Findings from 15 Years of TonerJet® Research

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A Race for Superior Print Quality

TonerJet has since 1986 been developed with the expressed purpose to be faster than Ink-jet and lower in manufacturing cost than Electro Photography. During the latest six years these efforts have been focused on color applications. Today, 15 years after the first premature attempts to create some dots on a piece of paper, it could be of general interest to summarize the findings from this extensive work with relatively small resources.

The inherent conceptual features of TonerJet - speed, cost and size of product are still unchallenged by other technologies. The 350 man years spent on R&D has consequently been focused on keeping up with a competitive print quality. A race where we today can claim an equal quality to many commercial EP-products. However, equality will not be enough, for any novel technology, and Array and its partners will continue its inexhaustible efforts for superiority also in print quality.

As the case for all aperture based print technologies, high frequent vertical line noise or stripes constitutes an inherent print defect. The most obvious and effective solution, the one chosen for ink-jets, -Interlacing was implemented only two years ago. Nevertheless, Interlacing is a mean to hide basic technical imperfections. Any research team developing novel print technology must spend tremendous time to understand the route course of any and all imperfections. Many of these is to be found in electrostatics, physics and surface chemistry inside and adjacent to the aperture it self.

This paper will high light the time consuming obstacles of this race for dot size uniformity, less scattering and print process robustness in a holistic view of these 15 years of R&D with a novel non impact printing technology. *(This paper does not provide any specific scientific results).*

Introduction—TonerJet

TonerJet is a so-called direct print technology. This means that the toner can be transferred directly to the paper or other print medium, thereby avoiding the intermediate storage needed in a laser printer. The result is fast printouts, since there are fewer processing steps, as well as low manufacturing costs and high operating reliability, since fewer components are involved.

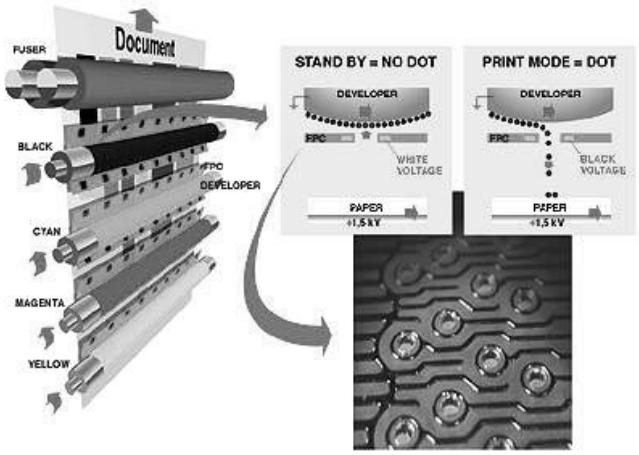

Figure 1. Schematic Principle of TonerJet

The toner cartridges in a TonerJet printer are mounted in series – cyan, magenta, yellow and black. Charged toner is transported to a flexible printed circuit board (FPC), which is fitted with an array of microscopic holes. Each hole is surrounded by a ring electrode connected to a printer controller via a high voltage driver. The printer's paper feeder passes the sheet of paper between the FPC and a background electrode set at 1 kV. The electrostatic field created by the background electrode is strong enough to literally shoot the particles of toner through the holes and onto the print medium. The process is controlled by changing the voltage on the ring electrodes. On standby, no toner passes through the holes in the FPC, but changing the voltage for a few ten thousandths of a second causes a small jet of toner (hence the name TonerJet) to pass through the hole onto the print medium. Each jet of toner forms a dot on the paper. Dots from neighboring holes overlap to form letters and images. Lastly, the document is fused with heat and pressure, causing the toner to bond to the paper. Meanwhile, the FPC is cleaned and the next page is ready to be printed. In total, TonerJet needs three process steps to create a color printout.

Although TonerJet is suited for both monochrome and color printing, its advantages are most apparent with color applications. TonerJet offers a low-cost application of the tandem principle, which means that the four print units are arranged in series along the width of the paper. A printout in color is therefore just as fast as a monochrome printout.

The Time Consuming Paradox

We sometimes hear the reflection – "Why does it have to take 15 years to develop a new print technology? – There simply has to be something wrong with your invention".

Well, TonerJet is in good company. Both EP and Ink Jet required at least the same amount of efforts and time to become ready for successful market launches.

The Paradox illustrated in figure 2, seems to be the major time consumer when developing any novel print technology.

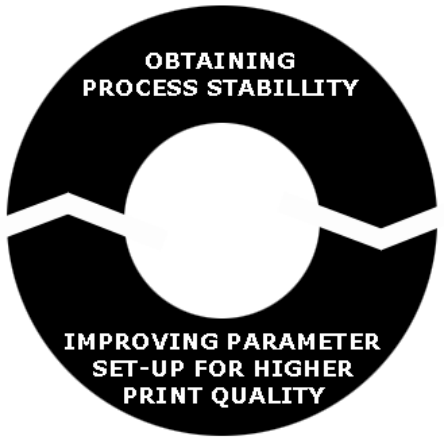

Figure 2. The Time Consuming Paradox when developing an Inter Disciplinary new Technology

One needs a physically stable object, to study, when improving parameters for better print quality *at the same time as* –One needs specified and fixed process parameters when creating a physically stable process.

1987 – 2000: Trial-And-Error

Non Impact Print Processes operate under conditions where a large number of dependent inter disciplinary features interact. By just changing one single parameter, this whole sensitive system of dependencies might be jeopardized.

Array hold doctrines, such as test results with scientific validity, from the early 90's which are worthless or even wrong, today. The scientific object studied ten years ago is no longer valid.

This chain of required inexhaustible parameter changes and test environment verifications imposes a time consuming Trial-And-Error research method.

Neither Array, nor its highly regarded licensees or partners has found any other way than just starting in one assumed optimal ballpark of the multi dimensional parameter matrix and then just test. Any effort to predict or analyze TonerJet, like comprehensive FEM-applications, Particle Simulations packages, High Speed Film tools or Taguchi methods has only ended up as fragmented means to explain a chaotic world of physics, mechanics, chemistry and electronics.

(Specific examples of problems, findings and their implications on the progress will be given during the oral presentation, as illustrations to this chapter.)

2001 - : Scientific Research

It requires an extraordinary portion of persistence to maintain this search for increased know-how. However, the reward is that this chaotic world will be penetrated and to a reasonable degree understood one day. For Chester Carlson and Xerox it took some decades. For our ink jet pioneers it took a little shorter time. For TonerJet it took 15 years.

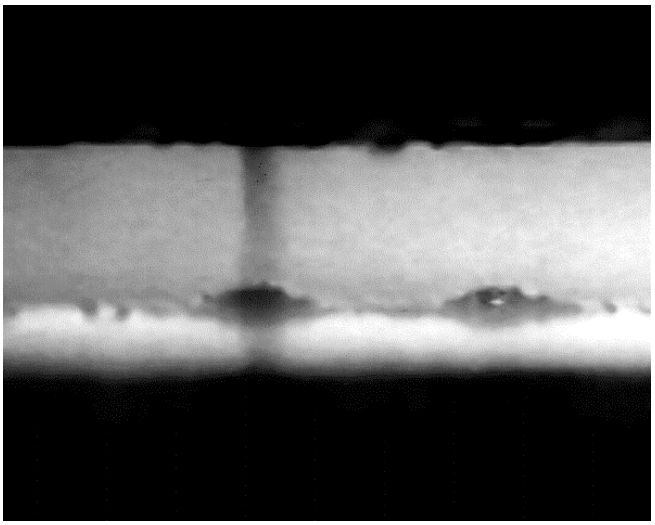

Figure. 3. High Speed Film Capture of Toner Particles ejected from one aperture directly to the paper.

Array decided to close the era of Trial-And-Error earlier this year. The scientific scoop of TonerJet is now mapped out and regular, in depth, research for individual parameters is meaningful. A basic platform of test environment, performing up to todays standard of print quality, has been obtained, defined and specified. The final approach for superiority, not only in speed and cost, but now also for print quality, has begun.

As an example, correlation between the number of toner particle agglomerating on the aperture walls and the specific field pattern adjacent to the aperture can be studied, theoretically predicted and experimentally verified with scientific validity for decades to come. More over, when being able to create in depth understanding, of an individual

feature like this, single pixel uniformity is expected to be improved, within short, beyond what is possible for EP.

Conclusion

TonerJet has taken a lot longer to develop than first expected. When finally now, after 15 years, being able to state the technology as ready for fine tuning, in order to supercede EP and Ink Jet also in print quality, one can state that any novel non impact print technology will require substantial time and efforts before commercial usage. This might be the reason why few new technologies reach the industrial level.

References

1. J. Johnson, O. Larson. A direct printing process. *IS&T NIP 9* p.509, 1993
2. J. Johnson. An etched circuit aperture array for TonerJet printing. *IS&T NIP 10* p.311, 1994
3. J. Johnson. TonerJet Color Printing. *IS&T NIP 12* p.267, 1996
4. O. Larsson. TonerJet the single pass solution for office color printing. *IS&T NIP 13* p.737, 1997
5. D. Nilsson, B. Bern. Dot Deflection Control A novel multiplexing method for TonerJet. *IS&T NIP 13* p.740, 1997
6. A. Sandberg. TonerJet Tandem Color has reached prototype stage. *IS&T NIP 14* p.180, 1998
7. H. P. Starck-Johnson, A. Berg-Palmqvist. Uniformity in solid areas with the TonerJet printing technology. *IS&T NIP 15* p.289, 1999
8. A. Berg-Palmqvist, J. Åkesson. Tools for simulation of particle motion in a TonerJet printer. *IS&T NIP 15* p.276, 1999
9. K. Bergman. High precision laser manufacturing and plasma cleaning of apertures in TonerJet Printing. *IS&T NIP 15* p.272, 1999

Biography

Ove Larson is the inventor of TonerJet®, a toner based non-impact printing technology. As the founder of Array AB in 1987, the patent holder and research company for TonerJet, Mr. Larson is today the Chairman of the Board and main shareholder of Array. Array AB is since more than five years a public company listed on the Stockholm Stock Exchange.

During Ove Larson's first 12 years as the President for Array he contributed to the R&D with many additional inventions and patents. Today, Array holds more than 450 patents and patent applications around TonerJet, sole or together with its licensees. Back in 1994 a monochrome TonerJet MFP was launched by Deutsche Telekom and ITO/Trety. Since 1995 all R&D has been focused on color applications. For color applications Array has five licensees or R&D partners Minolta, Trety, Matsushita, Epson and FujiXerox.

Ove Larson, was born in Gothenburg 1954 and became a Master of Science in mechanics at Chalmers University of Technology in 1980, in the same city. Ove Larson was recognized for his achievements in 1997 in connection with an inauguration of TonerJet Center in Yokohama, held by Her Majesty the Queen of Sweden.