# Fabric Coating and Printing Conjoined in a Single Inkjet Textile Printing Process

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## Abstract

*A new inkjet textile printing system that conjoins fabric coating and printing in a single process was studied with the aim of developing a system that would enable printing directly on untreated fabric. As this new system was studied, factors that controlled printing quality such as feathering and printing optical density were found.*

## Introduction

The use of inkjet textile printing has grown in recent years because it enables quick delivery of orders and accommodates small orders since it does not require plate making.

However, inkjet textile printing requires coating of the fabric before actual printing. It is necessary to use coated fabric to avoid feathering, which is caused by ink penetration between fibers. In addition, the use of coated fabric makes fixation of dyes more efficient, avoiding washout of the dyes in the steps of steaming, washing, and drying. These advantages are illustrated in Figures 1 and 2.

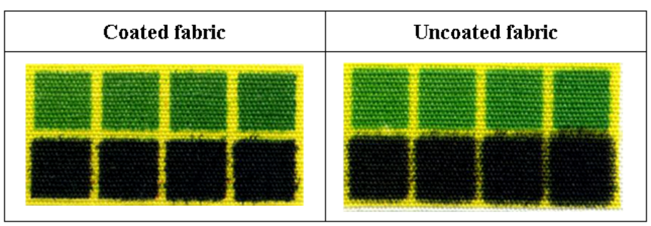


***Figure 1.*** *Fabric coating and the feathering of images*

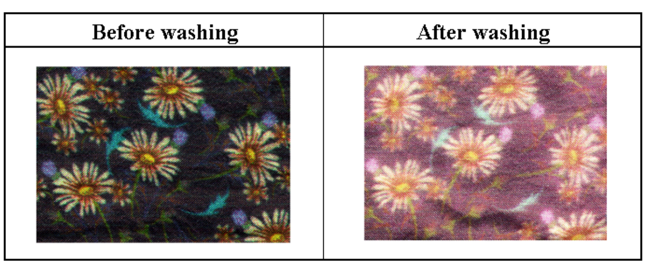


***Figure 2.*** *Insufficient dye fixation on uncoated fabric*

Figure 3 compares coating and printing in conventional and in our experimental inkjet textile printing. In the conventional method, coating and printing take place in two separate processes, while in our experimental method, coating and printing are conjoined in a single process.

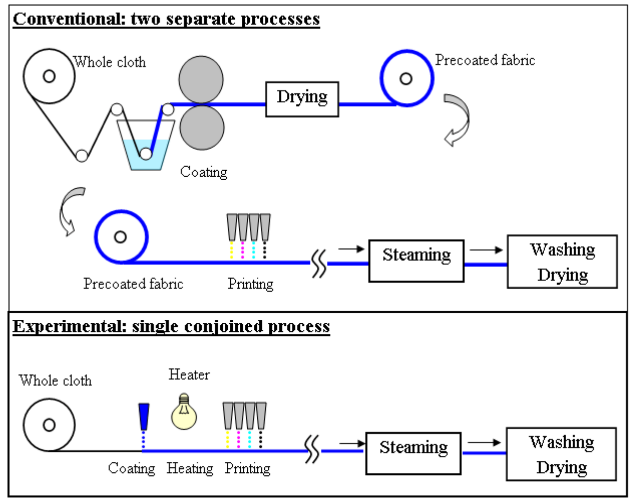


***Figure 3.*** *Coating and printing in conventional and experimental inkjet textile printing*

The prime objective of printing on a coated fabric is to suppress feathering. In conventional inkjet textile printing, the fabric is coated by padding or other methods with a paste that includes water-absorbing resin, thus creating an ink absorbing layer. [1], [2]

Figure 4 illustrates how the absorption of ink by a swelling, super-absorbent polymer controls feathering.

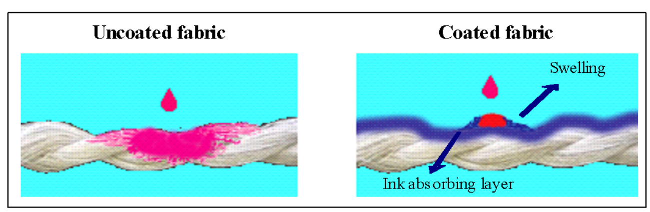


***Figure 4.*** *Control of feathering via fabric coating*

Control of feathering in this way can also improve fixation. Dye can be localized on the surface of the fabric because the diffusion of ink in the yarn is suppressed by the coating. This same localization can also improve the printed optical density. The amount of coating paste used depends on the kind of resin and fabric, and is approximately 10 to 40 g/m$^2$. Sodium alginic acid or polysaccharide derivatives of carboxymethyl-cellulose, etc. are typical of the super-absorbent polymers used.

However, super-absorbent polymers are impractical for our experimental single-process system because they result in high viscosity when they are dissolved in water. In general, the allowable viscosity of liquid for jetting is below 20 mPa sec., and the amount of sodium alginic acid in ink corresponding to 20 mPa sec. is less than approximately 1wt%. This is unrealistic because it would involve jetting 1 to 4 liter/m$^2$ of ink on fabric, far exceeding the capacity of fabric.

Therefore, a method of coating different from conventional precoating is necessary to control print quality. In response, we have studied a method of controlling feathering and optical print density by conjoining the processes of coating and printing and by using a different coating. In this report, we mainly present the effect of this on feathering.

## Experimental

The influences on feathering by the viscosities and surface tensions of a dye ink and a coating ink, and by an on-line heater drying process were determined. Viscosities and surface tensions were controlled by the amounts of additive resins and surfactants, respectively. Table 1 presents experimental parameters and levels.

**Table 1. Experimental parameters and levels**

| Design parameters | | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| Dye Ink | Amount of resin | 0% | 2% | 5% |
| | Amount of surfactant | 0% | 0.1% (surfactantA) | 0.3% (surfactantB) |
| Coating Ink | Amount of resin | 0% | 2% | 5% |
| | Amount of surfactant | 0% | 0.1% (surfactantA) | 0.3% (surfactantB) |

As an alternative method of evaluation, 10 µl of dye ink was dropped on a fabric surface with a micro syringe, and its diffused diameter was measured as a measure of feathering. Influences on feathering were evaluated with two experiments, TEST 1 and TEST 2. In TEST1, the coating ink was dropped on fabric, and the dye ink was immediately dropped atop the coating ink, after which the diffused diameter was measured. TEST2 was conducted in the same manner except that the fabric was dried with a heater immediately after dropping the coating ink and before dropping the dye ink.

The effects of the viscosity, surface tension, and the on-line heater drying process were confirmed with a test printer built based on the Konica Minolta textile inkjet printer "Nassenger V." Using four dye-based inks (YMCK), the width of feathering at the edge of the composite image was measured.

## Results and discussion

### Effects of viscosity, surface tension, and drying

Figure 5 shows the influence on feathering of the viscosities and surface tensions of dye ink and coating ink, along with the effects of heater drying.

In TEST 2, in which heater drying was used, feathering was influenced more greatly by viscosity than by surface tension; feathering was minimized by the viscosities of both the dye ink and the coating ink. These results were consistent with results derived from the Lucas-Washburn equation, which theory explains the capillary penetration of a liquid. [3],[4]

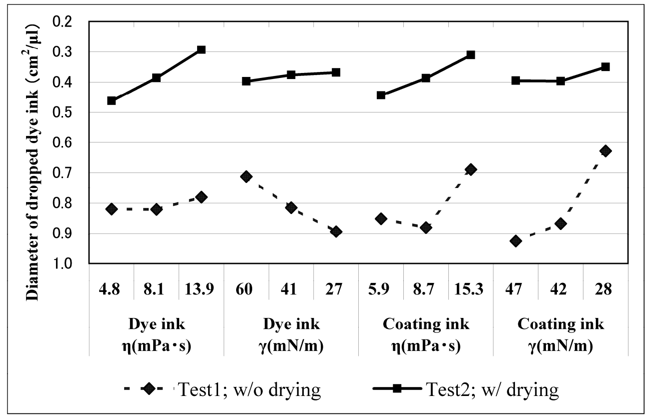


***Figure 5.** Effects of factors on feathering ($\eta$: viscosity , $\gamma$: surface tension)*

<Lucas-Washburn equation>

$$l = \sqrt{\frac{r\gamma\cos\theta}{2\eta}\, t}$$

$l$ : Penetration length, $r$ : Pore size, $\gamma$ : Surface tension
$\theta$ : Contact angle, $\eta$ : Viscosity, $t$ : Time

In TEST 1, which did not use heater drying, the contribution of surface tension was greater than in TEST 2. Feathering was minimized by higher surface tension of the dye ink and by lower surface tension of the coating ink. Finally, a comparison of the two test results indicate that the heater drying strongly decreased feathering.

In contemplating the difference in the results of TEST 1 and TEST 2, feathering was not caused by capillary pressure because the void of the fabric was filled with the coating ink in the absence of heater drying. Rather, the spreading of dye inks was caused by the wetting behaviors of the coating ink and the dye ink, which was controlled by the surface energy difference of those inks.

The results above suggested the possibility of controlling feathering effectively by increasing of viscosities of the dye ink and the coating ink, and by adopting heater drying.

### Selection of solvent

Selection of a suitable solvent for the experimental single conjoined process system was studied. As mentioned above, increasing the viscosities of the coating ink and the dye ink suppressed feathering, especially in conjunction with drying. Drying concentrated the inks and increased their viscosities in situ to effectively minimize feathering.

Further, ink viscosity also influenced jetting stability. An increase in the viscosity of ink on the surface of the inkjet head brought on by drying caused a decrease in the velocity of the first drop jetting from the head, a phenomenon referred to as decap or lack of jetting. Therefore, to both minimize feathering and maintain jetting stability, a lower viscosity at the initial drying time of ink on the surface of the head, but a rapidly increasing viscosity of the ink deposited on the fabric, would be ideal.

We then evaluated the effects on viscosity of increasing concentrations of four solvents with drying. In this experiment, the amounts of resin and solvent before evaporation were 2wt% and 30wt%, respectively. Figure 6 shows the rise in viscosity that increasing concentrations of solvents obtained. The vertical axis of the graph indicates specific viscosity $(\eta-\eta_0)/\eta_0$ ($\eta$ : viscosity of solution, $\eta_0$ : viscosity of solution without resin), which measures the effect of the resin on viscosity upon drying.

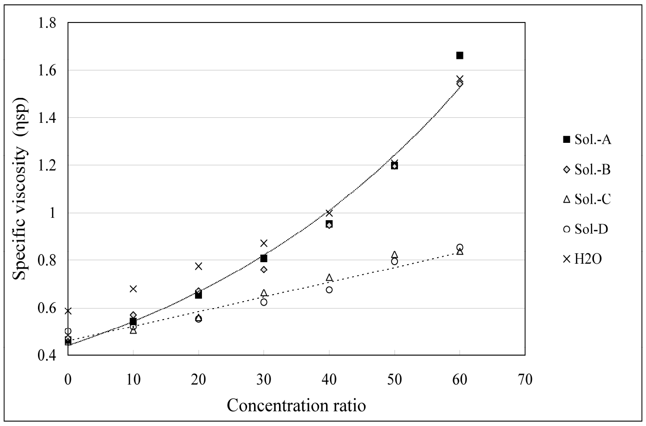


***Figure 6.*** *Relationship between specific viscosity and concentration ratios of solvents*

At low concentrations, the specific viscosities of the mixtures with solvent A and solvent B were lower than without a solvent; specific viscosities then rapidly increased with higher concentration rates. In contrast, the specific viscosities of the mixtures with solvent C and solvent D increased linearly with concentration rates upon drying. As a result, we chose solvents A and B for our system.

### *Confirmation by inkjet print*

The results above were confirmed with a test printer incorporating our experimental single conjoined process. Figure 7 shows the relationship between feathering and the viscosities of the coating ink and the dye ink. Feathering was minimized by increasing the viscosity of the dye ink. The viscosity was controlled by the amount of resin and solvents. Increasing the viscosity of the coating ink obtained the best results. In contrast, the surface tension of the coating ink did not affect feathering in the range of 56 to 29 mN/m. The results of TEST 2 were reproduced in actual prints.

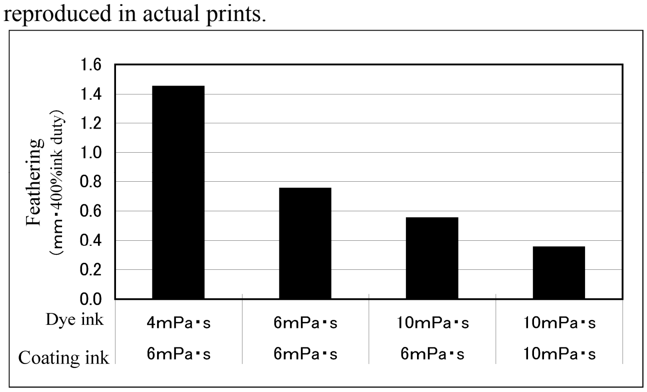


***Figure 7.*** *Relationship between feathering and viscosities of dye ink and coating ink*

Results obtained with the test printer are shown in Figure 8. Feathering was minimized by using highly viscous dye ink and a coating ink with resin and selected solvents.

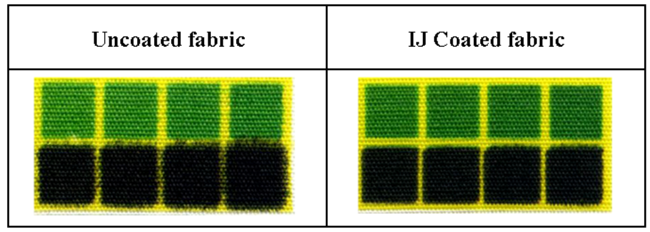


***Figure 8.*** *Effect on feathering of single conjoined coating and printing process*

Figure 9 compares the color gamuts of the single conjoined coating and printing process and the conventional separate coating and printing process. The conjoined coating and printing process system provided a color gamut similarly wide as the conventional inkjet printing system.

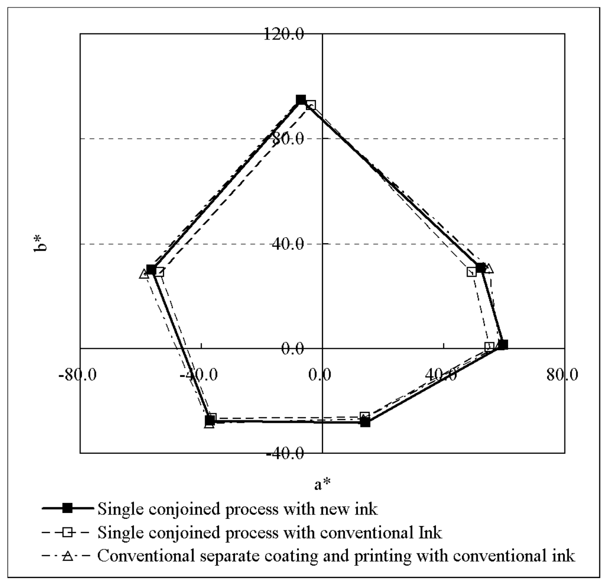


***Figure 9.*** *Color gamuts of prints*

## Conclusion

Based on the capillary penetration model of untreated fabric, we found that feathering was controlled by the viscosities of the coating ink and the dye ink and by the drying process. We confirmed the results with the test inkjet printer; the level of the feathering was suppressed greatly, and we obtained fine printing optical density and jetting stability.

In continuing the work reported here, we plan to contribute to the further development of inkjet textile printing not only in the improvement of productivity but also in the expansion of the applications of and addition of new functions.

## References

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[3] H.Ura, JAGAT tech.sminar (2004)
[4] I.Kimura, H.Maeda, JP Patent 3428742

## Biography

*Masayuki Ushiku received his M.S. degree in physical chemistry from Aoyama Gakuin University in 1992. He joined Konica Corporation in the same year. He has worked in the development of inkjet paper for many years and is now focused on the development of inkjet ink.*