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Development of Image quality and reliability enhancing technology for 29 x 23 size digital inkjet press "KM-1"

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Abstract

We have developed a single-pass inkjet digital press AccurioJet KM-1, which can achieve off-set like high image quality with high productivity, 3,000 sheets per hour.

To success in the commercial printing field, high image quality and high consistency are required to be achieved.

For achieving high image quality, undesirable image defect such as banding should be improved. Therefore we have classified image banding into two, narrow banding (streak) and wide banding.

To solve the narrow banding issue, we developed a unique halftoning and a nozzle compensation techniques by means of image simulation process. We also improved the wide banding issue by adjusting the dot size and the dot density.

As for the high consistency, we developed a streak detection system, which scans images on every sheet, checks the existence of streaks, and feeds the results back to the image compensation systems.

Introduction

Recently commercial printing field has started to shift from analogue printing to digital printing, because of increasing job number of "small lot", shortening of lead time, personalization and so on.

Aiming for entering into this market, we tried to satisfy the requirements in this field such as high productivity, media flexibility, high image quality and high consistency, with our inkjet technology.

In terms of high productivity, we adopted a single-pass printing technology and a gripper-type paper transport system which can realize duplex printing with high stability. In terms of high image quality, we developed a new print head, KM1800i, which can deposit ink-dots in high frequency with high accuracy.[1] We also developed a new UV curable inkjet ink which can realize the high image quality and media flexibility. [2]

The single-pass inkjet printing technology, one of the key technology for the high productivity, is still a big challenge for image processing. There is no redundancy which can hide an undesirable image defect so-called "banding". It is essential to solve the banding issue for achieving high image quality accordingly. We developed various image compensation/ correction techniques and achieved the high image quality. We will report what we achieved in the development.

Technological Achievement

Outline of the AccurioJet KM-1

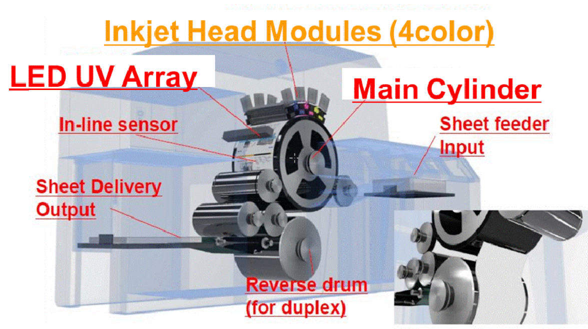

Figure 1. *Structural illustration of AqurioJet KM-1 system*

Figure 1 illustrates the structural outline of AccurioJet KM-1. Media, set in the sheet feeder, are transferred to the main cylinder. Inkjet heads jet the ink to form the image on the media, and the deposited ink dots are fixed by UV light emitted from the LED lamps. A page-wide inline image sensor is installed between the LED UV array and the sheet delivery output. The image sensor scans a printed "streak detecting" chart. The scanned results are transferred to the image correction system to solve the banding issue.

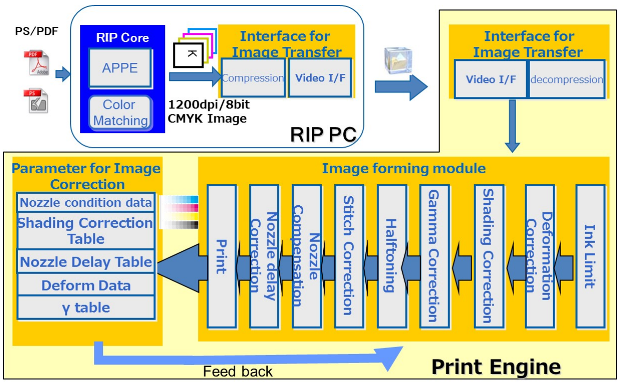

Figure 2. *Outline of the image correction data flow*

Figure 2 illustrates the outline of the image correction data flow. To solve the banding issue, the halftoning, the nozzle compensation, and the shading correction are processed by this flow.

Approach to offset like image quality

To improve the banding issue, we have classified the image banding into two, "narrow banding (streak)" and "wide banding."

We investigated their structure and mechanism thoroughly, and we found new techniques to improve them. We solved the narrow banding by adopting unique halftoning technique and nozzle compensation technique developed by using image simulation process. The wide banding, on the other hand, was improved by using dot size adjustment and dot density adjustment.

Halftone screen pattern optimization - Print image simulation

On the first to think of the halftone pattern, we examined the impact of image-processing parameters on the image quality. We utilized a simulation technology of image for the study. Focusing on dot deposition patterns seen in images printed by KM-1, we quantified the dot shape tendency relationship as a function of a distance and overlapped amount between adjacent deposited dots. Figure 3 is an example of a printing pattern which was performed to obtain a simulation parameters. We found that a coalescence of deposited dots proceeded in non-linear manner; the line width and the center of gravity of deposited dots were affected by the dot deposition pattern.

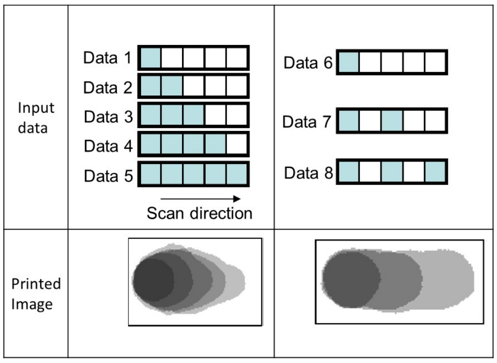

***Figure 3.** Example of obtaining the parameters for dot pattern simulation. Line width and line length were varied depending on variable input data patterns.*

Figure 4 is an illustration of a comparison between the actual printed image and the predicted image by the simulation. We found a good correlation in dot displacements and dot patterns.

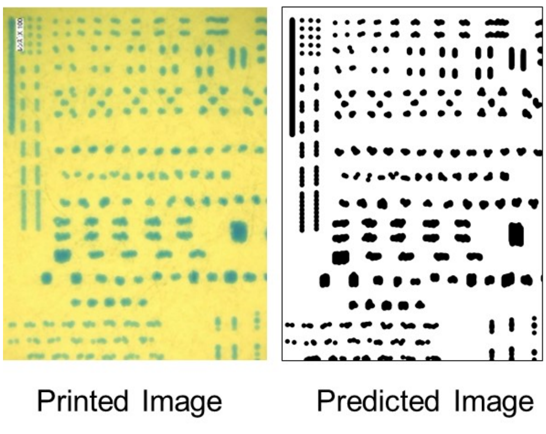

***Figure 4.** Comparison between a printed image and the predicted image.*

Halftone screen pattern optimization - Optimization of halftoning

We optimized the halftone pattern by using the aforementioned image simulation technique then. We simulated the impact of dot displacement in the main- and sub-scanning directions on the generation of the “narrow banding” (streak). We varied the extent of the displacement in the nozzle array direction (x-axis) and the paper feeding direction (y-axis) independently and predicted images.

In the dot pattern generated with a conventional half-toning technique, we found that the “streak” was very sensitive to the displacement along the x-axis. The non-linearity, which was found in the dot coalescence process, enlarged the input deviation of the center of gravity of dots to larger displacement of dot deposition and yielded the “streak” as shown in Figure 5-1. Considering the results, we developed a new halftoning technique that did not enlarge the deviation of the input to larger deposition displacement. Figure 5-3 shows the result based on this new technique. Introducing a unique algorithm, we found that it could suppress the enlargement of the “streak.”

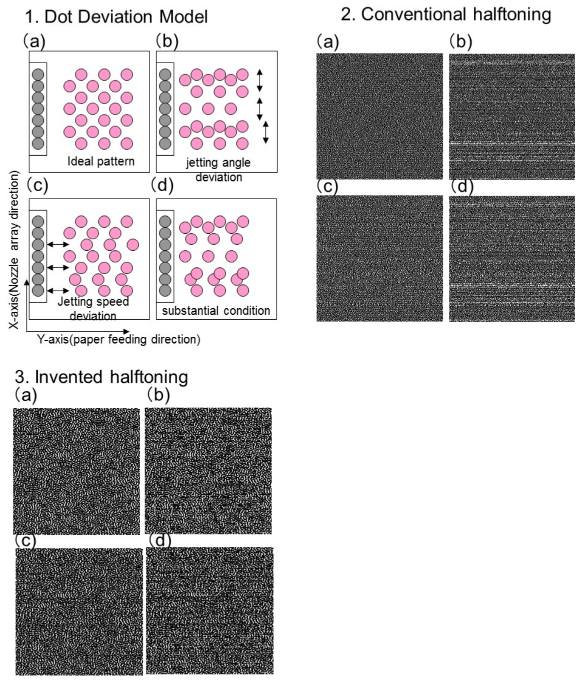

***Figure 5.** Simulated example of dot patterns under dot position’s deviation. X-axis and y-axis are defined as nozzle arrangement direction and media convey direction respectively. 1(a)-1(d) indicate dot position deviation models. (a) Dot positions are in an ideal position, (b) dot positions are deviated along only x-axis, (c) dot positions are deviated along only y-axis, (d) dot positions are deviated along both x-axis and y-axis. 2(1)-2(d) show simulated images based on a conventional halftoning pattern and 3(1)-3(d) show simulated images based on an invented halfoning pattern.*

Nozzle compensation

In a single pass inkjet printer, streaks can be recognized even one deviated nozzle is exist. For achieving offset image quality, those kind of streaks should be eliminated.

In order to deal with this issue, we have focused the coalescence of deposited dots to design a compensation pattern.

A print head module of KM-1 consists of two heads. Each head has 600 nozzle per inch (npi) resolution and staggered a half pitch to achieve 1200 npi resolution. The two heads are fit together along paper the feeding direction. Accordingly we found a unique phenomenon that dot coalescence behavior was affected by the dots’ placement order.

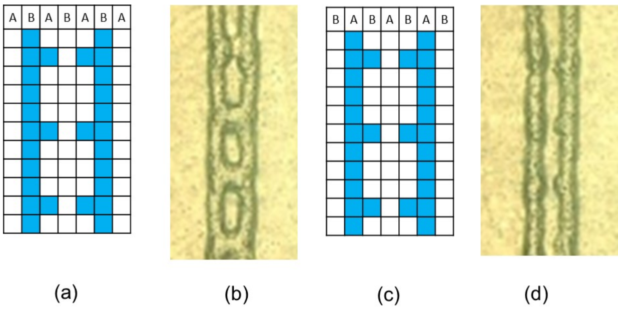

Figure 6. *Differences of coverage depending on a differences of dot placement order. (a) and (c) indicate input images while (b) and (d) indicate printed results. Data in column A was printed before data in column B was printed.*

Figure 6 shows the effect of placement order on the printed image. Figures 6(a) and 6(c) illustrates dot placement orders; data in column A was printed before the data in column B was printed. Figures 6(b) and 6(d) are the printed image with KM-1 and correspond to the placement orders 6(a) and 6(c), respectively.

The overall pattern was the same, 6(a) and 6(c), however, their printed images 6(b) and 6(d) were totally different. The placement order affected the adjacent dots' coalescence behavior, and affected the images. As a result, a performance of the nozzle compensation become unstable. In order to keep a good performance, we developed a suitable compensation patterns which suppress the coalescence.

Precise adjustment of print heads

Precise adjustment are a very important subject for suppressing the streaks and the bandings. Such imaging issues are not solved without fine adjustment even any image correction method is applied.

Skew adjustment of the print head is one of the most important adjustment processes. If the adjustment is not good enough, droplets from the nozzles cannot be placed at right position and various parameters such as coverage, gloss value, hue, and other performances such as the streak, can be varied. Some results are shown in Figure 7.

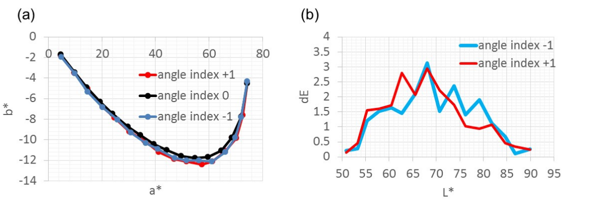

Figure 7. *(a) indicates a* and b* variations between 0% to 100% dot coverage of magenta ink under different skew angles. (b) shows a relationship of L* (lightness) and dE (delta-E; color difference). Color difference at angle index +1 and -1 were calculated between angle index 0 and each angle index.*

Image coverage and density of a printed sample was different depending on the head skew even single color was used. We found that the extent of the deposited ink drops, dot size, was affected by the head skew, and could result different optical dot gain. We developed a fine angle adjustment method and introduced to KM-1 for realizing the same color between adjacent heads accordingly.

Shading Correction

In terms of a density correction for inkjet, there are two ways of correction, changing sizes and changing numbers of dots.

Gloss of an image depends on a percentage of dots. Figure 8 illustrates of the relationship between the dot coverage percent and the gloss value. The gloss is sensitive to the dot coverage and changes dramatically with deviation of it. Therefore it is preferable to correct the density not by changing the dot coverage by the dot size to keep the gloss.

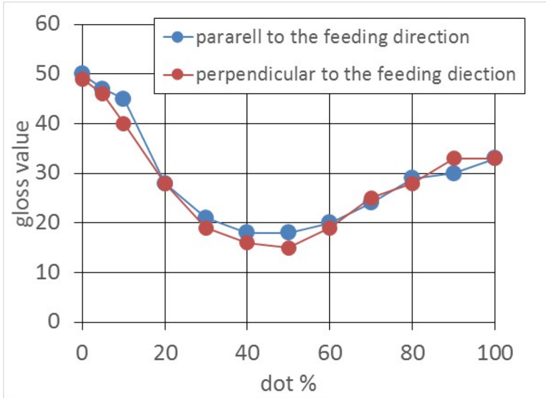

Figure 8. *60° Gloss value dependence of dot % on a coated paper.*

A voltage that drives the piezo element of the print head is one of the parameter to change the ink-drop size and the dot size accordingly. Each print head has a unique sensitivity to the voltage. Each print head may not yield the same size of the ink drops and the dot with the same voltage. It may cause the density variation in heads, "inter-head banding."

To compensate the sensitivity variation of the driving voltage and the "inter-head banding," we introduced an in-line detection/compensation system. It measures density of printed dots for each print head and adjusts the driving volume to get the same dot sizes and density on the fly.

We succeeded to suppress the "inter-head banding" by applying the system, however, there was a density deviation in one head unsolved. Such deviation, "intra-head handing," was caused by ink drop-size deviation and jetting angle deviation. In this case, we found that the unevenness depended on a density level. We developed a two-dimensional look up table (i.e. nozzle positions vs. density level), and adopted to KM-1 to suppress the "intra-head banding."

Streak detection chart

The jetting conditions and parameters may change during printing, and we tried to improve the imaging issues on the fly as we reported above. To detect the variation over time, we developed a streak detection chart and added it at the end of every sheet. It is simple but we can apply to any kind of correction such as nozzle stitching, shading, nozzle compensation, and so on, for avoiding detection failure. The system prints another chart for nozzle missing when it detects the streaks and feeds the information back to the compensation system.

Conclusion

We have developed image correction systems for achieving offset like image quality. Main points were to understand a behavior of printed dots on the substrate for suppressing unwanted defects.

We continue to improve the technologies reported here and to make effort to shift the market from analogue to digital by the newly developed UV-curable inkjet technology.

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Author Biography

Toshiyuki Mizutani received his MSc. Degree in 2003 from Tokyo university of Science. He joined Konica Corporation in 2003. He belongs to the R&D Division, Inkjet Business Unit, and engages in the development of inkjet systems.