

A New Compact High Resolution Solid Ink Print Head and its Application to a Plate Making Printer

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Abstract

A new ink jet printhead of the push mode type has been developed for use with solid ink and applied to a direct plate-making printer, Model SJ02A, for the offset press. Stack piezoelectric transducers (PZT), that displace in the direction of polarization, permit jetting of solid ink at frequencies in excess of 20 kHz. Standard dot density is 600 dpi. Drop size is modulated, by driving the transducers in a multi-pulse mode. A press plate is constructed by jetting hydrophobic solid ink from the printhead onto the hydrophilic plate. The plate is used directly on the offset press. Advantages of this printing system are the elimination of the developing process, and allowing use of various plate materials, such as, paper based plate, film plate, and aluminum based plate. The printhead can also be used to successfully jet liquid ink of viscosity in the range 5 - 20 cP, and thus can be applied to industrial printers in general.

Introduction

Various types of ink jet printheads have been produced and supplied to a variety of markets[1]. In 1992, Dataproducts introduced the JOLT desktop color printer, a unit that prints solid ink at a resolution of 300 dpi. Recently, we have developed a new solid ink printhead, JOLT2. Based on the pusher type of design of the original JOLT printhead[2], the new JOLT2 printhead is packaged in a more compact configuration and uses stack PZT. As a result, the resolution and operating frequency of the JOLT2 printhead are much higher. Since solid ink is hydrophobic and can be used to print on almost any media, the JOLT2 printhead is ideally applied to the direct plate-making printer. This paper describes the characteristics of the JOLT2 printhead and the outline of the SJ02A printer.

JOLT2 Printhead

Specifications and Structure

Table 1 shows the specifications of the JOLT2 printhead. The dot density is twice that of JOLT. The multi-nozzle arrangement of 384 jets and the high frequency drive enable printing at a high speed.

Table 1. Main specifications of JOLT2 printhead

Item	Specs
Dot density	600 dot / inch
Nozzle number	384
Nozzle arrangement	12 rows x 32 nozzles/row
Drive frequency	- 20 kHz
Drop speed	- 13 m/s
Ink viscosity	11 cP (solid ink)

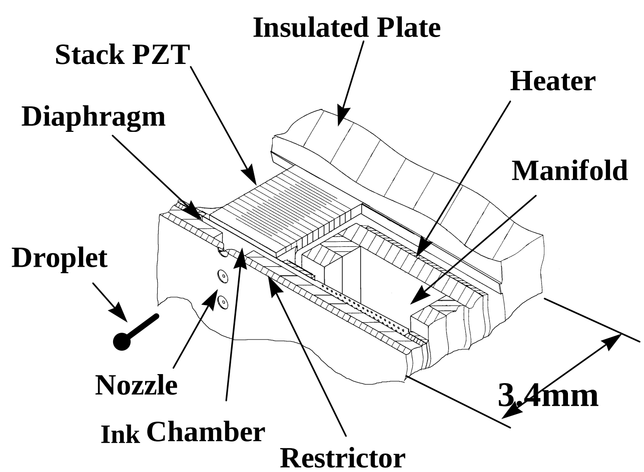

Figure 1. Structure of Printhead

Figure 1 shows the structure of the printhead. Nozzle components include a diced stack PZT, a diaphragm, a restrictor, an ink chamber, and an orifice. One end of the PZT is bonded to a fixed substrate and the other end is bonded to a flexible diaphragm adjacent to the ink chamber. A heater is supplied for melting the ink in a common ink supply manifold. The restrictor limits the amount of ink that flows into the chamber from the manifold. The ink is absorbed into the ink chamber, pressurized and ejected in the form of droplets from the orifice.

Characteristics of the printhead are as follows: All components of the printhead that come in direct contact with the ink are made of stainless steel except for the orifice, which is of nickel. Owing to the side by side placement of stack PZT and the manifold, the thickness of the printhead is small, only about 3 mm.

Actuation of Firing Droplet

First of all, the solid ink is heated at 130 degree C, and the phase of ink changes from solid to liquid. According to the capillary phenomenon, the melted ink flows into the ink chamber from the manifold after passing through the filter and the restrictor.

The expansion and contraction of the PZT fires ink droplets. When a positive potential is impressed to the signal-input terminal, the PZT becomes extended, and when the potential difference is removed, the PZT contracts and returns to the former state.

Ink is compressed in the ink chamber by the expansion of the PZT and is absorbed from the manifold into the ink chamber by the contraction of the PZT.

The voltage and pulse width impressed to the PZT electrodes controls the velocity and volume of a droplet. Drop velocity refers to the head speed. However, tail speed is not variable, being about 5 m/s, regardless of the head speed.

Drop shapes are as follows: If drop velocity is about 5 m/s, the droplet is spherical. On the other hand, if the head speed quickens more than the tail speed, the head is round and the tail part is like the string.

Method of Selecting Drive Pulse Width

The authors drove the printhead using a waveform of rectangular shape. The drive pulse width was selected by the following method[3]. Figure 2 shows the variation of drop velocity ratio with the pulse width, at three different frequencies. Drive voltage of each pulse width was the value needed to obtain a drop velocity of 13 m/s at 2kHz. The voltage was not changed even though drive frequency was changed.

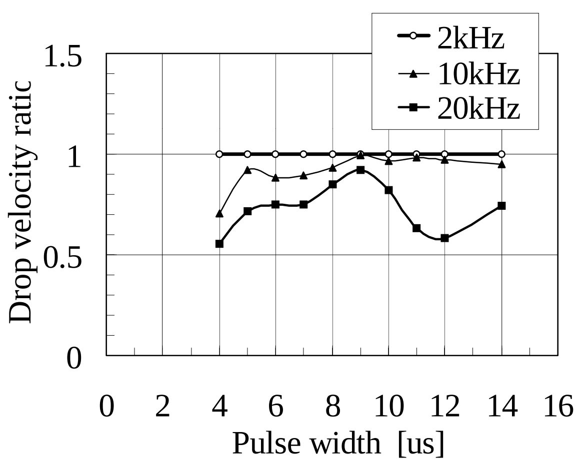

Figure 2. Pulse width vs. Drop velocity ratio at drive frequency of 2, 10, 20kHz . Drop velocity ratio is given by measurement value divided by 13m/s. Drive voltage of each pulse is constant at 2kHz.

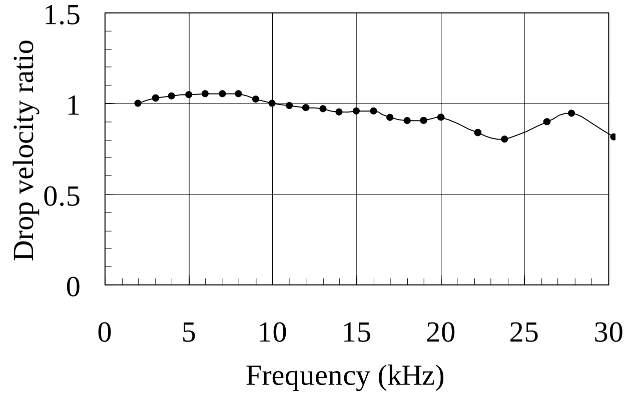

Figure 3. Drive frequency vs. Drop velocity ratio . Drop velocity ratio is given by measurement value divided by 13m/s. Drive voltage is constant at 2kHz.

Drop velocity variation would cause dot placement error on the media. The more the variation in the drop velocity, the poorer the print quality. And, the smallest possible variation in drop velocity would be most desirable. Thus the pulse width of 9 us will be chosen from Figure 2. According to our experiment, when the pulse width was extended or drop velocity was increased, the drop volume tended to increase. As a result, dot size increased. Hence, it is significant to select an appropriate pulse width and drop velocity to obtain a required dot size. We use 9 us as the drive pulse width in 600 dpi operation. We believe that the frequency dependence seen by the pulse width would relate to the Helmholtz frequency of the ink chamber.

Frequency Characteristic

Figure 3 shows the frequency characteristic of the printhead. In the experiment, the pulse width was 9 us and the voltage was selected to provide a drop velocity of 13 m/s at 2 kHz. A remarkable lack of variation of drop velocity ratio was seen from 2 to 20kHz.

It is possible to fire this printhead at frequencies as high as 20kHz, because the resonant frequency of the PZT and the Helmholtz frequency are high. By using a short length of the PZT of only 2mm and small ink chamber volume, the resonance frequency of the PZT is 360 kHz and the Helmholtz frequency is 90 kHz.

The eigenfrequency (f) of the PZT is given by,

$$f = \frac{1}{4 \cdot L} \sqrt{\frac{1}{\rho \cdot S_{11}^{E}}} \qquad (1)$$

where L is length of PZT, ρ is density of stack PZT material, and S_{11}^{E} is the longitudinal elastic compliance of stack PZT.

Equation 1 shows that the PZT frequency increases with the reduction of the PZT length. Moreover, The Helmholtz frequency (F) given by,

$$F = \frac{1}{2\pi}\sqrt{\frac{L_n + L_i}{(C_c + C_d)\cdot L_n \cdot L_i}} \quad (2)$$

$$C_c = \frac{V}{\rho_i \cdot c^2} \quad (3)$$

where C_c is fluidic compliance due to liquid compressibility, C_d is compliance for transducer, L_n is inertance of orifice, L_i is inertance of restrictor, V is ink chamber volume, ρ_i is ink density, and c is sonic velocity in the liquid.

Equations 2 and 3 show that the Helmholtz frequency is inversely proportional to the square root of the ink chamber volume [4-5], provided $C_c >> C_d$ which is usually the case.

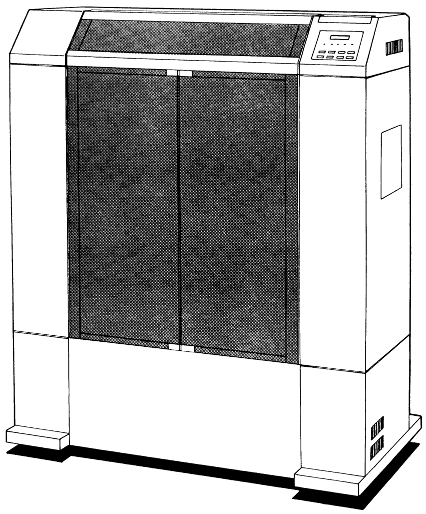

Figure 4. Direct plate making solid ink jet printer SJ02A

Application of Printhead

Direct Plate Making Solid Ink Jet Printer

CTP (Computer to Plate) will be a product which makes the best use of the merit of the solid ink jet of being capable of printing on any media. Figure 4 shows that the appearance of the SJ02A[6]. The SJ02A is composed of the printhead, the fixation part for installing a press plate, X-Y stage for scanning the printhead to form the dot on media, and the controller for reading digital data. The electrostatic adsorption mechanism is used to fix media. The maximum size of media is fixed up to A2 wide. The print speed is selected from two kinds of printing mode: first mode and normal mode. The text of A2 wide is printed in 1.5 minutes at first mode. Printing media are paper based plate, film plate, aluminum based plate, and plain paper. The print color is usually black.

The number of plate wear in paper based plate, film plate, and aluminum based plate is about 5,000, 10,000, and 50,000 sheets, respectively.

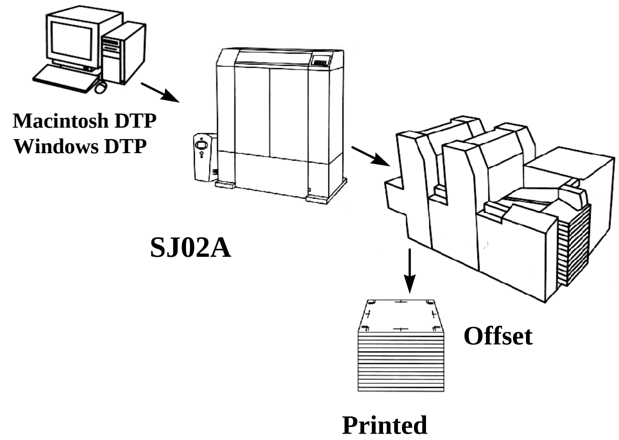

Figure 5. SJ02A direct plate making system

Plate Making Process

Figure 5 shows the plate making process by the SJ02A. The character, the figure, and the image are transferred to the printer as the digital data made by desktop publishing treatment. Afterwards, ink drops are jetted from the print head to a plate. As for ink, it is cooled quickly and hardens on the plate. Hydrophobic solid ink directly forms the character, the figure, and the image on the surface of hydrophilic plate beforehand. The plate is fixed to an offset press without developing. In offset printing, the adhesion part of the solid ink sheds water and the offset ink gets to it.

Feature of Printer

- A complete dry process is achieved.

The printer contributes to environmental protection because a development machine and new drain equipment, etc. are unnecessary.

- Printing material is not selected.

Direct plate making material, such as paper, film, and aluminum can be used. The printer adjusts to various needs.

- High picture quality is made.

A beautiful picture quality is achieved because there is neither putting on nor scattering of the toner generated by the leather beam printer.

- Multipurpose use of the device is achieved.

It is possible to use the SJ02A as a monochrome printer using plain paper.

Summary

A printhead of 384 nozzles of the push mode type has been developed for solid ink. It uses stack PZT that displace in the direction of polarization. A dot density of 600dpi and the high frequency of 20kHz are achieved. The printhead has been applied to the direct plate-making printer for the offset press.

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Biography

Nobuhiro Noto received his B.E. from Hokkaido University, Japan in 1981. He joined Hitachi Koki Co., Ltd. in 1981 and is now a senior engineer of Katsuta Research Laboratory.