Improvement of image quality in single pass UV inkjet printing.

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Abstract

This report introduces factors to improve image quality obtained by single pass inkjet printing with UV ink. As reported at NIP24, this study is made with 600 dpi single pass inkjet printheads, capable of single pass printing at 847 mm/s in 108 mm print swath. In the former study, authors concluded that image quality could be sharper by higher pass speed in case of single pass inkjet printing, since amount of ink flow on a media surface before curing can be restricted. However, it was revealed that fast printing speed could suffer image quality with unevenness of image surface created with thick ink layer. In order to solve the problem, approaches are made from both ink and printhead properties. Firstly, static surface tension of UV ink is lowered from 30 to 22-25 mN/m. It is expected to maintain enough dot gain with smaller drop volume, which makes ink layer thinner. Also, color density of ink has to be enhanced to keep equivalent color range with thinner layer. Secondly, printhead is modified in terms of optimum drop volume range from 5 – 19 to 4 – 12 pl for modified ink. Also, drop placement accuracy is improved by increasing drop velocity. As a result, thickness of ink layer is reduced from12.7 microns to less than 9.6 microns on a gloss coat media. As a result, appearance of color images are much improved. It is achieved UV ink named AGORA G1 developed by Agfa Graphics.

Introduction

Since the public presentation of the piezoelectric drop on demand line inkjet printhead with 108 mm print width and 600 dpi single pass resolution in year 2005 [1], the authors have been working to expand its capability for industrial applications.

As a part of development activity, this printhead was modified to apply UV inkjet printing to cover wider range of substrate. In the past report for NIP 24, it was discussed how printing speed and curing method influence on image quality through behavior of UV ink dropped on inabsorbable media. According to the conclusion, image profile gets sharper as time to curing become shorter. And, wet-on-wet color printing has sufficient quality if printing speed is fast enough to prevent color mixture by drop flow on media before curing [2].

However, it did not cover another unnatural visual effect with UV prints caused by thickness and unevenness of ink layer. As curing time gets shorter, ink layer can be thicker since it does not have sufficient time to be flown on media before curing. Moreover, it requires a certain amount of ink to get sufficient coverage in case of single pass printing. As a result, ink layer can be thicker even more than necessary and may spoil image quality. Not only from image quality but also economical view point, it is not efficient.

In order to improve image quality and efficiency, we aimed to get sufficient coverage with minimum amount of ink that can be flown over various media. In other words, it was aimed to optimize printhead design for UV inks with lower surface tension and viscosity. This report treats changes in ink properties, design of the inkjet printhead and print test results by using them.

Printhead Specifications

As referred above, the first UV model was designed to maximize drop volume to get enough coverage with inks having relatively high viscosity and surface tension. However, thank for cooperation with ink makers, we have had more choices in ink with lower viscosity and surface tension. By making use of them, we have modified printhead design to improve image quality.

Following table 1 shows summary of printhead model history. And, figure 1 shows appearance of current commercialized model KJ4A-GD06AHG-STDC2.

Table 1: UV inkjet printhead model history

Generation	1st	2nd	3rd
1. Model Code	KJ4A-CD06AHF	KJ4A-GD06AHG	Latest (TBD)
2. Ink Type	UV		
3. Dimension	200(W) x 25(D) x 60(H) mm		
4. Number of Nzl.	2,656		
5. Print Width	108 mm (4.25 inches)		
6. Resolution	600dpi (print width direction)		
7. Max. Drive Frq.	20 kHz		
8. Drop Volume	5 - 20 pl	6-14 pl	4-12 pl
9. Optimum Viscosity	7.0 – 8.0 mPa*s	6.5-7.5 mPa*s	5.5-6.5 mPa*s
10. Optimum Surface Tension	30 – 35 mN/m	22 – 25 mN/m	

Figure 1 *Appearance of KJ4A-GD06AHG-STDC2.*

Ink Properties

In case of single pass printing, such factor as surface unevenness, or thickness of ink layer, is more sensitive to image quality than in wide format applications since prints are usually looked in closer distance. Therefore, specialized inks for single pass printing have been required.

As it is mentioned above, more UV inks with lower viscosity and surface tension, which are beneficial for single pass application, are available now. Of these inks, AGORA G1 developed by Agfa Graphics achieved the lowest viscosity and surface tension among available inks for KJ4A. Having tried print test with this ink, it was confirmed that sufficient coverage can be achieved on gloss coat paper with 12 pl, which is the least volume as ever achieved. Representative properties of AGORA G1 are compared with those of ink for 1st generation printhead in table 2.

Table 2: Modification of ink properties.

Generation	Original UV ink	AGORA G1
Viscosity	8.0 mPa*s@45° C	5.9 mPa*s@40° C
Surface Tension	35 mN/m	22 mN/m
Density	1.02 g/cm^3	1.08 g/cm^3

Printhead Design Optimization

Firstly, image quality was improved with minimum drop volume reduction to get enough coverage by making use of lowered surface tension and viscosity from the original ink. Also, these modifications allow KJ4A-GD06AHG series to raise drop velocity 20% faster than the original model. It made much contribution to stabilize drop placement accuracy.

Although KJ4A-GD06AHG improved image quality in terms of surface flatness, its minimum drop volume is increased to 6pl from that of the original, 5pl. As a result, image granularity became more visible.

Then, to erase granular impression from prints, it was aimed to reduce the minimum drop volume. According to following equation (1), drop volume can be decreased without reducing drop velocity by shrinking nozzle size [3].

$$V_m = K \cdot \frac{\pi^2 Q}{T_C A} \qquad (1)$$

V_m: Drop velocity
K: Constant (2 in case of pull-push mode)
Q: Drop volume
T_C: Acoustic period of drop ejector
A: Nozzle cross-sectional area (average)

Together with nozzle size, other channel elements shown in figure 2 were reconsidered to optimize jetting performance for low viscous ink such as AGORA G1. It makes acoustic energy propagation efficient in a drop ejector but could be suffered too much residual oscillation. So, firstly, cross sectional area of restrictor was reduced to enhance damping effect after drop ejection. Secondly, actuator compliance was decreased to restrict the deformation for smaller drop ejection. These changes in channel design and their effects on jetting performance are summarized in table 3.

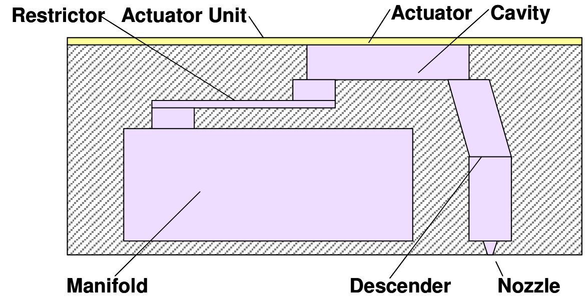


Figure 2 *Cross sectional view of a drop ejector.*

Table 3: Modification in channel design.

Channel element	Compared to 1st generation model.
Nozzle Outlet Area	69.4%
Actuator Compliance	89.6%
Restrictor Cross Sectional Area	60.0%
Jetting performance	**Compared to 1st generation model.**
Drop velocity	127.3%
Max. drop volume	63.2%
Min. drop volume	80.0%
Acoustic period	98.0%

Print Test

Test Conditions

By using the latest model, monochrome and color printing tests were made. Figure 3 shows a schematic expression of a printer used for them. As shown in the figure, a substrate fixed on the table passes under the four printheads aligned with a UV lamp. By using the test printer above, monochrome and color prints were made at conditions summarized in following table 4.

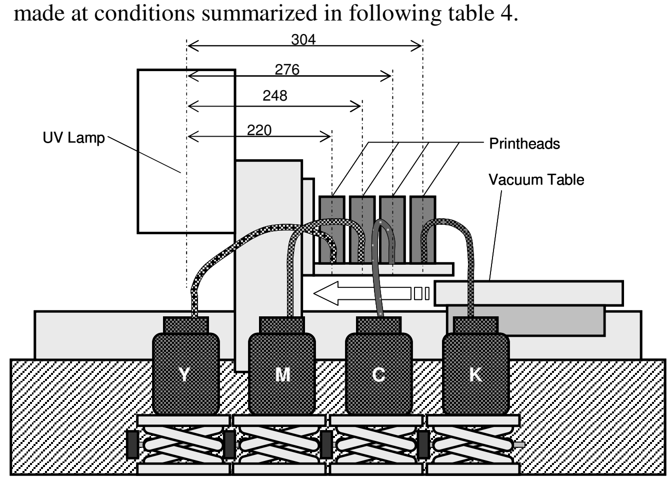


Figure 3 *Test Printer.*

Table 4: Printing Test Conditions

1. Image	Monochrome character and bar code, Color image (ISO400)
2. Fire Freq.	20 kHz
3. Feeding Rate.	846.7 mm/s
4. Method	Wet on Wet
5. Ink and Lamp	Curing Energy: 60 mJ/mm Lamp Power: 120 W/cm (Passing twice)
6. Media	Gloss coat media

Results and Discussions

We made comparisons of print quality by latest model with those of the 1st generation printhead and original ink.

First of all, thickness of ink layer was measured by using non-contact surface roughness measuring machine on bar code prints shown in Figure 4. As shown in the figure, average ink layer thickness of the new printhead is 9.6 microns whereas it is 12.7 microns with the original. In spite of reduction in thickness, AGORA G1 keeps equivalent optical density.

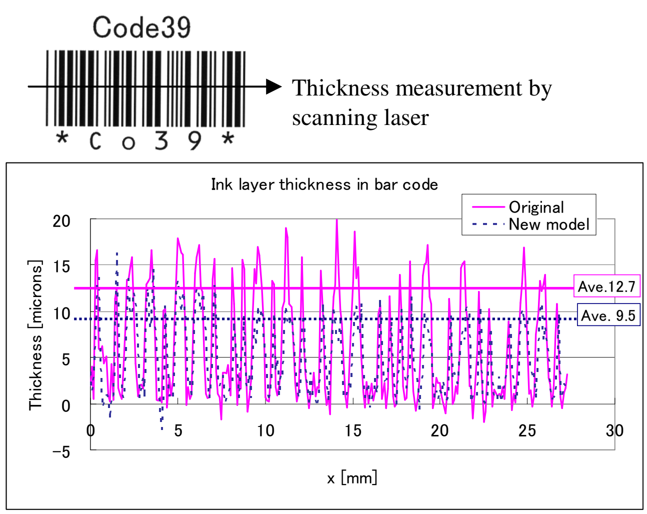
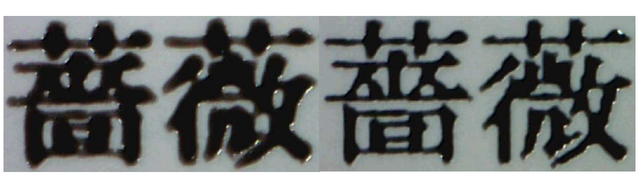


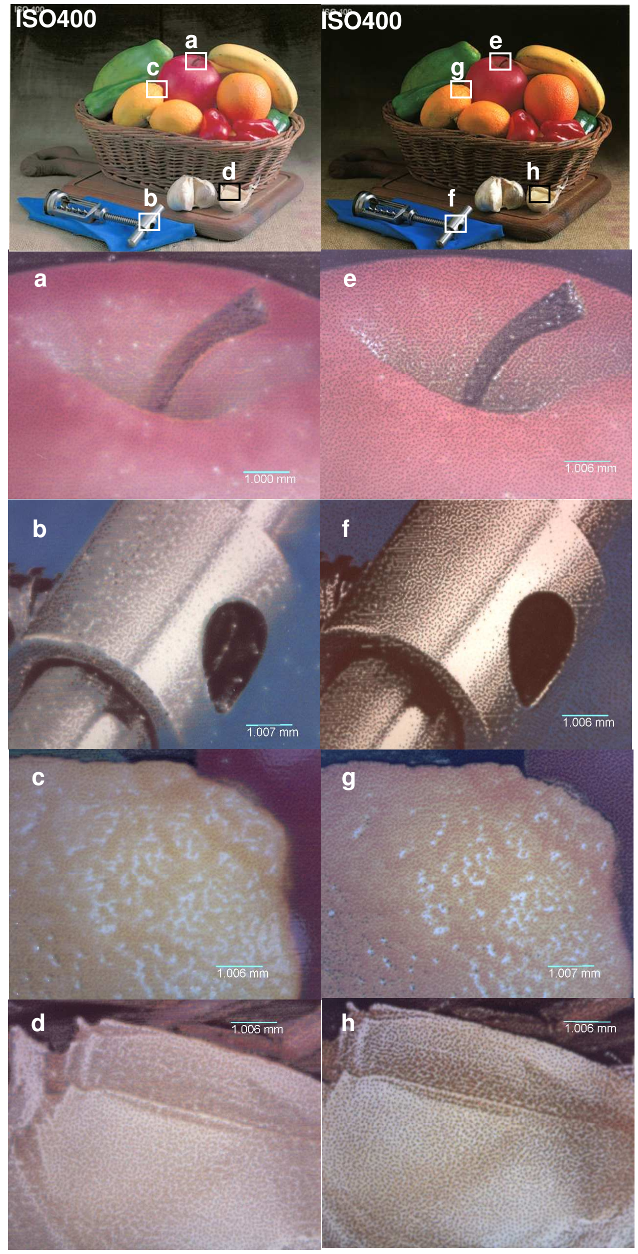
Figure 4 *5 Points Characters*

Figure 5 shows Chinese characters printed by using both printheads and inks in binary with 19 and 12pl drops respectively. In case of 1st generation model, profile of characters is expanded and lines get thicker. As a result, it causes difficulty in recognition by naked eyes. However, by making use of smaller dot gain, much sharper and clearer characters are obtained by using new printhead and ink.



(a) 1st generation (19pl) (b) Latest model (12pl)

Figure 5 *5 Points Characters*



(a) 1st generation (5/13/19pl) (b) Latest model (4/8/12pl)

Figure 6 *Color images (ISO400)*

Figure 5 shows 4 level grey scale color images printed with 5/ 13/ 19 and 4/ 8/ 12pl drops by 1st generation and latest models respectively. Both prints are adjusted its appearance to minimize unevenness and granularity.

In case of 1st generation printhead, it is necessary to include 19pl drop as the maximum grey scale level to secure coverage. But, it cannot be utilized in images so frequently to minimize unevenness of ink layer. As a result, we could not obtain appropriate prints without sacrificing dynamic range in color density. In addition, due to mixture of colors at their boundaries, profiles of objects in an image are easily lost their sharpness.

Comparing with the print by original model and ink, the one printed with AGORA G1 by the new printhead shows excellence in its surface flatness, dynamic range in color tone and sharpness in profile. Especially, it allows natural expression for shade in image by utilizing grey scale with small drops as shown in the figure.

Conclusion

Improvement of image quality in single pass UV inkjet printing is studied in both ink properties and printhead design.

Firstly, UV inks with lower viscosity and surface tension enabled to reduce drop volume from 19pl to 12pl for securing enough coverage on gloss coat paper. As a result, ink layer thickness in a barcode image could be reduced to 75.5% of the one printed with original printhead and ink, especially in case of AGORA G1 by Agfa Graphics, of which viscosity, surface tension are 5.9 mPa*s@40°C and 22 mN/m respectively.

Secondly, it was achieved not just by modification in ink properties but also in printhead design. Nozzle size was shrunk together with actuator compliance to reduce drop volume range available from printhead. Also, the restrictor got narrower in its cross sectional area to damp residual oscillation after drop ejection propagating in less viscous ink. As a result, drop volume range reduced from 5 – 19 to 4 – 12 pl with drop 27.3% higher velocity.

Thirdly, by using AGORA G1 together with the latest UV printhead, image quality was much improved. Small characters become sharper in their profiles. And, thinner ink layer brought natural impression in color prints. Also, grayscale consists of smaller drops (4/8/12pl) allows wider tone dynamic range. It can be utilized to express fine tone change in shade.

References

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Author Biography

Shin Ishikura joined Kyocera Corporation in 1995. Since then, he has been in development section for print heads and their components. He received his degrees of M.S. and M.Eng. from Liverpool John Moores University and Kanazawa University respectively.

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