Xeikon Trillium : the Next Generation of High Quality, High Speed and Low Cost Sustainable Digital Printing

Lode Deprez, Werner Op de Beeck, Wim Libaers, Mathias Van Remortel, Dirk Gijsbrechts ; Xeikon Manufacturing NV, Lier, Belgium

Abstract

Trillium has been shown as a technology demonstration at Drupa 2012. This paper wants to explain in detail how the new printing system from Xeikon works and what specific challenges had to be overcome in order to make the technology mature. Xeikon wants go for new challenging markets where printing at high speed, at high quality, at high page coverage and with a cost lower than inkjet opens new market and business opportunities, especially on commercially available coated offset papers. Moreover there is also the sustainability aspect that no VOCs are used and that the printed materials are perfectly deinkable.

Introduction

Dry toner electrophotography has been optimized for the last decades and is approaching the limits of what dry toner technology can offer in terms of speed, image quality and lifetime of the components. There is certainly room for further enhancement but going more than 2 times faster compared to today will be very difficult to establish. The toners have followed a similar trajectory and have become more and more complex and have been equipped with special shapes (like potatoes in FA-toner) and/or special structures (like core shell in QA-toner) and have driven the technology and printing performance even further. It is certainly not finished yet but also here it will be very hard and difficult to make further leaps forward in terms of printing speed and cost.

Digital printing at high substrate speeds (equal or higher than 1 meter per second) with an acceptable cost and an offset like image quality is still a desire that hasn't been fulfilled so far. Therefore Xeikon has been looking for a technology that has potential to start at a much higher speed point with a lower cost, combined with the image quality and resolution that printers and customers expect from an electrophotographic digital press.

Trillium

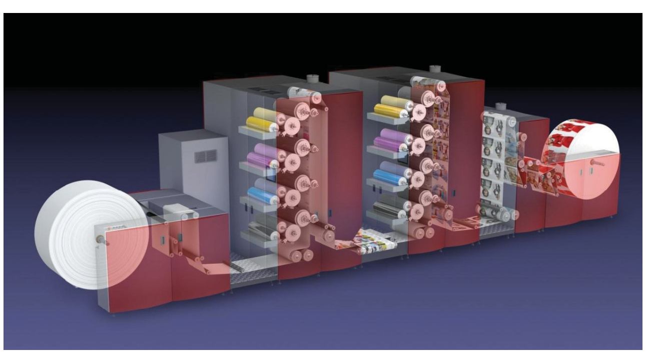

Figure 1. *Trillium two tower duplex printing machine*

In its first iteration, Xeikon's Trillium-based press will be a roll-to-roll configuration that consists of two towers, each with four printing stations (CMYK – See Figure 1). This enables duplex 4/4 printing with precise front-to-back registration as well as precise registration of each color separation. Future configurations could add additional towers (and additional colors) for a wider color gamut and potentially the introduction of special colors to more accurately address brand owner requirements.

The Trillium imaging process

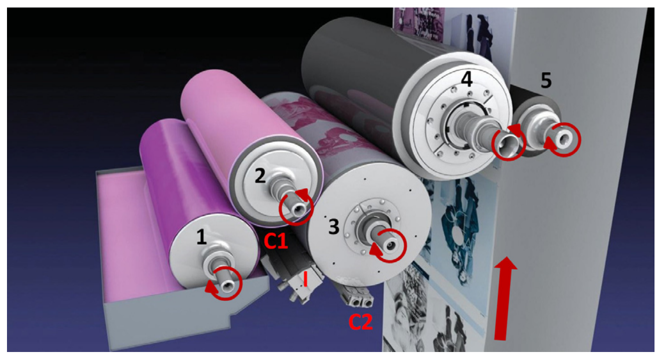

Figure 2. *Detail of Trillium printing station*

The Trillium imaging process consists of several highly-engineered and precise process steps as the image is created and the liquid toner for each color is applied to the substrate. A combination of conventional and digital imaging technologies have been incorporated to deliver optimum reliability, quality and throughput. Figure 2 depicts the roller configuration for each printing station, of which there will be eight in the initial Trillium-based press. Within each Trillium imaging station, there are 4 zones where toner and/or image are transferred. Each of the four rollers is seamless so there are no seams or repeats, staying true to Xeikon's principle of endless print.

The first roller (1) in the process is an anilox roller that picks up the non-charged liquid toner dispersion. This is an engraved roller type that is well-known in the conventional printing world for its ability to ensure even transfer of ink. Roller 2 is the doctor roller or development roller. Trillium liquid toner is a dispersion of polyester toner particles that are specially produced, downsized and shape modified to a small particle size in the 1,5 to 2 micron range (Figure 6). The shape of this toner is ellipsoid which is different to the typical potato shaped Xeikon dry toner, which is also larger in size (6-8 micron range).

Onto the second roller (2) the positive charging process takes place whereby the toner particles are compacted onto the surface of the roller (Figure 3). This step not only charges the toner but also prevents the pigmented particles would come into contact with the photoconductor surface on places where the latent image is not present eliminating background noise.

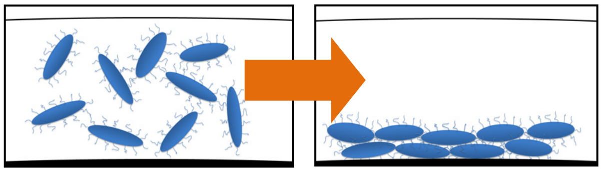

***Figure 3**. Charging and compaction at location C1*

The photoconductor roller (3) allows LED imaging to take place. The photoconductor roller is charged (C2) and imaged (I) at 1200x3600 dpi using Xeikon propriety LED imaging technology just before the development takes place in the NIP between rollers 2 and 3. The compacted toner layer on the doctor roller that has not been used in the imaging process is discharged, removed from the surface and transported back to the main ink system for reuse.

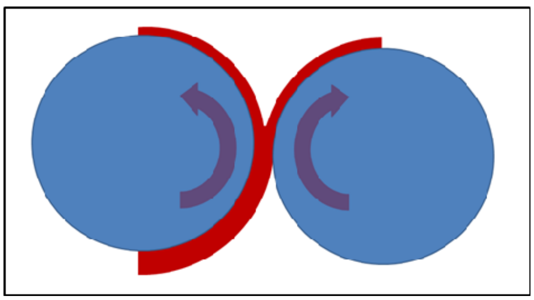

***Figure 4**. Carrier reduction by break-up of liquid layer*

New compared to the Xeikon dry toner technology, is an intermediate step where the image is transferred to the next roller, the intermediate roller (4). This is very similar to an offset printing blanket. The use of an intermediate roller gives more flexibility towards the transfer to different substrates with different roughness. At the same time it protects the photoconductor surface from being damaged or negatively influenced from the paper substrate and also takes part in the carrier liquid removal process as described below. After the final transfer using a bias transfer roller (5), the substrate moves to the next station where the process is repeated for the next color.

Different technology

The Trillium technology is significantly different from the HP/Indigo liquid toner technology. Table 1 is summarizing some of the major differences.

The Trillium liquid toner is a polyester toner dispersed in a pharmaceutical white oil that does not require evaporation. The printing process starts with a 5 micron thin layer of a 20 to 30 % concentrated liquid toner dispersion in the developing unit. This high concentration is the reason for higher viscosity of the liquid. The white oil is mechanically removed during the different transfer steps of the digital printing process by layer break-up (Figure 4) resulting in 75-85 % removal of the carrier liquid before the toner finally transfers to the substrate. This means there are no VOCs in the printing process. The type of carrier liquid is chosen in such a way that it has the highest possible purity and safety approvals. Both the ink and the residual white oil in the paper are removed during the flotation process of the deinking step [1], yielding white deinked pulp with no dirt specks present [2]

The development and transfer processes are electrophoretic transfer steps whereby the toner particle is forced to move over a very short distance under the application of a suitable electrical field. Due to short travel distances (5 micron or less) a very accurate and high quality development and image transfer can be realized at high speeds (up to 2,5 meter per second has already been shown). This is called “Wet on Wet” (WOW) transferring using micro gapping.

***Table 1**. Differences in liquid toner technology*

Property	Xeikon Trillium	HP/Indigo
Toner concentration in liquid toner shipped to customer	35-45 %	20-25 %
Toner concentration in developing unit	20-30%	2 %
Toner resin system	Polyester based	Polyethylene based
Charging	Just before development	Chemical charged during preparation
Carrier liquid flash point	> 110°C, > 230°F	< 70°C, < 158°F
Deinking behavior in paper recycling [2]	OK	Problems of dirt specks
Carrier liquid removal	mechanical	evaporation
FDA 172.878 [3]	OK	-
FDA 172.882/884 [4]	OK	OK
Image formation	“Wet on Wet” on final substrate	“Wet on Wet” on an intermediate drum
Transfer to substrate	electrostatic transfer followed by fusing	after evaporation, coalescence and temperature increase the film transfer process is purely adhesive
Fusing	Combination of non-contact and contact	Transfuse

This process results also in a very thin layer of liquid toner being applied to the substrate. Typically, four layers of current dry toner technology result in an approximate thickness of 20 microns; with Trillium technology, the four-layer thickness is about 4-6 microns. This implies a need to use much less material to achieve the required image quality, which in turn implies a lower cost. In fact, the process uses at least about one-third less toner than traditional dry toner electrophotographic processes. This also enables a thinner final colorant film on the substrate, which has an image quality advantage through a physically flatter refractive response to light.

Challenges

In the evolution from a technology demonstration to a working prototype printing 8 colors we have faced different challenges.

Due to the application of large potential differences (several 100's Volts) over very small distances very high electric fields are established between the rollers. The conductivity of the carrier liquid has to be kept constant at all times in order to prevent charge injection or loss of charge during the different transfer steps. For the toner it is crucial to have the right dispersing agent interaction with the toner particle not only during the making of the toner, but also during storage, printing and fusing.

If, on the one hand, the dispersion stability of the toner system is too high, the toner particles will not coalesce to realize adhesion onto the substrate and to make the right polymeric film. This ends with toner that has no adhesion to the paper. On the other hand, if the dispersion stability is too weak, the toner cannot be stored or handled inside the machine. Xeikon established to define a toner technology that combines all these aspects. It uses a special dispersing agent which is carefully located at the surface of the toner system to form a dispersion with the right stability. At the moment of fusing the temperature is brought above the glass transition temperature of the resin system at the same time causing the dispersing agent dissolve into the toner system matrix.

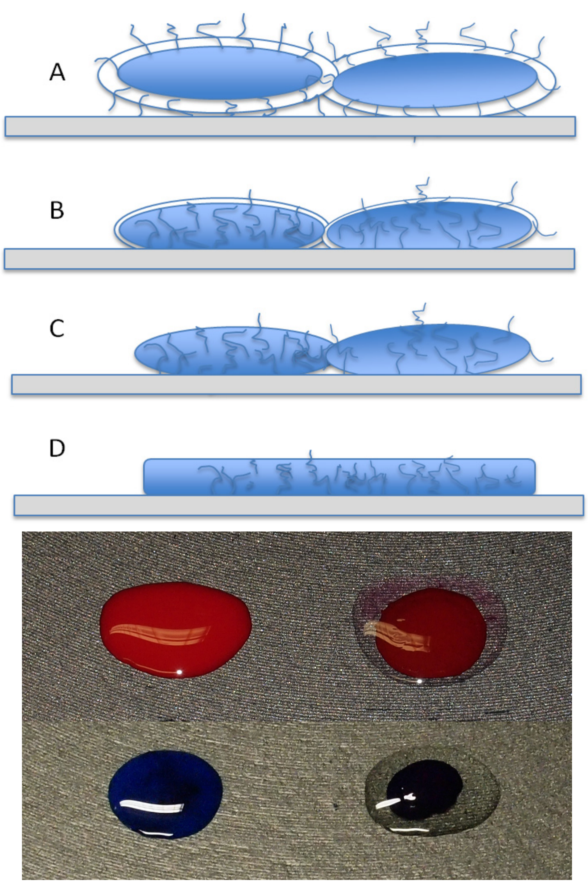

***Figure 5**. Coalescence induction of liquid toner in Trillium system*

This is shown in Figure 5 where in status A the toner particles are transferred onto the final substrate. In a first section of the fusing station the temperature is increased whereby the dispersing agent is dissolved into the resin system reducing the dispersion stability and removing the last amount of carrier liquid from the toner surface.

Finally the complete stability has been removed (status C) resulting in a coalescence (surface energy driven). This specific toner design allows the reuse of the carrier liquid (even after fusing) without the problem of increased conductivity due to an increase of the dispersing agent concentration into the carrier liquid phase.

This also can be seen when the toner dispersion is heated (see photo in Figure 5). In the drops on the left side no or partial coalescence took place within a few seconds when heated at 130°. In the drops of the right side a clear separation took place creating a carrier liquid phase and a 100 % pure polyester phase.

When such toners are used in the printing process very high coverage (up to 400 %) can be printed without any problem and without adjusting the heat or the printing speed which results in a non-wrinkled paper substrate.

Two step fusing

The initial step of the fusing zone therefore is a non-contact zone where heat is transferred to the toner system without any contact. This allows the toners to coalesce in a continuous film while simultaneously the basic adhesion onto the substrate is realized. This all happens at temperatures around or below 100°C. This initial toner film is then further treated by contact fusing finally adjusting the gloss and the adhesion up to the desired level.

Dispersion stability during print

The toner circulation is an important aspect of the printing process. The ink layer formation on the doctor roller has to be continuously established in the same manner starting from independently acting toner particles. When the toner has been charged and compacted, the discharge and removal has to be performed in such a way that the toner particles are in the same individual state as before the initial application onto the anilox roller. It has been observed that it is not easy to remove the compaction memory from the toner system ; it frequently results into a phenomenon called "caking". This caking refers to a toner-toner interaction due to the loss of a part of the dispersing agent which was present on the surface of the toner particle. When this happens the thixotropic behavior of the dispersion is completely changed forming high viscosity clusters which disturb the normal transporting circulation. It's not completely clear which part of the process is dominantly responsible for this dispersing agent reduction (charging, rubbing, decompaction, cleaning, pigment type,…), but it has been discovered that adding a controlled amount of dispersing agent during the printing can solve this problem as long as some crucial properties (viscosity, toner concentration, conductivity, …) of the dispersion are kept within certain ranges.

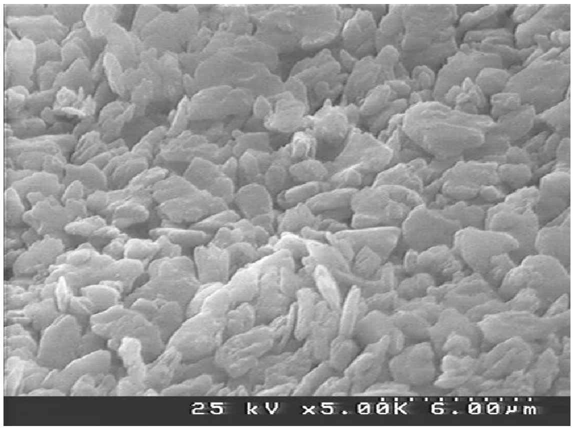

***Figure 6**. SEM picture of the Trillium toner particles used in the dispersion with an average particle size below 2 micron*

Conclusions

Trillium as liquid toner technology offers a very high potential for high speed digital production machines. It is not the kind of technology that will be found in small printers because there is a lot of liquid handling and control involved which is probably hard to downsize. It has a huge potential to higher speeds (full quality) and the potential of going completely sustainable in terms of carrier liquid (vegetable oils or oils derived from vegetable materials) and resin system (where more and more polyester resins containing monomers from bio material are becoming available).

Further reading about the market potential and background of the technology can be found in the white paper about this technology [5] or a YouTube movie [6].

Acknowledgement

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References

[1] Sonja Jamnicki , Determination of mineral oil content in recycled papers, EFPRO- CEPI Innovation in Paper, Early Stage Researcher (ESR) Workshop European Paper Week, 13-15 November 2012, Brussels.(http://www.cepi.org/system/files/public/epw-presentations/2012/innovationinpaper/EFPRO_CEPI_Jamnicki.pdf)

[2] Axel Fisher, INGEDE Activities in Digital Print Deinking, INGEDE Symposium, February 13, 2013, Munich. (http://www.ingede.com/ingindxe/symp/symp2013/symp2013_07_fischer-col.pdf)

[3] FDA 172.878 means liquid can be used : as a release agent, binder and lubricant in or on capsules and tablets intended for addition to food, as a release agent and lubricant for bakery products, as protective coating on raw fruits and vegetables , as a component of hot-melt coating on frozen meat, as dust control agent for wheat, corn, soybean, barley, rice, oats and sorghum

[4] FDA 172.882/884 means liquid can be used : as a component of insecticide formulations for use on processed food, as a component of coatings on fruits and vegetables, as a component of (un)coated food-contact surface of paper and paperboard intended for aqueous and fatty food, as a component of (un)coated food-contact surface of paper and paperboard intended for dry food

[5] Cary Sherburne , Xeikon Trillium : A Printing Technology Breakthrough (https://www.xeikon.com/downloads/Xeikon-Trillium-A-Printing-Technology-Breakthrough.pdf)

[6] http://www.youtube.com/watch?v=zhs333m-fwU

Author Biography

Lode Deprez is Vice President R&D Consumables & Process Group at Xeikon. He received his PhD in organic synthesis at the University of Ghent in 1990. He was active during 9 years in the R&D development department of Agfa and was specialized in diffusion transfer based silver halide printing plates for CTP applications. From 1999 he joined the toner R&D department at Agfa and became responsible for this R&D group before it moved to Xeikon in 2000. He is the named inventor or co-inventor on more than 60 patent applications (published and pending) all in the field of (digital) printing.