Designing and Optimizing New Microchannel Architectures to Approach High Frequency Inkjet

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Abstract

This work develops several new designs of micro-channel architectures (*arches*) and promotes successfully the jetting frequency from commercial 6 kHz to 12 kHz in a large drop weight of 70 ng. These printheads with different arches of ink micro-channel were fabricated to be investigated by the tests and analyses including dot size, circularity, drop appearance, and frequency response of mass-jetted. These arches mainly comprise two stages of channels and provide with various specific features. The results show most of these designs are able to successfully jet weighty drops of 65~75 ng and keep low change of drop weight while frequency increases over 10 kHz. The characteristics of different features are also evaluated for jetting performance. These new micro-channel designs indicate a new way to approach much higher speed for inkjet printing.

Introduction

The printheads of ink jetted with thermal bubbles have become the most widely-used in commercial printing. Owing to the demand of high speed and high resolution on inkjet printing, it's inevitable to make efforts in enlarging inkjet frequency availably. If the resolution was upgraded from 600 dpi to 1200dpi, the available jetting frequency must be enlarged double to keep the same print speed. Currently many products have announced the ability of jetting in the frequency above 12 kHz. However, it appeals to approach this expected frequency by making the drop size reduce to about 10 picoliter due to get quick refilling. Although it's an inevitable trend to make drop size small, in fact, the printing speed has not been promoted when the best resolution is chosen. To really upgrade the printing speed, an effective deal is to design and evaluate the micro structure of ink flow at a certain drop size. At this work, we concentrate on developing several new designs of micro-channel architectures (arches) and evaluating the performance for their most available frequency.

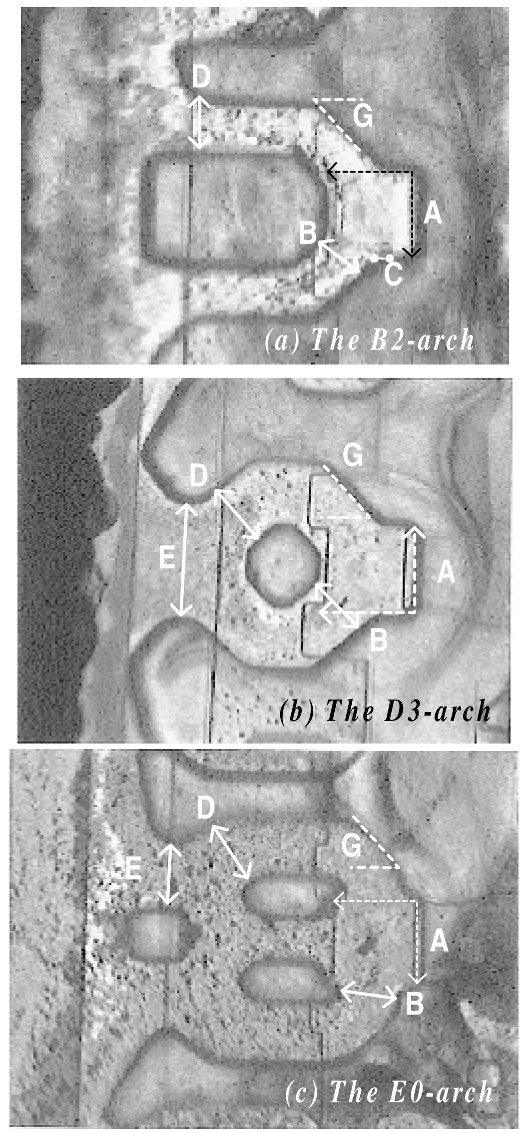


Figure 1. The main three types of micro-channel architectures designed for evaluation.

Table 1 Specific Features Designed in Tested Arches.

Features	A	B	C	D	E
	Chamber Size (μm2)	Outlet Width (μm)	Outlet Location (μm)	Inlet Width (μm)	Entrance Width (μm)
B0	54 x 67	32 x 2	-21	32 x 2	As Inlet
B1	54 x 67	32 x 2	-10	32 x 2	
B2	54 x 58	32 x 2	4	32 x 2	
B3	54 x 58	32 x 2	4	32 x 2	
B4	54 x 58	38 x 2	11	38 x 2	
D0	54 x 58	32 x 2	4	42 x 2	68 x 1
D1	54 x 58	32 x 2	4	32 x 2	68 x 1
D4	54 x 58	38 x 2	4	38 x 2	68 x 1
E0	54 x 58	32 x2 + 28	0	42 x2 + 28	38 x 2
E1	54 x 58	32 x2 + 38	0	42 x2 + 28	38 x 2
E2	54 x 58	32 x2 + 28	0	42 x2 + 38	38 x 2

Features	F	G	H	I
	Channel Length (μm)	45 deg Elbows	Wall Periphery (μm)	Wall Surrounded Ratio (Λ)
B0	76	1	54 x3 + 10	0.71
B1	73	1	54 + 35 x2 + 26	0.62
B2	127	1	54 + 24 x2 + 26	0.57
B3	76	1	54 + 24 x2 + 26	0.57
B4	94	1	54 + 16 x2 + 26	0.5
D0	~ 95	2	54 + 22 x2 + 33	0.58
D1	~ 102	2	54 + 23 x2 + 33	0.59
D4	~ 104	2	54 + 23 x2 + 18	0.53
E0	~ 125	2	54 + 16 x2 + 20	0.47
E1	~ 125	2	54 + 16 x2 + 10	0.43
E2	~ 125	2	54 + 16 x2 + 20	0.47

Experimental Design

We adopted the printhead chips with the heaters of the resistance 29 Ω and size of 42 × 42 μm^2. Subsequently, several arches were constructed from the different design of micro chambers and channels made of the thick film developed-out. These arches mainly comprise one or two stages of channels and provide with the thick-film islands of asymmetry shape and number, which thereby form the B-series arches (the entrance by outlet of 2 by 1), the D-series arches (1 by 2), and the E-series arches (2 by 3), respectively. Figure 1(a) shows one of the B-arches, noted B0 ~ B4, with the features of double channels and once 45° flow elbow. Figure 1 (b) shows one of the two-stage D-arch formed by an inner island and a wide entrance, noted D0 ~ D4, with the significant feature of twice 45° flow elbows. Figure 1 (c) shows one of the two-stage E-arches formed by 3 inner islands and two wide entrances, noted E0 ~ E2. All design features of the adopted arches are numerically list in Tab.1 and noted in Fig. 1. Another feature is the wall-surrounded ratio Λ of the effective wall-surrounded periphery to the chamber periphery. This indicates that if the Λ is designed low, the ink will be supplied enough but the firing chamber will be surrounded incompletely. All arches were designed to on purpose get the same drop weight of about 70 ng. In addition, these arches function as one or two sieves out of at least two size particles by 2 channel stages, which stand for getting the higher particle tolerance but not degrading the fluid velocity. The characteristics of ink used herein were measured to get the surface tension of 47.7 dyne/cm and the viscosity of 2.63 cps. The relationships between the jetting and these design features will be described and discussed.

Results and Discussion

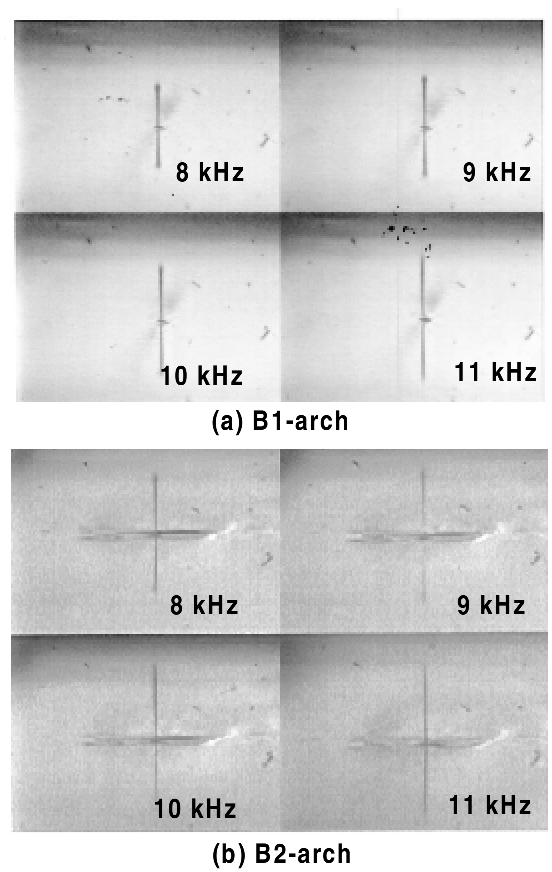


Figure 2. Photoimages of drops jetted from (a) B1-arch and (b) B2-arch at 8~11 kHz jet frequency, respectively.

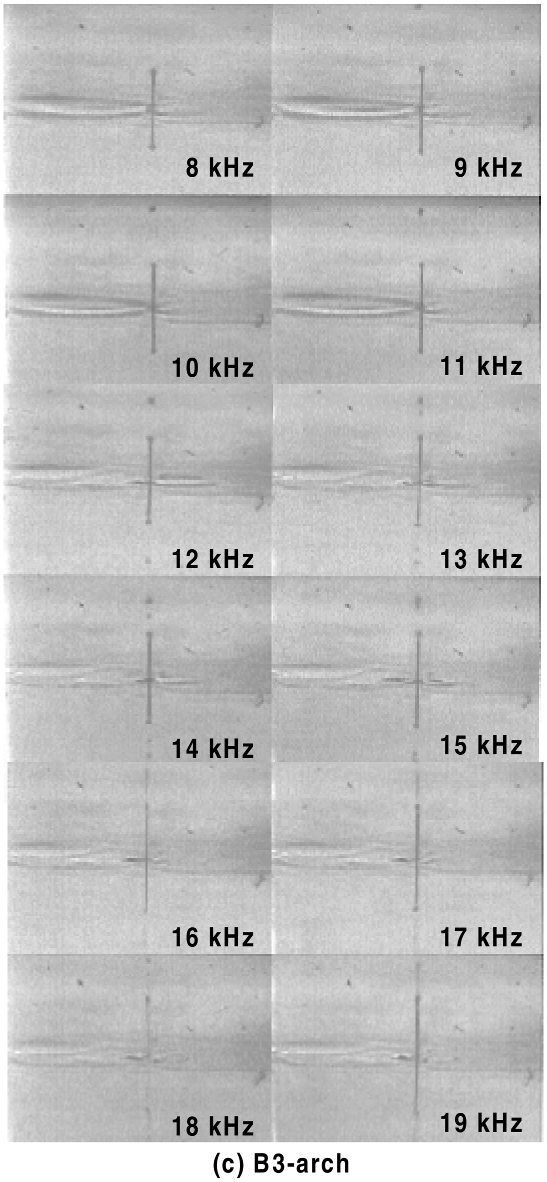


Figure 2(c) Photoimages of drops jetted from B3-arch.

The phenomena of drop jetted are first demonstrated. The ink drops were formed by the voltage pulse of 12.9V and 2.4µs. Figure 2 ~ 4 shows the drop images caught by the camera with different jetting frequency and in a certain delay time. As shown in Fig.2, all B-arches can keep the round drops as the frequency is 9 kHz, and the B3-arch shows the highest jetting frequency of 19 kHz in all samples. The round drops jetted from orifices indicate that the arch can exhibit a high refilling damping to form the next bubble after the quickly finished refill. Due to the longer channels, the B2-arch show the available frequency of only 9 kHz. Because of too large chambers, the B1-arch can't get the available frequency of >9 kHz. The B4-arch can approach 15 kHz (not shown) by enlarging the channel width. The D-series arches of twice elbows never jet the round drops once operating the frequency higher than 9 kHz, shown in Fig. 3.

The E-arches generally jet the larger round drops and the short trailers at after, shown in Fig. 4. This reveals there is rather rapid collapse of bubbles since the voltage pulse is turned off. It's attributed to the arch refilled from 3 outlets can provide the ink enough and made the ink fill the bubbles up more efficiently. In addition, all the E0, E1 and E2-arches can get the round drops at the high jetting frequency of 12 kHz in spite of the thick-film wall surrounds the firing chamber in likely uncompleted.

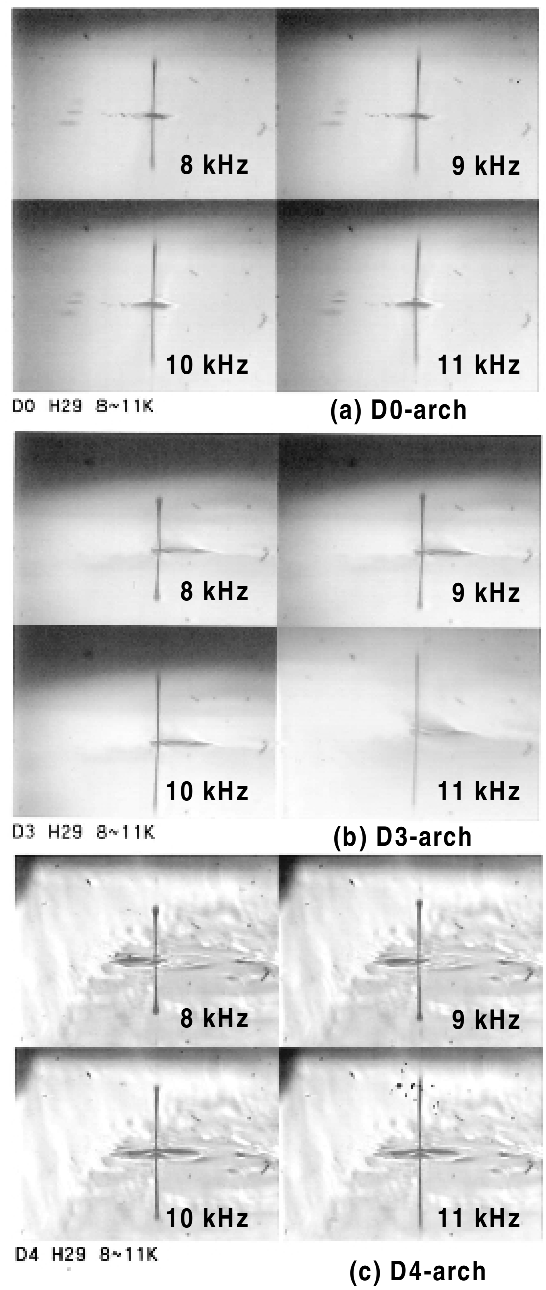
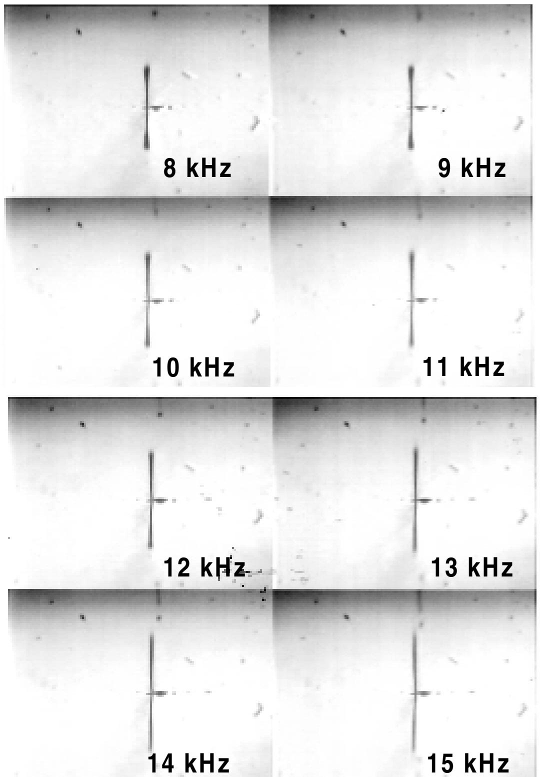
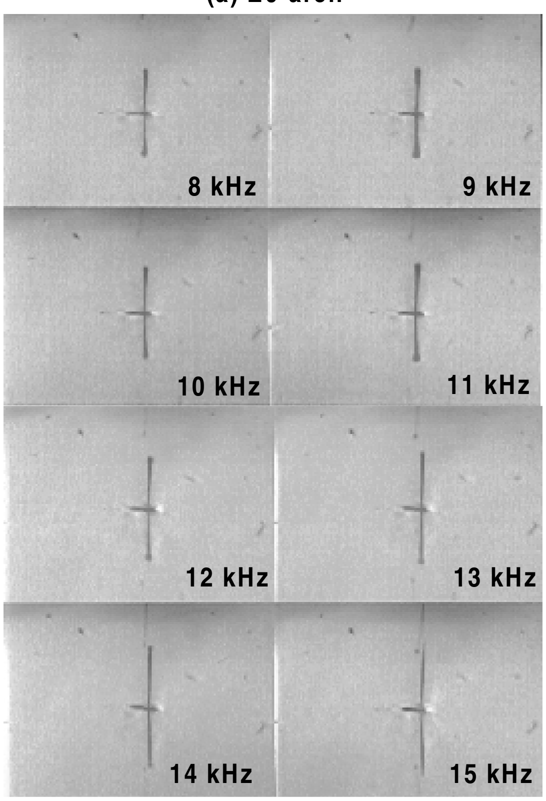


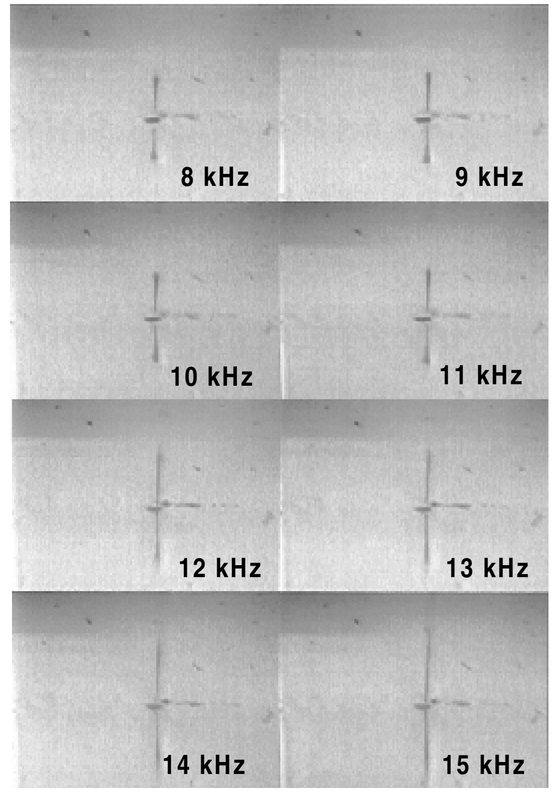
Figure 3. Photoimages of drops jetted from D0, D3 and D4-arch, respectively



(a) E0-arch



(b) E1-arch



(c) E2-arch

Figure 4. Photoimages of drops jetted from (a)E0, (b)E1 and (c)E2-arch at 8~15kHz, respectively.

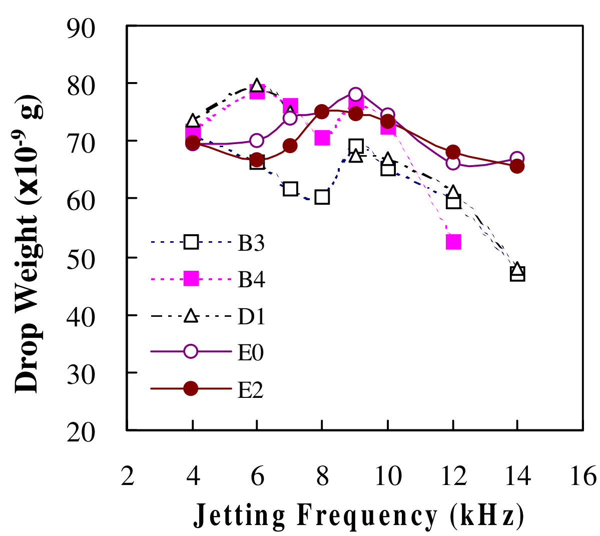


Figure 5. Frequency profiles of mass-jetted per drop in the main 5 arches.

Figure 5 shows the relationship between the jetting frequency and the average weight per drop in mass-jetted test. Most of the tested-arches are able to successfully jet weighty drops of 65~75 ng and keep low change of drop weight while frequency increases over 10 kHz. The drop mass of arches tested significantly splits when the frequency operates up to 12 kHz. The drop mass jetted from the B4-arch falls down if over 10 kHz due to the feature of its longest channel. The B3 and D1-arches subsequently loss the drop mass if over 12 kHz. This reveals that in spite of the round drops of B3-arch can appear at 19 kHz, the drop mass has been lost. The available frequency of B3-arch should be substantially about 12kHz. The E0 and E2-arches can keep the mass of drops jetted with about 65~75 ng from 4 kHz to 14 kHz. In addition, the arches of low Λ such as the B4, E0 and E2 jet larger drops with respect to the others at normal frequency (6~10kHz). This implies a drawback that it accidentally enlarges the effective area of firing chambers if the low-Λ is adopted. After all, the E-series arches get the benefit of always supplying ink enough. Referred to the drop images of E-series arches, the substantially available frequency of E0 and E2-arch should be also about 12kHz, identical to the B3-arch, or the optimum of all B-series.

Table 2. Diameter and Circularity of Dots Jetted from Different Tested-Arches.

	Diameter (um)	Circularity		Diameter (um)	Circularity
B0	81.9	1.837	**D0**	84.48	1.893
B1	83.94	1.851	**D1**	83.47	1.825
B2	83.59	1.877	**D2**	82.78	1.779
B3	83.46	1.881	**D3**	84.09	1.806
B4	83.51	1.942			

	Diameter (um)	Circularity
E0	84.48	1.894
E1	82.87	1.983
E2	83.96	1.847

Table 2 lists the average diameter and circularity of dots printed out by the above arches, and all dot samples were printed at 8 kHz. The diameter and circularity is got from the calculation of dot periphery and dot area. Followed by the feature of ink supplied enough, the B4 and E-series arches exhibit the undesirably large circularity. In comparison between Table 1 and Table 2, it seems to be aware that the lower Λ is adopted, the larger drop but the poorer circularity are also got. According to all the above results, the B3-arch shows the available frequency as high as the E-series, and prints dots with the better circularity. The E-series own the largest mass-jetted per drop at 14 kHz but degrade the print quality. The D-series with 2 elbows hinder the ink flow and are unsuitable at > 9 kHz.

Conclusion

This work evaluates the performance of inkjet from various type arches. Several arches successfully jet the ink drops of 65~75 ng wt. at 12 kHz. In our results, the too large chambers can't get the available frequency of >9 kHz. Single 45º elbow designed in the dual-channel arches is better than the others. The optimum length and width of channel can promote to the high frequency jetting, such as the B3-arch. If decreasing the wall-surrounded ratio (Λ), the arch can jet the rather large drops at normal frequency, enlarge the jetting frequency and get a short ink-trailer. However, this design affects the real chamber area and appears to be detrimental to the dot circularity in normal printing.

Biography

Opto-Electronics & Systems Laboratories, Industrial Technology Research Institute (OES/ITRI) was engaged in designing and developing inkjet printheads since several years ago and always stood a foremost position in Taiwan. We have developed a variety of inkjet chips, orifice plates, bonding tapes, black/color ink and cartridges already and led them to be manufactured. Our printhead products can exhibit a well printing quality and a satisfactory lifetime. Now we concentrate on developing the printheads with high resolution and high printing speed, and wish to become available in market in the near future.

Chien-Hung Liu joined the Print Head Development and Manufacturing Section of OES/ITRI in 1999. He received his M.S. and Ph.D from Institute of Electronics of National Chiao-Tung University, Taiwan. His interest lies in the design of printhead chips and micro-architectures.

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Chun-Jung Chen joined the Printing Department of OES/ITRI since 1990. His interest lies in the electronic photoimages. He is the department manager.