New Bubble Jet Head Technologies Used in Canon Color Bubble Jet Printer BJC-70

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Abstract

Compact printer has been required by personal system computer users. And size of printing device is an important matter for down-sizing. We have developed new bubble jet devices named 'BC-10, BC-11' and separated ink cartridges 'BCI-10, BCI-11 black and color'. Bubble jet printing system is suitable for small sized design because of it's accumulated structure. We minimized size of new devices by looking over each size of parts. And we constructed new automated assembly lines which can assemble various parts precisely at high speed.

Introduction

The principle of new ink jet technology, named 'Bubble Jet Technology' afterward, is found by Conon Research Center in the later 1970's.[1] At that time, we had been surveying new technology suitable for high speed color printing. One day, a researture found a phenomenon that the boiling pressure in a narrow tube causes the ink ejection, using a needle and a soldering copper. From then, we have been investigating practical application of this phenomenon. In 1982, we published 'Bubble Jet Technology' for the first time.[2]

Our first product is saled in 1986, named 'BJ-80', loaded with print head having 24 nozzels in 180dpi density. This print head is non-exchangeable, so-called 'permanent head' and exchangeable separated ink tank is connected to that head. This type of permanent head is developed and applied for 'BJ-130' having 48 nozzles in 360dpi density, 'BJ-300/330' having 64 nozzles, 'BJC-800/820' having 4 color heads for business-use printer, and 'BJC-600' for desk-top color printer. Another type of head is exchangeable print head, so-called 'disposable head'. First printer of this type is 'BJ-10' in 1990, and 'BC-01' as a print head cartridge. Next system is 'BJ-200' and print head is 'BC-02'.

Late in 1992, we had been studying new concept concerning desk-top and note-printer. Concurrently, the trial production of 128 nozzles heads had been finished. From these examinations, finally, we set planning to produce 4 sorts of print head cartridges, partially composed of common parts.

Early in 1993, we started to develop 4 new devices, 'BC-20' for monochrome printing 'BC-21' for color printing used for desk-top printer and 'BC-10', 'BC-11' used for compact note-printer. This paper will descrive design of BC-10 and BC-11, especially about key technologies of these devices and down-sizing.

Specifications of 2 Devices

At the biginning of this project, specifications of these new devices, shown in Table 1, were set up. BC-11 has 64 orifices and nozzles for the black printing, and 24X3 orifices and nozzles for the color printing aligned in a same line. BC-10 has 128 orifices and nozzles for monochrome printing, therefore it can print 2 lines of characters simultaneously. The target of ink refilling time in channel for each ejection was fixed at 100us. From these matters, muximum printing speed becomes 555c.p.s.. However this printing speed is determined from efficiency of printing head, mainly the refilling time and also design of printer. In the case of BJC-70, to reduse the power of carriage moter for cost-down, the carriage speed was fixed at 0.44m/sec. Therefore head driving frequency is 6.25kHz at BJC-70.

Shrinking size causes decrease of the ink amount. At first, we set a value, 30 or 40sheets, as a smallest volume of printing sheets from 1 ink cartridge. And this is the typical value of printing sheets in a month for note-printer users, on inquiry. This number of printing sheets decide volume of BCI-11 (Ink cartridge for BC-11), and the height of this head is fixed on the length of BJ-chip including heater-bord, nozzle-plate and base-plate. For Shrinking size, especially the height of this printer BJC-70, length of BJ-chip is minimized at the value of 21mm determined by base-plate length mainly. From this length, height of this head is fixed. This height and the Ink amount of ink cartridge BCI-11 determine depth and width of print head BC-11. BC-10 is designed at the same size of BC-11. And ink amount of BCI-10 (Ink cartridge for BC-10) is determined from this size. The number of printing sheets of BCI-10 becomes 170 sheets.

Besides, BJ-chip of BC-10 is same parts of BC-20, used by BJC-4000 desk-top printer. And also BJ-chip of BC-11 is same parts of BC-21.

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Table 1. Specifications of BC-10 and BC-11.

	BC-10	BC-11
The Number of Nozzles	128	Bk; 64, Color; 24×3
Printed Dot Centers	0.00278”	0.00278”
Response Time	100(~160)us	160us
Volume of Drop(Vd)	85ng	Bk; 75ng, Color; 40ng
Size(mm)	40D×45W×25.8H	40D×45W×25.8H
Ink Weight	9.5g	Bk; 2.9g, Color 2.3g×3
The Number of Printing sheets (by 1ink-cartridge)	170 (1500characters /sheet)	Bk; 40 (1500char./sheet) Color;35(7.5%/sheet)
Head Life	3000 sheets (typ.)	2000 sheets (typ.)

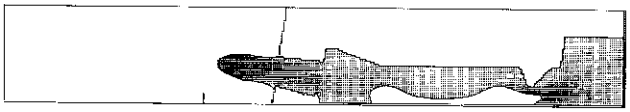
Channel Fluid Dynamics

Response Time

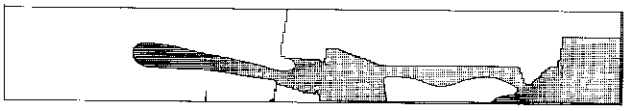
Nozzle and channel structure, and the drop formation figured by computer simulation are shown in Figure 1. Figure 1(A) shows a state after 5us from the heater was fired, (B) shows a state of 15us, and (C) shows a state of 22us. In this figure, the volume of drop is 85ng, and it indicates the cross section through the center of the channel about BC-10. Target of response time which is time from firing heater pulse to ink refilling in the channel was fixed at 100us. To approach this problem, some dimensions are investigated. From development of the past products, it was known that mainly length, height and width of channel and shape of the projection located above the heater have influence on the response time. By using 3D fluid flow calculations, the above-mentioned each dimension was fixed. For shortening the response time, the length of channel was redused to 300um. Decrease of fluid resistance in a channel causes meniscus (air and ink interface) vibration after refilling ink in the chanell, together with shortening the response time. And meniscus vibration causes instability of drop formation originated from adhered ink around orifices. The projection in the channel has a function to reduce the meniscus vibration, resulted from redusing ink flow to the chamber connected with the plural channels in the time when the vapor bubble on the heater is extending. Therefore the shape (height from upper side in the channel) of this projection is formed as high as possible less than the height of obstruction to refill ink in the channel. From these factors, nozzle and channel structure of BC-10 is characterized by being short length and having a high projection.

Figure 2 shows a frequency peculiarity of BC-10, the relationship between the driving frequency and the speed of drop (Sd), and also between the driving frequency and the volume of drop (Vd). The variation of Sd and Vd up to 10kHz is permissible to practical use, and then Sd becomes faster, Vd is on the decrease over 10kHz. Over 10kHz the instability of drop formation deteriorates dignity of printed matter.

(A) 5us after heater fire.



(B) 15us after heater fire.



(C) 22us after heater fire.

Figure 1. Channel Cross Section Showing Drop formation about BC-10

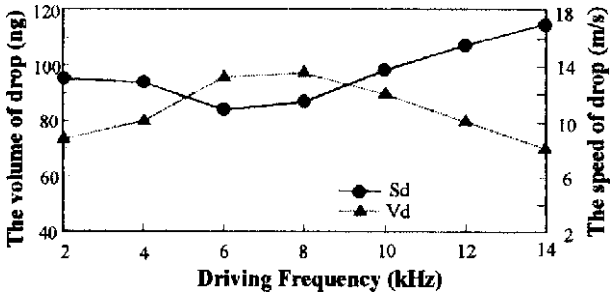


Figure 2. The Relationship between Driving Frequency and the Speed of Drop (Sd), the Volume of Drop (Vd)

Redusing Satelite Dots

Second subject at the high speed printing is redusing the satelite dots (small dots adhered nearby main dot) at printed matter. This is occured from the tail of the drop having different ejecting direction from the tip of the drop. Accordingly, tip and tail of the drop must be in the

same ejecting direction and this is achieved by adjusting the angle between orifice center and channel center. Figure 3 shows the drop formation, figured by using 3D fluid flow calculations in the case of enlarging the above-mentioned angle. In this case, the angle is set at 14degrees, and it shows a state 22us after the heater fire. In comparison with Figure 1(C), it was known that tail of drop is pulled toward downward.

This phenomenon is confirmed by experimental work. Figure 4 shows a relationship the angle between orifice and channel center versus the distance between main dot and satelite dot on the printed matter. At the point of 10 degrees, the tail of the drop follows the tip-drop at same ejecting direction, therefore the distance between main and satelite dot on the printed matter become shortest at both printing directions (forward and reverse scanning direction of head). From this experimental result, the angle between orifice and channel center was fixed at 10 degrees.

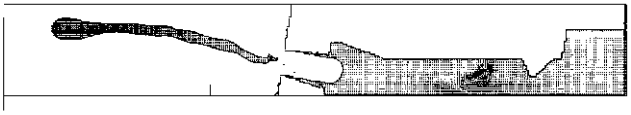


Figure 3. Drop formation in the Case of the Angle between Orifice and Channel Center is set at 14 degrees

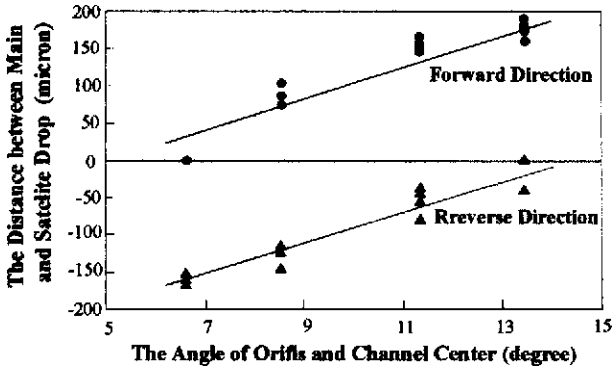
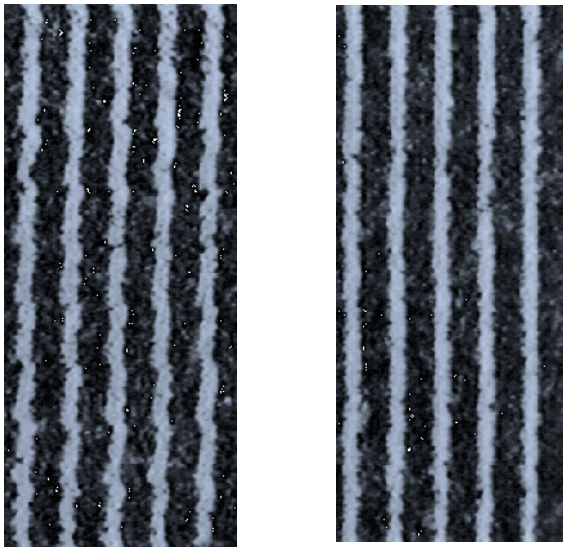


Figure 4. The Relationship Angle between orifice and channel center versus Distance between main and satelite dot on a printed matter.

Drive System

The pressure from vapor bubble in the channel has influence on the drop formation in the neighboring channel. From this pressure, the ink-flow to the neighboring channel at it's refilling time is obstructed, and this action causes instability of the drop formation. So we chose new drive system that the adjacent heaters are not drived simultaneously. In the case of BC-10, the following will explain this drive system.

Plurel heaters (128 heaters) are divided into some blocks (8 blocks) which include some adjoining heaters (16 adjoining heaters). At first, the ends of heaters in each block are fired simultaneously. Next time, neighboring heaters in each block are fired 6.25us later (In the case of driving frequency 'fop' is 10kHz. If fop is 6.25kHz, fired time becomes 10us later.). From the repetition of this action, 16 heaters in a block are fired in order. The row of orifices is inclined 3.6 degrees (=$\tan^{-1}$ 1/16) toward scanning direction. Therefore ejected drops from adjoining 2 heaters in the different blocks form a line at the printed matter. Figure 5 shows 2 pattern of lines printed by above-mentioned means and the former means (Plurel heaters in a block are fired simultaneously, and neighboring blocks are fired in order). It was known that this driving means is better than the former means in the quality of printed matter.



(A) (B)

Figure 5. The Quality of Printed Matter, (A);Driving Means by BC-10, (B);Former Means.

Compact Composition

Figure 6 shows the key parts of BC-11. Heater-board, base-plate and P.W.B. (Printed Wired Board) are shown. Size of heater-bord is 13.8×4.5mm (At BC-10, the heater-board size is 10.5×2.35mm). In this chip, there are 64 heaters forming vapor bubbles for monochrome printing and 24×3 heaters for color printing, transistors array for firing each heater, shift registers and latches used to drive each transistor, and 28 terminals connected with P.W.B. For cost-down mainly, it is constituted as small as possible. In nozzle-plate (invisible in this figure), there are 136 (=64+24×3) channels and orifices and 4 chambers, and these channels are connected with chambers of each color. Base-plate has a function to assemble heater-board, nozzle-plate, and P.W.B. Heater-board and P.W.B. are adhered on the base-plate, and nozzle-plate is fixed by a spring on the heater-board. As mentioned above, the length of base-plate almost determines the height of these devices which has a big influence on down-sizing of this printer. So, this is designed at a minimum length which can place heater-board and P.W.B.. Furthermore, the area of P.W.B. is designed at a minimum size which can contact securely with 28 terminals constituted in the carriage.

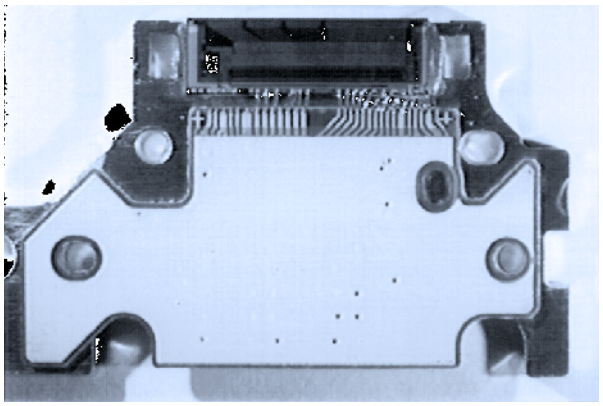


Figure 6. The key parts of BC-11

Manufacturing

For manufacturing BC-10 and BC-11, we made new automated assembly lines. In this assembly lines, above mentioned key-parts, heater-board nozzle-plate and baseplate, are constructed together by precise location using optical technology. Then, a spring is installed in a base-plate, fixing a nozzle-plate on a heater-board. And then, ink-cartridges, a ink-cartridge-holder including filters, and a ink-passage-part connected with a nozzle-plate, are constructed together, precisely at high speed. Finally, assembled devices print some images on the paper and artificial eyes judge the quarity of printed image on the many kinds of quality standard.

Conclusion

The channel shape suitable for high frequency driving, the angle of the orifice redusing satelite dots on the printed matter, new drive system for improving the printing quality, and the design of minimum size (especially the height) are developed for BC-10 and BC-11. And these technologies except the minimum size are applied to BC-20 and BC-21, used by BJC-4000 desk-top printer. The present subject about BC-10 and BC-11 is to achieve the large number of production.

The next step of these devices will be further improvement of the printing quality.

References

1. U.S.Pat. 4,723,129 (1988).
2. Hara, T, and I. Endo: "Bubble Jet Recording." *Gazo Denshi Gakkaishi (J. Inst. Image Electron. Eng. Jpn.)* **11**:66-71 (1882) [in Japanese].