Nozzle Plate Observations during Printing: Pooling and its Impact on Reliability

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Abstract

Many factors control the reliability of a print head during use. Apart from altering the jetting condition like drop velocity and frequency, reliability can be controlled during the development of the waveform for the ink/print head combination. It may also be modified through careful control of the components and the physical properties of ink.

Typically drops are observed in flight while waveform is developed to produce drops of the desired characteristics. Through close observation of the nozzle plate during this process it was noted how the non-firing neighbours of printing channels were prone to pool under certain conditions while pooling around the jetting channel would have been expected. Adjustment to waveforms to reduce the degree of pooling was found to improve printhead reliability.

Work did not concentrate solely on waveform development. Improvement to jetting and reliability was also found through fine tuning the composition of the ink. Similarly, conditioning the nozzle plate was found to slow the onset of pooling. This may offer an alternative approach to improving print reliability through ink or waveform modification since wiping the nozzle plate may be included as part of the maintenance routine.

Introduction

Several terms may be used to describe and quantify printhead reliability such as drop deviation, the formation of tick marks, the occurrence of lines dropping out and the onset of printhead flooding. Under certain circumstances these conditions may recover by themselves while at other times the failure may be unrecoverable. As a manufacturer of printheads, an approver of inks and a developer of waveforms, Xaar have access to many tools for measuring printhead reliability and offer some solutions to improve their operation.

One of the tools regularly used in measuring printhead performance through observing drops in flight when developing waveforms is the microscope rig. This comprises of a video camera which views drops ejected from a print head using a stroboscopic light source. A time averaged view of the drops is displayed. For higher resolution images a stills camera and a high speed flash source is used. The higher resolution allows detail that is missed by the video camera based instrument to be observed, for example satellite drops, accidental drop ejection and mist formation, under certain favourable conditions.

A waveform is a means of defining the timing of the movement of the channel walls in a piezoelectric printhead so that fluid movement is amplified by constructive interference of acoustic waves to the point that bulk ejection can occur. Ordinarily two pulses, one to move channel walls out and back, the other to move the channel walls in and back comprising of four transitions, are enough to eject a drop and these are notionally described as the Draw, Release, Reinforce and the Cancel edges. For greyscale printing, a multiple of these four transitions are required. The subtle relationship in timing of these transitions defines how the drop is ejected in terms of drop volume, drop velocity, degree of satellite formation, and as will be shown below, nozzle plate pooling.

Nozzle Plate Pooling

Issues arose with a particular ink used with the 1001 printhead concerning reliability and overall performance. On close inspection it could be seen that at high drops-per-dot (dpd) levels some ink collects around the jetting nozzle (Figure 1). This may be expected to occur when pumping so much ink through a nozzle for a period of time where any ink around the nozzle may interact with the pulses of ink that are ejected while the high grey level drop is formed. A dynamic equilibrium forms between ink accumulation and clearing and this is discussed below.

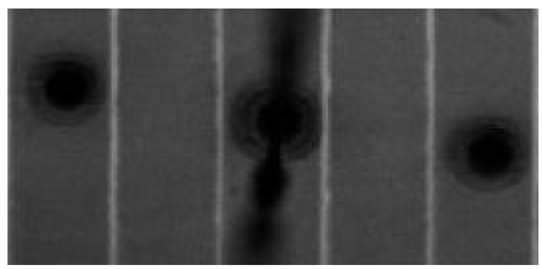

***Figure 1**. Ink accumulation around isolated nozzle after printing 200 lines of 7dpd drops at 6kHz.*

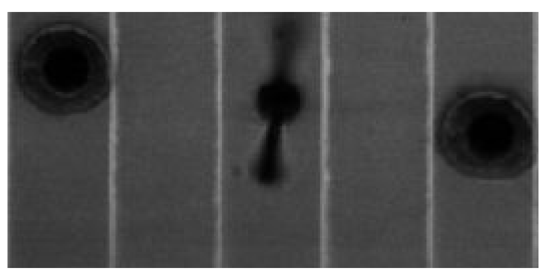

***Figure 2**. Ink accumulation around non-jetting nozzles after printing 200 lines of 1dpd drops at 6kHz.*

What was surprising was the degree of pooling that arose at low duty, when jetting 1dpd drops in a very low density image. As Figure 2 shows, ink pooled around the non-firing nozzles. A side-by-side comparison with higher dpd levels (Figure 3) shows that more ink collected in this low duty case than at high dpd.

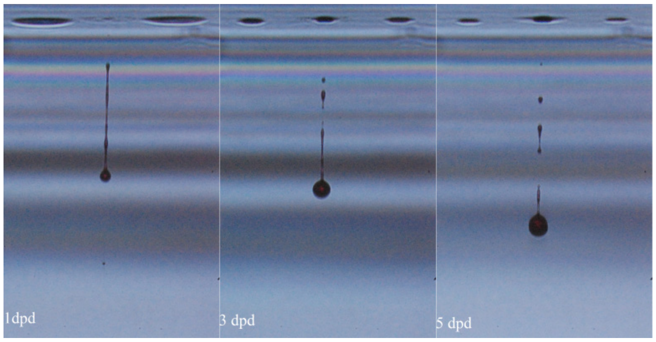

Figure 3. Ink accumulation around jetting and non-jetting nozzles when printing 10000 lines at 6kHz through an isolated nozzle at 1, 3 and 5dpd.

The collection of ink around the non-firing nozzles had effects that were clearly visible when looking at drops in flight that could be easily related to print quality issues. Figure 4 shows the effects the pools of ink over nozzles have on subsequent drops ejected through those nozzles. In the left images the 1dpd drops ejected through the pooled nozzles were clearly slower, in this example between 12% and 16% slower. In the right image the 1dpd drops ejected though the pooled nozzle were deviated, and again slower as shown by the shorter ligament trailing the drop.

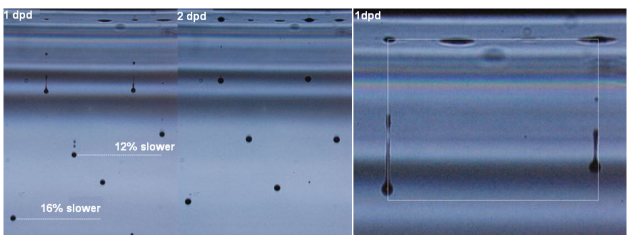

Figure 4. Effect of ink pools on subsequently ejected drops through these pools. Left; drops were slowed. Right, drops were deviated.

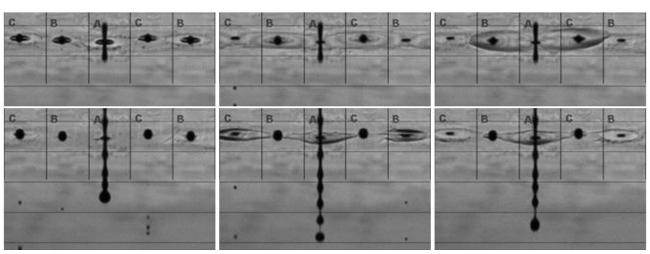

Figure 5. Microscope rig images taken while jetting 1dpd drops (top row) and 7dpd drops (bottom row). Left panels show printing at full duty, centre panels show printing at half tone and the right panels show printing an isolated nozzle

As indicated above the formation of pools around nozzles is a dynamic process. Fig. 5 shows microscope images of pools of ink forming around nozzles as well as some of the streams between nozzles as this ink migrated. An indication of the relative time taken for pools to form and clear is plotted in Figure. 6. At 1dpd, printing at full duty, small pools formed around the nozzles. These dissipated quickly after printing stopped. When a half-tone image or an isolated nozzle was printed pools formed around the non-firing channels. These spread to the jetting channel where the ink was actively absorbed. The more nozzles that were jetting the more quickly the pooled ink cleared. At 7dpd pools formed around the firing channel as described above. Pool growth was slower than was the case for pools formed around non-firing channels at 1dpd. For the half-tone or single pixel images the pools around the jetting nozzle spread to the non-firing neighbors. Again the pools dissipated after printing was stopped.

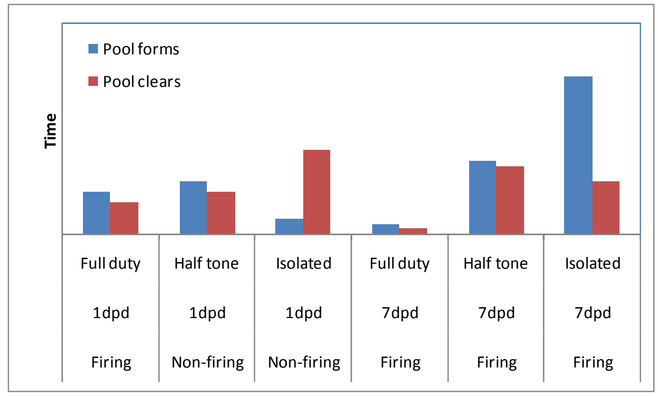

Figure 6. Relative time taken for pools to form (blue) and clear (red) around firing and non-firing nozzles, depending on image printed and the number of drops per dot. Full duty was with all nozzles printing while half tone was with every other nozzle printing. Pools quickly formed around non-firing nozzles when printing isolated nozzles at 1dpd and these were slow to clear. Conversely pools were slow to form around nozzles printing at 7dpd at full duty and these were quick to clear.

As indicated above the subtle relationship among the waveform edges may have an influence on the degree of pooling. In the specific example of pooling arising around the non-firing nozzle when jetting an isolated channel for a particular waveform, pooling around the non-firing nozzle was found to dramatically reduce when the gap between particular waveform edges was altered (Figure 7). However any improvements have to be balanced with other print performance indicators; drop velocity and volume at higher grey level values and their sensitivity to image composition.

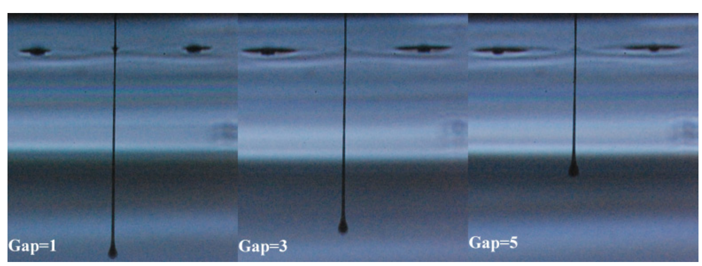

Figure 7. Degree of pooling formed around non-firing nozzles when jetting an isolated nozzle at 1dpd as a function of the time period ("Gap") between the Draw-Release and Reinforce-Cancel pulses of the test waveform.

The control of nozzle pooling thus far has been restricted to waveform tuning. A further solution may be to consider the interaction between the nozzle plate and the ink. Some combinations of ink and print head may be more prone to flooding and subsequent failure than others. A change in the surface characteristics or the material used in nozzle plate construction may be considered in the long term. A short term solution may be to apply a temporary coating to the nozzle plate. If done at regular intervals this may be considered during printhead maintenance cycles. During this study pooling was to occur most readily when the nozzle plate was freshly cleaned with solvent, less so after a prolonged period of printing (Figure 8). It was later found that wiping the nozzle plate in concentrated surfactant solution greatly reduced the onset of pooling.

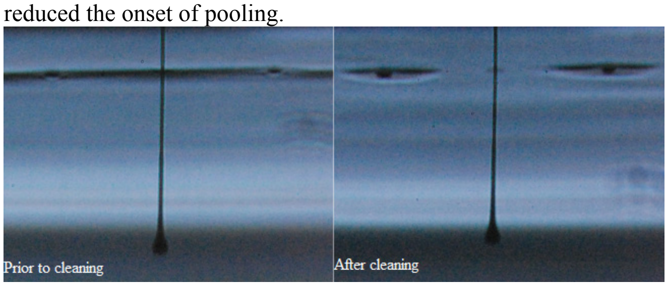

***Figure 8**. Pooling around non-firing nozzles when printing at 1dpd. When observed after prolonged initial printing the pools were slower to form (left) than when the nozzle plate was cleaned with solvent immediately prior to observation (right). The same effect of delaying pool formation was observed when the nozzle plate was wiped in concentrated surfactant solution.*

Conclusion

The pooling of ink around nozzles when printing at low duty is described. The combination of jetting 1dpd drops from isolated nozzles for a particular ink while developing waveforms gave rise to ink pools which formed around the non-firing nozzles. Fortunately some waveform tweaks were found to reduce the degree of pooling and these could be incorporated when looking at future printhead-ink combinations. Alternatively regular nozzle plate conditioning, possibly during maintenance cycle, may be considered.

Author Biography

Mario Massucci has a BSc in chemistry and PhD in physical chemistry from University of Bristol. He has many years experience in developing instruments in R&D in both academia and industry. He joined Xaar in 2007 as a research technologist and currently works on visualisation and measurement techniques along with simulation tools for current and future printhead designs.