Novel Aqueous Inkjet Ink Technology Realizing High Image Quality and High Print Speed

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Abstracts

In the inkjet technology, one important challenge is to achieve high quality image at high speed for various types of paper. However, within conventional technologies, there has been no technology that satisfies this challenge. To solve this issue, we developed the "DCLS (Double-Component Liquid System)" as a new ink marking technology. The DCLS technology, which uses an ink set comprising full-color pigment inks and a colorless treatment liquid, is a method of controlling image quality and drying by using the interaction of the inks and the treatment liquid mixed on paper.

This study showed the performance of DCLS technology as well as the effect of agglomerating agent in treatment liquid.

Introduction

The inkjet (IJ) printer, which is characterized by its inexpensiveness, small size, and feature of providing photo-quality images with an IJ glossy paper, is prevailing especially in the personal market. On the other hand, it is not as successful in the office market. This is mainly because the demand in the office market is to output business documents consisting mainly of texts and graphs on plain paper at high speed and in high quality. The conventional technologies could not fully satisfy this demand requirement. The existing conventional aqueous ink technologies are the FD (Fast Dry) ink that quickly penetrates into paper and the SD (Slow Dry) ink that slowly penetrates into paper. For printing on plain paper, the FD ink is excellent in high-speed print performance, but its image quality is insufficient. On the other hand, the SD ink is excellent in image quality such as in optical density, but reasonable high-speed printing could not be achieved. Thus, with plain paper recording, high-speed performance and high image quality are of conflicting factors and no technology has existed in satisfying both factors at the same time.

We, therefore, devised and studied our original DCLS (Double-Component Liquid System) method that uses inks and treatment liquid, with the motive to achieve a new aqueous inkjet technology that provides high speed/high quality for plain paper, by taking advantage of the features of the environment-friendly aqueous ink without using a heat-drying system.

FX/DCLS Technology Concept

The FX/DCLS technology is an ink set technology consisting of the FD pigment inks and colorless FD treatment liquid. The treatment liquid (TL) includes an agglomerating agent that functions to agglomerate the pigment/polymer of the ink when mixed with the ink (See Fig.1).

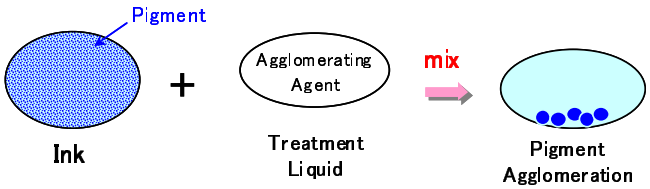


Figure 1. Basic Concept of Interaction Between Ink and Treatment Liquid

The illustration below shows a typical configuration of this system (See Fig.2).

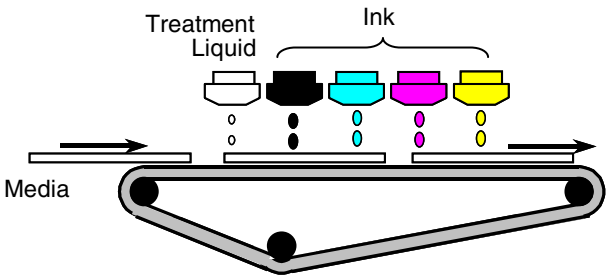
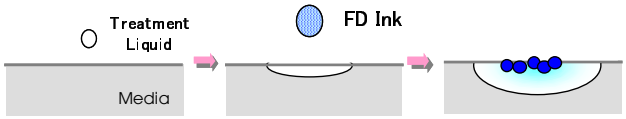


Figure 2. FX/DCLS System Concept

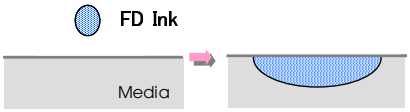
In the FX/DCLS technology, the agglomerated pigment is formed by the interaction between inks and treatment liquid on the recording media. Once the particle size of the agglomerated pigment becomes larger than the pore size of paper, the pigment cannot penetrate into paper and remains on the surface (near the surface) of paper at high density. As a result, a high quality image with high optical density and no bleeding can be achieved.

Meanwhile, at the same time as pigment agglomeration, the agglomerated pigment is separated from ink vehicle liquid. In the FX/DCLS technology, both the ink and treatment liquid are of FD composition, and high-speed print performance is achieved by making the vehicle component penetrated into paper at high speed (See Fig.3).

(a) DCLS Ink set



(b) FD Ink (without TL)



(c) SD Ink (without TL)

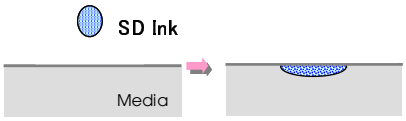


Figure 3. Penetration Behavior of DCLS Ink and Conventional Inks into Paper (Image)

In the past, the following two technologies were well known as a technology using interaction of inks and other liquid. The first is a technology that uses dye inks and treatment liquid containing cationic polyamine compound.[1)] This technology is effective to improve waterfastness of dye and optical density. However, it is not suitable for high-speed printing because of slow drying. The second technology is an ink technology that uses black SD pigment ink and color FD dye inks containing multivalent metal salt, etc.[2)] This technology is effective to improve optical density of black images and intercolor bleeding, but is not suitable for high-speed printing also because of slow drying of black ink. Thus, in the conventional technologies, the ink technologies that use interactions have been known, but each methods aim to improve a particular image quality item, and no existing technology has realized high-speed performance and high image quality at the same time.

The FX/DCLS technology is a concept aiming at high speed and high image quality (including good waterfastness and lightfastness) for plain paper, which could not be achieved by the conventional inkjet technologies, by using FD pigment ink and FD treatment liquid.

Experimental

In this study, a series of inks that contain pigment (polymer dispersed pigment / self dispersible pigment + hydrophilic polymer), water-soluble organic solvent, surfactant, and DI water, and several treatment liquids that contain agglomerating agent (organic acid / multivalent metal salt / polyamine compound), water-soluble organic solvent, surfactant, and DI water, were used.

For printing, single-pass printing was performed using several Fuji Xerox manufactured prototype heads. For recording media, plain papers (P Paper/C2 Paper (Fuji Xerox)) were used. Print condition was adjusted so that the treatment liquid fits the range from 0 to 30 percent to ink in mass ratio.

Optical density was measured using X-rite 404 (product of X-Rite, Inc.).

To evaluate feathering and intercolor bleeding, a line pattern was printed, and the level of bleeding was quantified by subjective evaluation.

For high-speed print performance, drying time of solid pattern was evaluated, in which the printed part was observed with a CCD camera, and the time of ink penetration into paper was measured.

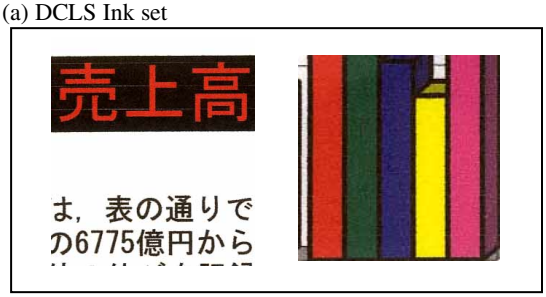
For the depth of ink penetration into paper, the section of the printed part was observed with a digital microscope.

Results and Discussion

Output Behavior

Fig.4 shows an image printed on plain paper using the FX/DCLS ink set.

(a) DCLS Ink set



(b) FD Inks (without TL)

(c) Black SD Ink and Color FD Inks (without TL)

Figure 4. Print Image : (a) DCLS Ink set , (b) FD Inks (without treatment liquid), (c) Black SD Ink and Color FD Inks (without treatment liquid)

As shown above, the FX/DCLS ink set achieved high quality image where the optical density was high and intercolor bleeding was reduced as well as in feathering. The image quality is almost the same as SD ink.

Next, the relationship between drying and optical density of the FX/DCLS ink was shown in Fig.5.

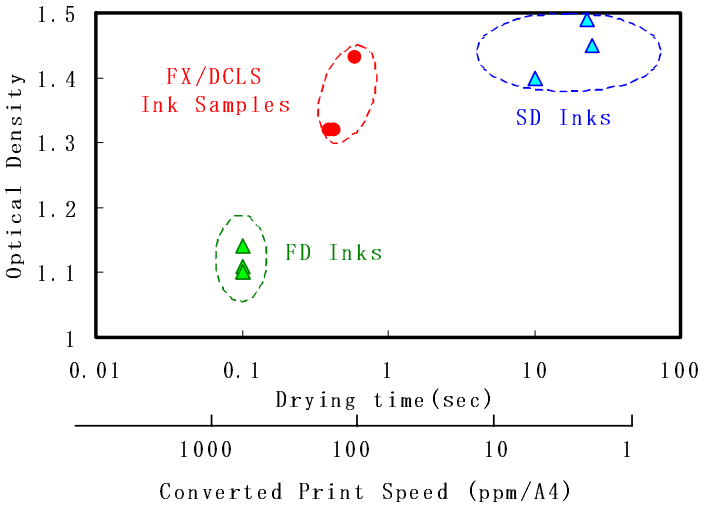


Figure 5. Relationship between Drying Time and Optical Density

As shown above, in the conventional technology, optical density decreased as drying time improved. In comparison, the FX/DCLS ink technology was a technology that achieved high-speed performance of more than 100ppm with the almost same image quality as SD ink.

Pigment Distribution inside Plain Paper

In general, ink drying is described as an action of ink penetrating into paper. The penetration action can be described using the Lucas-Washburn equation [3,4] (Equation (1)). [5,6]

$$h = \sqrt{\frac{r \times \gamma \cos\theta \times t}{2\eta}} \qquad (1)$$

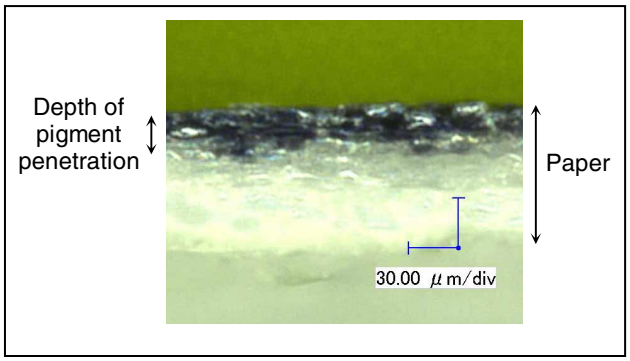
"h" indicates depth of penetration," r" size of capillary, "t" time, "γ" surface tension of liquid, "η" viscosity of liquid, and "θ" contact angle.

It is often described that FD ink rapidly penetrates into paper because γcosθ of FD ink is large, while SD ink slowly penetrates into paper because γcosθ of SD ink is small.

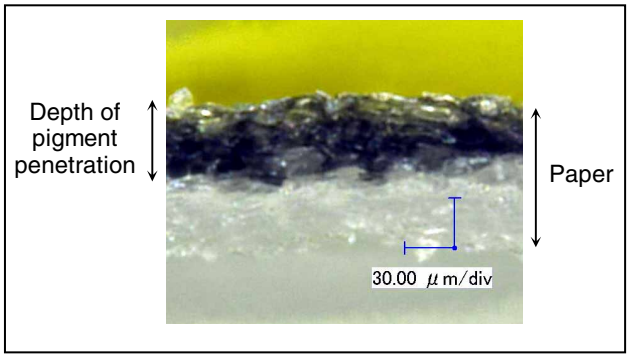
With the conventional inkjet pigment ink, the size of pigment particles is small enough in comparison to the pore size of paper, which allows pigment to penetrate inside paper when ink penetrates. In comparison, FX/DCLS uses a concept in which pigment penetration into paper is inhibited by pigment agglomeration.

A cross section of paper on which an image was printed using each of FX/DCLS ink set, SD ink, and FD ink, was observed and compared in depth of pigment penetration (See Fig.6).

(a) DCLS Ink set



(b) FD Ink (without TL)



(C) SD Ink (without TL)

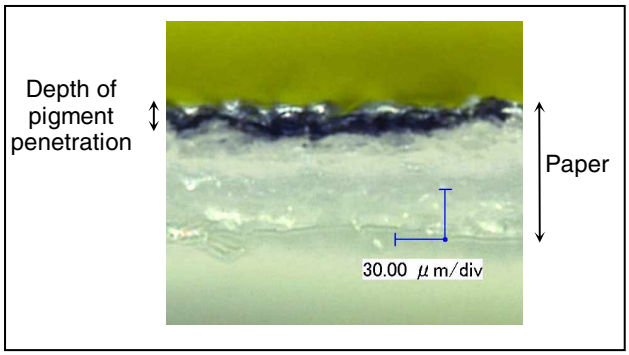


Figure 6. Cross Section of Printed Paper

The depth of penetration of the FX/DCLS ink set was about 25μm, which is equivalent to about 28% of paper thickness (90μm). As a result of being calculated in the same way, the depth of FD ink and SD ink penetration was 50% and 20% respectively. Thus, it was confirmed that the depth of pigment penetration of the FX/DCLS ink set is shallower than FD ink.

Effect of Agglomerating Agent in TL

Next, we varied the ratio of treatment liquid for each type of organic acids used as agglomerating agent and compared their optical density behaviors to ink. The result is shown in Fig.7.

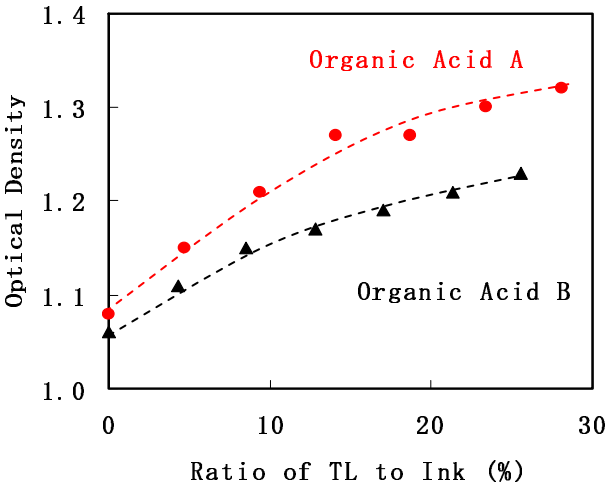


Figure 7. Relationship between Ratio of Treatment Liquid to Ink and Optical Density

It was confirmed that optical density tends to increase as the ratio of treatment liquid increases. In addition, it was found out that optical density differs depending on the chemical structure of organic acid when compared, using the same ratio of treatment liquid.

Therefore, we examined the relationship between the concentration of carboxylic acid in the treatment liquid and the viscosity of the mixture of ink and treatment liquid by varying the concentration of carboxylic acid included in the treatment liquid. (Fig 8).

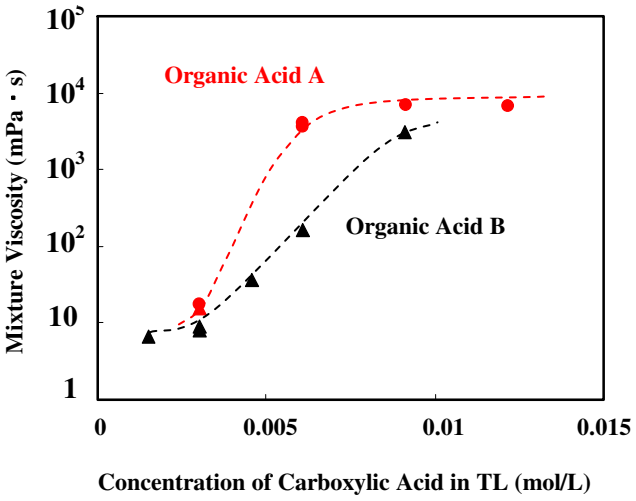


Figure 8. Relationship between Concentration of Carboxylic Acid in TL and Viscosity of Ink/TL Mixture

As the concentration of carboxylic acid in the treatment liquid increased, the viscosity of the mixture also increased. In addition, it was found out that the viscosity of the mixture increased further when organic acid A was used. This tendency was consistent with that of Fig.7.

Next, the titration curve of each organic acid is shown below (Fig.9).

Organic acid A had a smaller acid dissociation constant (pKa) and had a tendency to reduced pH more.

From the above result, it can be speculated that it is possible to enhance pigment agglomeration by reducing the pKa of organic acid and to increase optical density.

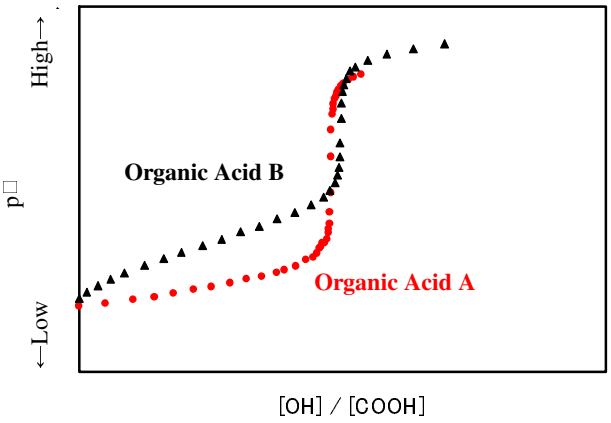


Figure 9. Titration Curve of Organic Acid

Conclusion

We proposed and studied the new FX/DCLS method to achieve the coexistence of high print speed and high image quality. The FX/DCLS ink set, which consisted of FD pigment inks and an FD treatment liquid, were designed so as to interact between inks and a treatment liquid. By optimizing the composition of inks and a treatment liquid, high-speed performance of more than 100ppm and high image quality equivalent to SD ink can be realized at the same time without heat-drying system.

References

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Author Biography

Takatsugu Doi received his master's degree in chemistry from the University of Tokyo (1993). Since then he has worked in the Corporate Research Laboratory at Fuji Xerox. His work has focused on the development of inkjet inks.