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Synergistic Effect of Pre-Treatment Solution and Inkjet Ink to Control Coloring Characteristics on Fabric

Yoshitaka Miyajima, Nao Kozaka, Takuya Sonoyama, Hiroshi Kiguchi;
Seiko Epson Corporation; Hirooka Office, 80 Harashinden, Hirooka, Shiojirishi, Nagano-ken 399-0785, JAPAN

Abstract

In textile field, digital textile printing has recently expanded its presence as a practical option for printing designs on fabrics, and many users of digital textile printer has actually attempted to widen their business. However, there are many factors that affect printing qualities on fabric. One of these factors is pre-treatment. Owing to proper pre-treatment depending on fabric types, various chemical reactions or chemical interactions between ink and fabric are strictly controlled in printing and steaming processes. Furthermore, adjusting the compositions of pre-treatment solution enables us to control coloring characteristics on fabric under user's printing environment. As a result, high printing quality is achieved by digital textile printing.

Thus, in this paper, we focused on pre-treatment process and attempted to alter coloring characteristics on fabric by changing key material such as thickener in the pre-treatment solution.

Introduction

Recently, digital printing technology has been widely applied in textile fields because various core technologies such as inkjet printheads and inks have been developed to realize high productivity with high printing quality. Actually, we have developed piezo inkjet technology, which achieves high output quality, high speed printing and improved scalability from serial printheads to lineheads.[1]-[7] As a result, we have already developed inkjet textile printers (Monna Lisa series), which make it possible to print designs on various fabrics with high quality in the international market (Figure 1).

Figure 1 The latest model is Monna Lisa Evo Tre.

Nowadays, printing qualities required from customers have been diversified more and more because customer's applications are widespread from casual wears to high fashion brands. However, it is not always easy to respond these technical requests from customers by only developing printheads and inks as in the past. For example, the most important color in customers' ink set changes frequently depending on their daily jobs. That is, in some jobs the color density of Cyan is the most important, on the other hand, in other jobs the color density of Black becomes the highest priority. In these cases, although customers have to adjust coloring characteristics flexibly and drastically according to their daily jobs, general methods such as image processing are not always enough solutions to obtain satisfactory results and they have to consider exchanging their ink set for another one depending on the situation.

To adjust coloring characteristics, we would like to focus on pre-treatment process before printing with inkjet printer (Figure 2). Pre-treatment is an essential process among digital printing processes to achieve high printing quality on various types of fabrics. Owing to appropriate pre-treatment, the chemical interactions between colorants in inkjet inks and fabrics are controlled strictly in digital printing processes such as steaming. As a result, high printing quality is achieved. If the pre-treatment is not carried out properly, digital printing quality lower dramatically and customers never obtain satisfactory outputs even if they use digital textile printer with high degree of accomplishment.

Generally, pre-treatment solution used in pre-treatment process is consisted of some chemical materials such as thickener, urea and pH adjustment material. In this study, we focused on these chemical materials, especially thickener, used in pre-treatment solution and evaluated whether changing thickener type makes it possible to alter the coloring characteristics on fabric.

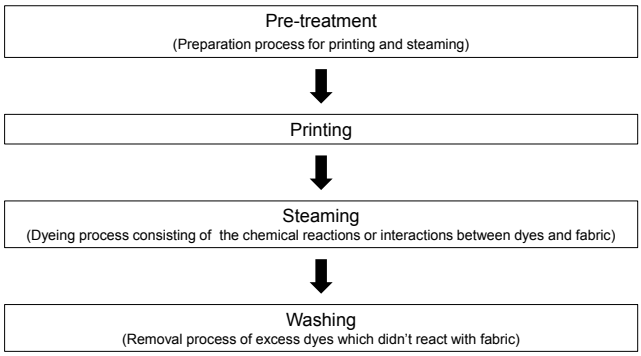

Figure 2 Processes of digital textile printing. Pre-treatment is the first step and affects printing quality significantly.

Basic materials of pre-treatment solution

Basic materials of pre-treatment solution are shown in Table 1. Thickener is the key material to control printing qualities such as OD (Optical Density) value, sharpness and penetration. The viscosity of pre-treatment solution is prepared in optimal range by adjusting additive amount of thickener to control sharpness and penetration of ink. Changing thickener type also makes it possible to alter coloring characteristics as shown in the experimental results later.

pH adjusting agent is necessary to control pH in steaming process. As shown in Figure 2, chemical reactions and interactions between dyes and fabric occur in steaming process under optimal pH range. If pH value is not optimal range, the printing qualities such as OD values lower because the efficiency of chemical reactions and interactions are inefficient.

Urea is used to keep steaming temperature (e.g. 102^{o}C) constant in steaming process. In steaming, steam gas absorbed on fabric surface changes to liquid state emitting heat because this phase change from steam gas to liquid water is exothermic reaction. As a result, overheating occurs on the fabric and various chemical reactions or interactions are not controlled properly because the actual temperature on the fabric itself is higher than original temperature. To suppress this overheating, urea is important. Urea has a feature of absorbing heat in dissolving in water because this reaction is endothermic reaction. Thus, if optimal amount of urea is in fabric by pre-treatment, above overheating can be suppressed because this endothermic reaction occurs when urea dissolves in the water which generates from phase change of steam gas absorbed on fabric surface.

Preservative is necessary to keep quality of pre-treatment solution because it prevents bacterium growth which causes decomposition of urea. However, the life time is within several months even when preservative is used in pre-treatment solution. So, after pre-treatment solution is prepared, it is preferable for the solution to be consumed as soon as possible.

Table 1 Basic material for preparing pre-treatment solution.

Material	Function
Thickener	Adjusting viscosity to control coloring characteristics
pH adjusting agent	Adjusting pH to control interaction between dyes and fabric
Urea	Keeping temperature constant in the steaming process.
Preservative	Keeping quality of pre-treatment solution during long-term storage.

Experimental

First of all, we would like to explain the fabric type and the technical problems addressed in this study. Although there are many fabric types in the international market for digital textile printing, we focused on PolyAmide (PA) or PolyAmide Elastomer (PA/Ela) fabrics in this study. PA and PA/Ela fabrics have been printed by digital textile printer for many applications such as sportswear and innerwear, and the requests for printing various designs on these fabrics has increased gradually. As a result, users of digital textile printer have found it necessary to change coloring characteristics according to what they have to print on PA or PA/Ela fabrics. For example, in sportswear such as swimsuit, color density of Cyan ink tends to be more important than other color's densities because higher color density of Cyan tends to be demanded for designs for swimsuit. On the other hand, in other jobs, other colors become more important. Although, in these cases, users have to adjust color density with various methods such as image processing, it requires to time and effort to do so. Additionally, there may be cases where they can't adjust color density unless they exchange their ink set itself for another ink set. Considering the above problems, in this study, we focused on pre-treatment solutions to alter coloring characteristics of acid inks on PA or PA/Ela fabrics without exchanging ink set and attempted to propose pre-treatment as one solution to solve above problems.

Evaluation of changing thickener type

Whether changing thickener type affects color characteristics was investigated. Actually, we prepared two pre-treatment solutions (Pre-A and Pre-B) containing different thickener types to print some printing patterns on PA/Ela fabrics with acid inks. In Pre-A, thickener A was used as a thickener; on the other hand, thickener B having different molecular structure from thickener A was added in Pre-B. In regard to other materials, urea and ammonium sulfate (pH adjusting agent) were used. Then, both pre-treatment solutions were prepared by using water without containing polyvalent metal ions which has a possibility of causing undesirable reactions such as dye aggregation. Additive amount of each material was adjusted to prepare both pre-treatment solutions at the almost same viscosity and pH value. After preparation of these pre-treatment solutions, PA/Ela fabrics were pre-treated by Pre-A or Pre-B and these fabrics were printed and post-treated (steaming and washing) at the following conditions.

Steaming conditions: Steaming temperature 102^{o}C,
Steaming time 30 min

Washing conditions: (1) Washing at room temperature for 5 min
(2) Washing with at Laccol STA (2g/L) at 55^{o}C 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.

The results are shown in Figure 3. In Figure 3, OD values in using pre-A tended to be slightly higher than OD values in using pre-B except for Cyan ink. In Cyan ink, OD value in using pre-B was superior to OD value in using pre-A remarkably. OD values of other colors (Orange, Blue, Red, and Cobalt) were also compared by the same way and the results indicated that OD values in using pre-A were slightly higher than OD values in using pre-B (data not shown). Thus, these results indicate that Pre-B can enhance only Cyan OD value apparently. According to Figure 3, although the difference of Cyan OD values between Pre-A and Pre-B was about 0.2, this difference was enough large for users to recognize the difference of OD. As a result, when users would like to print designs requiring with high color density of Cyan, they can print the designs by using Pre-B as a pre-treatment solution without exchanging their ink set.

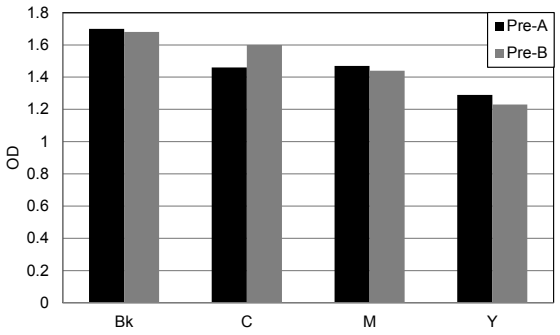

Figure 3 Comparison of OD values in using pre-A or pre-B as a pre-treatment solution. The OD values were measured by FD7 (KONICA MINOLTA).

Furthermore, when PA/Ela was pre-treated by Pre-B, all inks could penetrate from surface to the back side more compared with the case of using Pre-A (Figure 4). In regard to other colors (Orange, Blue, Red, and Cobalt), the same tendency was also observed (data not shown).

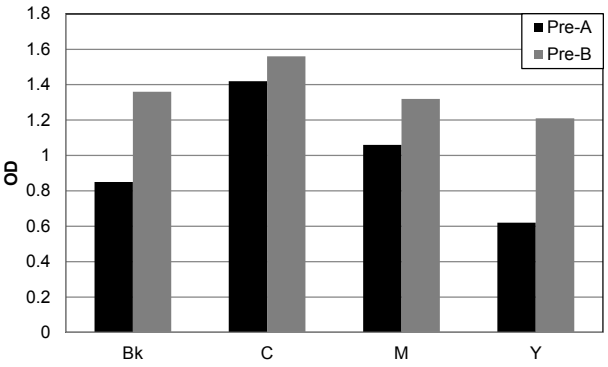

Figure 4 Comparison of OD values on back side (not printed side) in using pre-A or pre-B as a pre-treatment solution. The OD values were measured by FD7 (KONICA MINOLTA).

These results indicate that thickener B can promote penetration of all inks investigated in our experiments. As a result, in the case of printing designs (especially simple designs) on fabric having great contractibility with acid inks, pre-treatment solution such as Pre-B containing thickener B is more preferable to be used because of this outstanding penetration characteristic as shown in Figure 4.

On the other hand, the sharpness in using Pre-B is inferior to one in using Pre-A. Actually, bleeding was easier to occur in using Pre-B compared with pre-A when complicated designs and patterns were printed (Figure 5). Thus, when users would like to print delicate and complicated designs which are never printed by traditional printing methods on fabric, the combination acid inks and pre-treatment solution such as Pre-A containing thickener A is more preferable to be used. That is, according to users' jobs, they can alter coloring characteristics very easily by choosing the thickener types in pre-treatment solutions without exchanging their ink set.

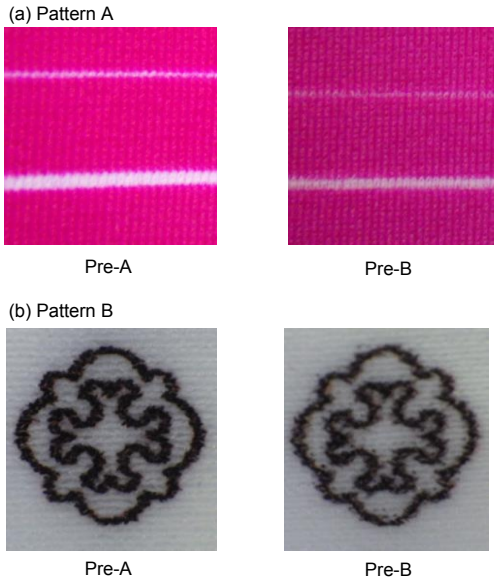

Figure 5 Comparison of bleeding.

pH dependency of OD value

Optimizing pH of pre-treatment solution is important to control coloring characteristics (especially OD value) on fabric because the interaction between acid dyes and fabric is mainly electrostatic interactions between anionic acid dyes and cationic amino groups on fabric surface. Actually, as pH of pre-treatment solution was lower from 7 to approx. 3, OD value was higher gradually because the amino groups of fabric were cationized to react with anionic acid dyes. On the other hand, when pH was strong acid conditions (e.g. pH < approx. 3), OD value was lower because fabric itself was damaged under strong acid conditions. Thus, pH value was adjusted to approx. 3 to achieve maximum OD value in our experiment. Although only pH dependency of Cyan ink was shown in Figure 6, the same tendency was observed in other color inks, too (data not shown).

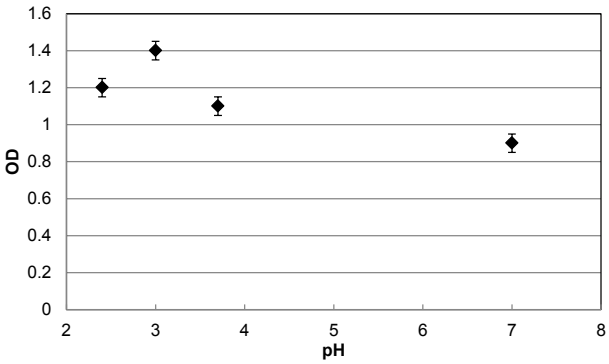

Figure 6 Correlation between pH of pre-treatment solution and OD values of Cyan ink on PA/Ela fabric. The OD values were measured by FD7 (KONICA MINOLTA). Pre-treatment solution was prepared by using the following materials (Thickener A, urea, citric acid and water). Note that pH value of this pre-treatment solution was changed by adjusting additive amount of citric acid.

Summary and future work

In this paper, we investigated whether pre-treatment makes it possible to alter coloring characteristics or not from the aspect of thickener type. As a result, all experimental results indicate that pre-treatment affects printing qualities and it is important for us to accumulate knowledge of pre-treatment solutions.

Although we focused on pre-treatment in this paper, there are other methods such as image processing to alter coloring characteristics on fabric. However, the most important thing is that users of digital textile printer can obtain satisfactory printing results by using various methods for adjusting coloring characteristics. Pre-treatment or image processing is nothing but one approach to realize users' technical requests. From this point of view, it is very important for us to provide these users with total solutions and total supports from pre-treatment to post-treatment for the purpose of addressing their technical problems and realizing their requests.

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Author Biography

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 solution for digital textile.