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Shear-mode Piezo Inkjet Head with Two Recirculating Paths

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Abstract

A "harmonica chip," a technology unique to Konica Minolta, is characterized by low heat generation, high frequency drive, and a compact multi-row structure. Based on this technology we have developed products of thin high-resolution IJ heads such as KM1024i and KM1800i.

KM1024a-RC is a new product of Konica Minolta with an ink recirculation function added to the harmonica chip. The recirculating path has been designed to exhibit sufficient recirculation performance against pigment sedimentation and drying of ink, and also enables stable jetting.

In this report, we introduce two recirculating paths structure for the excellent recirculation performance of the KM1024a-RC, and the evaluation results of recirculation performance and jetting performance.

Introduction

Inkjet heads for industrial applications are required not only high image quality but also high productivity and compatibility with various inks, and ink recirculation near the nozzle has attracted attention. Recirculation head can refresh the ink in the ink channel and the nozzle by constantly discharging the ink from the recirculating path communicating with the ink channel, and can prevent pigment sedimentation, the ink drying in the nozzles, and the nozzle missing due to air bubbles. A typical recirculation head has a recirculating path design that is configured of an individual recirculating path connected to each ink channel and a common recirculating path where the individual recirculating paths merge. In the early stage of the development of KM1024a-RC, we found that there are several issues in applying the typical recirculating path design to the harmonica chip, so we developed a new recirculating path design optimized for a thin high-resolution harmonica-type recirculation head.

Design outlines

Figure 1 shows the appearance of KM1024a-RC. As shown in Figure 2, the head width is 19.5 mm, and the nozzle is 3.4 mm wide. KM1024a-RC is the industry's thinnest recirculation head and has a unique recirculating path design.

Two recirculating paths

The ink channels are arranged at high density in the harmonica chip, and the chip has a narrow rectangular channel shape in the channel row direction. When an individual recirculating path (a path where ink flows from ink channel to a common recirculating path) is set at one end of the ink channel, the ink will stagnate on the opposite end due to its narrow shape. The ink stagnation will stagnate jetting-hindrance, such as air bubbles and pigment sedimentation, on the opposite end and the hindrance will not be discharged. To solve the issue we designed to set two separate ink recirculating paths at both ends of the ink channel. The ink will flow effectively to the paths and will not stagnate inside the channel, and the hindrance will be discharged completely from the channel. This two-paths-design is the key technology of the newly developed printhead, KM1024a-RC.

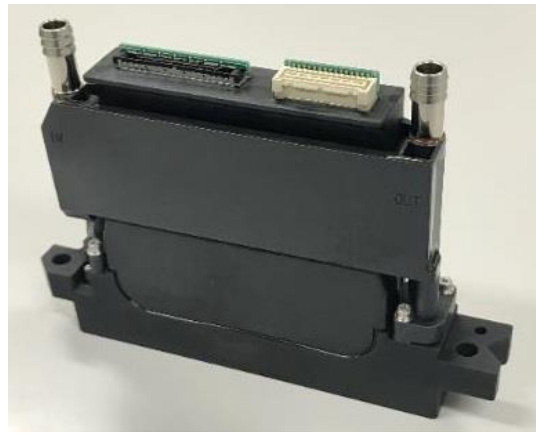

Figure 1. *KM1024a-RC.*

Figure 2. *KM1024a-RC.view from the nozzle surface*

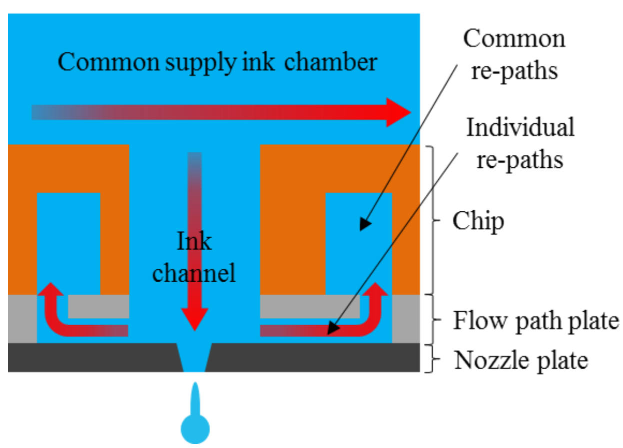

Figure 3. *Two recirculating paths structure.*

Suppression of "recirculating path" crosstalk

The pressure wave for ejection may escape from the ink channels to the common recirculating path via the individual recirculating path. It will cause crosstalk between the ink channels. This is "recirculating path" crosstalk, and it will cause fluctuation of velocity of ink droplets. To solve the issue, we took two actions as below.

The first action was to increase the impedance by increasing the length of the individual recirculating paths. It reduced the pressure waves that escaped to the common recirculating path. The second action was to increase the volume of the common recirculating path to increase the compliance. It reduced the pressure wave that returned from the common recirculating path to the ink channel. As shown in Figure 3, we cut a deep groove to form a common recirculating path in the harmonica chip.

Air damper in the common ink chamber

The pressure waves can escape from the ink channel not only via the individual recirculating path to the common recirculating path, but also via the gate of the ink channel to the common ink chamber. The latter escape has less impedance and the level of pressure wave leakage will be larger, and it will also cause the fluctuation of droplets' velocity. To solve the issue, we installed a damper to absorb the pressure wave. It reduced the pressure wave that returned to the ink channel. As shown in Figure 4, an air damper made of a thin film was installed in the common ink chamber just above the ink channel, and the crosstalk in the common ink chamber was suppressed.

This air damper has another role. When the printhead repeats all-ejection and all-non-ejection, the pressure wave resonates in the common ink chamber. It will also affect adversely to the jetting. The air damper will absorb effectively and suppressed the pressure wave resonance. The KM1024a-RC can be adapted to any printing pattern since the air damper is designed to have sufficient compliance for this purpose.

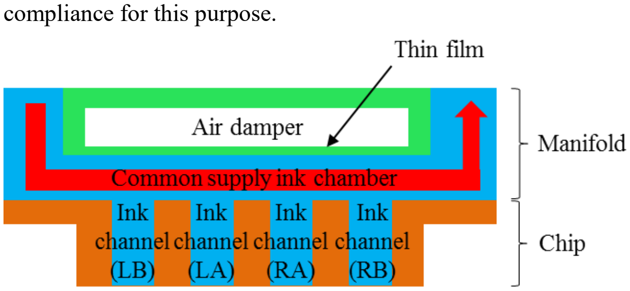

Figure 4. *Common supply ink chamber structure.*

Results and Discussion

The head performance was evaluated using KM1024aLHG-RC. Its features are summarized in Table 1. The minimum droplet size is 25 pl, and it can jet up to 240 pl at 6 kHz by "multidrop" mode. The standard recirculation flow rate is about 80 ml per minute, depending on the ink viscosity.

	KM1024aLHG-RC
Number of nozzles	1024 (256 × 4)
Nozzle resolution [npi]	360 (90 × 4)
Print width [mm]	72
Ink viscosity [mPa·s]	10 - 14
Applicable ink	Solvent, Oil, UV, Water base
Dimensions (WxDxH) [mm]	131 x 19.5 x 99
Jetting frequency [kHz]	14kHz (25-79pl multi) 6kHz(240pl multi)
Recirculation flow Rate [ml/min]	80ml/min at ⊿15kPa

Table 1. *Specifications of KM1024aLHG-RC.*

Air bubble discharging performance

First we evaluated air bubble discharging ability. We jetted a test ink from the head while recirculating the ink. We stopped the ink supply, and air bubbles were taken into the channel from the nozzles by meniscus break. We resumed ink supply and evaluated drop velocity and angle then. We confirmed that all returned to the initial state.

In this evaluation, the ink supply stop time was set to 10 seconds. Within this period, all the ink inside the head was ejected. Therefore, it can be said that it was one of the most severe conditions. When the ink supply was resumed after 10 seconds, ejection from all the nozzles (1024 nozzles) returned to the initial state. From this result, it was presumed that there was no convective ink in the head. It was found that even if ejection failure occurs due to the inclusion of air bubbles, automatic recovery was performed without maintenance.

Ink drying prevention

The water-based ink is highly dry, and in the non-ejection state, water easily evaporates from the meniscus surface in the nozzle. This increases the viscosity of the ink in the nozzle, causing drop velocity decrease or mis-firing. This phenomenon is called decap.

When the ink is recirculated, the viscosity-increased ink in the nozzle is refreshed. The decap reduction effect was evaluated in combination with shaking wave (to add fine waves just to vibrate the meniscus). Figure 5 shows the results of evaluating the decap when standing by for a certain period using a water-based ink. The drop velocity was decreased by 24% when waiting for 10 seconds without recirculation and shaking wave. On the other hand, when the ink was recirculated or the shaking wave was added, the drop velocity was recovered. When the both were further combined, the drop velocity did not decrease at all.

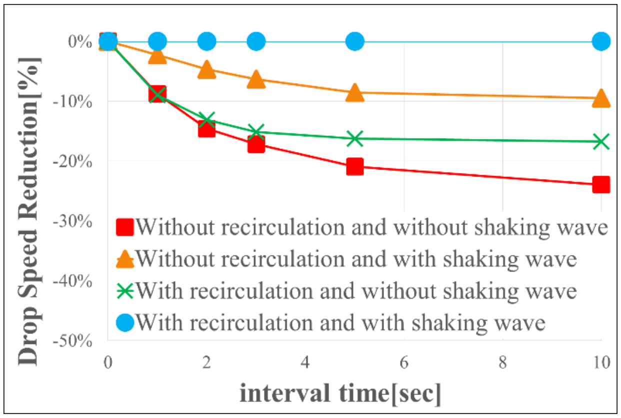

***Figure 5.** Decap of water-based ink.*

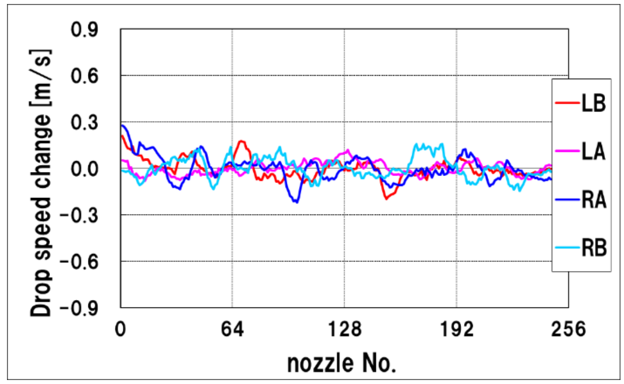

***Figure 7.** Crosstalk after measures.*

"Recirculating path" crosstalk

As mentioned above, pressure waves propagate via common recirculating path to adjacent ink channels. This crosstalk can be defined as the difference between the velocity distribution (reference velocity 6 m/sec) when each nozzle is driven at low frequency and the velocity distribution (reference velocity 6 m/sec) when all the nozzles are driven at high frequency.

Fig. 6 shows the evaluation results of the recirculating path crosstalk of the prototype head, and Fig. 7 the KM1024aLHG-RC. This crosstalk is caused by pressure waves generated in the ink channel, and the more the number of pulses, the more severe. The evaluation, therefore, was performed in 8 dpd mode in which 8 drops are ejected in 1 cycle.

As shown in Figure 6, the effect of crosstalk appears in the velocity distribution remarkably in the prototype head that has not taken any particular measures. On the other hand, it can be seen in Figure 7 that the measures show an effect. The velocity fluctuation was suppressed within ± 0.3 m / sec; we confirmed that the level does not affect to the printed image adversely.

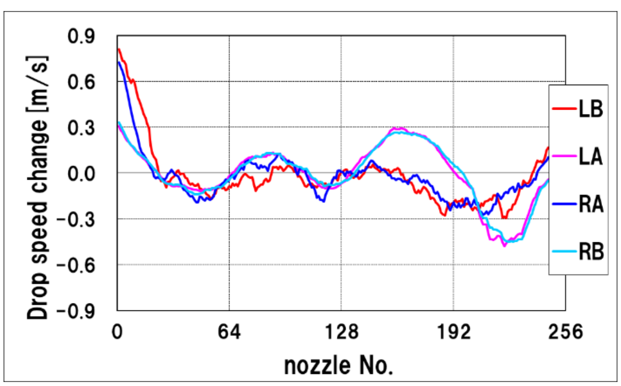

***Figure 6.** Crosstalk in the early development stage.*

Pressure resonance

Pressure resonances were evaluated in all frequency bands that could be used in actual use. A fringe pattern repeating the all-nozzle ejection and all-nozzle non-ejection was printed, and the period of the fringe pattern was varied from 2 kHz to 1 Hz to measure pressure variation. The 1 Hz fringe pattern refers to repeated printing of 0.5 seconds of all nozzle ejection and 0.5 seconds of all nozzle non-ejection. In this measurement, ejection was performed in 3 dpd mode.

In the structure without the air damper, pressure resonance occurred in a specific cycle, and it was confirmed that nozzle missing occurred in the printing test. On the other hand, with the KM1024aLHG-RC having an air damper, nozzle missing did not occur in all frequency bands. This indicates that the air damper is fully effective.

Conclusion

KM1024a-RC is the industry's thinnest recirculation head, combining excellent recirculation performance and jetting performance. Recirculation heads are expected to be in demand, especially for single pass printers, Konica Minolta will develop new applications by developing the KM1024a-RC series, which can use solvents, oils, UV, and water-based inks, from small to large droplets.

References

[1] Hideo Watanabe, Tetsuo Okuno, Shinichi Kawaguchi, Hikaru Takamatsu, and Masato Ueda, Proc. IS&T's 27th Int'l. Conference on Digital Printing Technologies (NIP27) (IS&T, Springfield, VA, 2011), pp. 282-285.

[2] Shinichi Nishi, Kazuo Asano, Daisuke Ishibashi, Akiko Kitami, and Kumiko Furuno, Transactions of Japan Institute of Electronics Packaging, Vol. 2, No. 1, pp.75-78. (2009).

[3] Mark Crankshaw, Mark Rulman, Hanifeh Zarezadeh, Maëlle Douaire, and Angus Condie, Proc. IS&T's Int'l. Conference on Printing for Fabrication (NIP32) (IS&T, Springfield, VA, 2016), pp. 207-211.

Author Biography

Hikaru Hamano received his B. S. and M. S. degree in Mechanics from Keio University in 2004 and 2006. He joined KONICA MINOLTA, Inc. in 2006. Since then he has been engaged in the development of ink jet printheads. He has focused on research and development of recirculation heads for 4 year.