Adaptability of Piezoelectric Inkjet Head

Tomoaki Takahashi
SEIKO EPSON Corporation
Shiojiri, Nagano, Japan

Abstract

In recent years, inkjet printing technology has been applied to various fields, including home and office printers, all the way to large format printers used in the professional arts. Because of the different demands required for each application, we have had to adapt our inkjet technology to a wide array of inks, media, printing speeds, and different droplet sizes. Comparatively, it's easy to develop unique print heads specifically adapted to each application. However it's impractical to produce various types of inkjet heads with respect to print head production. The key is to produce a print head that is adaptable to different applications

To design a print head that is both adaptable and manufacturable at the same time, the use of waveform control must be considered. By employing a waveform control method known as MLP type MACH, we can change the properties of droplets dynamically. Droplet mass can be widely changed while leaving the droplet velocity as same, or droplet velocity can be changed while leaving the droplet mass the same.

This paper is intended to show the characteristics and key technology of the piezoelectric inkjet heads, and their ability to adapt to various applications requiring differing inks and sizes of ink droplets.

Introduction

Today, ink jet printers are used in a majority of offices and homes because of their excellent performance and competitive price. As in the case of other conventional products, ink jet printers have plenty of product lineups, from home printers to office printers, from beginners to professionals, and from small to large size printers. It is common that each lineup offer different features such as printing speed, number of ink colors available, and printer sizes. Each application places different demands on the printer. For instance, the most important thing required in printing documents is speed. On the other hand, the most important thing in printing digital-photos is quality and smoothness, rather than printing speed. In this instance, controlling droplet size is crucial in creating satisfactory digital-photos. In addition, there are many kinds of printing media and inks, each one requiring a different suitable droplet size.

Recently, ink jet technology has spread into other industrial fields. Increasing attention is being placed on ink jet technology to satisfy applications requiring the dispensing of inks and other liquids onto a variety of media.

Although manufacturers of ink jet print heads welcome this new attention, it often seems that each new application requires an entirely new design.

Overview of Applications

Home & Office

Ink jet printers have became so common that new types of inks and media are being developed one after another to improve print image quality and attract customers interest.

Table 1. Applications at Home and Office

Appearance	Application
Conventional Printer / Large Format Printer/ Mobile Printer	Document, Picture, Poster, Proofing, Post Card, CAD, CD-R, T-shirt, etc.
Multi-Function Printer	Copy, Fax, & same as above.
Card Printer	Business card, Tag, etc.
Postmeter	Postage stamp, Logotype

Table 2. Applications at industrial fields

Appearance	Application
Marking printer	Product information on product itself or package: Serial No., Production date, Logotype, etc.
Manufacturing device	Textile, Wall painting, Color filter, Coating, OLED Display, TFT, Soldering, etc.

Industrial Applications

The principle behinds ink jet technology is very simple; the firing of droplets from nozzles at a target. Noting the performance and reliability of conventional ink jet printers, many engineers have sought to apply this technology to other applications that require the dispensing of a wide variety of liquids.

The Piezoelectric Print Head

The piezoelectric inkjet head incorporates a mechanism that transforms piezostriction into a volumetric change in the pressure chamber. This volume change induces an oscillating ink flow that generates droplets from a nozzle orifice. Epson has developed two types of the piezoelectric inkjet heads in terms of the mechanism of the piezo transducer.[1]

MLChips (Multi-Layer Ceramic with Hyper Integrated Piezo Segments) type MACH

To meet the market demand for low-cost and high performance inkjet printers, EPSON developed MLChips MACH (Multi-layer ACtuator Head), in 1995.[2] The principle of the transducer, shown in Figure 1, is similar to the conventional piezo head. The piezo strips are not independently manufactured, but processed and sintered together with the flow channel substrate as a single layered ceramics structure. It is necessary to make both the vibration plates and the piezo laminate thinner to meet the requirement of jetting fine droplets. By taking the approach of unifying the core components of the head without machining and gluing, the MLChips have broken the barrier, allowing higher performance in a smaller package, as compared to conventional piezo heads.

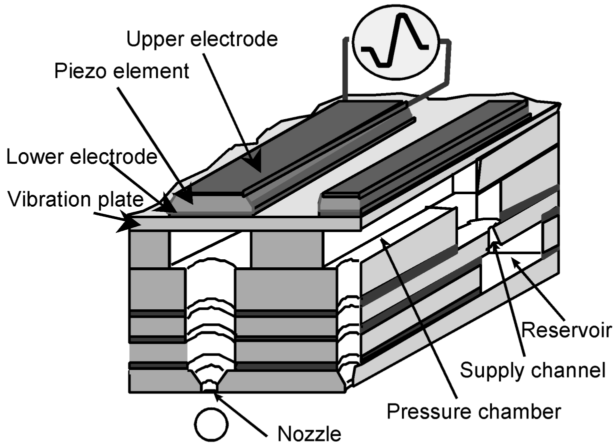

Figure 1. Structure of MLChips type MACH

EPSON has developed a new inkjet head with multi-layer piezo actuators called MLP type MACH, and introduced a new printer with MACH in 1992.[3] The MLP type MACH, shown in Figure 2, has multi-layer piezo elements sliced into thin pillar shapes. One end of the pillar array is fixed to a base, and the other end is connected to the vibration plates of the pressure chambers. This piezo element becomes shorter when voltage is applied, deflecting the pressure chamber by a transverse piezoelectric effect. The MLP actuator can transfer the piezostriction directly into displacement of the vibration plates regardless of the pressure chamber size. To reduce the droplet size, the MLP type MACH can easily reduce the pressure chamber size. Because the displacement of the piezo element is proportional to the supplied voltage, the volumetric change in the pressure chamber is also directly proportional. Therefore, the properties of the ink droplets are easily controlled by varying the driving waveform. In terms of achieving high performance over wide variety applications, the MLP type MACH is superior to MLChips type MACH and other types of piezoelectric ink jet heads.

MLP (Multi-Layer Piezo) Type MACH

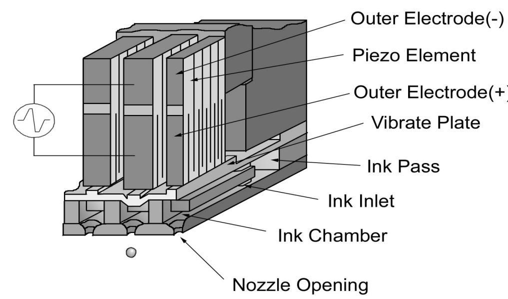

Figure 2. Structure of the MLP type MACH

Driving Waveform

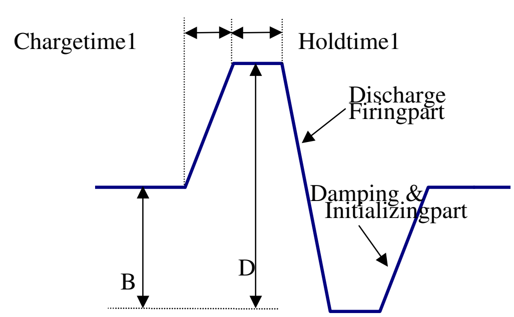

Figure 3. Pull-Push-Pull waveform to generate normal size droplets: The 1st charge pulse (Pull) excites ink oscillation and starts to draw ink meniscus inward, followed by a discharge pulse (Push) to push the meniscus outward and eject the ink droplet. A 2nd charge pulse (Push) is set to cancel the previously generated oscillation.

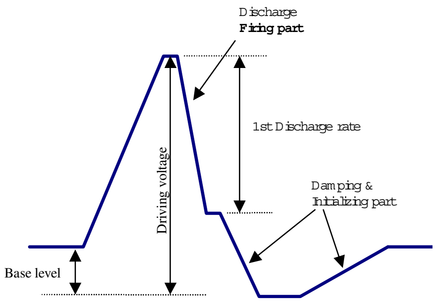

Figure 4. Pull-Push-Push-Pull waveform to generate smaller droplets: The 1st large charge pulse (Pull) and following small discharge pulse (PUSH) make the ink droplets smaller. The 2nd discharge pulse (PUSH) and 2nd charge pulse (Pull) is set to cancel the previously generated oscillation.

Property Control

Driving Voltage

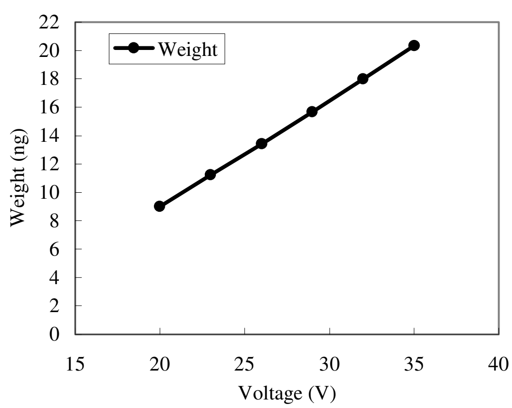

Figure 5. Droplet weight vs. driving voltage: Pull-Push-Pull waveform.

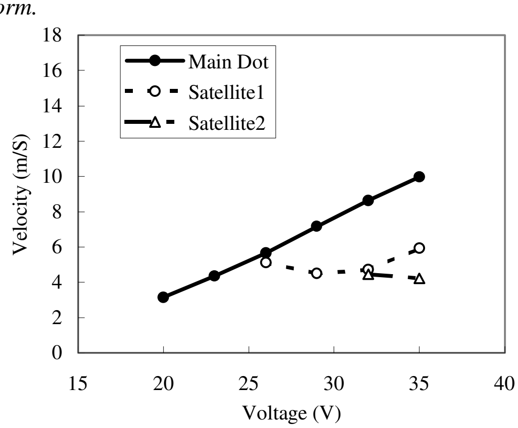

Figure 6. Droplet velocity vs. driving voltage: Pull-Push-Pull waveform. Satellite 2 represents a tail of satellites in cases where many satellites appear.

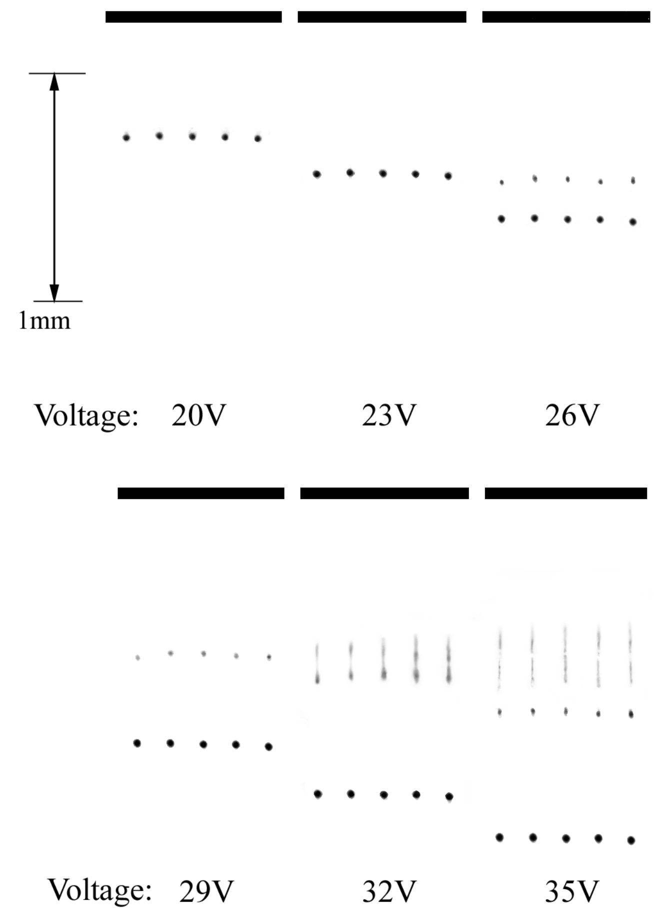

Figure 7. Droplet appearance changed by driving voltage

Droplet mass or velocity is easily controlled by changing the driving waveform as described below. Figures 3 and 4 show typical waveforms used in MLP type MACH.

The easiest way to change the properties of ink droplets is to change the driving voltage. Higher voltages increase the ink droplet's mass and velocity, as shown in figures 5 and 6. However, in this case, mass and velocity change at the same time. It is very difficult to change the relationship of droplet mass to velocity without changing the dimensions of the nozzles. It is important to control the droplet's velocity, in terms of quality of printed images and reliability of ink jet device.

Slower velocity decreases the accuracy of a droplet's landing position, and requires decreasing the distance between the print head and the target. On the other hand, if the droplet's velocity is too high, more satellites appear, sometimes forming a mist. The mists make printed image quality bad and may damage the printer itself by accumulating on critical components.

Figure 7 shows the droplets appearance at each voltage. At 26V and higher, satellites appear, at 32V and above, the satellites separate to become an unstable mist. At this point, the droplet's velocity is approximately 9m/S being driven at 32V (see Figure 6). To avoid the generation of mists, we have set the typical droplet's velocity around 6 to 7m/S.

Waveform Control

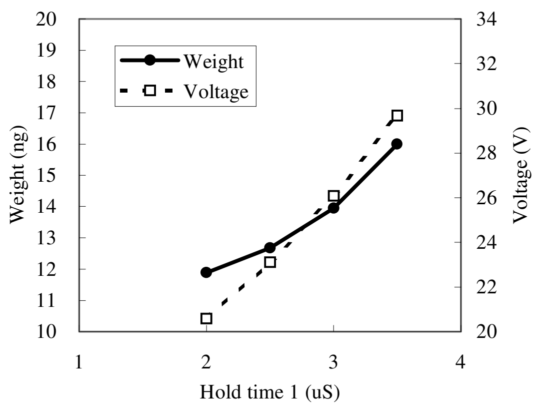

Figure 8. Droplet weight vs. Hold time1 of Pull-Push-Pull waveform: Driving voltage is chosen to keep droplet velocity 7m/S.

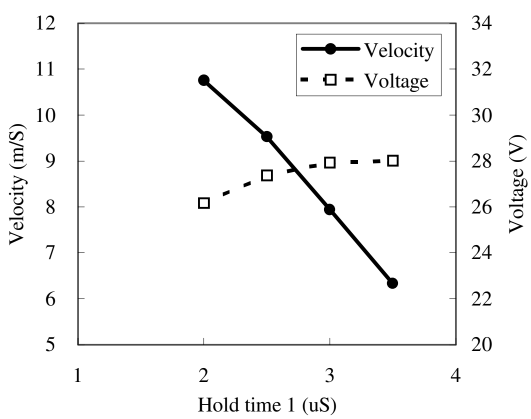

Figure 9. Droplet velocity vs. Hold time1 of Pull-Push-Pull waveform: Driving voltage is chosen to keep droplet weight 15ng.

To adapt to various applications and various inks, different droplet sizes are often required, or even when the droplet size required is same, ink property is different that will require some adjustment. If the difference is relatively small, voltage control can be used. But in case of a big difference, voltage control is not adequate to select a suitable velocity as described above. By waveform control, MLP type MACH can change droplet mass dynamically.

Figure 8 and 9 show examples of the properties (weight and velocity) controlled by waveform modifications. Hold time 1 of Pull-Push-Pull waveform can control the weight of the droplets. Droplet weight can be selected in the range of 12 to 16ng while keeping the droplet velocity constant at 7m/S. As an alternate, droplet velocity can be selected in the range of 6 to 11 m/S while keeping the droplet weight constant at 15ng.This is accomplished by changing the Hold time1. When a firing pulse is applied at a different phase of the ink oscillation excited by 1st Pull wave, droplet weight can be controlled. Also, base level or charge time1, and combinations of them can be used to control droplets property.

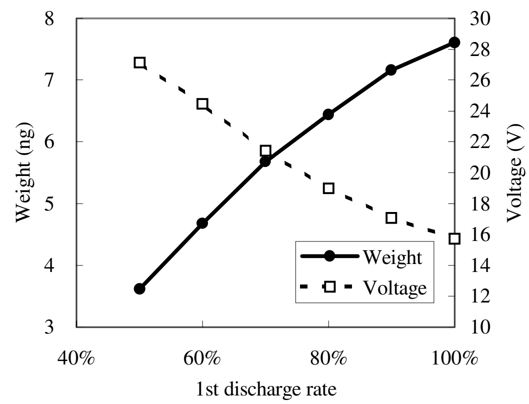

Figure 10. Droplet weight vs. 1st discharge rate of Pull-Push-Push-Pull waveform: Driving voltage is chosen to keep droplet velocity 7m/S.

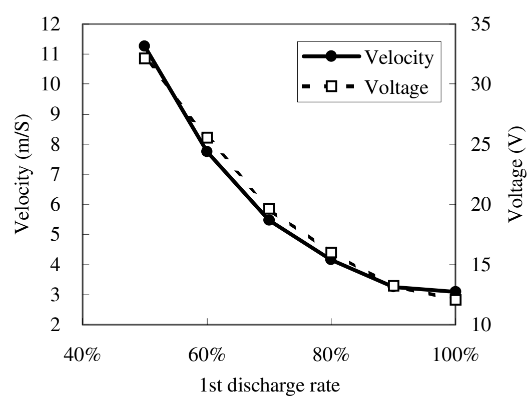

Figure 11. Droplet velocity vs. 1st discharge rate of Pull-Push-Push-Pull waveform: Driving voltage is chosen to keep droplet weight 5ng.

Figure 10 and 11 show examples of the droplets property controlled by 1st discharge rate of Pull-Push-Push-

Pull waveform. Droplet weight can be chosen from 3.5 to 7.5ng leaving the droplet velocity at 7m/S. As an alternate possibility, droplet velocity can be chosen from 3 to 11 m/S leaving the droplet weight constant at 5ng. When changing the 1st discharge rate, i.e. when the ratio of 1st Pull and 1st Push is changed, the property can be controlled. Also, base level or pulse timing, and a combination of both can be used to control droplets property.

Applications of MLP type MACH

Table 3. Applications of MLP Type MACH

Product	Specification
PM-900C	Photo printer, Japanese domestic model Nozzle number: 672 (96*7rows) Droplet's sizes per unit pixel; Mode1: 13/26/39pl Mode2: 5/ 9 /22pl Mode3: 2/ 5 /11pl Ink; Dye based ink Special features: Four-directional borderless photo-printing
Stylus Pro 10000/ 10000CF	Large Format Printer (up to 44inches) Nozzle number: 1080 (180*6rows) Droplet's sizes per unit pixel; 5/ 11 /23pl Ink; 10000:Dye based ink 10000CF:Pigment based ink

Our latest MLP type MACH heads are based on a same architecture. Dimensions of nozzles, piezo elements, ink chambers and ink inlets are same. Waveform control method is used on a photo quality home printer PM-900C. It has 3 different printing modes. Mode 1 uses multi-shots of Pull-Push-Pull waveform. Mode 2 and 3 use MSTD (Multi-Sized Droplet Technology [4]). Different droplets sizes from 2pl to 13pl can be ejected from a head and each droplet has around 6 to 7m/S velocity by waveform control method. By controlling the droplets velocity, printing on the CD-R media and four-directional borderless photo printing can be achieved.

In addition, another head, which has the same architecture but different size, is used on Stylus Pro 10000 and 10000CF, which are LFP (Large Format Printer). Stylus Pro 10000 uses dye-based inks, and 10000CF uses pigment-based inks. Waveform control method is also used to achieve different droplets sizes, and voltage control method is used to adjust slightly different properties of inks. Specifications of these printers are shown in Table 3.

Conclusion

The characteristics of waveform control method used on MLP type MACH was studied. Droplet mass can be widely changed while leaving the droplet velocity as same, or droplet velocity can be changed while leaving the droplet mass the same. MLP type MACH with waveform control method can adapt various new applications without changing a head design.

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Biography

Tomoaki Takahashi graduated from Tohoku University, dept. of physics and joined in SEIKOSHA Corporation in 1985. He had researched TFT display, electrophotographic printing process, and inkjet printing system. In 1996, he joined in SEIKO EPSON Corporation and currently is working on ink jet head development. He is now a chief of ink jet head development team in TP Research and Development Dept.