Research on Ink Droplet Placement on Moving Substrate

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Abstract

Many factors affect the ink droplet placement, such as aerodynamic interactions between droplets in flight and the movements of air caused by droplet streams and the motion of print-head and substrate. In this paper, a special experiment has been designed to check the influence on droplet placement exerted by substrate movement. We can ascertain the influences through checking the shape of droplet and the distance between two rows of droplet. In this experiment, the distance between printing head and substrate and the ink droplet flying velocity has been considered. From the experimental result, we can analysis the droplet placement characteristic under the condition of moving substrate, and the result could be helpful to the web feed inkjet printing technology.

Introduction

Digital inkjet printing is an important image printing technology, and also ink jet printing is one of the fastest developing printing technologies. Currently inkjet printing applied sheet-feed format, it means that the substrate is moving relative to the ink jet print head. This kind of production efficiency is not high, and also consumes long time. In this paper, we restructured an ink jet printing machine, so that the print head and the substrate can be moved freely as we need, by these experimental sets, we can find rules of droplet placement and formation on the movement substrate, and these rules will be useful to web-feed ink jet printing.

Droplet formation

Currently, common ink jet printing presses use piezoelectric crystal as droplet driving equipment [1]. The droplet size and shape are affected by the ink viscosity and the driving waveform on piezoelectric crystal, except that, the geometry of the orifice and the structure of print head also affect droplet [2]. From prior art, we can find that, ink jetted from the orifice by the driving of the piezoelectric crystal, after droplet left print head, affected by the viscosity of ink, the droplet is not exactly round in shape, but with a long tail [3]. During the droplet pass through the distance between print head and substrate, the droplet become to a big droplet and some small satellite droplets [1]. As shown in fig.1, under ideal condition, droplet and satellite droplet will placed at the same position on the substrate, and then a circular dot formed, but affected by the movement of substrate or print head, the shape of the droplet will change [4]. This paper is based on the prior art about droplet formation theory, and by analyzing the experimental data to conclude the droplet placement rules on moving substrate. At the same time, we change the distance between substrate and print head, then observed the variety of droplet on the substrate, so that we can find the formation characters of droplet and satellite droplets.

Experimental and analysis

To the common inkjet printing press, the print head is moving relative to the substrate. Here we use Epson 1390 printer, but we changed the structure of the machine, so that the print head and the substrate can move freely as we wish. We use photo as the substrate and appropriative ink for Epson. During the experiment we changed the moving velocity and distance between print head and substrate, so that we can print image under different condition. After printing, we check the image with QEA (quality engineering associates), so that we can get the parameters and characters of droplet under different printing condition. Analyzing the parameters and characters of droplet we can find the droplet placement rules on moving substrate.

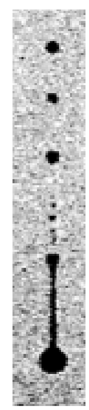

Figure 1 formation of satellite droplet

We check the droplet placement under two conditions. First we just move print head at different velocity but keep the substrate stillness, and second we keep the print head stillness but moving the substrate at different velocity, so that we can find some differences between two printing ways.

Under the first condition, we printed the image as shown in figure 2, and the print head moving velocity (v) is 0.37m/s, then we change the velocity to 0.55m/s. After printing we can found the image under different conditions, figure 3 shows the image of microscope printed at v=0.37m/s, to figure 4, v=0.555m/s, on theses photo we can find different shape of ink droplets.

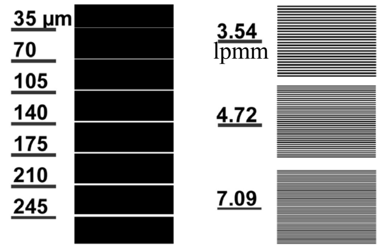

***Figure 2** printing image*

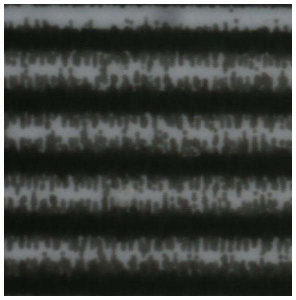

Figure 3 *microscope image of droplet shape (v=0.37m/s)*

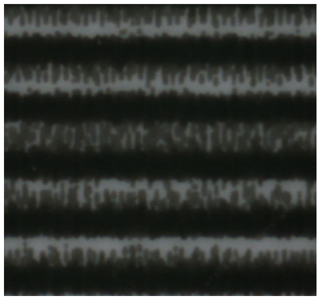

Figure 4 *microscope image of droplet shape (v=0.555m/s)*

During this experiment we print the image on figure 2, and we check the droplet formation by the image on the right of figure 2, the MTF is 4.72lpmm. From figure 3 we can find that at the moving speed of 0.37m/s, part of the space between two lines has been took-up by the satellite droplet. On figure 4 almost all the space has been took-up by the satellite droplet, and the print head moving velocity v=0.555m/s. By the parameters on figure 2, we know that the distant between two lines is 0.106mm. Then we got the width of line by QEA, in figure 3 the width is 0.182mm, so that the space width is 0.03mm, and then the droplet diffuse length is 0.038mm. As this kind of print head be concerned, common droplet diameter is 0.02mm, that means if the print head moved at 0.37m/s, the resolution of printing image will be reduced to one third of the ideal value.

To figure 4 the print head moving velocity is 0.555m/s, and on the image we can find that all the space has been took-up by the satellite droplet and from the space width we know the droplet tail is more than 0.053mm.

From the analyzing of two figures above, we can conclude that along with the fasting of print head moving, droplet tail will be longer and more satellite droplet appeared. So that we can say the length of droplet tail is directly proportional to the print head moving velocity.

Under the second condition, substrate moved vertical to the print head direction, so we print 30% neutral gray to analysis the droplet. The microscope image of droplet at different substrate moving velocity is shown below. The substrate moving velocity changed from 0.1m/s to 0.8m/s and the images are shown as figure 5 to figure 10.

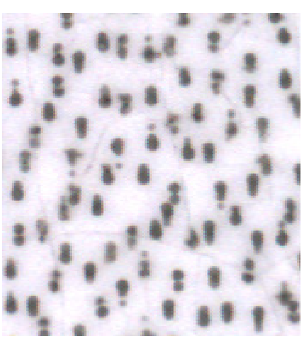

Figure 5 *droplet shapes with moving substrate (V=0.1m/s)*

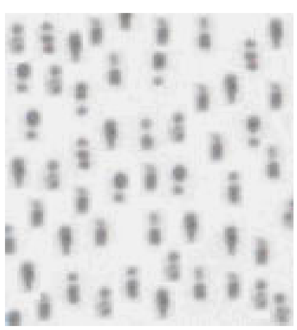

Figure 6 *droplet shapes with moving substrate (V=0.2m/s)*

Figure 7 *droplet shape with moving substrate (V=0.3m/s)*

Figure 8 *droplet shape with moving substrate (V=0.4m/s)*

Figure 9 *droplet shapes with moving substrate (V=0.5m/s)*

Figure 10 *droplet shapes with moving substrate (V=0.8m/s)*

From figure 5 to figure 10 we can find that droplet shape changed, as can be seen from figure 5, the ink droplet is similar to round. Then from figure 6, we can find the ink droplet become a little long, and also with more satellite droplet. Along with the fasting of substrate moving, we can find that droplet become longer from figure 7 to figure 9. But when the moving velocity is 0.8m/s we can find that it's very hard for us to divide droplet one by one, we can find only blurry line from figure 10. That means when the substrate moving velocity is at 0.8m/s, we can't print image clearly.

As can be seen from these figures, along with the fasting of substrate moving, the droplet tail become longer, at the same time satellite droplet appeared, especially when the substrate moving at the speed of 0.5m/s, ink droplet became to short line. It's means that when the moving velocity of substrate arrived at 0.5m/s, we can't print the image clearly. This is same to the condition that only moving the print head.

By QEA we can get the detail information about to the ink droplet, include droplet diameter, area, circularity and perimeter. We checked all the images shown in figure 5 to figure 10, and the droplet information in detail is in table 1. But for shorting of experimental set, we can only check the ink droplet information which can be discriminated, that not include figure 10, because the droplet in this figure is too small to be checked.

Table 1 droplet parameters under different print condition

Velocity of substrate moving(m/s)	0.1	0.2	0.3	0.4	0.5	0.8
Maximum diameter of droplet（mm）	0.023	0.031	0.055	0.062	0.058	0
Minimum diameter of droplet (mm)	0.010	0.010	0.009	0.007	0.007	0
Maximum area of droplet (mm^2)	0.00042	0.00049	0.00072	0.00058	0.00052	0
Minimum area of droplet (mm^2)	0.000143	0.000139	0.000141	0.00014	0.00014	0
Maximum perimeter of droplet (mm)	0.063	0.081	0.126	0.122	0.107	0
Minimum perimeter of droplet (mm)	0.018	0.018	0.019	0.016	0.016	0
Maximum circularity of droplet	1.333	1.22	0.98	0.86	0.96	0
Minimum circularity of droplet	0.409	0.362	0.32	0.285	0.32	0
Ideal resolution (lpmm)	21.7	16.1	9	8	8.4	0

From table 1 we can find that the maximum diameter of droplet is directly emotional to the substrate when the moving speed is below 0.4m/s, when the substrate moving speed at 0.8m/s, we can't check parameters of droplet, all the droplets become to blurry short lines. So first we can conclude that when the substrate moving speed is below 0.5m/s, we can get clearly droplet, when the speed exceeding 0.5m/s, droplet is blurry.

From above we know that the diameter of droplet is directly emotional to the substrate when the moving speed is below 0.4m/s, when the speed exceeding 0.5m/s, the droplet diameter becomes smaller. From last row of the table we can find that the ideal resolution is indirectly proportion to the substrate moving speed when the speed is below 0.5m/s but after 0.5m/s it is directly proportion to substrate moving speed. That means conflicts appeared. But combining with the image we can find that even the droplet diameter reduced, but the resolution never improved, because the droplet changed to many small satellite droplets, and the placement of the drop changed a lot. So in fact, even the droplet diameter become smaller, but resolution also falling.

Except above, we can also get information that droplet placement on the substrate is changed. It's means that the main droplet and the satellite droplet will placed on different position on the substrate, because them did not arrived at the substrate surface at the same time [5]. The phenomenon is caused by the ink and the moving substrate, due to the visco-elasticity, satellite must be form after ink jetted from print head, and then they go directly to the substrate [6]. For the reason that main drop and satellite will not arrived at the substrate surface at the same time, when the substrate moving, the main droplet and the satellite will placed on different position. But to the ideal condition, the main droplet and the satellite should be arrived at the substrate surface at the same time and also the same position, so that we can control the image quality [6]. What we want to do in the future is that we can let the droplet place on the ideal position even the substrate moving,.

From the analyzing above we can conclude that moving substrate will affect droplet placement and image resolution, if we want to change this condition, we need to solve droplet placement rules and reduce satellite droplet, this is important parameters for web-feed inkjet printer.

Under the third condition, we change the distance between print head and the substrate, and then check the droplet shape. As visco-elastic is concerned, the distance should be as small as possible, but to substrate, the distance should be far, so that we can improve print head adaptability to substrate. So a suitable distance is very important for print head, especially to inkjet print head [7].

From analyzing the droplet shape and size, we conclude the right print distance for different printers. The microscope images for droplet printed under different conditions are shown on the figure 11 to figure 14, and we can use figure 5 as the standard image. The distance "L" changed from 10mm to 25mm.

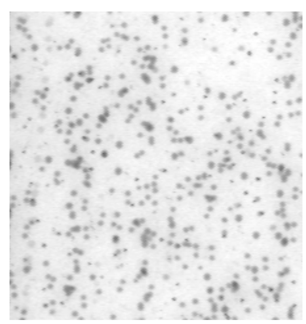

Figure 11 *microscope image of droplet shape (L=10mm)*

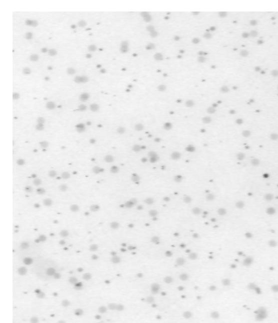

Figure 12 *microscope image of droplet shape (L=15mm)*

Compare figure 11 to figure 5, we can find that along with the distance between substrate and print head, more satellite droplets appeared. From figure 12 to 14, the droplet size become smaller, and we can't check them with QEA, we can only check them by comparing microscope images. From these figures, we can find the droplet changed obviously, especially on figure 14, the droplets has been atomized. On the microscope image we can only find tiny droplets, and the size of these droplet are too small to be check by QEA. So we can conclude that the distance between substrate and print head will affect droplet size and shape, and if the distance is more than 25mm, the droplet will become to tiny droplets. This kind of tiny droplet can't be used to form image.

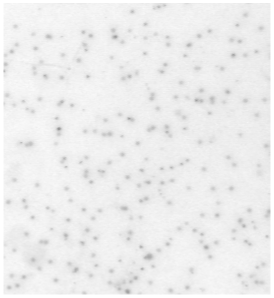

Figure 13 *microscope image of droplet shape (L=20mm)*

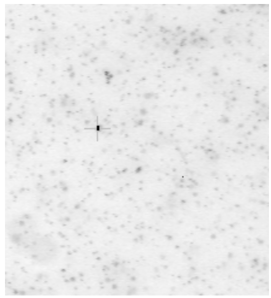

Figure 14 *microscope image of droplet shape (L=25mm)*

Conclusion

Digital inkjet printing is one of primary new print technology in the future, and web-feed inkjet printing is one of efficiency way to improve productivity of digital inkjet printing. Droplet placement rules on moving substrate are very important base data for web-feed inkjet printing. Based on prior art, by experiment and theoretically analyzing, we got conclusion as follow:

1). Under the condition of print head moving relative to substrate, the droplet shape and size changed along with the moving velocity. At the beginning, the droplet tail become longer when the velocity become faster, but after the velocity is faster than 0.5m/s, lot of satellite droplet appeared, and then the droplet become to short line, it can's be used to form image.

2). Under the condition of print head moving relative to substrate, variety of droplet shape and appearing of satellite droplet will affect resolution of print image, and the resolution inversely proportion to moving velocity.

3). The distance between print head and substrate is the primary factor affect the droplet shape and size, along with the increasing of distance, satellite droplet appeared, until droplet atomization.

4). We need to reduce or eliminate satellite droplet, and also control the droplet shape formation and placement on moving substrate by hardware improving, then web-feed digital inkjet printing could be achieved.

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