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Optimization of Pre-treatment Solution by Adjusting Thickener's Property to Fine-tune Coloring Characteristics on Fabric

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Abstract

In digital textile printing process, various factors affect printing quality on fabric. One of these factors is pre-treatment process. If this process is carried out to control chemical interactions between dyes and fabrics strictly, proper pre-treatment solution must be prepared depending on fabric types. Otherwise, high printing quality never realizes. Thus, in our previous work,[1] we focused on pre-treatment process and investigated the impact on coloring characteristics such as optical density and ink penetration on fabric in changing thickener which was one of the key materials in pre-treatment solution to realize high printing quality. As a result, we demonstrated that using two thickeners having different chemical structures from each other was much effective to adjust above coloring characteristics on fabric depending on required printing quality. However, in this previous work, we couldn't investigate and discuss whether controlling other parameters of thickener enabled us to alter coloring characteristics on fabric flexibly. Thus, in this paper, we focused on molecular weight of thickener as a parameter to affect printing quality on fabric and investigated whether changing molecular weight was effective to fine-tune coloring characteristics on fabric or not.

Introduction

Recently, digital textile printer has been recognized as a useable production machinery in textile fields because the progress of various core technologies such as print heads and inks enables their users to achieve high productivity with high printing quality.[2]-[8] However, as digital textile printers have been widespread in worldwide market, technical demands regarding printing quality and operability from their users have been diversified more and more. One of these technical demands is to adjust coloring characteristics such as color intensity, ink penetration and sharpness of printed design flexibly depending on various jobs of printer users. For example, when printer users would like to print geometric pattern on fabric in some jobs, sharpness of printed design is demanded. On the other hand, if they must print their designs on silk for scarf in other jobs, high ink penetration is essential. That is, the priorities of demanded coloring characteristics on fabric change depending on designs and applications. In these cases, many users would like to fine-tune coloring characteristics on fabric to realize desirable printing quality by using as a simple way as possible. However, it is not always easy to adjust coloring characteristics by using general ways such as image processing. Aa a result, in some cases, these users must consider exchanging their usual ink set into another set or, at the worst case, they can't avoid giving up the jobs.

To overcome this difficulty of controlling coloring characteristics on fabric, optimizing composition of pre-treatment solution is one of easy ways to alter printing quality because all things we must do is to prepare appropriate pre-treatment solution only. Thus, we have investigated the function of key chemical materials (especially thickener) contained in pre-treatment solution to meet various demands from printer users by optimizing compositions of pre-treatment solution.

Function of thickener in pre-treatment solution

In our previous work regarding pre-treatment solution for acid ink,[1] the function of key materials (thickener, urea, pH adjusting agent and preservative) were explained from the theoretical aspects and various experimental data demonstrated that changing thickener type was effective to adjust coloring characteristics on fabric. For example, Figure 1 indicates that OD (Optical Density) values of Cyan ink on polyamide elastomer fabric increased drastically by using thickener type B having different molecular structure from thickener type A in pre-treatment solution. Furthermore, we showed that selecting thickener type from the aspect of molecular structure depending on designs enabled printer users to adjust ink penetration and sharpness of printed design without exchanging ink set into another one (detail data are shown in our previous work[1]).

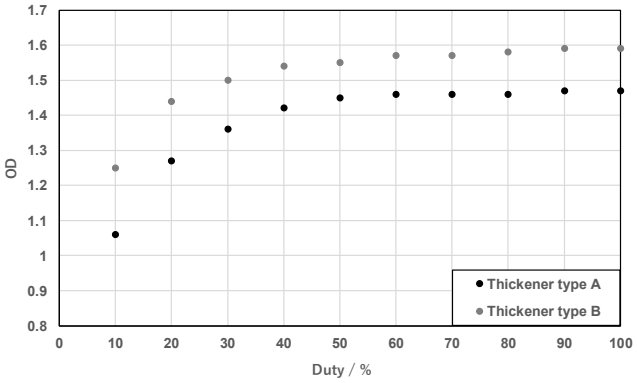

Figure 1. OD values of acid Cyan ink on printed side in using thickener type A or type B. The OD values were measured by FD7 (KONICA MINOLTA). Note that molecular structures of both thickeners differed from each other.

Experimental purpose

As shown in Figure 1, thickener is significant material to control coloring characteristics on fabric. Thus, in this work, we focused on thickener continuously and investigated whether changing other parameters of thickener was effective to control coloring characteristics on fabric or not. Specifically, we focused on molecular weight of thickener as a controllable parameter and attempted to alter coloring characteristics on fabric by using two thickeners having different molecular weight from each other properly.

Experimental procedures

We focused on printing qualities on PolyAmide Elastomer (PA/Ela) fabric in changing thickener's molecular weight in pre-treatment solution because PA/Ela fabric has been widely used in the various fields such as sport apparel and many apparel manufacturers demand to fine-tune coloring characteristics on this fabric flexibly depending on their designs. Thus, we investigated whether changing molecular weight of thickener enabled us to alter coloring characteristics such as OD value, ink penetration and sharpness on PA/Ela fabric or not.

Experimental procedures are shown below. Firstly, we prepared two pre-treatment solutions (Pre-A or Pre-B) containing different thickeners having different molecular weight. That is, thickener A was added in Pre-A and thickener B having larger molecular weight than thickener A was added in Pre-B. Regarding other materials in each pre-treatment solution, urea and ammonium sulfate (pH adjusting agent) were added to promote electrostatic interaction between acid dyes and amino groups on PA/Ela fabric in steaming process. As solvent, water without polyvalent metal ions was used because polyvalent metal ions had a possibility of causing undesirable reactions such as dye aggregation. Additive amounts of each materials were determined to prepare both pre-treatment solutions at the almost same viscosity and pH value. After preparing both pre-treatment solutions, PA/Ela fabrics were pre-treated by them via padding method and some evaluation patterns were printed on the pre-treated PA/Ela fabrics with acid inks. Finally, all printed PA/Ela fabrics were post-treated (steaming and washing) at the following conditions and evaluated from the aspects of OD values, ink penetration and sharpness.

Steaming conditions: Steaming temperature 102ºC,
Steaming time 30 min
Washing conditions: (1) Washing at room temperature for 5 min
(2) Washing with at Laccol STA (2 g/L)
at 55 ºC for 10 min
(3) Washing at room temperature for 5 min

Note that Laccol STA (MEISEI CHEMICAL WORKS, LTD.) was used as a soaping agent in washing process.

Experimental results and discussion

The results are shown in Figure 2. In Figure 2, OD values of Yellow, Magenta and Black inks were almost the same values regardless of the pre-treatment solutions. On the other hand, OD values of Cyan ink in using Pre-B was higher than OD values in using Pre-A remarkably. Regarding other inks (Red, Orange, Cobalt and Gray), OD values were also compared by the same way and the results indicated that OD values were almost the same values regardless of the pre-treatment solutions (Figure 3).

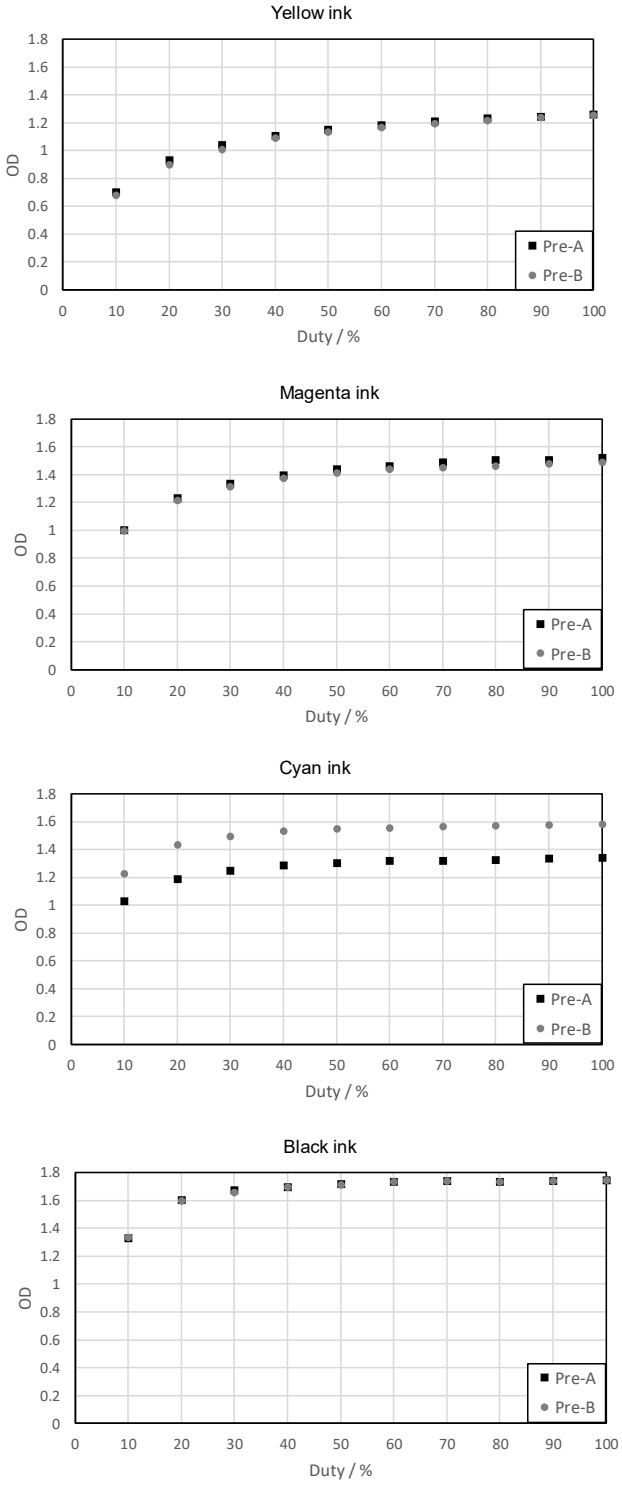

Figure 2. OD values of acid inks (Yellow, Magenta, Cyan and Black) on printed side in using Pre-A or Pre-B. The OD values were measured by FD7 (KONICA MINOLTA).

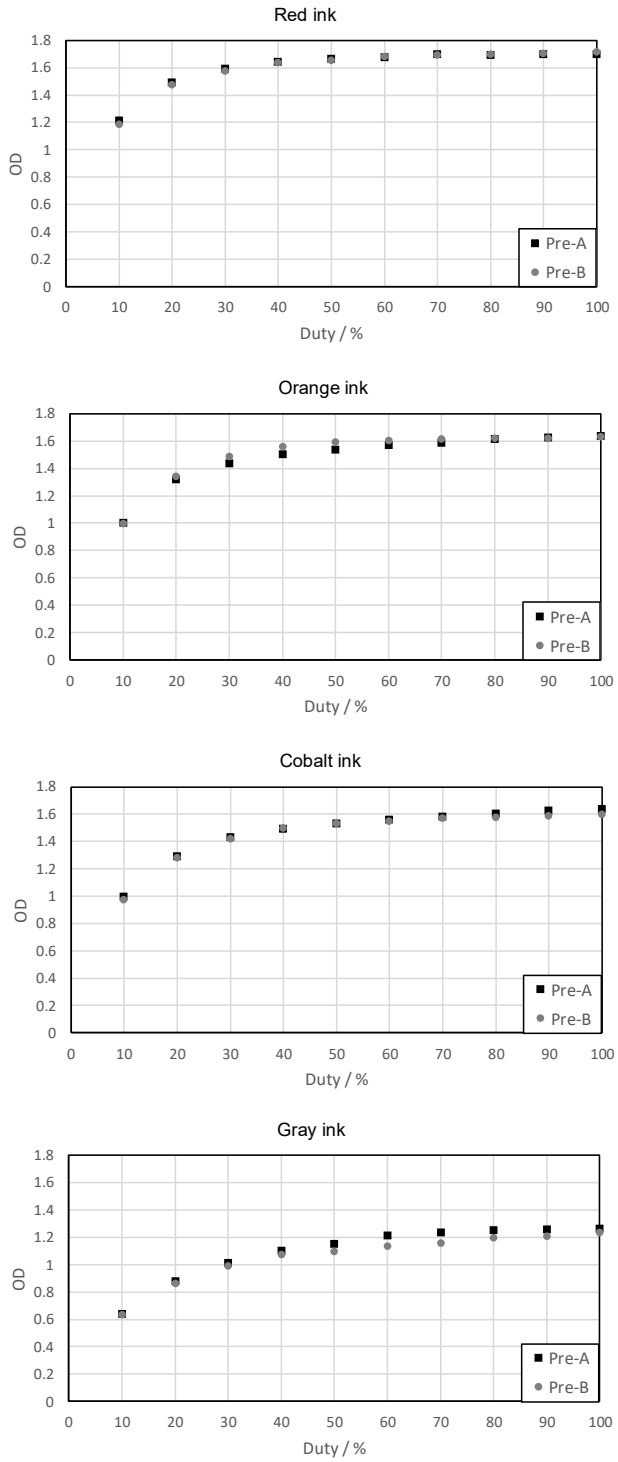

Figure 3. OD values of acid inks (Red, Orange, Cobalt and Gray) on printed side in using Pre-A or Pre-B. The OD values were measured by FD7 (KONICA MINOLTA).

That is, these results indicate that using Pre-B enabled printer users to make Cyan OD value much higher on PA/Ela fabric than the OD value in using Pre-A. Certainly, the difference of Cyan OD values at all duties was more than 0.2 at least according to Figure 2 and this difference was enough large for printer users to recognize the difference of Cyan color intensity. Thus, if color intensity of Cyan ink is the most important required quality, printer users can realize the higher OD value by using pre-treatment solution such as Pre-B instead of Pre-A without doing anything else.

Furthermore, when PA/Ela fabric was pre-treated by Pre-B, penetration of all inks from printed side to back side was enhanced remarkably, compared with the case of using Pre-A (Figure 4 and Figure 5).

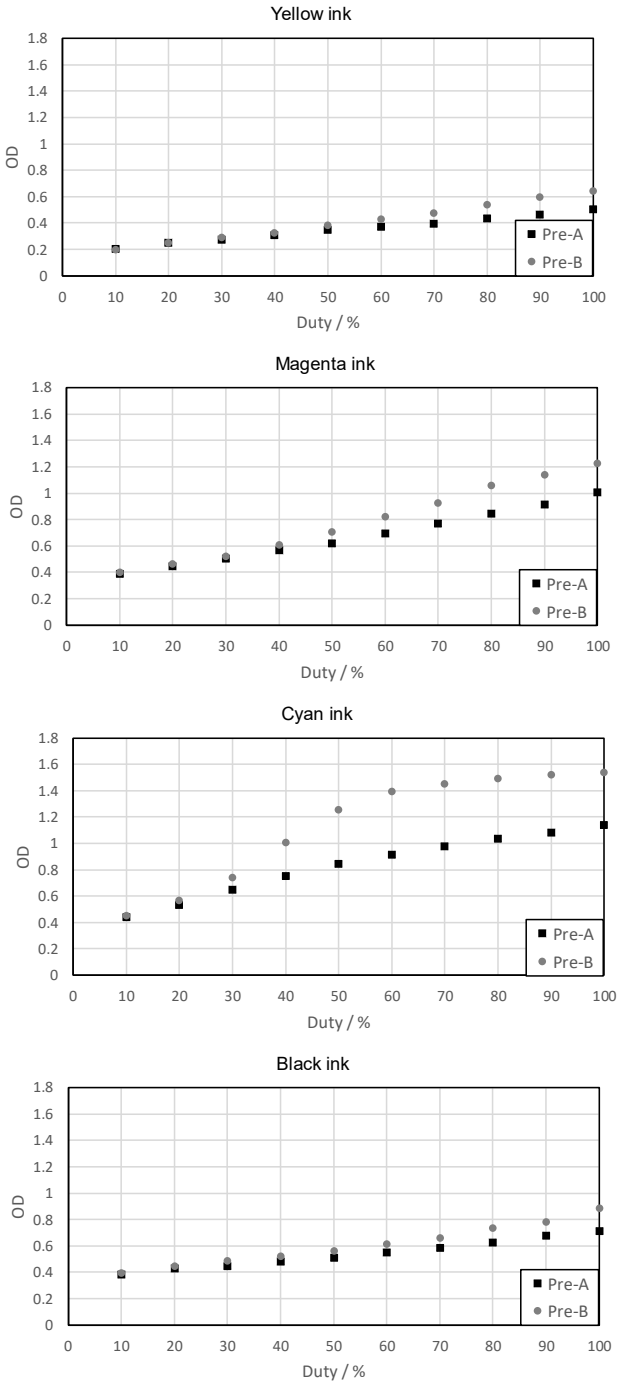

Figure 4. OD values of acid inks (Yellow, Magenta, Cyan and Black) on back side (not printed side) in using Pre-A or Pre-B. The OD values were measured by FD7 (KONICA MINOLTA).

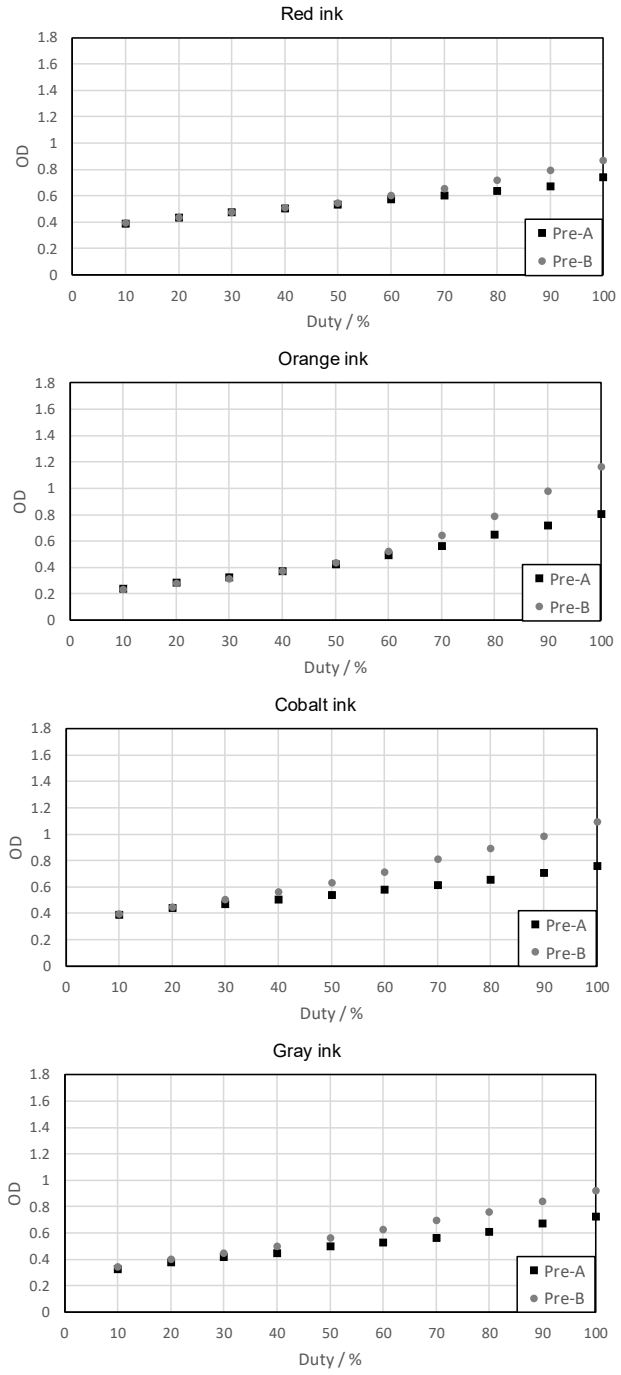

Figure 5. OD values of acid inks (Red, Orange, Cobalt and Gray) on back side (not printed side) in using Pre-A or Pre-B. The OD values were measured by FD7 (KONICA MINOLTA).

Especially, OD values of Cyan ink increased drastically in the above 40% duty areas. Regarding other color inks, the difference of OD values within the higher ranges of 80% duty - 100% duty were enough large for printer users to notice the difference easily. These results indicate that increasing molecular wright of thickener investigated in this work was effective to promote penetration of all inks used in our experiments. Thus, when some designs (especially simple designs) are printed on fabric such as PA/Ela having great contractibility with acid inks, Pre-B is more preferable pre-treatment solution because of this outstanding penetration characteristic as shown in Figure 4 and Figure 5.

On the other hand, as shown in Figure 6 describing the results of sharpness evaluations regarding Cyan ink and Magenta ink, their sharpness in using Pre-B was inferior to one in using Pre-A and bleeding was easier to occur in using Pre-B compared with pre-A. This tendency was also observed in the same evaluations regarding other inks, especially Orange ink and Cobalt ink which showed higher penetration in using Pre-B than penetration of other color inks in Figure 4 and Figure 5 (data not shown). Thus, when printer users would like to print delicate and complicated designs which are never printed by traditional printing methods on fabric, the combination of acid inks and Pre-A containing thickener A is more preferable to be used. That is, according to designs, printer users can alter coloring characteristics very easily by changing molecular weight of thickener in pre-treatment solutions without exchanging their ink set.

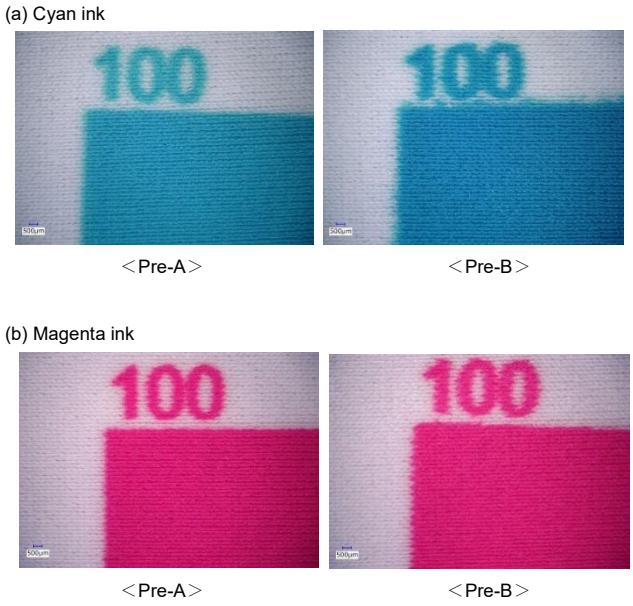

Figure 6. One example of sharpness evaluation comparing Pre-A with Pre-B. All images showed the evaluation patterns printed with 100% duty of each ink. Note that image magnification was 20 times.

Summary and future work

In this paper, we investigated whether coloring characteristics on fabric was altered by changing molecular weight of thickener in pre-treatment solution or not. As a result, all experimental data showed that changing molecular weight of thickener affected printing qualities and selecting the molecular weight depending on required printing qualities made it possible to adjust OD values, ink penetration and sharpness of printed design. According to our previous work,[1] changing chemical structure of thickener was also effective to alter coloring characteristics. Thus, it is worth optimizing thickener property from the aspect of chemical structure and molecular weight to meet various technical demands from printer users.

Although we focused on pre-treatment process in our all works, optimizing this process is nothing but one method to fine-tune coloring characteristics on fabric. In fact, there are also other methods such as image processing and mechanical ways to do so. The most important thing is that we must construct various technologies to adjust coloring characteristics on fabric flexibly and drastically and propose the appropriate method to printer users from among them. Thus, supporting these users from pre-treatment to post-treatment is essential to address their technical problems and realize their demands.

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Yoshitaka Miyajima received his Ph.D from the University of Tokyo, Chemistry & Biotechnology Dept. in 2009. He joined Seiko Epson Corporation in 2009 and has since worked on the development of inkjet inks. Now, his primary responsibilities are research and development of inks and pre-treatment solutions for digital textile printing.