New Developments of Shear-Mode Piezo Inkjet Heads for Industrial Printing Applications

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Abstract

Piezoelectric inkjet printheads have many advantages such as a wide range of ink compatibility, flexibility in drop control, and high durability, and are widely used for industrial printing applications. Among piezoelectric heads, shear mode printheads are low power consumption and easy to manufacture wide print width heads.

We have developed a new type of shear mode head, in which electric capacitance of actuator is minimized and ink flow paths and electrode connections are significantly simplified, by the use of new, high efficiency actuator design.

Two types of 1024 nozzles heads with nozzle density of 360 npi and wide print width of 72mm have developed. (1) KM1024 is the 3 cycle operation type and power consumption per nozzle is reduced by 50% compared to conventional KM512 printhead. (2) KM1024i is the independent operation type with four rows of 256 nozzles and has achieved firing frequency of 35kHz at a drop volume of 14pl.

Introduction

Inkjet printing technology has expanded the application range to the industries such as textile printing, electronic devices, graphics art printing, building materials and so on. Growing demands in the industrial inkjet printing are calling for high resolution, high productivity, and a wide range of ink compatibility. To meet these demands, high firing frequency, wide print width, and low power consumption are required for industrial inkjet heads.

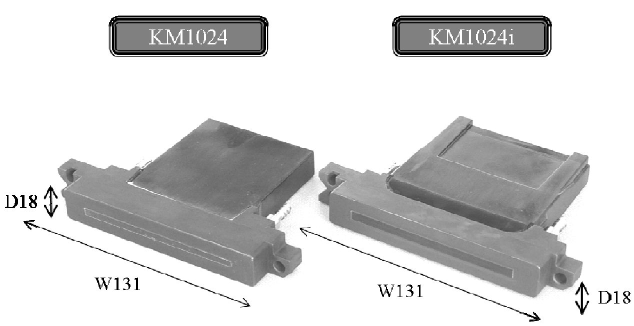

***Figure 1**. KM1024 & KM1024i*

Shear mode piezoelectric inkjet heads have been used for over a decade for industrial inkjet printers. Shear mode has the advantages of low power consumption, high native resolution, and simple structure [1] [2] [3]. We have been manufacturing shear mode piezo inkjet printheads, as represented by KM512, for industrial printing applications.

Although shear mode printheads are low power consumption, there is a certain temperature increase during operation. To obtain higher firing frequency and large-scale integration of printheads, much lower power consumption becomes essential. Moreover, although shear mode has high native resolution of 180cpi (channel per inch), nozzle density of a printhead has been limited because of manufacturing difficulties such as electrode connection and supply of ink to actuator.

Table1: Specifications

Printhead Name	KM1024	KM1024i
Number of Nozzles	1024 nozzles	
Resolution	360npi (nozzle pitch 70.5μm)	
Row	180npi x 2rows	90npi x 4rows
Actuator	Piezoelectric shear mode	
Drive type	Shared wall 3cycle drive	Independent drive
Drop Size	14pl	
Frequency	12.8kHz	35.0kHz
Print Width	72mm	
Dimensions	W131xD18xH89	W131xD18xH94
Weight	< 140g	< 150g
Internal heater	Available	

To meet these challenges, we developed KM1024 and KM1024i with a new shear mode piezo actuator. Power consumption per nozzle of KM1024 is reduced by 50% compared to KM512 through the use of a new, high efficiency actuator. Appearances of KM1024 and KM1024i are shown in Figure 1.

As the print width is 72mm and the head width is 131mm, staggered layout of printheads can be used. The head depth is ultra-slim of 18mm. The same mount wing design ensures interchangeability of both types of heads on the same mount system. The main futures of KM1024 and KM1024i are listed in Table 1. While our product line contains printheads with different drop volume (L:42pl and S:6pl), we discuss M (14pl) type in this paper.

There are two types of architecture to drive the shear mode printhead actuator; 3-cycle operation and independent operation. KM1024 is the 3-cycle operation printhead with nozzle density of 360npi with two rows of 180npi. While shared wall 3-cycle structure utilizes all the channels for droplet ejection and achieves high nozzle density of 360npi, there are limitations in the firing frequency, which is becoming insufficient for high-end inkjet printers [4].

While an independent operation head has higher firing frequency, its nozzle density is half that of 3-cycle head at the same channel density. To solve this problem, KM1024i with four rows of 256 nozzles was developed.

This paper will discuss the development of 1024nozzles printheads produced by the low power consumption actuator and the four rows structure.

Base Printhead Architecture

The shear mode actuator is based on a piece of PZT with channels sawn by a dicing saw machine to form ink channels. The remaining parts form walls. Figure 2 shows a schematic of the conventional shear mode head (eg:KM512).

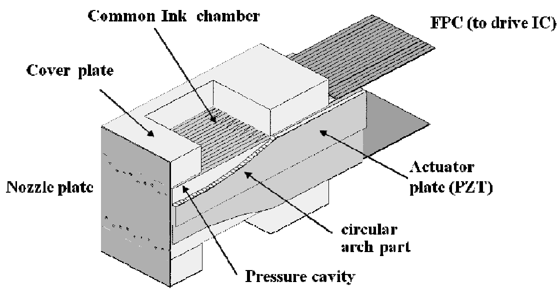

***Figure 2**. Schematic perspective view of CT structure (KM512)*

Two actuator plates are bonded by epoxy based adhesives to produce laminated head structure having two rows of channels with one nozzle plate. Circular arch is formed by use of a round blade of the machine. This part functions as an ink flow path to the pressure cavity and an electric current path from an electrode on the surface of channels to outer driving circuits. This type of structure is named CT (chop and traverse) structure after the motion of the blade. CT structure uses the circular arch part cleverly and is time-tested standard.

However, the walls of the circular arch part is also pezoelectric capacitor and have much the same electric capacitance as the pressure cavity, thus power consumption increases. Capacitance of a circular arch part is relatively high for an inkjet head with small drop size. This makes high frequency operation difficult by temperature rise.

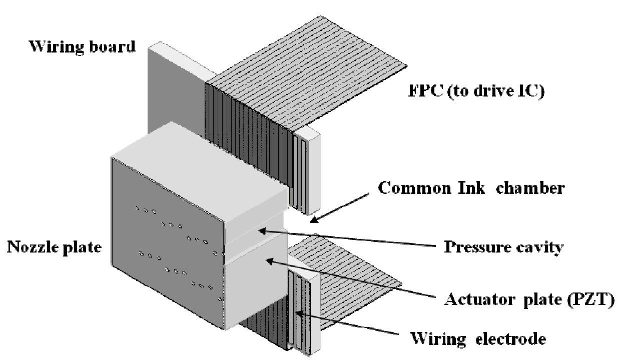

***Figure 3**. Schematic perspective view of HA structure (KM1024)*

To develop the potential of shear mode head and achieve high performance, we adopted a new architecture.

Figure 3 shows the basic component of KM1024. Two actuator plates are bonded as is the case with CT head. The driving electrodes on the walls of the pressure cavity are connected to the wiring electrodes on the wiring board. This type of structure is named HA (harmonica) structure after the appearance of the head chip.

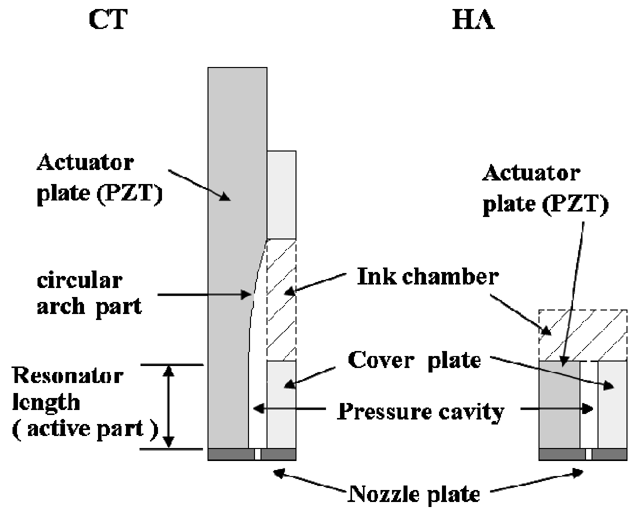

***Figure 4**. Actuator longitudinal cross-section*

Longitudinal cross section parallel to the channels of CT type and HA type are shown in Figure 4 (It shows here one actuator plate for simplicity). Both heads have the same resonator length when the drop size is the same. The compact and simple design of HA head without circular arch parts has a number of advantages. The size of actuator plate is the same as resonator length and PZT usage is minimized. As there is no circular arch part, electric capacitance is half of CT head. The CT head in Figure 2 needs two manifolds in order to supply ink chambers with ink. The HA head employs only one manifold and the pressure cavity connects directly with a common ink chamber without ink passing through the circular arch part.

This dramatically simplifies the ink flow from the ink chamber to the pressure cavity and makes ink priming easy. As ink channels usually remain vertical and air bubbles in the pressure cavity are ejected upward into the common ink chamber, it has merits of good air purging ability.

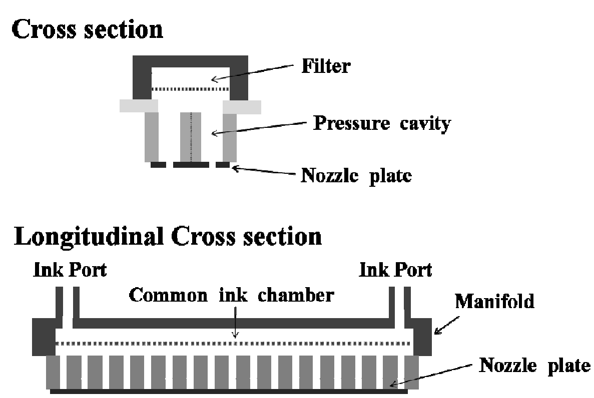

***Figure 5**. KM1024 & KM1024i cross section*

Moreover, this design without the circular arch part makes pressure cavity refilling time after ink ejection shorter, and is advantageous for high frequency operation.

Figure 5 shows schematics of ink flow passage. KM1024 has two symmetrical ink ports. As both can be used for inlet or outlet, one head can connect to another head in series. This expands the possibility of printer design. Demand for ejecting of ink containing fine particles is now growing. Ink circulation system preventing ink from particle sedimentation can also be built.

Table2: Actuator electric characteristics

	Capacitance (pf)	Drive voltage (V)	power consumption (relative)
KM1024	800	13	0.33
KM512	1600	16	1.00

Table 2 shows electrical characteristics of actuators. The dimension of the actuator channel is both 2.5mmL x 310µmH x 82µmW. The capacitance of KM1024 is half that of KM512 and drive voltage is lower than KM512. Calculated power consumption per channel is reduced drastically to 33% of KM512. Actual power consumption per channel of KM1024, including drive IC's, is half that of KM512.

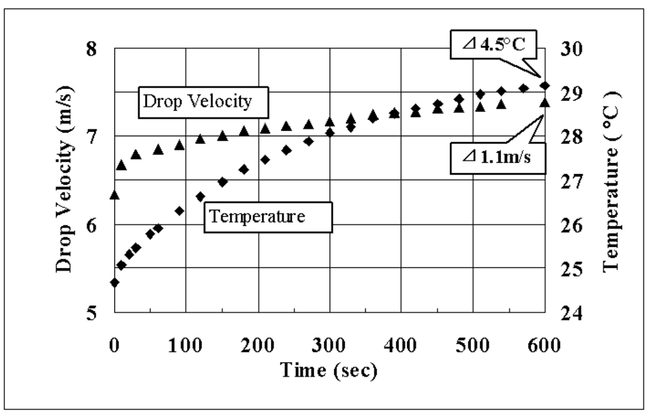

***Figure 6**. KM1024 Drop velocity and Head Temperature*

Figure 6 shows Drop velocity and Temperature rise of KM1024. All nozzles are fired. Driving frequency is 10.5kHz and driving voltage is 12.9V. Ink viscosity is 10cP and surface tension is 32mN/m. Even if the power consumption is low, heat generated in actuators and driving circuits in a print head raises the temperature of the head, resulting in increase in the drop velocity, with decrease in viscosity of the ink inside. Temperature rise after 10 minutes operation is 4.5°C and low enough to control drop ejection. In practical use, the driving voltage applied to the channel walls is reduced according to the temperature of the head in order to keep the drop velocity constant. Thus temperature rise becomes lower than that of this result.

Four Rows HA Structure with 1024 independently addressable nozzles

We achieved low power consumption by HA structure, however, demand for high firing frequency is growing. For a shared wall 3-cycle shear mode inkjet actuator, the entire channel is used for ink ejection. In this 3-cycle mode, only one third of the channels are fired at the same time, so the resulting firing frequency is reduced.

Well-known approach is adoption of independent drive. In this case, air channels are formed on both side of ink channels, and ink channels can be driven independently at higher firing frequency without being affected by neighbor channels.

Although the pumping ability of the head increases, its nozzle density is obviously reduced by half at the same channel density. It is difficult to increase the channel density from 180 cpi to 360 cpi, from the viewpoint of actuator design and manufacturing technology. Laminating actuator plates to form multilayer structure is also difficult, especially for CT structure.

In order to solve these problems, we have developed HA structure with four rows of 256 nozzles.

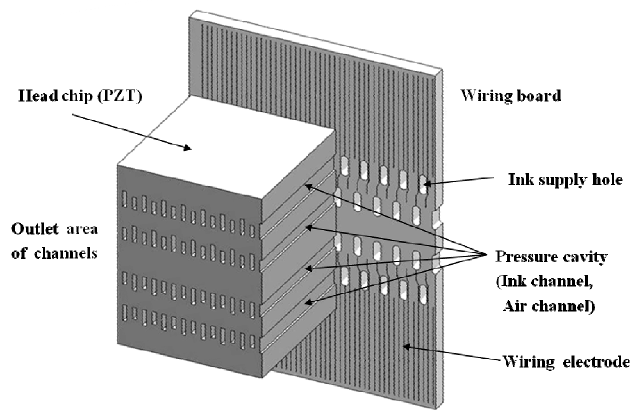

***Figure 7**. KM1024i Schematic perspective view of actuator*

Actuator of KM1024i is shown in Figure 7. Air channels and ink channels are formed alternately. Channel density is 180cpi, thus nozzle density per row is 90npi. We achieved nozzle density of 360npi with four layer structure.

The wiring board has ink supply holes that supply ink channels with ink. Air channels are sealed with the wiring board to prevent ink from flowing in. Supply of ink to ink channels is easy for HA head with multiple rows of nozzles.

Figure 8 is a photograph of the rear surface of the head chip. Connecting electrodes are formed on it and electrically connected with the wiring electrodes on the wiring board. The wiring electrodes are connected to the driving circuits (not shown in the figure). Wiring electrodes for two rows of nozzles are disposed on one side of the wiring board.

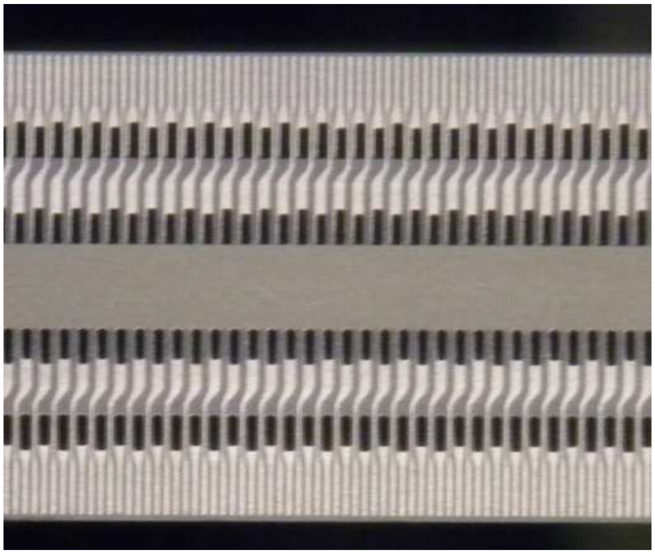

***Figure 8**. KM1024i Rear surface of head chip*

Figure 9 shows frequency response of KM1024i. Drop volume at 10kHz is 14pl. Driving voltage is 9.6V. Ink viscosity is 5.7cP and surface tension is 41mN/m. As the firing frequency is increases, remnant pressure wave vibration of the previous firing starts to affect the following ejection, causing drop velocity to fluctuate.

Lower viscosity ink is more susceptible to this effect because of its lower flow resistance. Therefore the maximum firing frequency for stable ejection depends on the ink properties used and is about 35kHz in this case.

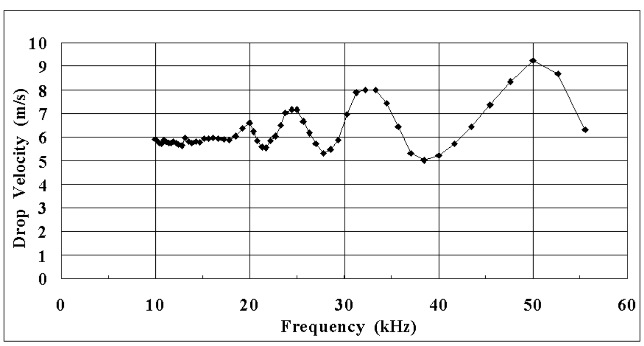

***Figure 9**. KM1024i 14pl Frequency response*

Drop velocity and Temperature rise of KM1024i are shown in Figure 10. Driving voltage is 9.6V. The firing frequency is 27kHz. The head is mounted on an aluminum plate. Temperature is measured by an internal thermister in the head. When one row of 256 nozzles are fired, temperature rise is 0.9°C. When all 1024 nozzles are fired, temperature rise is only 2.1°C. The bottom curve shows the drop velocity for all nozzles firing. The velocity rise is only 0.5m/s. As described above, this rise becomes lower in practical use at a constant drop velocity.

Combined with the ultra-slim and space-saving printhead shape, this low-heat-generating actuator makes KM1024i suited to fit multiple printheads into a smaller space for high productivity. Eighty-one KM1024i are used in a new Konica Minolta inkjet textile printer, Nassenger Pro1000, to achieve high printing speed.

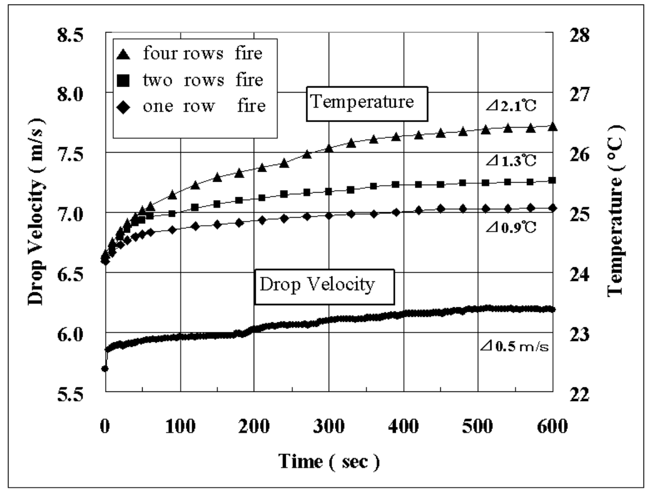

***Figure 10**. KM1024i Drop Velocity and Head Temperature*

Conclusion

New piezoelectric shear mode inkjet printheads for industrial printing applications have been developed. We have achieved remarkably low power consumption through the use of a new, high efficiency piezo actuator. KM1024i has achieved the independently addressable firing nozzle with nozzle density of 360npi.

We demonstrated that HA structure is very useful in developing high-speed, high-resolution, and low-heat-generating printheads with the extremely simple ink flow path and the slim frame. The shear mode printhead with HA structure should be one of the most promising designs.

References

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Author Biography

Hideo Watanabe received his B.S.(1982) and his M.S.(1984) in physics, both from Kyoto University. He joined Konishiroku shashin kogyo, the forerunner of Konica Minolta in 1984, where he developed thin film devices. Since 1996,he has focused on the development of inkjet head.