Evaluation of the standard Deviation of Droplet Speed on Grey-Scale Technique of DoD Inkjet Printer

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Abstract. The print quality of an inkjet printer is determined by the quality of the droplets. The droplet quality of a DoD inkjet printer is affected by speed variation between the droplets that generated from different nozzles. The effectiveness of a preliminary vibration using the W waveform design to generate spherical droplet without satellite and ligament has been denoted from previous studies. The waveform design considered to influence the speed variations of droplet. The standard deviation of droplet speed from different waveform design was investigate and evaluated. In this study, it is evidenced that by performing rear-wave adjustment on the W wave design can effectively reduce the standard deviation of droplet speed and produce the highest average speed.

Keywords: DoD inkjet printer, waveform design, standard deviation, multi-drop method

1. Introduction

The target and challenge in inkjet technology related to the quality of an inkjet printer are to develop high-speed printers with good print quality. The application demand inkjet printer is increase capability on droplet velocity [1]There are two major categories in inkjet technology principles, namely continuous and drop-on-demand (DoD) processes. In DoD, each droplet will be ejected through the selected nozzle to produce ink droplets directed at the print surface [2]. In achieving a good print quality, we must ensure that every nozzle from the printhead can produce a droplet which similar speed. The smaller speed difference of droplets from different nozzles, the better print quality will be produced. A study investigated droplet behaviour through the volume and speed of a droplet, as well as the occurrence of ligaments and satellites. This study shows that there is an anomaly in the droplet speed that caused by the instability of the vacuum, not because of the actuation voltage [3]. Several studies investigate the droplet speed [4]. Those studies are in agreement that both speed and volume of a droplet are determined by the actuation voltage given [5], [6], [7]. The greater voltage will generate the greater pressure applied to release the droplet. This higher pressure will make more
droplets coming out with greater volume and a higher droplet speed. These studies did not examine how the influence of the waveform design on the speed difference between droplets on Drop on Demand (DoD) inkjet printers. Previous studies study that investigated the droplet volume and velocity with different keep time (t_{keep}) or dwell time of high-frequency driving waveform stated that there is a linear relationship between keep time and droplet behaviour [8], [9], [10]. Another study evaluated the standard deviation of single droplet diameter and volume by different trigger of delay time [11].

The standard deviation of droplet speed was not considered in that study. In this study, we examined the speed and standard deviation of the droplets generated by the DoD inkjet printer. There are several waveforms that have different preliminary vibrations. The waveforms chosen are those will produce spherical droplets without satellites and ligaments. In addition, this study used the multi-drop ejection method which is still not widely discussed. It sometimes called as the concept of multi-pulse grayscale printing is the technique of firing a number of ink droplets within a short period of time, from a single channel. It will generate different volume of droplets depend on pulse number of actuation voltage. The number of droplets will be merged in flight before contact to print surface to form a correspondingly variable-size printed dot in the print surface. [12]

2. Research Method

This study used experiment device to observe droplet behaviour called IJ DOT GENS which is connected to a PC to provide signals to the piezoelectric printhead. The experimental scheme is shown in Figure 1.

Figure 1. Experimental Device and schematic diagram
The liquid used in this study was Dowanol with the same viscosity. Frequency used was 1 kHz and a head temperature of 25 degrees Celsius. The Actuation Voltage used is also equal, which is 14 V. The experiment study was conducted to investigate the standard deviation of droplet speed for different waveform design. This study was using multi-drop ejection method for five main pulse with additional preliminary vibration and suppressing vibration. Five main pulses used pull-push method or negative waveform with parameter of $t_{down} = t_{keep} = t_{up}$ respectively 2µs. The main pulses and suppressing vibration pulse are shown in figure 2. The parameter of $t_{down} = t_{keep} = t_{up}$ for suppressing vibration pulse respectively 1µs with 50% actuation voltage. Several types of preliminary waveform design that were used in this study as shown in Table 1.

| No | Waveform Name | Waveform Design (Preliminary) | Remark |
|----|---------------|-------------------------------|--------|
| 1  | Full W preliminary vibration | ![Waveform Design](image) | No cut $t_{down} = t_{keep} = t_{up} = 2\mu s$ $t_{wait} = 0\mu s$ |
| 2  | Cut Front W preliminary vibration | ![Waveform Design](image) | Cut 20%, 30%, 40% Voltage $t_{down} = t_{keep} = t_{up} = 2\mu s$ $t_{wait} = 0\mu s$ |
| 3  | Cut Back W preliminary vibration | ![Waveform Design](image) | Cut 20%, 30%, 40% Voltage $t_{down} = t_{keep} = t_{up} = 2\mu s$ $t_{wait} = 0\mu s$ |
| 4  | Cut Front-Back W preliminary vibration | ![Waveform Design](image) | Cut 20%, 30%, 40% Voltage $t_{down} = t_{keep} = t_{up} = 2\mu s$ $t_{wait} = 0\mu s$ |

![Figure 2. Main pulse and suppressing vibration pulse](image)
3. Result and Discussion

The waveform so called “W waveform” is an initial wave as preliminary vibration, without causing ink to be ejected from the nozzle chamber. This preliminary vibration is able to avoid the push-pull type of piezoelectric inside printhead from water-gun effect. The preliminary vibration as shown in table 1 was added to the five main pulse for greyscale technique with multi drop ejection method. This preliminary waveform function is as the backpressure or negative pressure to withstand high pressure from wave superposition result of multi pulse. The suppressing vibration at the end of waveform design will also reduce the residual vibration that tend to lead the satellite occurrence. It is recognized that the droplet velocity is proportional to the amplitude of the pulse, but retraction speed is inversely proportional to the amplitude of the pulse [13].

The scale up voltage of each sequencing pulse in multi drop ejection method with proper adjustment will make each drop will merge without ligament or satellite remains. By using various kinds of waveform designs that have different preliminary vibrations, we can see that there is a difference in the speed for each droplet from each selected nozzle. The selected nozzles are 10 nozzles in each observation. It is important to understand that in this study, only the waveforms that produce spherical droplets are compared. It has been confirmed that the waveform used in this study is a waveform that will produce droplets without satellites and ligaments. Hence, the additional thing that can improve print quality is the small speed difference between the droplets. This shows that the waveform will be able to produce droplets that have a stable velocity. The influence of waveform design is shown in Figure 3. It depicts that the droplet from waveform design with full preliminary vibration will produces the highest droplet speed. On the other hand, the smallest adjustment both on front and back wave of preliminary vibration will generate the lowest speed of droplet.

As for the difference in speed of each droplet can be seen in figure 4. The figure shows that full preliminary vibration of W waveform also makes a small speed variation than others. The waveform design with 40% adjustment both in front of back wave of preliminary vibration also shows better performance than 20% and 30% adjustment. It was stated previously that the target of this study is to determine a wave form design that can produce high velocity droplets and has the smallest standard deviation of droplet speed.

Both quality parameter of inkjet printer is shown in figures 5 - 8. It can be seen that from the whole waveform design and considering these two parameters, the full W waveform denote the best performance. It shows that the full wave of preliminary vibration is an optimal quantity that can produce sufficient back pressure to withstand the amount of pressure generated by the multi-drop ejection method. This preliminary vibration is also proven to be effective in reducing the residual vibration that can cause the satellite and ligaments to occur. The stability of each droplet to be released simultaneously at different nozzles can also be achieved, which indicates minimal crosstalk that occurs.
Conclusion

The results of research using analysis and practical study using different waveforms show that the waveform that uses full preliminary vibration without adjustment has the highest speed and the lowest standard deviation of velocity between droplets. Adjustments made to either the front wave or the back wave by 40% have also proven effective in producing spherical droplets without satellites and ligaments with acceptable standard deviation. Full W preliminary vibration with additional suppressing vibration is proved to be a viable waveform for reducing residual vibration and crosstalk to generate stable droplet behaviour among different nozzle.

Figure 3. Influence of waveform design on droplet speed
a) Full preliminary versus different front wave adjustment
b) Full preliminary versus different back wave adjustment
c) Full preliminary versus different front-back wave adjustment
d) Front-back wave adjustment with different $t_{\text{wait}}$
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Figure 4. Droplet observation result of different waveform
Figure 5. Full versus cut front wave of W preliminary vibration on droplet speed and standard deviation of droplet speed

Figure 6. Full versus cut back wave of W preliminary vibration on droplet speed and standard deviation of droplet speed
Figure 7. Full versus cut front wave of W preliminary vibration on droplet speed and standard deviation of droplet speed.

Figure 8. Different $t_{\text{wait}}$ of front-back wave of W preliminary vibration on droplet speed and standard deviation of droplet speed.
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