The Development of New Disperse Dye Inks for Inkjet Textile Printing

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Abstract

Disperse dye inks are used in the inkjet textile printing of polyester fabrics. We aimed at developing a black disperse dye ink consisting of yellow, magenta, and cyan dyes that met the exacting requirements of safety, image durability, and storage stability. One difficulty we met was dye particles tending to aggregate/agglomerate, leading to sedimentation and the threat of head clogging and/or inferior color reproduction. We discovered that rapid adsorption and desorption exchange of dispersants and the wetting ability of the dyes' surfaces appeared to control the system's stability. Based on this, we succeeded in developing a stable black disperse dye ink.

1. Introduction

The inkjet printing system has not only been used at home but also begun to be extended to industrial use recently, since it has many advantages, including its low equipment and running cost as well as applicability to various recording materials. In the textile printing field, in particular, this system has been drawing attention as a system that meets demands for quick delivery, manufacturing of a wide variety of products in small quantities and sample production, taking advantage of its non-plate-making charactertistics.[1)]

Konica Corp. launched its first inkjet textile printing system, Nassenger KS-1600, in 1998. This system has since been widely used for dyeing of apparel, industrial material such as car sheets, interior material like tapestries, and advertising media including banners, flags and short curtains.

The inkjet technology for textile and that for paper have much in common but are largely different in two aspects. One difference is that the inkjet technology for textile requires pre- and post-processing. Since textile is unable to absorb ink sufficiently, it is necessary to provide an ink absorption layer, which is referred to as pre-processing. After printing, the process of making ink fast to fabrics by heating, humidification or pressurization and washing to remove the pre-processing agents and non-fast dye are necessary. The other is the difference of coloring agents used according to the types of textile (types of fabrics). For instance, dispersion dye inks are used for polyester fabrics, while reactive dye inks are used for cotton.

Since the polyester fabric is widely used for apparel and industrial materials, dispersion dye inks for these applications are important.

Disperse dye inks are produced by dispersing hydrophobic dye particles in water, and this very process poses two problems. One is the safety concern of materials. Many disperse dyes have safety problems in the material itself or in its impurities. The other is their shorter storage stability. In most cases, color paste for textile printing is used within a few days after its preparation, whereas color inks for inkjet printing need to be stored for far longer period, and this requires severe storage stability.

We aimed at achieving the following targets in the development of disperse dye inks:

1) High material safety
2) Good storage stability
3) Excellent color fastness of prints.

In this paper, we present our efforts to develop a safe and stable black disperse dye ink.

2. Results and Discussion

As dye's stability and durability against light, water, sweat, and abrasion limits the stability and durability of printed image, so the dye's safety defines the safety of it. To achieve the development targets, therefore, we proceeded with development in the following order:

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1) To choose a group of stable and durable dyes

2) To pickup a very safe dye from the chosen group

3) To develop a disperse formulation having excellent storage stability using thus selected dye

2.1. Image Durability

We examined the dye's stability ratings in conventional screen-printing systems, and chose stable yellow, magenta, cyan, and black dyes. We then checked their stability and durability in inkjet textile prints.

2.2. Dye Safety

Dye safety was of our paramount concern. We evaluated the mutagenicity of selected stable dyes, and most were found positive in AMES testing. We did find yellow, magenta, and cyan dyes that satisfied safety as well as specifications for image stability and durability. But unfortunately no black dye tested negative. Therefore we decided to formulate a black ink by combining yellow, magenta, and cyan dyes.

2.3. Storage Stability

We worked on the development of a black disperse dye ink having excellent storage stability by mixing the yellow, magenta and cyan dyes selected based on the results of the stability and safety evaluation.

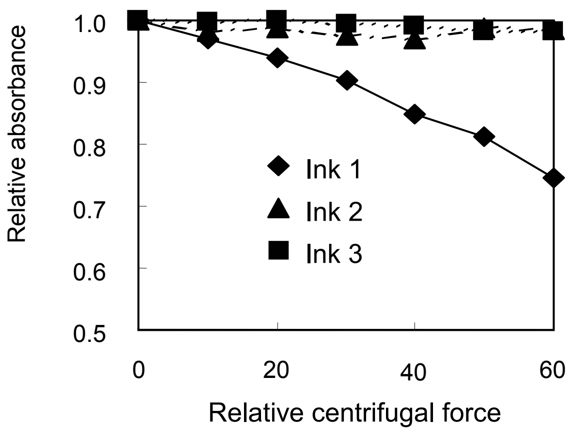

Fig. 1 Sedimentation properties of three inks

First, dispersion conditions including formulation and machine conditions were optimized for each dye, and then three were mixed into Bk ink (ink 1). As a result, dispersion formulations including the types of dispersant became different for different color dyes.

Fig. 1 shows the sedimentation properties of the three inks. The horizontal axis shows relative centrifugal force and the vertical axis shows the relative absorbance of the inks. Absorbance of ink 1 decreased with the increase of centrifugation force, and dye particle sedimentation was thus indicated.

When ink 1 was filtered with a metal mesh, colored inclusions were caught on the filter. Fig. 2 shows an electron microscopic view of the colored inclusion. It was revealed that dye particles aggregated/agglomerated to form larger particles (dye flocculation).

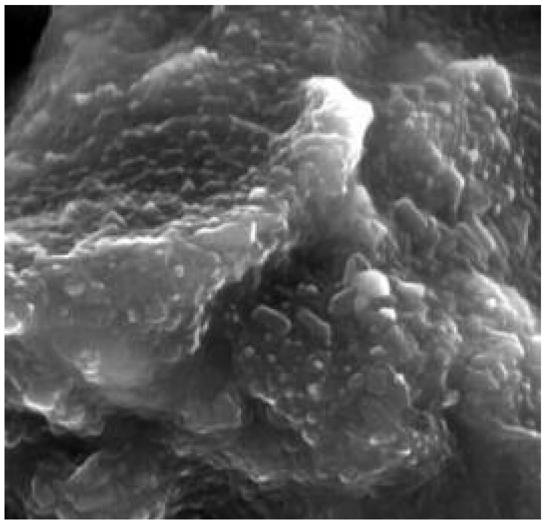

Fig. 2 Ink1 Flocculation

Change in the amount of free, unadsorbed dispersant to particle surface was examined to clarify the cause of this flocculation. Fig. 3 shows change in the free dispersant concentration with elapse of time. The horizontal axis shows relative storage period, and the vertical axis shows change in the amount of free dispersant in terms of the ratio of initial amount of dispersants to the amount after storage with time. Since free dispersant B decreased with time in Fig. 3, we assumed that adsorption and desorption of the dispersant occurred on particle surfaces, leading to the instability of the system, and that this resulted in occurrence of the dye ink flocculation, leading to sedimentation.

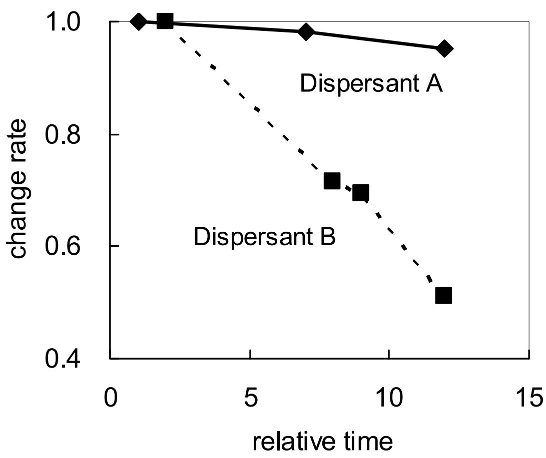

Fig.3 Decrease of unadsorbed dispersant in Ink 1

Based on the results for ink 1, ink 2 was formulated with unified dispersion formulation using the same dispersant for all three dyes. Fig. 4 shows the viscoelasticity of ink 1, 2 and 3. The horizontal axis shows shear rate and the vertical axis shows viscosity. The increased viscosity of ink 2 at the low shear rate was observed.

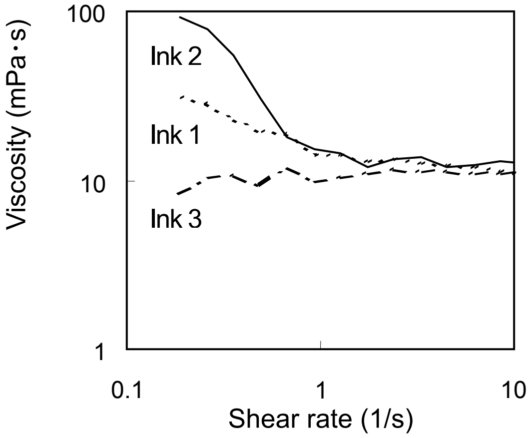

Fig. 4 Viscoelasticity of three inks

When ink 2 was filtered with a metal mesh and inclusions caught with the filter were examined by electron microscopy, ink flocculation was observed (Fig. 5).[3] This was identified as Dye C by spectroscopic analysis.

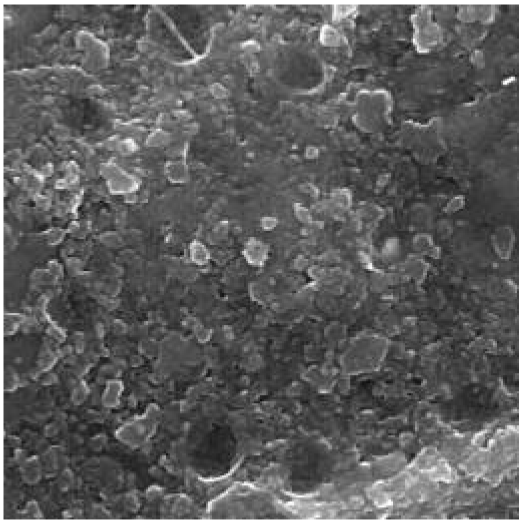

Fig.5 Ink 2 flocculation

Surface energy of three dyes comprising ink 2 was measured. The results are shown in Fig. 6. The vertical axis shows the wet ability of the dye surfaces. In this graph higher the value means that the dye surface gets wet easier, indicating that dye C is more difficult to get wet.

Judging from the above results for ink 2, we concluded that insufficient adsorption of the dispersant to dye C surface induced flocculation.[4,5]

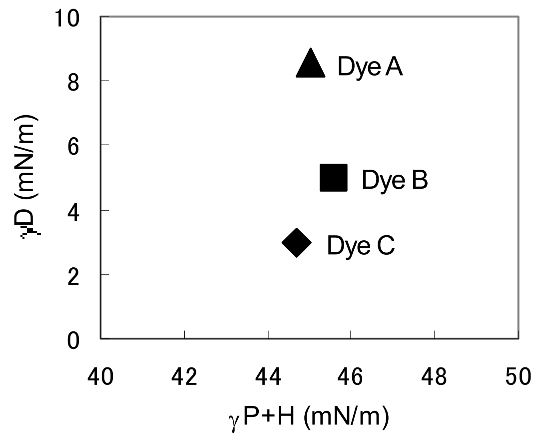

Fig. 6 Ink 2 dye surface energy

Based on the results for inks 1 and 2, ink 3 was made by using the same dispersant to the three dyes to prevent adsorption-desorption phenomenon. In addition to this, introducing an auxiliary agent for the dispersion of dye C to prevent its flocculation was found effective for stable dispersion.

As a consequence, neither sedimentation nor structural viscosity of ink 3 was observed, as we expected (Figs. 1 and 2). No inclusions were caught on the filter by filtration.

Fig. 7 shows the sedimentation properties of ink 3 and competitors' black dye inks. The storage stability of ink 3 is superior to that of the other two inks.

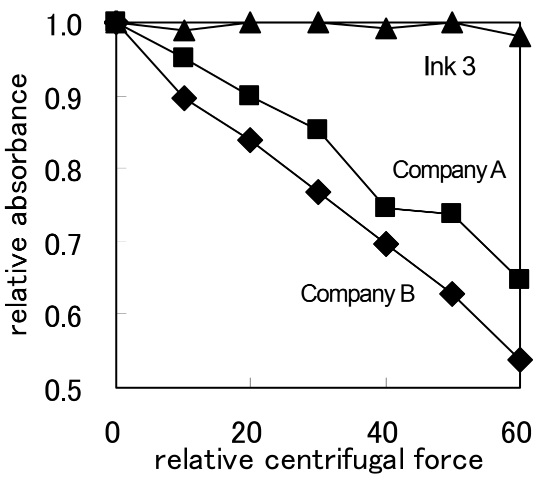

Fig. 7 Sedimentation properties of three inks

3. Conclusions

Our development target was to obtain a black disperse dye ink for textile inkjet printing that is safe, highly resistant to light, water, sweat, and abrasion, and has high storage stability. Combining three dyes of cyan, magenta, and yellow, we formulated several black disperse dye inks. We encountered obstacles of rapid adsorption and desorption exchange of dispersants and poor dye surface wetting ability. However, after adopting an appropriate single dispersant and an auxiliary agent, we succeeded in developing black disperse dye ink that met our objective. This new black disperse dye ink has achieved the following targets:

1) High safety of the material
2) Good storage stability
3) Excellent color fastness of prints.

The ink is marketed as black disperse dye ink for Nassenger-II

4. Experiment

4.1 Preparation of the black disperse dye ink

Yellow, magenta and cyan dyes were dispersed individually with a horizontal mill disperser and three dispersion solutions were obtained. Three black inks with composition shown in Table 1 were prepared by mixing these dispersion solutions with various additives.

Table 1. Composition of three black inks

Ink#	Dispersant	Auxiliary agent
1	Optimized for each dye	Not added
2	Same for all dyes	Not added
3	Same for all dyes	Added

4.2. Evaluation of Material Safety

The three black inks were evaluated for the following items in accordance with the in-house criteria[2]:

- Acute toxicity
- Irritancy (eyes and skin)
- Sensitization
- Chronic toxicity
- Mutagenicity (Ames test)

4.3. Dye Surface Energy

Each dye was palletized and contact angles to water, nitro methane and diiodine methane were measured with CA-V contact angle meter (Kyowa Interface Science Co., Ltd.). Dye surface energies were calculated from the obtained contact angles using the Young-Fowkes equilibrium.

4.4 Evaluation of Ink Properties

Each ink was centrifuged and the absorbance of the supernatants was measured at fixed intervals with an UV-3200 spectrophotometer (Hitachi.). The sedimentation property of the inks was expressed as the ratio of initial absorbance to absorbance after centrifugation.

The viscoelasticity of the inks were measured with an MCR 300 modular rheometer (Physica Messtechnik GmbH).

Electron microscopic images were obtained with an S-800 scanning electron microscope (Hitachi.).

Light fastness, water fastness, and the fastness of color to perspiration, to washing and laundering, and to abrasion were evaluated according to corresponding Japan Industrial Standards.

• References

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