

High-quality Imaging Technologies for Color Bubble Jet Printers

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Abstract

The image quality of color Bubble Jet Printers has been progressed through various technologies, such as PWM control of the printhead heater current for stabilizing the volume of an ink droplet, optimizing of ink penetration speed and several other contrivances for producing crisp black text images and bleedless color images, and multi-pass printing for eliminating banding. Besides these improvements on the printers, newly developed print media have contributed to provide higher image quality and also widened the variety of printing including fabric sheets.

For further improvement of the quality of color images, "photographic grade," some solutions are the higher resolution and multi-level printing. The above mentioned technologies are also effective in these improvements.

Introduction

Recently, multimedia including CD-ROM or Internet has become popular worldwide and the trend is continuing. Printers, as the output device for these multimedia, also increased since major printer manufacturers lined up color printers at reasonable prices from 1993 to 1994.

Color inkjet printers has various advantages such as small-size, fast print speed, low initial and running cost, capability of plain paper printing and low print noise compared with other technology-based printers. Moreover, color inkjet printers have become to be able to print much better quality image than before.

In this paper, as the representative of ink jet printers, the author chose color Bubble Jet Printers, ink jet printers developed by Canon Inc., and discusses its high-quality imaging technologies.

Printhead Control Technology

The Bubble Jet Printers eject ink droplets from printhead nozzles by the force of vaporized bubbles heated inside the nozzles, as shown in Figure 1.

There are several keys to obtaining high quality image using this printing method. It is essential to ensure the dot placement accuracy on the print medium; insufficient dot placement accuracy cause jaggies in a printed line or unevenness in printed colors. Also, to stabilize the volume per ink droplet; fluctuation of the volume deteriorates the density uniformity on the print medium. The Bubble Jet Printers adopts a unique measure for this purpose.

Generally, as the temperature of the ink rises, its viscous resistance decreases and consequently the volume per ink droplet increases. The Bubble Jet Printers are equipped with an environmental temperature sensor and an inner head temperature sensor. Both serve to stabilize the ink droplet volume by controlling the pulse waveform for printhead heaters. The pulse waveform basically consists of double pulses, i.e., prepulse and main pulse, as shown in Figure 2. Their pulse widths do not vary while the time interval between them varies as the printhead temperature changes. By controlling the time interval during which the heat generated by a prepulse is transferred to the ink, the printer produces a fixed amount of ink droplet from the nozzle without changing the energy applied to the printhead.

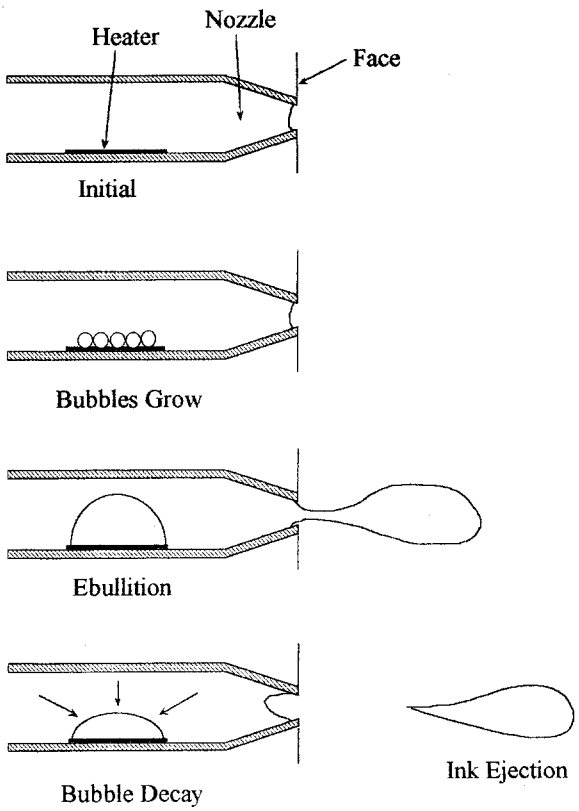

Figure 1. Ink Ejection of Bubble-jet printer

One of basic keys to obtaining high quality image is high print resolution; in other words, to put more dots into an unit area on the print medium. The print resolution of ink jet printers has increased dramatically; it was 300-360 dpi (dot per inch), but now some of the ink jet printers have

doubled the resolution (600 - 720 dpi), such as BJC-610 manufactured by Canon Inc. Another key is multi-level printing, i.e., the method in which the printhead shoots multiple dots to the same position on the print medium.

For both high print resolution printing and multi-level printing, the number of dots per unit area is not proportioned to print density, so some considerations are requested for halftoning. One more problem is placing more dots on an unit area of the print medium requires reduction of the volume per ink droplet. The reason is the amount of ink the unit area can absorb is limited. The volume reduction itself is not very difficult, for it is just a matter of the design of printhead nozzles and heaters. However, there are secondary problems which require higher dot placement accuracy and frequency of ink ejection. The above-mentioned double pulse method helps solve these problems.

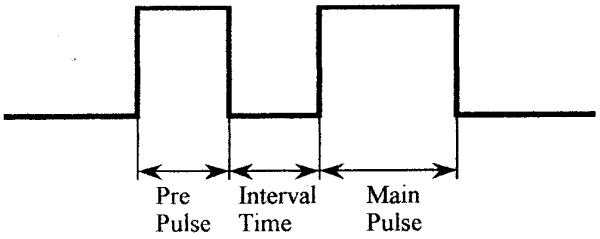

Figure 2. Double Pulse Wave Form

Ink

The main characteristic of ink that affects image quality is its penetration speed into the print medium. Generally, slow penetration ink stays on the surface of the print medium. Therefore, it shows high density printed image and little blots around mono-color part ("feathering"). Thus, it is very suitable for black crisp image like characters. However, it causes rather large blots around the border between different colors ("bleeding") and it takes somewhat long time to get dry. On the contrary, fast penetration ink has less bleeding and more feathering. (See Figure 3)

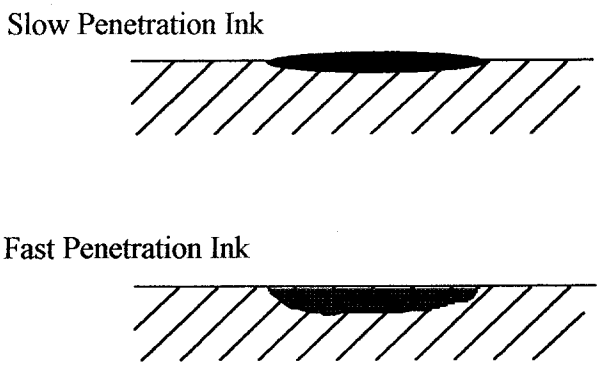

Figure 3. Ink Penetration on Paper Surface

Canon Bubble Jet Printers in the "BJC-600" Series manufactured by Canon Inc. adopt fast penetrating and vivid color QS ("Quick Set") ink. They are equipped with nozzles which are positioned in four parallel rows of black, cyan, magenta, and yellow so it can print high-speed bleedless color images. On the other hand, Bubble Jet Printers "BJC-4000" Series, also manufactured by Canon Inc., not only use QS ink for CMY colors, but also HS ("High Solid") ink for black to improve black text print quality. HS ink is rather slow penetrating and water fast. In order to print with both QS and HS inks simultaneously, the following two methods are introduced:

(1) Time lag printing by vertically aligned nozzles of color printhead

Black, cyan, magenta, and yellow nozzles of the Color BJ (Bubble Jet) Cartridge BC-21, used with the BJC-4000, are aligned vertically in the stated order, as shown in Figure 4. For black monochrome print, all the 64 nozzles for black are used to print at high speed. For color print, however, only the top 24 black nozzles, far from the color nozzles, are used to print black, which produces a slight time lag between black and color ink ejection onto the print medium. This interval allows the black ink droplets to be placed first to dry enough to prevent bleeding before the color ink droplets are placed. This method reduces bleeding drastically.

(2) Composite black transformation at boundaries between different colors

In order to reduce further bleeding, the BJC-4000 is capable of determining boundaries between a black and color area from image data. Part of the black area which touches the color area is processed as composite black, which consists of black and color dots.

Printing Process Control

Even though these technologies help very well increase printed image quality, errors in the nozzle dimensions can cause uneven printed image and inaccurate paper advancing can produce banding. As countermeasures against these problems, the Color Bubble Jet Printers uses multi-pass printing. Multi-pass printing divides image data into multiple image layers using masks with given dot patterns and integrate them into the complete image by printing through different print passes.

In multi-pass printing, the more image layers decreases the unevenness in printed image but result in longer printing time. To minimize the longer printing time, in the high quality print mode of the BJC-600, multi-pass printing is performed by bi-directional printing. However, this remedial method may cause unevenness in the printed colors between two print directions because a color that is placed first onto the print medium dominates the other colors placed later. Therefore, mask patterns are optimized so that colors of dots with different placement order are distributed

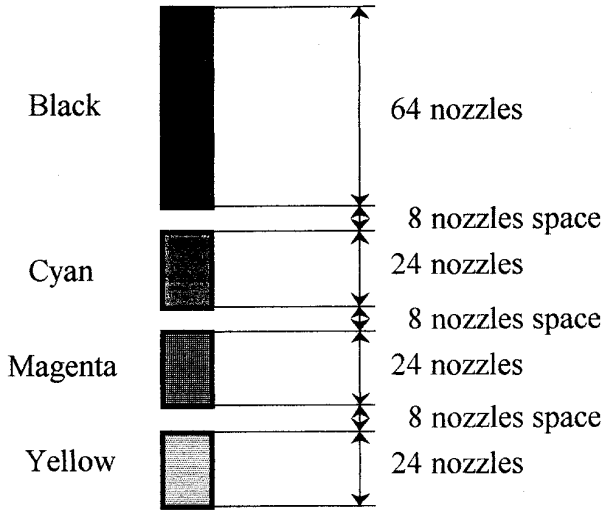

Figure 4. BC21 (Color Head for BJC-4000) Nozzle Layout

over layers as equally as possible. On the other hand, the BJC-4000, which performs only uni-directional printing, adopts masks whose patterns are randomized to obtain the best results in multi-pass printing.

Print Media

Many of the above mentioned technologies about Bubble Jet Printers are related to print on plain paper. Some newly developed print media solve part of the problems described above without these technologies. For example, specially coated paper does not cause feathering even with fast penetration ink because the coated surface allows the ink to stay only on the surface. Such new print media have contributed not only to improvement in image quality (e.g., glossy paper and high gloss film), but also to widen the variety of printing (e.g., fabric sheets).

In Future

Beside these hardware approaches to high image quality, software approaches are also effective. For example, the optimization of color processing is essential to obtain vivid color image; especially, treatment of black, i.e., optimization of parameters for under color removal and black generation, drastically reduces picture granularity. With the help of such new image processing method, above mentioned higher resolution and/or multi-level printing, Bubble Jet Printers will achieve further improvements in quality of color images soon, i.e., “photographic grade”.