A New Water-based Inkjet Ink for Plain Paper Printing

Hirotaka Iijima, Atsushi Tomotake, and Yasuhiko Kawashima; 1st R&D Group, R&D Division, Konica Minolta IJ Technologies, Inc.; #1 Sakura-machi, Hino-shi, Tokyo 191-8511, Japan

Abstract

Offices have recently seen an increase of inkjet printing on plain paper. Two types of ink have been used for this printing: water-based ink and oil-based ink. However, there is a trade-off between the two. Although water-based ink offers sharp images, it also results in significant curling of plain paper after printing. Conversely, although oil-based ink allows curl to be suppressed, it results in poor image quality with low density. By carefully controlling the ink's absorption into and penetration of plain paper, we developed a new ink that achieves both image quality and curl suppression.

Introduction

Because of such features as low printer and running costs and a wide range of compatible recording media, inkjet printing has expanded in both consumer and commercial markets. Ideal ink properties vary with the print media used, so there have been developed a variety of inks such as water-based inks, oil-based inks, UV inks, solvent-based inks, hot-melt inks, and others. Of these, water-based and oil-based inks are typical of those used in offices and in light production with non-coated, plain paper.

Unfortunately, water-based and oil-based inks each have their drawbacks. Water-based ink offers safe materials, sharp images, and high optical density with low print-through, but when used with plain paper, the paper curls unacceptably after printing. Conversely, oil-based inks allow suppression of paper curl, but at the cost of poor image quality with low density and high print-through.

Especially with two-sided office printing, what has been needed is an ink with the strengths of both types of ink and the limitations of neither. By focusing our attention on ink absorption and paper penetration, we developed an inkjet ink that provides safety, sharp images, low print-through, and low curling with plain paper.

Experimental

Printing

Commercially available water-based inks, oil-based inks, and our newly developed ink were used with a commercially available line aligned inkjet printer (Epson PX-V600 printer) to print on plain paper (Konica Minolta J Paper).

Evaluation of curling

Solid images were printed with the above three inks at 23oC, 55%RH on A4 size plain paper, and the prints were maintained in that environment for seven days. Curling was then measured at the four corners of the paper.

Evaluation of optical density

The optical densities of both sides of each print were measured in Status A condition.

Results

We first examined the water-based and oil-based inks for their curling and print-through properties. In Fig. 1, print-through is indicated on the horizontal axis as the optical density ratio of the back versus the front of the paper, where the greater the value the greater the print-through. Curl is indicated on the vertical axis, where the greater the value, the greater the curl. The water-based inks, A, B, and C, gave minimal print-through but showed excessive curling. In contrast, the oil-based inks, a and b, resulted in no curling, but they exhibited a high degree of print-through. Because of this trade-off, none of the inks displayed acceptable performance.

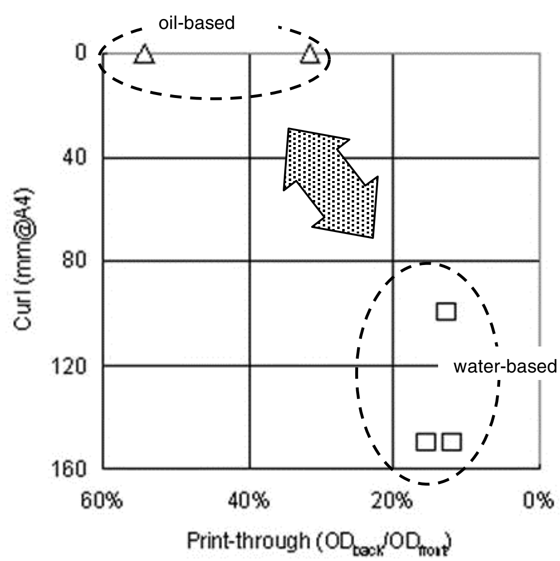


Figure 1. Print-through and curl levels of water- and oil-based ink

We then compared the curling and print-through properties of our new ink with those of the water-based and oil-based inks. Fig. 2 shows that the new, "non-curl" ink suppressed curling on par with the oil-based inks. In Fig. 3, the coupling of high optical density on the front of a print with low optical density on its back indicates minimized print-through. Here the results show that the new ink was comparable in print-through performance to the water-based inks.

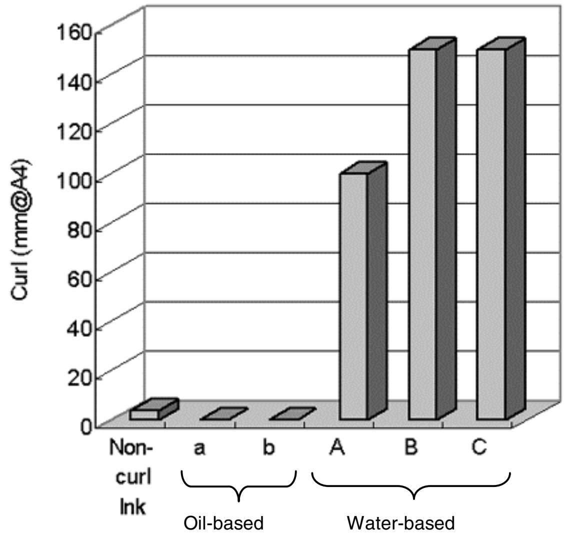


Figure 2. Curl levels of water-based, oil-based, and the new ink.

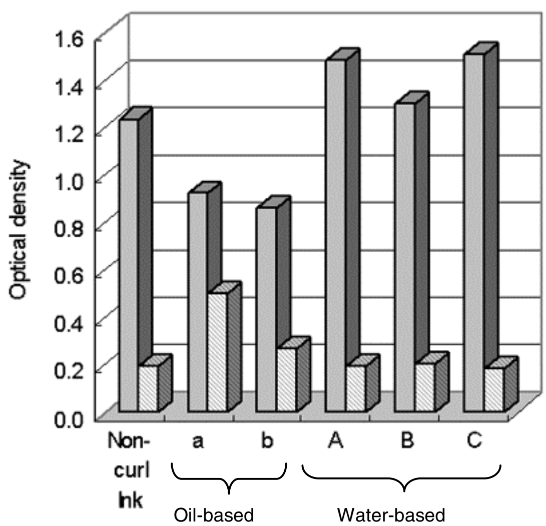


Figure 3. Optical density of the front ( ) and back ( ) of a print by water-based, oil-based, and the new ink.

The enlarged images in Fig. 4 compare text printed with the water-based ink, the oil-based ink, and the new ink. The water-based ink produced sharp, very dark text. In contrast, the oil-based ink obtained characters with blurred edges and which were much lighter. The new ink produced text whose sharpness and darkness were comparable to those of the water-based ink.

Fig. 5 shows cross-sectional images of prints printed with the water-based ink, the oil-based ink, and the new ink. Where the oil-based ink penetrated nearly to the back of the paper, the water-based ink and the new ink left their colorants anchored at the near-surface.

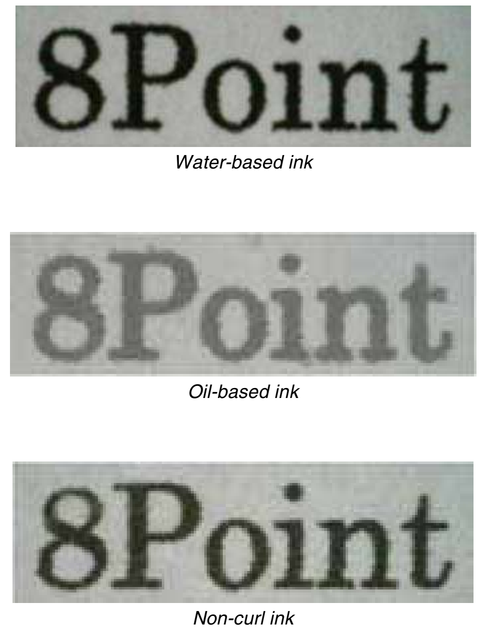


Figure 4. Text images printed by water-based, oil-based, and the new ink.

Discussion

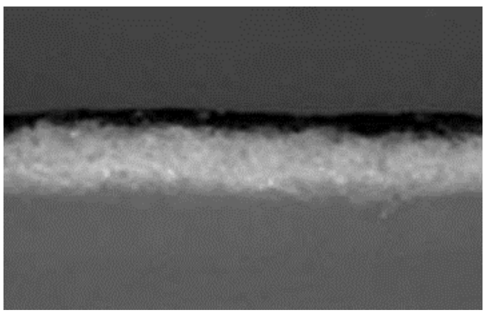
To suppress curling here, we studied its mechanism. Water and water-miscible organic solvents, which constitute water-based ink, are known to be absorbed by the hydrophilic cellulose fiber of paper media.[1] The absorbed water and water-miscible organic solvents disrupt the hydrogen-bonding between cellulose polymer chains that constitute the cellulose fibers. This causes the fibers to swell. The swollen fibers cannot hold their original shape, and accordingly the papers curls.[2] In contrast, because of the hydrophilicity of the cellulose fiber, the fiber absorbs nearly none of the hydrophobic oil-based ink, so the fibers retain their shape, and accordingly curling does not occur.

The same mechanism explains the observed print-through and blurring that were observed. The water-based ink is absorbed by the near-surface cellulose fiber so that the colorants are fixed at the surface. This leads to the high optical density of the prints. In contrast, the oil-based ink interacts very little with the cellulose fiber; instead, it penetrates the interspaces of the fibers. Because of vertical penetration, the colorants are carried into the central layers, and optical density is accordingly low. Because of horizontal penetration, the colorants broaden the images and blur their edges.

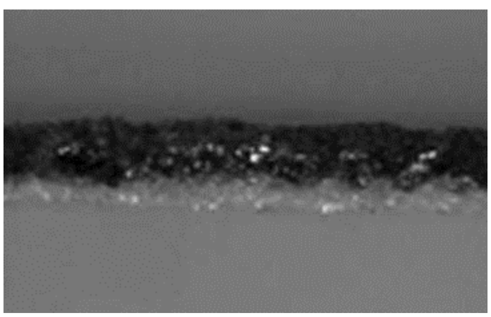
With this mechanism in mind, we made a thorough investigation of water and solvent behavior. Our aim was to attain minimal curling, high optical density on the paper's front, low optical density on the paper's back, and sharp text images.

We began by reducing the amount of water in the ink. As mentioned above, the paper's hydrophilicity can affect both the absorption of the ink by the cellulose and the interlayer penetration by the ink. In attempting to decrease absorption by changing the water content, we found that there was an optimal point of balance between absorption and penetration.

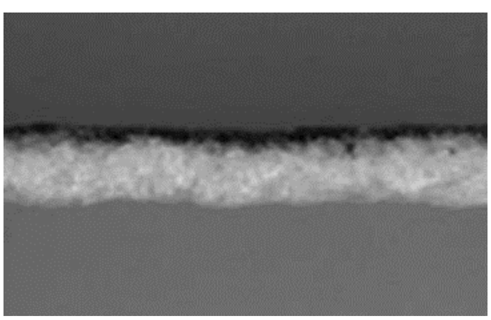
Simply decreasing the water content, however, could not satisfy all performance demands. We therefore investigated the effects of a wide variety of solvents on print-through and curl, and we discovered unique solvents that, in combination with water, raised performance. We also discovered that these solvents increased decap, or open time, i.e. the time the print-head can idle without leading to problems when printing starts up again. The longer open time reduces the need for print-head maintenance, which is a serious matter with printers that have line aligned print-heads, such as the printer used in our study.



Water-based ink



Oil-based ink



Non-curl ink

Figure 5. Cross-sections of water-based, oil-based, and the new ink.

Conclusion

Our objective was to develop a new ink that offered sharp text images and high optical density with two-sided printing on plain paper without curling. The absorption of the ink by the paper's cellulose fibers and the interlayer penetration of the paper by the ink were found to control image quality and curling. With the reduction of water content and the discovery of unique solvents, we developed a new inkjet ink that provides high image quality and minimal curling in addition to longer open time.

References

[1] Toshiharu Enomae, Fumihiko Onabe, Masato Usuda, Japan Tappi J. (Kamipa Gikyo-shi), 44, 811 (1990).

[2] Toshiharu Enomae, Fumihiko Onabe, Masato Usuda, Japan Tappi J. (Kamipa Gikyo-shi), 45, 285 (1991).

Author Biography

Hirotaka Iijima received his B.S. (1989) and his M.S. (1991), both from Yokohama National University. He joined Konica Corporation in 1991, where he developed digital materials for silver photographic systems. Since 1995, he has focused on the development of inkjet materials.