

Long-Stable Jetting on Thermal Ink Jet Printers

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Abstract

In the small color printer market, long life of print heads is a key factor to realize running cost reduction and a non-disposable engine for environment-friendly use. In the Thermal Ink Jet (TIJ) printers, kogation of ink components onto the heater due to thermal cycle caused shorter life of the heads.

To solve this problem, we studied a removal method of kogation by a drive pulse called a “Recovery Pulse” which is different from that for printing. As the result, we have found that kogation can be removed efficiently from the heater by adding the recovery pulses with smaller drive energy than that for normal printing. That is, apparently this recovery is made not by a cavitation induced self-healing, but by the mechanism of residue floating or detachment. Based on the study, it can be concluded that the recovery pulse using the mechanism is effective for removal of kogation.

Subsequently, we have developed a system to utilize the recovery pulses in the maintenance operations effectively and vary the drive method of print heads depending on the print history (aging). As the result, we have realized a non-disposable TIJ print head using water fast inks.

Introduction

We have developed and launched a low-end printer in June 1998 (Fig. 1). One of the printer features is small size, but B4-size paper (-257 mm) printable. Its print head structure is dual type that consists of black and color as shown in Fig. 2. This print head has a permanent life firing waterfast dye-based inks which was realized by an ink deposition (kogation) control technology that we are going to present in this paper.

Figure 1. Fuji Xerox Jet Wind 300C.

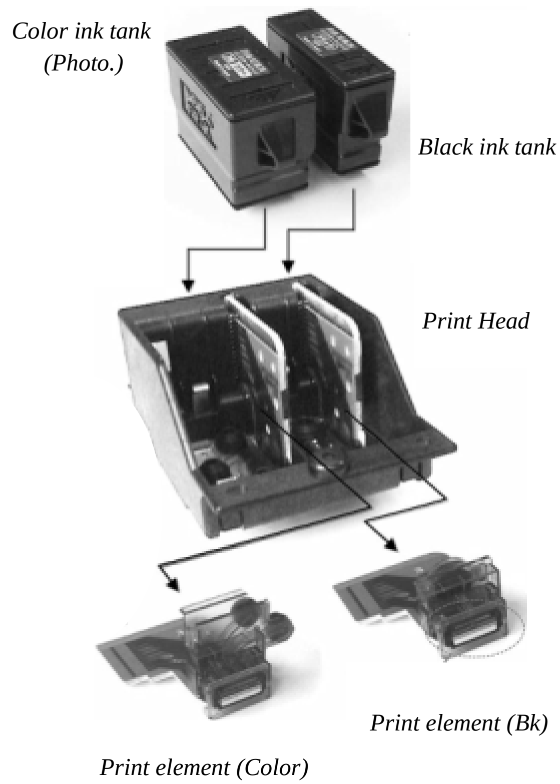

Figure 2. Print head and ink tank.

Kogation Study

Fig. 3 shows a degraded print sample after 2K prints of a 5% coverage paper. Kogation of the heater makes ink drops smaller in size and slower in jetting, resulting in printer shutdown. SEM photographs of the heater are shown in Fig. 4. Kogation residues on the heater surface seem to be detachable, and the thickness looks around several 10 nano meters.

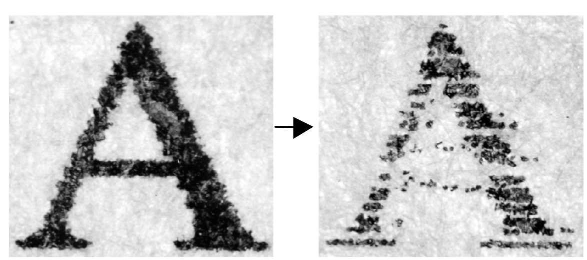

Figure 3. Print quality degradation by kogation.

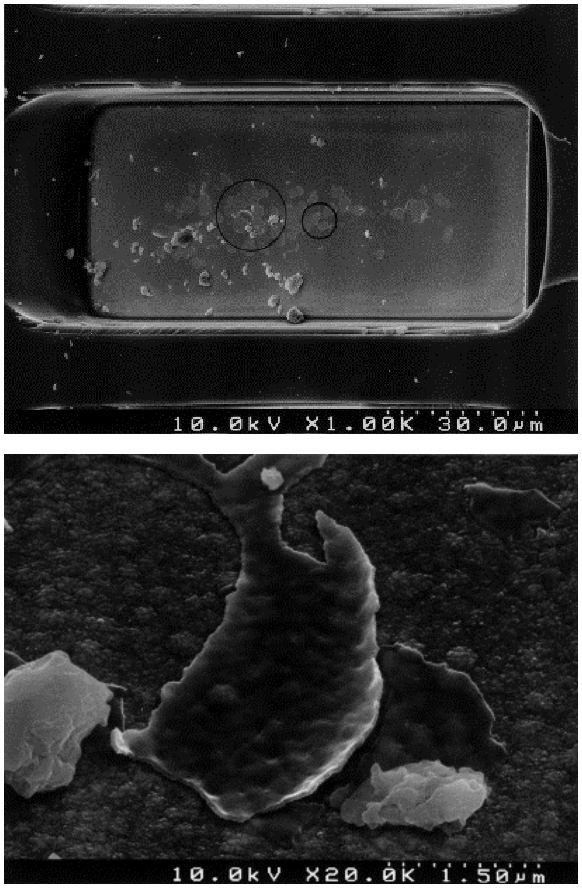

Figure 4. Kogation residues on heater surface.

Figure 5 shows the variation of drop velocity as a function of jetting pulse number. With the increase of pulse number, the velocity is decreasing, so we can see that thermal efficiency is decreasing with the growth of kogation. And also shown in Fig. 5, initially velocity is stable, but after the stable stage, the velocity is goes down by a periodical change of going up and down. We call the incremental recovery phenomenon of velocity in normal printing "a self-healing".

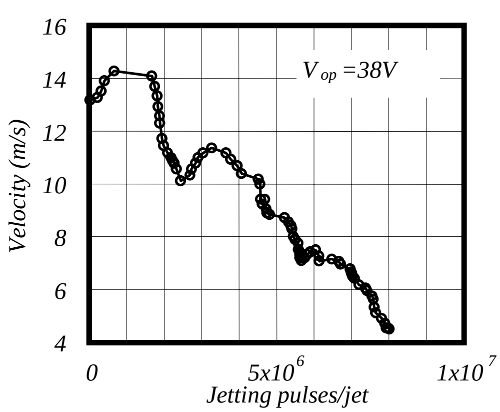

Figure 5. Change in drop velocity as a function of pulse number.

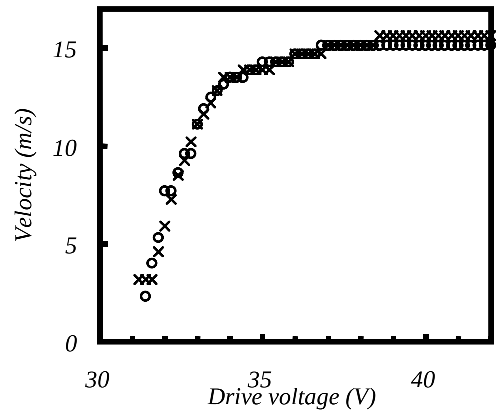

Figure 6. Drop velocity voltage characteristics.

We consider that the self-healing is carried out by cavitation force which attacks the heater surface, by which kogation residues are removed from the surface, and the thermal efficiency is recovered, resulting in the increase of drop velocity. Fig. 6 shows the voltage characteristics of drop velocity that saturates in the high voltage side. Cavitation force is considered to depend on the size of bubbles, and the drop velocity reflects the bubble size. Hence, the cavitation force should be saturated at higher voltage.

The slope of velocity decay shown in Fig. 5 represents a fluctuation per pulse, which suggests a growing speed of kogation. We estimated the slope/initial velocity to obtain the decrement rate per pulse from the initial. As shown in Fig. 7, fluctuations are small at 39 V or lower, however, above 39 V, the decrement rate goes up with the increase of voltage. This shows that the saturation of cavitation force caused a sudden increase of kogaton.

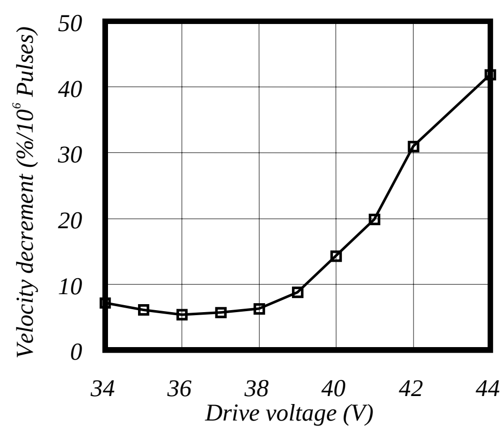

Figure 7. Kogation voltage characteristics.

Recovery Pulse [1]

By setting the drive conditions appropriately, kogation on the central part of the heater is self-healed by cavitation. However, kogation cannot be detached from the edge.

Unless residues on the edge are removed, kogation gets worse, resulting in the inability to jet.

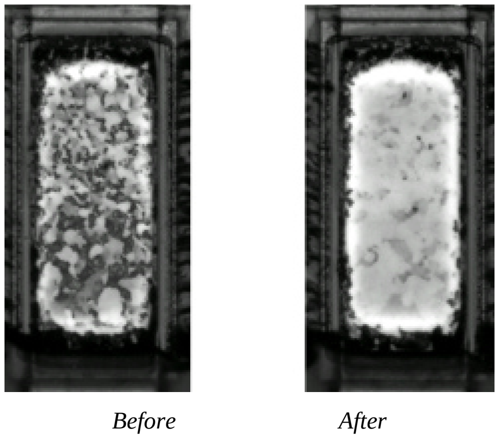

Figure 8. Kogatin detachment by Vth energy pulse.

When we measured the voltage to start jetting by decreasing the drive voltage, we observed a recovery phenomenon that the dot diameter reduced by kogation became smaller. After the measurement, we could see from Fig.8 that all residues including those on the edge were removed. Assuming that unstable jetting condition in the proximity of voltage threshold is effective for removal of kogation, we tried to realize it by controlling the width of a dual pulse[2].

Experimentally, we optimized and selected recovery pulse wave form. Video tape of kogation detachment will be presented at the conference.

We consider that recovery mechanism can be explained by bubble generation condition. In boiling curve [3], there is transient boiling under film boiling which is utilized in normal printing bubble generation. Bubbles by transient boiling have floating force at random area of the heater although bubbles by film boiling have cavitation force at the center of the heater at high temperature, where kogation increases at the same time as shown in Fig. 9.

We introduced a recovery pulse into the maintenance sequence as shown in Table 1. As a result, we didn't experience printer shutdown around 2K prints.

Table 1 Recovery Pulse Driving Method

Timing	Recovery Pulse Numbers	Print Pulse Numbers
Page	300	1×10^4
Tank	5000	1×10^6

Grade up Pulse

Recovery pulse was effective, but insufficient for stable operation because the dot diameter was decreased 10%, as shown in Fig. 10. Residues still remained at the edge of the heater in spite of the recovery pulse. We didn't utilize the increase of pulse numbers as a solution, because it will consume ink and time for maintenance greatly.

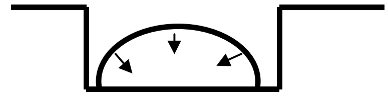

Fig.9-1 Bubble by film boiling

Kogation detachment by normal cavitation.

- *Cavitation force concentrated on the center of the heater.*
- *Kogation increase same time at high temperature.*

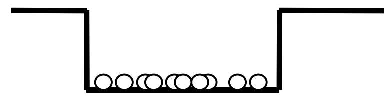

Fig.9-2 Bubble by transient boiling

Kogation detachment by perturbed condition.

- *Floating force at random area of the heater.*
- *No increase of kogation at the low temperature.*

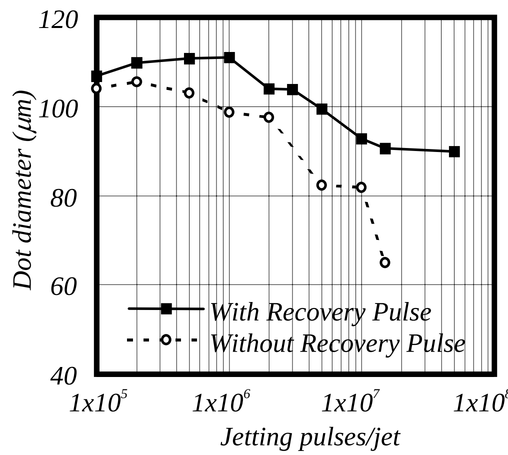

Figure 10. Dot diameter degradation by kogation

Again, we have developed another method to stabilize ink jetting which was named "grade-up pulse". Its concept was to increase the jetting energy to compensate heater area decrease by kogation.

Table 2. Two Step Jetting Pulse Grade up Method

Jetting Pulse	G-Up Timing	Jetting Pulse	Purpose
Initial	0~	.50+2.25	---
1st G-UP	1×10^6~	.50+2.50	Minimize Dot degradation
2nd G-UP	3×10^6~	.75+2.50	Dot diameter compensation

As shown in Table 2, not recovery pulses but printing (jetting) pulses are changed with reference to the total printed pulse numbers. Here, main pulse enhancement is expected to be effective for minimizing the dot degradation due to the increase of cavitation force, and pre-pulse enhancement is effective for increasing the drop volume. By this approach, fluctuations of dot diameter were kept within our specification. Namely, kogation problem was completely solved as shown in Fig. 11.

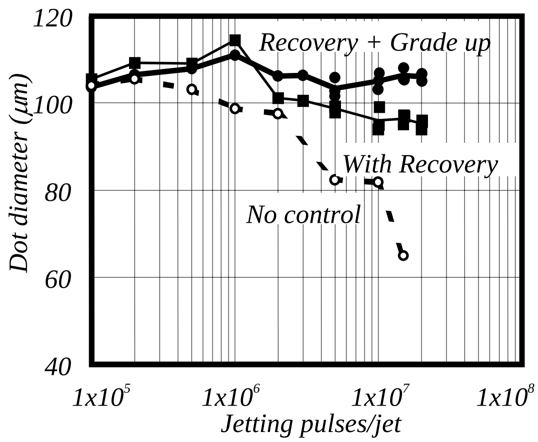

Figure 11. Dot diameter variation by optimized drive pulse.

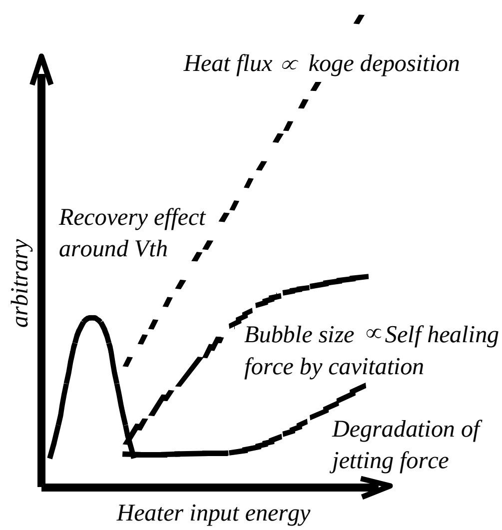

Figure 12. Conceptual kogation mechanism

We consider our control method including the relationship between recovery and grade-up mechanisms (see Fig. 12). Recovery effect around the voltage threshold prevents the increase of kogation, and grade-up pulses enhance the self-healing ability, by which the jetting performance is not degraded, and it stays at its initial condition. Note that a grade-up pulse does not work well and just increases kogation when no recovery pulses are driven.

Conclusion

A long-life permanent print head has been realized by utilizing waterfast inks. Our kogation control system widens the range of progressive inks usage for future thermal ink jet systems.

References

1. Masaki Kobayashi, Kazunori Onishi, Masashi Hiratsuka, Naoki Morita, "Removal of Kogation on TIJ Heater", *Pan-Pacific Imaging Conference* / Japan Hardcopy '98, pp.326-329, July 15-17, (1998).
2. N. Koitabashi, H. Tajika, "High-Quality Image Technology for Bubble-Jet Printing", *Electrophotography* Vol. **33**, No.2, pp.177-184, 1994.
3. H. Uchida : Dennetsu Kogaku, *Heat Conductivity Engineering in Japanese*, 1969.