Study on Image Quality of Page width Ink Jet Printing ; Image Banding due to Chip to Chip Variation of Performance

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Abstract

Page width Ink Jet printing is powerful printer for fast printing speed and low printing cost. But page width printer consists of multiple head chips array across the printing media, the chip to chip variation of jetting performance causes to banding image. In this study, evaluation of individual ink Jet Head chip is performed, and the result is correlated to printed image quality by array type ink jet head especially in bending. Drop volume and trajectory error of ejected ink drop are measured and analyzed. The enhancement technology is presented to compensate for image variation across the printing media.

Introduction

The ink jet printing has been applied to the major printer product due to low cost ownership and color printing solution. But scanning type ink jet cartridge is hard to print fast compare to electro-photography device. Therefore, ink jet printer is confined to SOHO (Small Office and Home Office) market. In order to overcome printing speed restriction of shuttle type ink jet cartridge, the page width ink jet printing is the strong candidate due to low cost fast printing solution. [1] [2]

Compared to electro photography, Page width printing has simple printing process and requires simple mechanism for printing paper path. The Ink has more cost-effective and eco-friendly than toner. Therefore, Page Width Ink Jet Printing is the powerful printing solution for its cost-effective and fast printing speed and eco-friendly printing.

Image Banding of Page Width Printing

Page width printing is composed of multiple ink jet head chips. In case of single path printing, Each head chip should has strictly same performance because small deference of printed dot quality between head chips cause to the image banding across the printing direction. Fig.1 shows the image banding of page width ink jet printing in gradation test pattern. If we can apply multi path printing to page width printing, It is possible to compensate for image banding by a couple of compensation methods. But If we print the image by single path for fast printing speed, Image banding across the printing direction should be the critical issue of image quality. Human eye is very sensitive to the image difference between the image printed by each single head.We can make numerical criteria that human eye detect the difference by Optical Density. By observation of test patterns which have various Optical Density, we can decide the limit value of Optical Density difference in which human eye can detect the difference of images to be 0.02. As this value is almost the limit value of spectrometer resolution, the observation of Human eye is the more effective method to judge the image banding than optical density measurement.

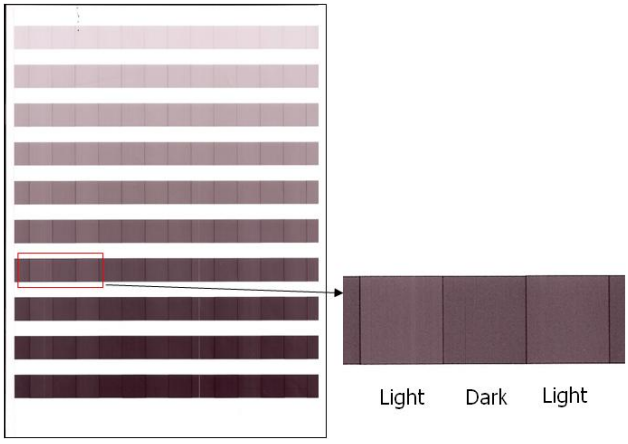


Figure 1. Image Banding due to Chip to Chip Variation

Page width Printing Device

In this study, we devised the page width printing device by thermal ink jet printing head. The each head chip has 4 color ink feed slot (C,M,Y,K) and 2 rows of nozzles per color. We could

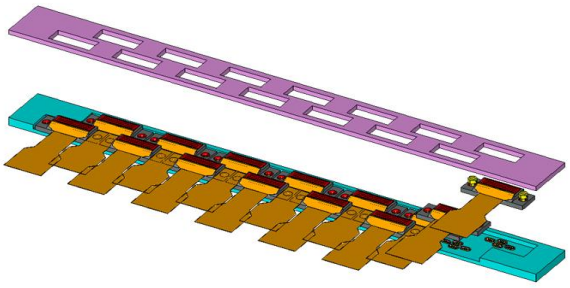


Figure 2. Page Width Printing device by Array Head chips

minimize the size of head chip arrays by applying head chips which has 4 colors per head. The head chips are placed in 2 rows in order to overlap the nozzles in edge side between the adjacent head chips. Fig.2 shows the shape of Page Width Printing Ink Jet Head arrays which is composed of 14 single head chips. The drop volume of Ink Jet Head is 3 ~ 4 pl, and nozzle pitch is 1/600 inch in a row. (half of pitch shifted between two rows)

Printed Dot Accuracy of Single Head Chip

In case of ink jet printing, The printed dot is a basic element for printed image. Therefore, In order to characterize the image banding of printed image, we must analyze the dot accuracy of Ink Jet Head. Fig.1 shows the test pattern for printed dot. This pattern is designed to check the overall dot accuracy. The printed dots from the all of nozzles are placed in equal space for each other because human eye can easily detect the defect of dot accuracy in equally spaced dot pattern in ease. The nozzles are arranged in two rows haft pitch shifted, and we named each row as odd and even row. In order to check the Odd and Even nozzle individually, Test pattern is designed separately and integrated one pattern called Odd/Even Gap Pattern (in Fig.3). We define the X,Y axis of Printed Dot according to the printed direction. The printing media moving Direction is Y-Axis, and the transverse direction of media is X-Axis. The test pattern is designed to arrange in equal X and Y spacing. In ordinary case, the dot accuracy is determined by drop ejection trajectory error. If dot accuracy is bad, the printed dots are overlapped each other, and the coverage of printed area decrease. This phenomena causes to the decrease of optical density. Therefore dot alignment error of each chip is important factor to

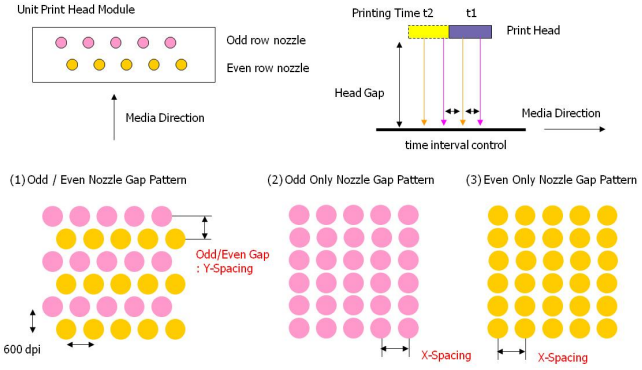


Figure 3. Test Patterns for Printed Dot Accuracy

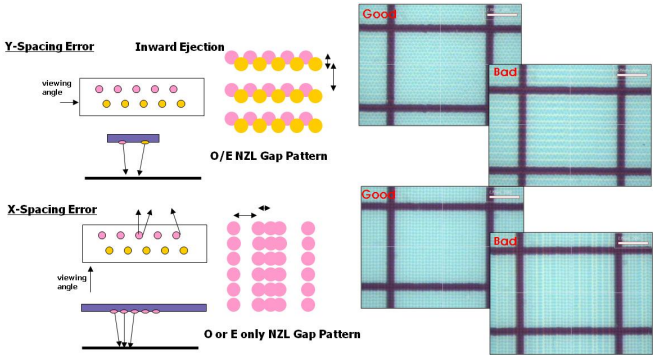
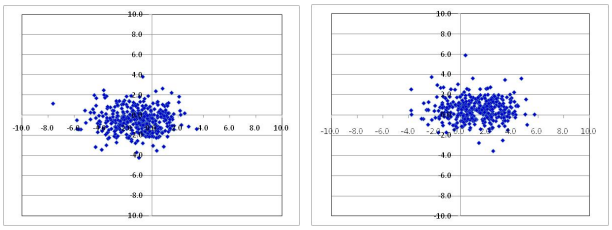


Figure 4. Dot Location Offset Error in X and Y direction

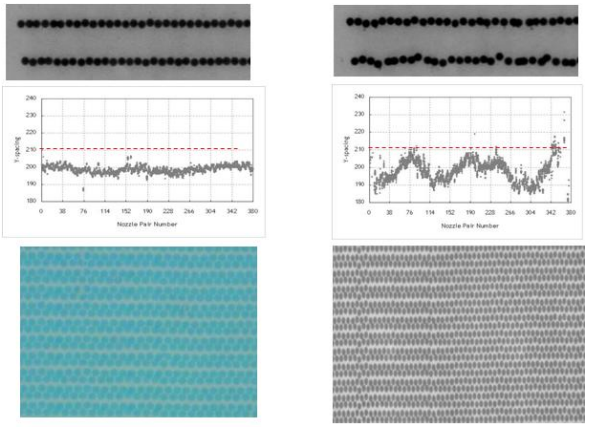
determine optical density. If there is trajectory errors in single head chip, we can detect the non-uniform image of the test pattern, and we can observe easily the trajectory error of printed dot in microscope. (Fig. 4)

Fig. 5 shows the measured data for alignment error of the head that we have fabricated. The standard deviations of odd/Even, X,Y axis are calculated under 2 microns, and these are good dot accuracy. But even though ink jet head has good dot accuracy, It happens to show poor quality for Odd Even nozzle Gap Pattern, In this case, if we print Odd, Even nozzle pattern separately, there would be no defect in patterns. It means that there are ink drop trajectory problems between odd and even nozzles. In usual case, to calculate dot alignment error from the measured x, y data of printed dot, the ideal point of printed dot is calculated from the average of measured points. This process ignores the spacial correlation between odd and even nozzles. By way of improving test pattern, we can measure the dot placement of odd and even nozzles. Fig. 6 shows the improved test pattern and measured data of printed dot in Y axis. The distance between odd nozzles and even nozzles in head chip layout is 210.7 micrometer.(10dots, 1dot =1/1200 inches) The left figure (a) in Fig.6 shows that average value of distances between the odd and the even nozzles are under the 10 dots, and it means that Ink droplets in odd and even nozzles is ejected to the paper inwardly in Y axis. In that case, dots from the each nozzles gets together and causes to decrease of optical density due to increase of non printed space. The right figures (b) shows the another phenomena that distance between the odd and the even nozzles varies in a nozzles rows direction.



(a) Odd Nozzles (B) Even Nozzles

Figure 5. Dot Alignment Error of Odd/Even nozzles in a Head



(a) Inward Ejected Pattern (B) Wavy Pattern

Figure 6. Dot Placement Errors in Y axis direction

To verify the inward jetting phenomena, the behavior of ink drop is observed by stroboscope. (Fig.7) The figure shows the behavior of ink drop between the nozzle and the paper. In case of abnormal jetting, the ink drop from the odd and the even nozzles flies to the paper inwardly. This observation shows that the coverage of image decrease due to inward ejection even if the trajectory errors of single head chip are small. In case of ink jet printing, trajectory errors depend on the distance between nozzle

surface and paper. Furthermore, inward jetting causes to critical trajectory error between the odd and the even nozzles.

In another point of view, If ink drop eject inwardly, printed image quality would be very sensitive to the paper path mechanism. In case of page width printing, It is difficult for the head chip arrays to be positioned precisely with printing media due to width of head chip arrays. Consequently, if ink drop eject inwardly, image quality of printer become too sensitive to mechanism.

Inward jetting phenomena is basically due to structure of head chip. The performance of ink drop ejection is very sensitive to surface of nozzle plate, and the residual stress of nozzle plate in fabrication process cause to the distortion of structure. Therefore, the structure of ink jet head should be fabricated very precisely.

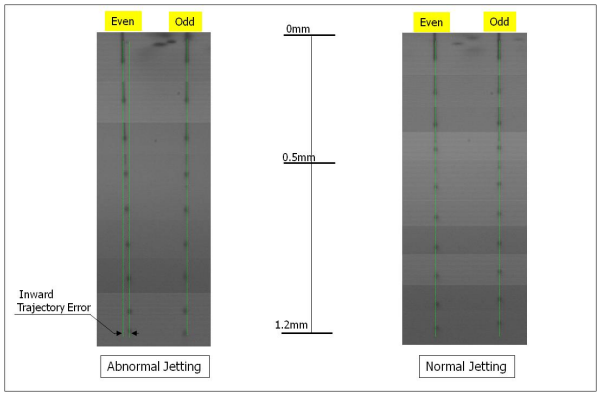


Figure 7.Inward Trajectory Errors between Odd and Even Nozzles

Image Banding of Page Width Printing

The Page width printing device consists of 14 single head chips. In order to accomplish printing quality, the differences of performance among the head chips should be minimized. Fig.8

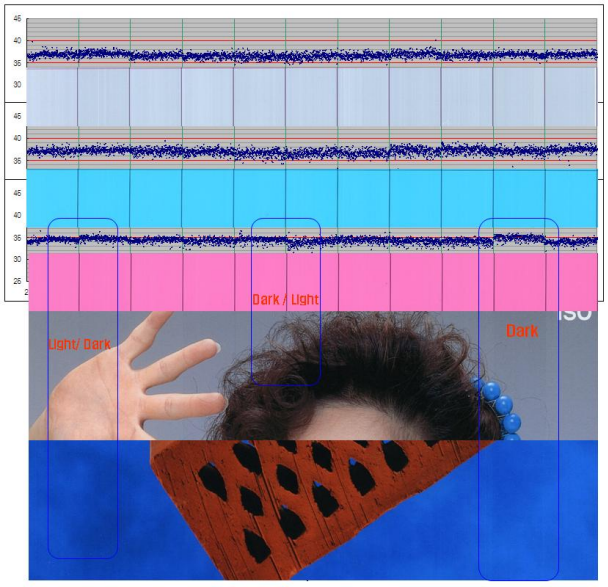


Figure 8. Image banding due to difference of dot size

shows the correlation between image banding and dot size of each single head chips. In case of single path printing, if there is difference of dot size between chips displaced in each other, the image banding easily occurred. The positions of Image banding coincide with boundary point of neighboring head chips which have different dot size. (Fig.8) The dot size is determined by drop volume of ink jet head, and drop volume is basically determined by nozzle diameter, and ink chamber structures. But the drop volume is affected by temperature of chip and physical property of ink, and it is difficult to equalize the drop volume of all the head chips in page width printing device.

Fig.9 shows the example in image banding of page width printing device. Test patterns of magenta, cyan and dot size (measured dot diameter printed in photo paper) and trajectory error in X-Y axis.

The third head chip from left end, has small dot diameter comparing to the other chip. The human eye is very sensitive "comparative effect" in difference of dot size, and the difference causes to the image banding. The another image banding is caused by streak. The streak is primary due to the trajectory errors in X-Y axis. The positions of streaks coincide with the position in which the trajectory error (Y-axis direction) occurred in. In this case, the cause of trajectory error is some addicted material in ink chamber, and the material is the reactant of ink component and the structure of ink supply path and head chip material, but there are many causes resulting in trajectory errors, like air bubble in ink chamber, plugged nozzle, surface degradation of nozzles, material trapped in ink chamber, deformation of Head chip micro structure, etc. The streak is the critical defect resulting in image banding in the Page Width Ink Jet Printing devices, and all of components in printing device should be prepared for this defect in design.

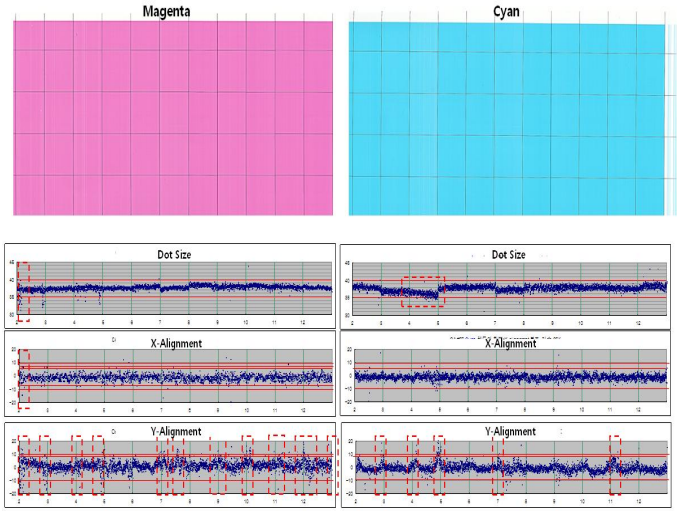


Figure 9. Image Banding due to defects of Printed Dot Quality

Compensation for Image Banding

The Inward jetting and dot size difference and streak, the factors resulting in image banding were studied as before. In order to compensate for the defects, some compensation method would be proposed. In first, inward jetting could be compensated for the modulation of interval between the odd and the even nozzles. The distance between the odd and the even nozzles is 10 dot. (1dot = 1/1200 inches). By using test pattern, the error caused by inward

jetting could be measured in ease, and the modification of interval between the odd and the even nozzles would be applied, and through the process, Image banding could be improved. (Fig.10)

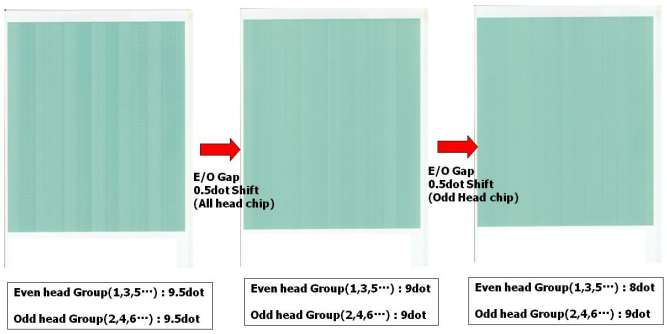


Figure 10. Compensation for the odd and the even nozzles

In second, the difference of dot size between head chips could be compensated for gamma correction for each head chips. By using the specific test pattern, the optical density of each head chips could be measured, and compensation gamma correction for each head chip, Image banding due to the dot size differences. In third, streak caused by missing or misdirected nozzles could be reduced by image compensation that transiting troubled nozzle to neighboring another nozzles for printing nozzle, but the effect of improvement would be limited.

Conclusion

In this paper, Image banding in Page Width Ink Jet Printing has been studied.

In first, single head chip composing Head chip arrays should have the Jetting performance satisfying image quality and required the performance criteria should be higher than one of scanning type ink jet head. In order to determine the limit of trajectory error of ink drop ejection, the criteria of inward or outward ejection should be considered.

In second, page width printing device should have the strict same performance ; the dot size, the trajectory errors. Because the human eye is very sensitive to difference between the neighboring head chips, image banding would be easily occurred in human eyes. Therefore, the performance of each head chip should be designed and fabricated enough to satisfy the requirement.

In third, some compensation method could applied to improved image banding , but the effect of improvement is limited, the page width printing ink jet device should have outstanding performance for printing.

References

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Author Biography

Oh Hyun Baek received the B.S. and M.S. degrees in mechanical engineering from Korea University, Seoul, Korea, in 1991 and 1993,, respectively. He joined Samsung Electronics Co, Ltd. Suwon Korea, and he worked on research and study of ink jet and Laser Beam printing process at the Digital Media Communication R&D Center. His recent research topic is focused on fusing technology