SPMC Technical Review

Inkjet Fixing Agents "DK Series"

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1. Introduction

Since around 2014, many companies have been outsourcing their printing operations in order to improve the efficiency of their economic activities. As a result, the demand for data print service (DPS), which provides integrated printing, enclosure, and shipping services, has increased. DPS mainly handles personalized invoices, statements, notices, and direct mail, which require small-lot, multi-variety, and quick-delivery printing. Inkjet printing is particularly suitable as a means of meeting these requirements because it does not require printing plates, that are time-consuming and costly to produce. Therefore, with the revitalization of DPS market, the introduction of high-speed full-color inkjet digital printers has increased, led by the major printing companies[1].

In response to this increased demand for inkjet printing, manufacturers in related industries have been improving their printers and inks. However, improving inkjet printability requires advancement not only in printers and inks, but also in substrates such as paper. Conventionally, dye ink had been mainly used in water-based inkjet printing devices because of its advantages in colorability and cost. Since dye ink tends to bleed with water, water resistance was the main required performance for inkjet paper in those days. The inkjet fixing agents “DK Series” were developed to meet this requirement.

However, required performance of the substrate for DPS has become diversified including multicolor printing suitability, high-speed inkjet suitability, etc. Accordingly, inkjet fixing agents are now required to have not only water resistance, but also a wide range of performance characteristics such as (1) print density, (2) strike through suppression, (3) barcode suitability, (4) edge bleeding suppression, (5) ink setting, and so on.

Based on the technology we have accumulated over years at resin development, we have continued to improve the inkjet fixing agents “DK Series” so that it can contribute not only to water resistance but also to printability[2), 3)].

In addition, the DK series can enhance inkjet printability on substrates such as film and fabric as well as paper. This review introduces the features of inkjet fixing agents “DK Series” and the evaluation results on various substrates (paper, film, and fabric).

2. Features of the DK Series

Our DK series is a water-soluble, high cationic resin composed of mainly polyamine resin. The DK series can enhance inkjet printability when using water-based inks by applying it to substrates such as paper, film, and fabric as a primer (pretreatment agent).

The mechanism of the DK series is shown in Figure 1. When water-based ink droplets ejected from an inkjet printer land on a substrate, the ink diffuses vertically and horizontally on the substrate. Due to the ionic bonding between the cationic DK series and the anionic ink, ink penetration in the vertical direction of the substrate is suppressed and more ink remains on the substrate surface. This enhances print density and suppresses strike through. Horizontal ink diffusion on the substrate is also suppressed, which improves barcode suitability

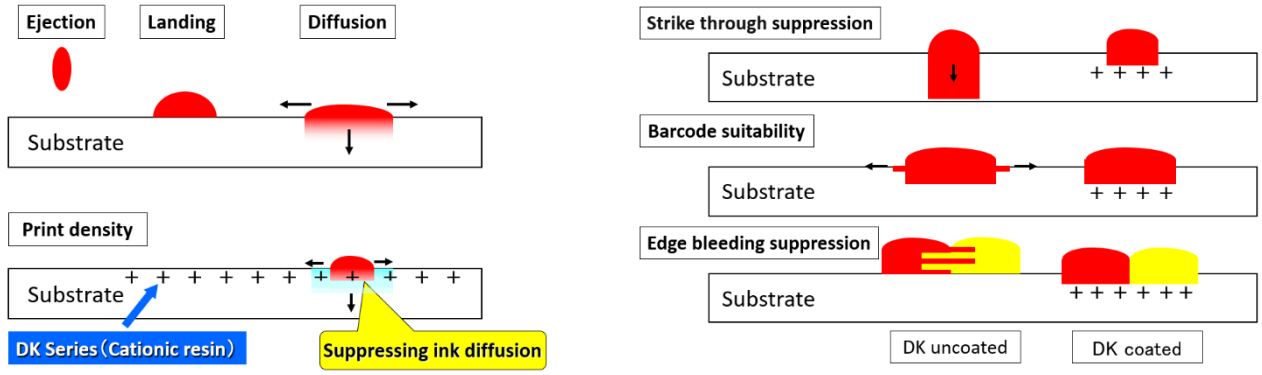

Figure 1. Mechanism of the DK series

Table 1. Characteristics of dye and pigment inks

	Dye ink	Pigment ink
Characteristic	Color materials are very small molecules that can express vivid colors.	Color materials are in particle form and stay on the substrate, enabling clear printing of letters and lines.
Use	Photo-printing	Document for long-term preservation, Poster, Printing for outdoor use
Advantage	Excellent colorability	Excellent water and light resistance. Feathering is unlikely to occur. Ink does not bleed easily.
Disadvantage	Inferior water and light resistance. Easy to cause feathering. ink bleeds easily.	Colorability is not as vivid as dye ink.

and suppresses edge bleeding in multicolor printing.

Inks used in water-based inkjet printing can be broadly classified into dye and pigment inks. The characteristics of each ink are shown in Table 1. Both dye and pigment inks have advantages and disadvantages, but the DK series is effective against both disadvantages. For example, dye ink has poor water resistance which causes the ink bleeding when printed materials get wet, but the DK series enhances water resistance by ionically bonding with dye molecules, making them hydrophobic and insoluble (Figure 2).

Pigment ink also has the disadvantage of not producing colorability as vivid as dye ink, but the DK

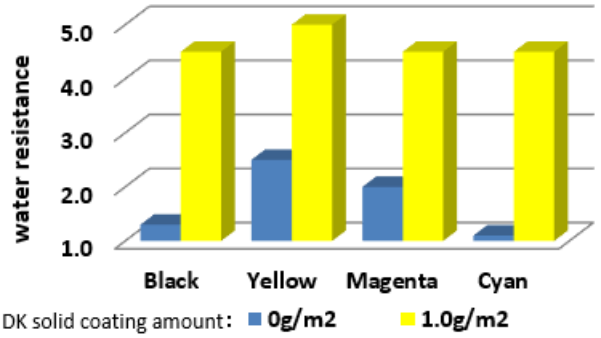

Figure 2. Water resistance evaluation result of dye ink

Substrate: Wood free paper, Coating method: Wire bar
Printing equipment: EPSON inkjet printer, Ink: water-based dye ink
Water resistance: Visual evaluation of ink bleeding after immersing the printed material in water for 30 seconds. (Excellent) 5 ⇔ 1 (Poor)

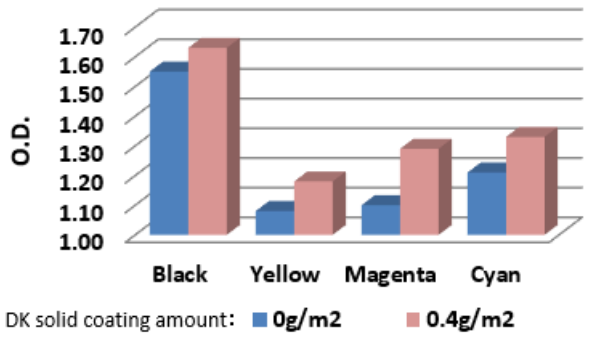

Figure 3. Print density evaluation result of pigment ink

Substrate: Wood free paper, Coating method: Wire bar
Printing equipment: EPSON inkjet printer, Ink: water-based pigment ink
O.D.: Print density (Optical Density) of solid fill area is measured by a spectrophotometer.

series instantly agglomerates pigment ink and fixes it to the substrate. As a result, print density can be increased as shown in Figure 3, and colorability can be improved. Specific inkjet printing results from the DK series are shown in Figure 4. To confirm the effect on the disadvantages of each ink, water resistance, barcode suitability, edge bleeding suppression, and ink setting were evaluated with dye ink, and print density and strike through suppression were evaluated with pigment ink. It was confirmed that the DK series improves each item of these characteristics. The benefits of the DK series are listed below.

- **Water resistance**: Ink bleeding when wet can be suppressed, making printed materials easier to read.
- **Barcode suitability**: Ink spreading along fibers (feathering) can be suppressed, making barcodes easier to read.
- **Edge bleeding suppression**: Ink bleeding at color boundaries can be suppressed, resulting in clear printed materials.
- **Ink setting**: Ink adheres to the substrate, preventing smudging immediately after printing and enabling high-speed printing.
- **Print Density**: Increasing print density results in printed materials with excellent colorability.
- **Strike through suppression**: Ink penetration to the reverse side is suppressed, making double-sided printed materials easier to read.

The standard coating amount of the DK series is about 0.2 to 1.0 g/m^2 (solids content) on one side. Water resistance, barcode suitability, edge bleeding suppression, and strike through suppression tend to improve in proportion to the coating amount of the DK series. However, if the coating amount of the DK series is too large, the ink may agglomerate excessively and the dot diameter may become smaller, resulting in lower print density. Therefore, it is necessary to determine the optimal coating amount of the DK series.

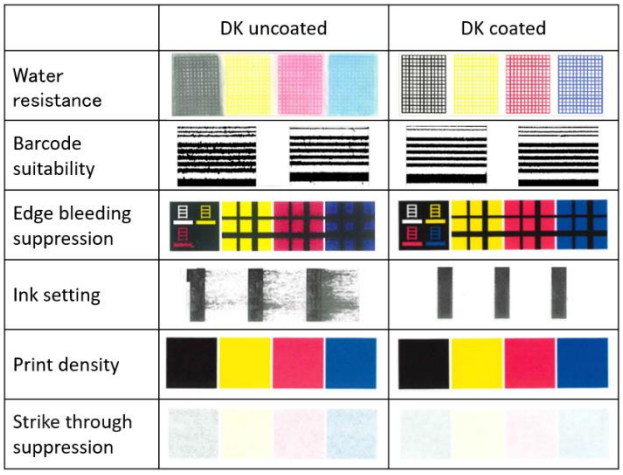

Figure 4: Inkjet printing results with and without the DK series

Substrate: Wood free paper, Coating method: Wire bar
DK coating amount: 0.4 to 1.0 g/m^2 (solids content)
Printing equipment: EPSON inkjet printer, Ink: water-based dye and pigment ink

- Water resistance: Visual evaluation of ink bleeding after immersing the printed material in water for 30 seconds.
- Barcode suitability: Visual evaluation of the degree to which the ink spreads along the fibers.
- Edge bleeding suppression: Visual evaluation of ink bleeding at color boundaries.
- Ink setting: The printed area was rubbed with a constant force after several seconds after printing, and the smudging was visually evaluated.
- Print density: Print density of solid fill area was measured with a spectrophotometer.
- Strike through suppression: Printing density on the reverse side of solid fill area is measured with a spectrophotometer.

3. The DK series evaluation results for each substrate

3-1. Paper

Inkjet paper gains various functions through the application of coating agents on its surface. The formulation of the coating solution affects the printability of the inkjet paper. Depending on the formulation, inkjet paper can be broadly classified into clear-coated paper and pigment-coated paper.

Clear-coated paper is coated with a surface strength agent such as starch or polyvinyl alcohol and a cationic

resin such as the DK series, using a size press or rod quantitative coater. In this case, the ink-receiving layer is the paper itself. This type of paper is widely used for invoices, statements, direct mail, text materials, book paper, advertisements, flyers, etc[1].

Pigment-coated paper is coated with porous pigments such as silica and alumina, binders, and cationic resins such as the DK series, using an air knife coater. In this case, the ink-receiving layer is porous pigment. The coated porous pigments give the paper excellent ink absorption, high-definition image quality, and high colorability. This type of paper is used for inkjet-specific paper, postcards, etc.

Recently, pigment-coated paper using calcium carbonate has also been launched to achieve multi-color printing with high-speed inkjet printing comparable to offset printing, as there is a demand for paper suitable for beautiful color advertisements.

When calcium carbonate or clay is used as a pigment, the viscosity of the coating solution is lower than that of silica or alumina, allowing preparation of the coating solution at higher concentrations. As a result, the drying time can be reduced, and the binder in the solution is less likely to penetrate the substrate (migration). Therefore, uneven distribution of the binder in the ink-receiving layer is minimized, high-definition images are obtained, and the surface strength of the ink-receiving layer is improved. However, since calcium carbonate is usually dispersed by an anionic dispersant, adding a cationic inkjet fixing agent to it may cause the calcium carbonate agglomeration and make the coating solution highly viscous. Therefore, we need to watch out the amount of cationic inkjet fixing agent.

Our DK6852 can also improve inkjet printability in the presence of calcium carbonate while keeping the viscosity of the coating solution low by adjusting its addition rate.

Figure 5 shows the viscosity of the coating solution when DK6852 was added to a coating solution containing calcium carbonate, clay and binder, while Figures 6 to 9 show the evaluation results when the coating solution was applied to base paper and inkjet printed. Figure 5 shows that when the addition rate of DK6852 was low, the coating solution showed a tendency to coagulate, and the viscosity increased. It was confirmed that further increase in the addition rate causes an excess cation in the coating solution, so that the coating solution shows a dispersion tendency and the viscosity decreases. The appearance of the solid fill area is shown in Figure 6. When DK6852 was not added, unevenness was observed in solid fill area, but the addition of DK6852 improved the unevenness and clarity. The evaluation results for barcode suitability and edge bleeding suppression are shown in Figure 7. The barcode suitability and edge bleeding suppression improved in proportion to the addition rate of DK6852. The print density and dot observation results are shown in Figures 8 and 9. It was confirmed that there is the optimal addition rate for print density. Due to the ionic bonding between the cationic DK6852 and the anionic pigment ink, ink penetration in the vertical direction is suppressed and more ink remains on the substrate surface, which increases print density. Figure 9 also shows that the addition of DK6852 has made the colorability of each dot more vivid. However, when DK6852 was added up to 10%, the ink became more agglomerated and the dot size became smaller, resulting in lower print density. Therefore, the optimal addition rate must be determined by comprehensively evaluating factors such as print density and coating solution viscosity.

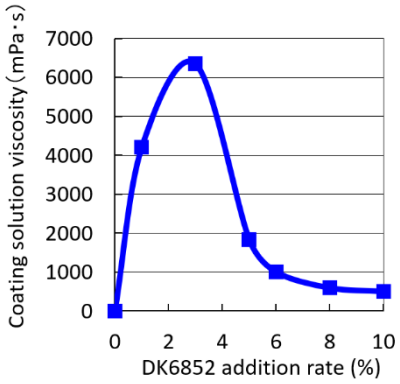

Figure 5: Plot of DK6852 addition rate versus coating solution viscosity

DK6852 addition rate: DK6852 solids addition rate to pigment solids

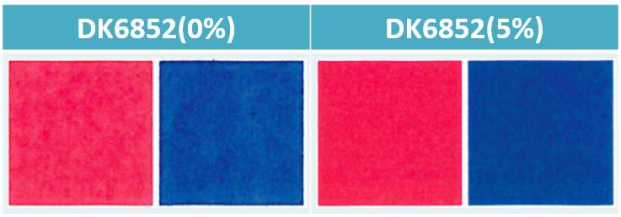

Figure 6: Appearance of solid fill area

Substrate: Wood free paper, Coating method: Blade coater
Coating solution coating amount of 6.0 g/m^2 (solids content)
Printing equipment: EPSON inkjet printer, Ink: water-based pigment ink

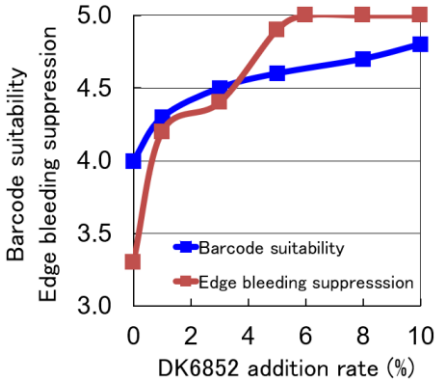

Figure 7. Barcode suitability and edge bleeding suppression

Barcode suitability: Visual evaluation of the degree to which the ink spreads along the fiber. (Excellent) 5 ⇔ 1 (Poor)
Edge bleeding suppression: Visual evaluation of ink bleeding at color boundaries. (Excellent) 5 ⇔ 1 (Poor)

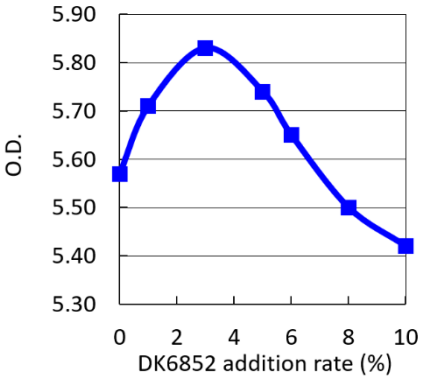

Figure 8. Print density

(Total print density of black, yellow, magenta, and cyan)

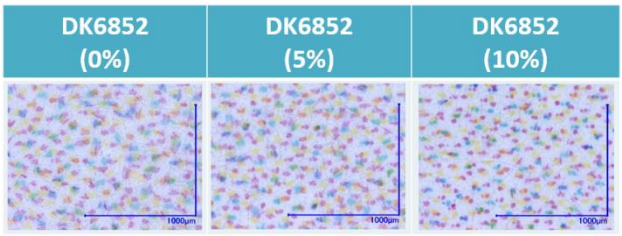

Figure 9. Dot observation result

Observation method: Dots on printed materials were observed using a microscope (200x).

3-2. Film

In flexible packaging printing on polyethylene terephthalate (PET), polypropylene (PP), and other films, print quality is important because the quality of the printed design directly affects sales. For this reason, the gravure printing method has been used for many years because of its ability to produce beautiful prints. Recently, inkjet printing using environmentally friendly water-based ink is also desired due to the following backgrounds.

- There is a growing demand for small-lot, multi-variety, and quick-delivery production led by recent changes in lifestyles and diversification of consumer needs, sales promotions and distribution, although gravure printing is suitable for mass production because it uses printing plates[4].
- Since most of gravure inks are oil-based and contain solvent, odor from the residual solvent can be a problem.

- UV ink is also available as inkjet ink, but the unreacted monomers remain in the ink, which can cause odor problems in printed materials.

Our DK6810 enables inkjet printing using water-based ink not only on paper but also on films. Figure 10 shows the inkjet printing results when DK6810 is coated on PET film. Inkjet printability, such as unevenness in solid fill areas, barcode suitability, and edge bleeding suppression, was greatly improved by the application of DK6810.

As described above, DK6810 can contribute to solving the problem of residual solvents and monomers, improving the printing work environment, preventing air pollution, and improving safety for the human body, while meeting the needs for small-lot, multi-variety, and quick-delivery production.

Figure 10: Inkjet printing results on film

Substrate: PET, Coating method: Wire bar
DK6810 coating amount: 0.4 g/m^2 (solids content)
Printing equipment: EPSON inkjet printer, Ink: water-based pigment ink

3-3. Fabric

Conventionally, screen printing is the major method of textile printing on fabrics. Recently, however, there is a growing demand for small-lot, multi-variety textile printing on fabrics. As a result, textile printing using inkjet printers (inkjet textile printing) is increasing.

Figure 11 shows the inkjet printing results when DK6804 was coated to a fabric (polyester). DK6804 coating suppressed strike through and edge bleeding and improved clarity.

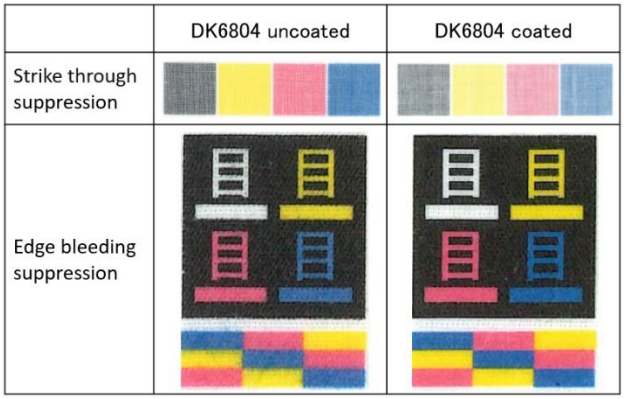

Figure 11: Inkjet printing results on fabric

Substrate: Polyester, Coating method: Wire bar
DK6804 coating amount: 1.0 g/m^2 (solids content)
Printing equipment: EPSON inkjet printer, Ink: water-based pigment ink

4. Conclusion

By using the DK series, water resistance, barcode suitability, edgy bleeding suppression, ink setting, print density, and strike through suppression can be improved when inkjet printing is performed with water-based ink. The molecular structure of DK series is designed to favorably interact with water-based inks by controlling the cation density, molecular weight, etc. The products can be used with various water-based inks, coating solution formulations, and substrates (Table 2). Through the DK series, we will support inkjet printing, which suits to the market's needs for small-lot, multi-variety, and quick-delivery for printed materials, from the standpoint of substrates, thereby contributing to more efficient economic activities. By enabling water-based inkjet printing on a variety of substrates, we contribute to the creation of a society that is friendly to people and the earth.

Table 2. Ink, coating solution formulation, substrate suitability of DK series

Product name	Solids content (%)	water-based ink		Coating solution formulation		Substrate
		dye	pigment	Clear coat	pigment coat	
DK6804	55	△	◎	○		Paper, Fabric
DK6810	55	○	◎	○		Paper, Film
DK6850	70	△	○		○	Paper, Fabric
DK6852	50	○	△		○	Paper, Film
DK6854	50	◎	△	○		Paper
DK6885	70	◎	○	○		Paper

＜References＞

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Profile

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