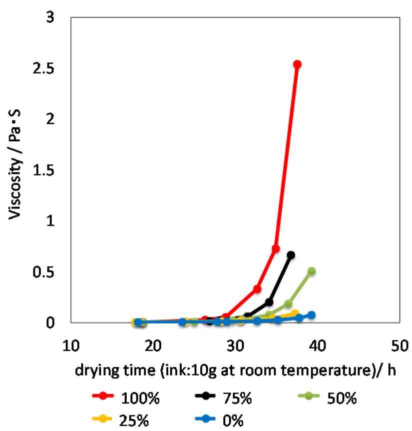


***Figure 4.** The viscosity of dehydrated ink with different pigment ratios of highly oxidized surface*

When the ratio of pigment with highly oxidized surface was higher, the viscosity of dehydrated ink was higher. This can be explained by eq.1 as follows.

$$V_R = \frac{4\pi\varepsilon a^2 \varphi_0^{\,2}}{2a+h}\exp(-\kappa h) + \frac{4\pi a}{v_1}(\varphi_2)^2\left(\frac{1}{2}-\chi\right)\left(\delta-\frac{h}{2}\right)^2 + V_{elas}(h) \quad (1)$$

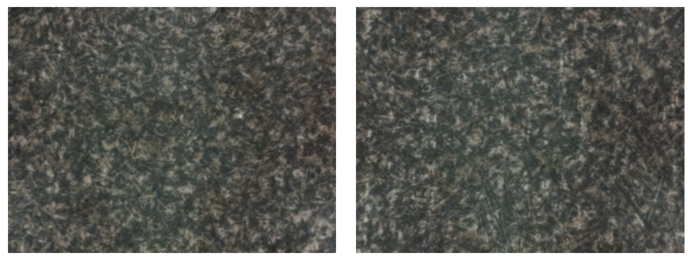
where a is radius of colloidal particle, h is the distance between the two particle surfaces, ε is dielectric constant, φ_0 is zeta potential, κ is the thickness of electric double layer, χ is the Flory-Huggins solvency parameter, φ_2 is the volume fraction of polymer within the brush layer, δ is the thickness of the brush, and ν_1 is the volume of one solvent molecule,

When the pigment ratio of highly oxidized surface is 100%, the second term of eq.1 would become lower because the zeta potential and electric double layer of dehydrated inks become lower as dielectric constant become lower. So the viscosity was considered to become higher by aggregation. On the other hand, when the pigment with highly oxidized surface is replaced with the polymer and the pigment with lower oxidized surface, two pigments are encapsulated with polymer and the second term is added. So, the viscosity was not increased as much.

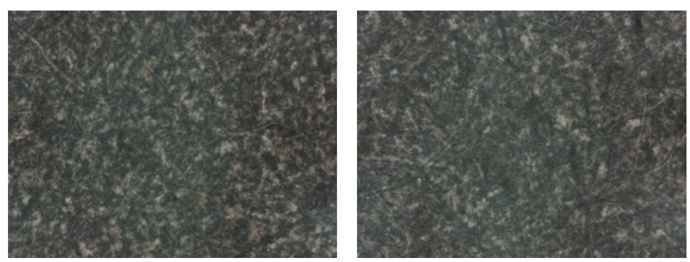
When the pigment ratio of highly oxidized surface was 100%, the viscosity increase was minimized.

Color heterogeneity of the printed area

The printed area on the non-treated paper 1 was observed. Figures 5 through 8 show the scale-up pictures of the printed paper surface. The ratio of pigment with highly oxidized surface was 100%, 75%, 50%, and 25%.



***Figures 5 and 6.** Printed areas of 100%(left) and 75%(right) pigment ratio of highly oxidized surface*



***Figures 7 and 8.** Printed areas of 50%(left) and 25%(right) pigment ratio of highly oxidized surface ratio*

There were a lot of white spots in the printed area of 100% of highly oxidized pigment ratio. The printed area was digitalized and separated into 3.56um squares, and then the density was measured at 256 gradations. The lower value reflects the higher optical density. The results are shown in Figure 9. Then the color density indicator was defined at 0-20 gradations and streakiness indicator was defined at 40-100 gradations. The schematic image of the indicator and the printing images is shown in Figure 10.

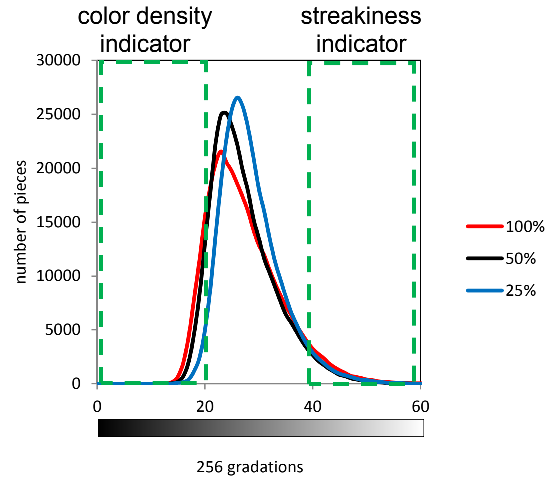


Figure 9. *The distribution of the color density of different pigment ratio of highly oxidized surface*

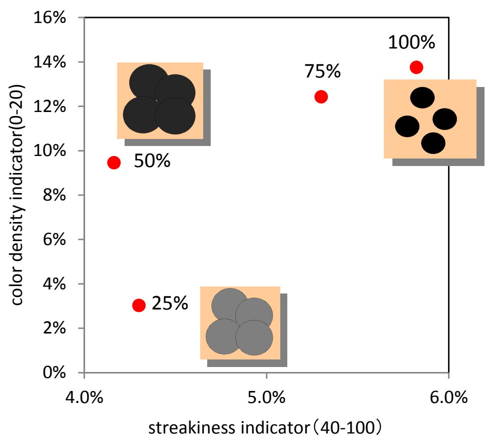


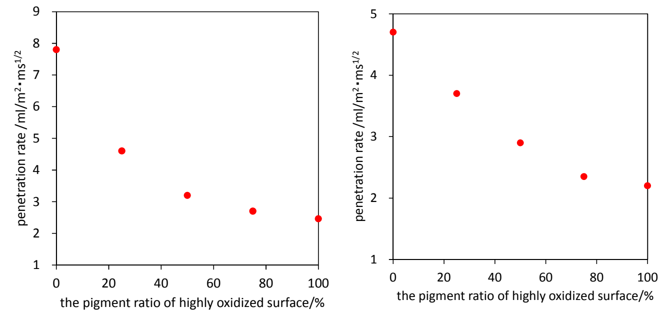
Figure 10. *The color density indicator and streakiness indicator of different pigment ratio of highly oxidized surface*

It was clear that when the pigment ratio of highly oxidized surface was higher, there were a lot of higher optical density areas but the whole area of the paper was not covered with the ink. To provide the higher optical density, two pigment ratios should be adjusted.

The penetration of inks for various papers

The aggregation of ink affects the spread (penetration) on the paper and this spread (penetration) determines the optical density. The viscosity of dehydrated ink becomes different depending on the ink composition. And it is important to study the interaction between ink and paper for good print quality (optical density). There are many kinds of treated papers, so the interaction of ink and several kinds of paper was studied especially with regard to the penetration behavior.

Figures 11, 12 and 13 show the penetration rate of inks into 3 papers.



Figures 11 and 12. *The penetration rate into non-treated paper 1(left) and 2(right)*

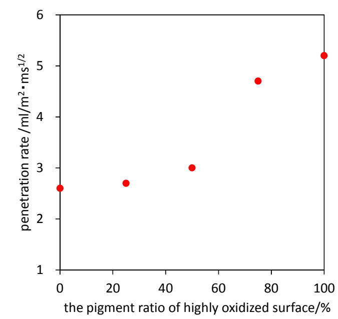


Figure 13. *The penetration rate into treated paper*

When the pigment ratio of highly oxidized surface was higher, the penetration rate into the non-treated paper was slower. It is clear that the aggregation of ink affected the penetration rate. This result is well correlated to the viscosity increase behavior.

The pigment dispersed by the polymer was more stable as shown in Figure 4. So the ink penetration rate into non-treated paper became too fast resulting in lower optical density. On the other hand, the ink with pigment with highly oxidized surface was easy to be aggregated. So the ink penetration and spreading into non-treated paper was slow enough to provide higher optical density. This result also supported the optical density hypothesis which is described in Figure 10.

Figure 14 shows the dot sizes of these inks on non-treated papers.

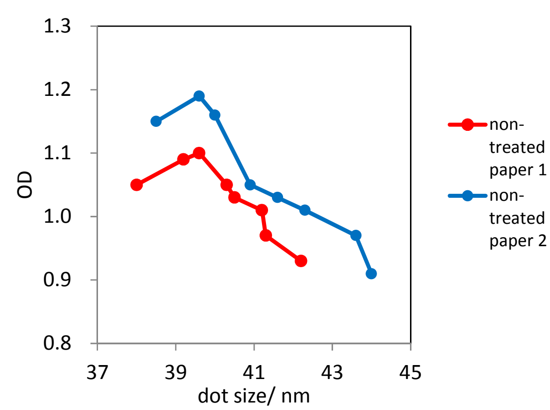


Figure 14. *The dot size of various inks on non-treated paper*

When the dot size was 40nm, the optical density on two types of non-treated papers was highest. So in this printing pattern and droplet volume, certain penetration performance (dot size=40nm) which lead highest optical density was supposed to exist.

This treated paper showed contrary performance to non-treated paper. When the pigment ratio of highly oxidized surface was lower, the penetration rate into the non-treated paper was slower. It might be caused by the interaction between pigment dispersion and paper additive that might block the penetration of the ink.

The effect of dispersing together with the polymer

The optical density of two pigments with different surface characteristic dispersed together with polymer was almost the same as that of the mixed dispersion of two pigments. But regarding the jetting stability of piezo and thermal inkjet printer and rub fastness, two pigments with different surface characteristic dispersed together with polymer showed better performance. The results of the jetting stability and the rub fastness on treated paper are shown in Figure 15 and 16. The jetting stability of dispersing together with polymer was set as 100% jetting stability to compare with that of the mixed one. The printed papers were rubbed with a non-printed paper to determine rub fastness.

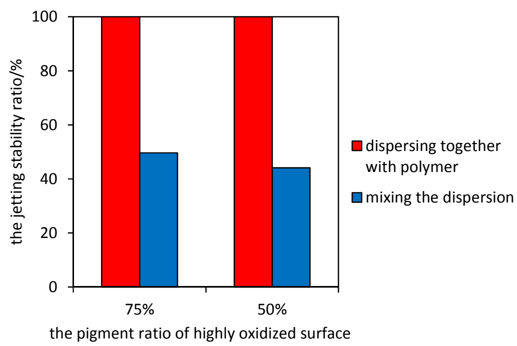


Figure 15. *The jetting stability ratio of dispersing together with polymer and mixing the dispersion*

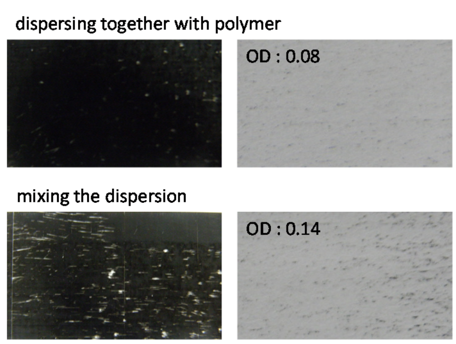


Figure 16. *Substrates in rub-fastness testing: printed papers (left) and non-printed papers with resulting optical densities (right).*

This better performance could be explained by the better dispersing stability and the better adhesion between the paper surface and the polymer-encapsulated pigment.

Conclusions

The optical density was found to be influenced by the penetration of ink into the paper. The higher optical density could be achieved by adjusting the ratio of two pigments to control the ink penetration rate into the various papers. Higher jetting stability and higher rub fastness are provided by dispersing two pigments together with the polymer.

References

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Author Biography

Satoshi Tanaka received his BS and MS in rheology from Kyoto University in 2006 and 2009 respectively. In 2009, he joined Kao Corporation and has been engaged in research and development of performance chemicals for inkjet printing technology.