Waterless Inkjet Process for High Speed Printing

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Abstract

The Xerox CiPress High Speed Waterless Ink Jet System uses many Solid Ink inkjet technologies from existing office products. One significant difference between the office Solid Ink products and CiPress is the printing architecture. The office ColorQube family of products first builds an image on a drum in multiple passes and transfers that image to paper when complete. The CiPress production system prints directly to paper and the ink is subsequently spread mechanically using high pressure. This process requires careful control of the paper temperature to achieve the best image quality.

Introduction

Xerox announced the CiPress 500 high speed waterless ink jet system for continuous web printing in 2011 [1]. More recently Xerox announced the CiPress 325 enabling even higher image quality for lower volume printing customers [2]. The CiPress 500 and CiPress 325 use the same printing process but at different speeds, 500 and 325 feet per minute (fpm), respectively. See figure 1 for a layout of the CiPress architecture. The CiPress system uses waterless solid ink inkjet technologies from the office ColorQube products [3] including modular printheads, phase change ink, and an image sensor for registration and missing jets compensation. The major difference between the CiPress architecture and the ColorQube architecture is how the ink is delivered to the paper and mechanically spread. The CiPress uses a jet direct to paper process followed by a cooling roll and ceramic heater to control the ink temperature prior to mechanical spreading. The ColorQube uses the offset process where the ink is jetted onto an intermediate metal drum before simultaneously transferring and mechanically spreading the ink on the paper. In this process the metal drum determines the ink temperature before transferring and spreading. This paper describes the process physics of leveling or equalizing the ink temperatures to a target value independent of local area coverage for both printing architectures.

The modular printheads and image sensor have been previously discussed [4] and will not be addressed here. Here, we focus on the properties of the phase change ink and the interaction with the printing process for both architectures considered.

The direct to paper and offset process use a similar resin-based ink that is solid at room temperature and liquid in the heads for jetting [5]. Because the ink undergoes a temperature phase change when the drops are jetted to the relatively colder paper they immediately increase in viscosity and remain on the top of the paper rather than being absorbed by the paper fibers. Therefore the printer is well suited to printing on inexpensive uncoated papers without any pretreatment prior to printing. Because there is no water or solvent in the ink, there is no need for any drying after printing.

Another phase change ink advantage over aqueous based inks is the ability to recycle the paper after printing. Aqueous inks are often difficult to remove from the paper during the recycling

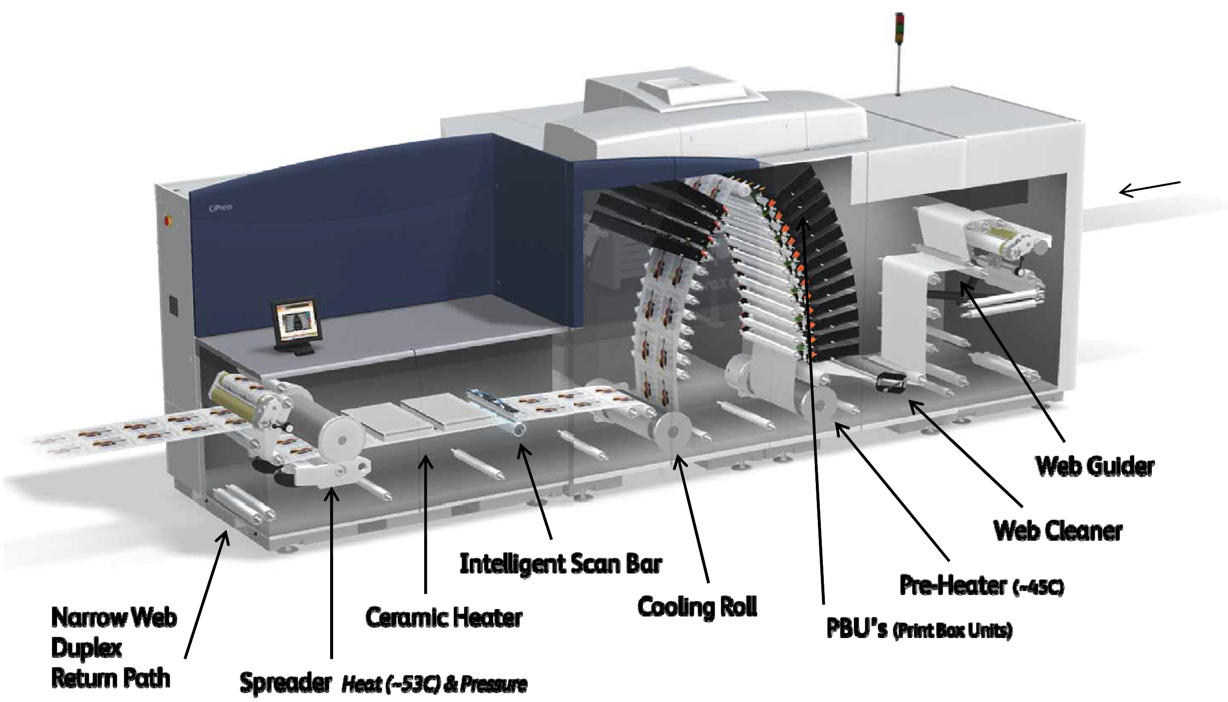

Figure 1 – Schematic of Waterless Inkjet Process for High Speed Printing

process and require a change in the deinking chemistry from the standard deinking process [6]. Because solid ink sits primarily on the surface of the paper as toner does, recycled prints may be deinked using the standard techniques used in the deinking industry [7].

Figure 2 shows the typical logarithm of viscosity versus temperature for a phase change ink. The ink viscosity spans several decades between jetting and room temperatures. The spreading process occurs in a middle soft state for the ink. If the ink is too cold prior to the application of pressure in the spreading process, then poor ink spread results in poor image quality. If the ink is too hot when pressure is applied, then the ink is pushed into the paper causing show through. For these reasons it is desirable to control the ink temperature within a narrow range prior to the spreading process in both architectures.

Direct to Paper Printing Process

A diagram of the CiPress printing process is shown in figure 1. The paper web enters the printer where the web guider aligns the web to the internal components within the engine. Because the solid ink adheres well to uncoated paper, there is no need for any paper preconditioning such as the application of a binding layer. Neither is there a need for any specially pretreated papers. The paper then passes by a web cleaner which removes loose debris from the web prior to the jetting zone.

After passing the web cleaner the web enters the pre-heater roll where the paper is heated to 45C before it enters the jetting zone. The heated paper passes along a series of print box units which contain print heads that eject ink horizontally on one side of the paper. The paper temperarture is maintained throughout the jetting zone to 45C except where ink was placed. The temperature where ink was jetted to the paper depends on how much ink was laid down. For example secondaries (2 layers of ink) are much warmer than sparse halftones.

After leaving the jetting zone, the paper and ink touch the cooling roll where most of the excess heat due to the ink is extracted. Next the paper and ink pass by the intelligent scan bar that captures images printed on the web at a resolution of 600 spi in the cross process direction and at a resolution in the process direction that depends on the speed of the web. The high speed sensor has sufficient resolution in the process direction to sense any misalignment of the print heads with an accuracy of less than 10 microns. The paper then passes by a ceramic heater that finally brings the ink and paper temperature to the target mechanical spreading temperature of 55C.

Following the ceramic heater, the web passes through a spreader. The two rolls of the spreader are under high pressure to give good adhesion of the ink to the paper and enable good image qualtiy through the spreading of the solid ink, without penetrating the paper and causing showthrough. The spreader drum is held at a temperature of 53C

After the spreader the web can then either exit the machine for further processing, or be flipped and printed with a second engine for duplex. Narrow webs can be guided through the duplex return path for complete duplex printing within a single engine.

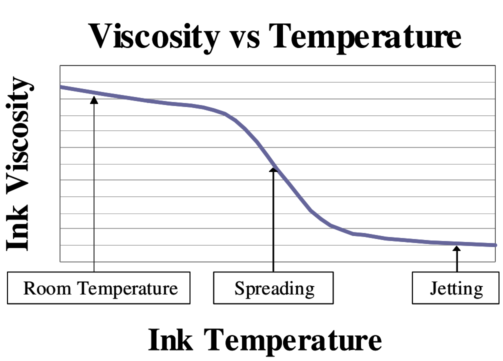

Figure 2 – Ink Viscosity versus Ink Temperature

Offset Printing Process

The process of printing an image in an offset process on paper breaks down to three basic steps [8,9]:

1. A drum maintenance unit cleans the drum surface of any residual ink from a previous print and applies an extremely thin layer of release agent to the clean metal print drum surface.
2. The heated printhead sprays drops of molten ink onto the rotating image drum very precisely. The print drum is maintained at an intermediate temperature (55 °C). The ink droplets striking the oiled image drum change almost instantly from a molten liquid to a malleable semisolid. A high resolution full-color image is built on the image dum in multiple passes with the drum maintenance unit cammed out.
3. The paper to be printed passes through a preheater into a pressure nip formed by a pressure roller and the image drum. Under heat and pressure the image transfers from the drum onto the paper in a single pass. By the time the paper exits the printer the ink has fully set and the print is immediately ready for use or can be immediately duplexed.

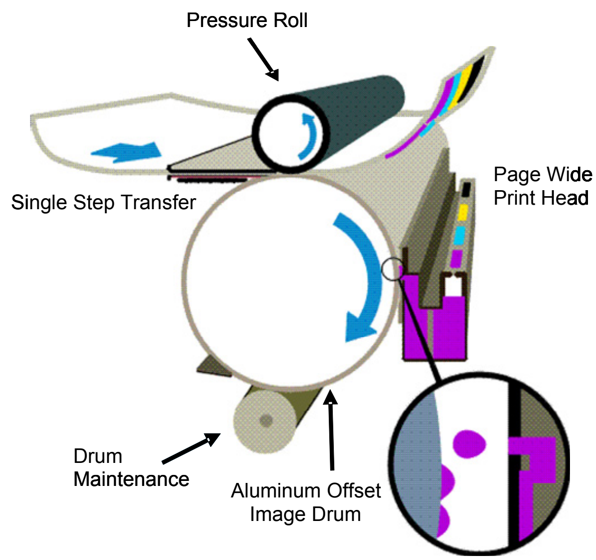

Figure 3 – Offset Print Process

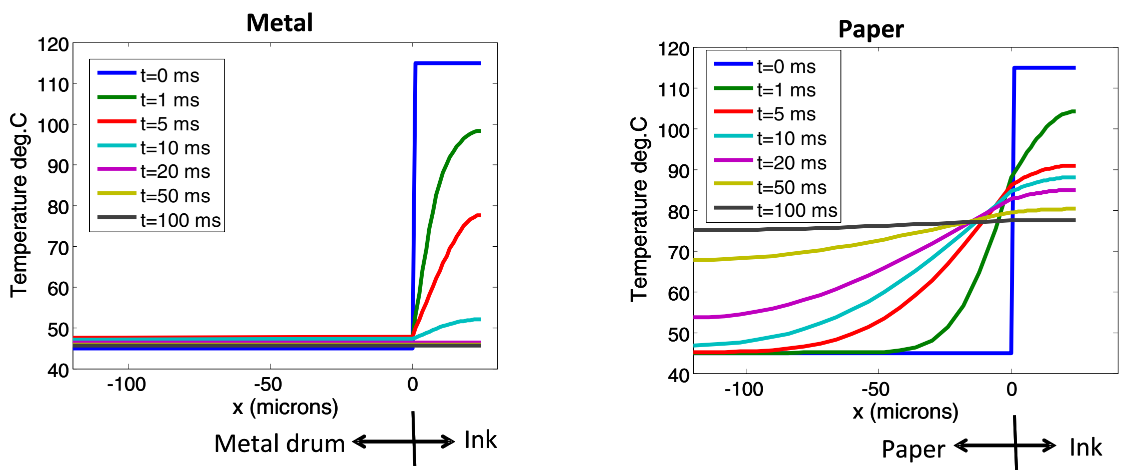

Fig. 4: Cooling and solidification of 250% AC ink jetted onto metal drum (left) and paper (right). Initial drum/paper temperature is 45 deg C and ink temperature is 115 deg C. Ink collapses to the drum temperature for metal drum, while paper temperature increases as ink cools and solidifies.

Ink Temperatures

Figure 4 shows the primary difference in ink temperature versus time after jetting for the two print processes considered here. These simulation results are based on a model of transient heat conduction in the ink and substrate including the thermodynamics of solidification. The offset process which uses a metal drum quickly brings the ink temperature to the drum temperature as shown on the left side of figure 4 within 20ms. The direct to paper process is much more limited in its ability to quench the ink temperature in both time and final temperature. Almost 100ms is needed for the ink and temperature to reach their final temperature which can be much higher than the initial paper temperature. It is this reduced ability to remove heat from the ink by the paper and environment that makes the high speed direct to paper process more challenging than the offset process.

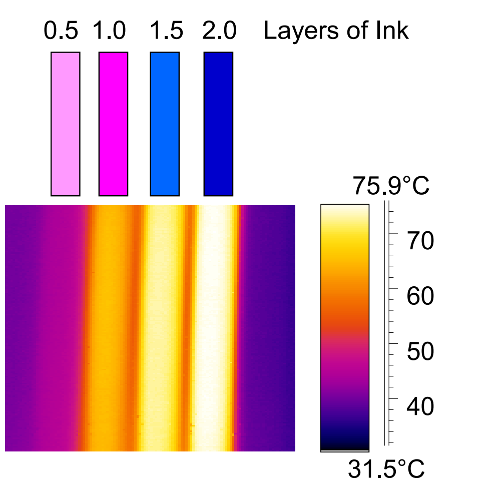

Figure 5 – Thermal image of paper with ink after jetting zone.

Figure 5 shows an additional complicating factor due to local area coverage's within a print. The ink temperature after jetted on paper depends on how much ink was put down. Therefore secondary's or two layers of ink are warmer than primary colors. Figure 5 shows the ink temperature dependence on area coverage, with ink temperature varying from the paper temperature for sparse halftones to a maximum temperature for a blue secondary color.

Therefore, the high speed print process needs to level the ink temperature independent of area coverage and remove enough heat to bring the ink temperature to the target temperature prior to spreading.

The maximum amount of heat that needs to be removed can be understood by knowing the maximum ink area coverage which is typically governed by secondaries or two layers of ink. The latent heat of solidification dominates the thermal equation for heat removal. For example, if only room temperature air cooling was used, the distance needed between the jetting zone and the spreader would be about 500 feet. To enable the high speed printing with only a few feet between the jetting zone and spreader, an efficient heat removal mechanism is needed.

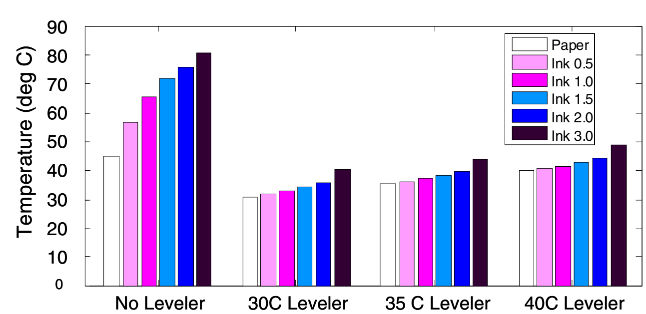

Fig. 6: Effect of cooling roll (leveler) and ink coverage on paper temperature at 500 fpm

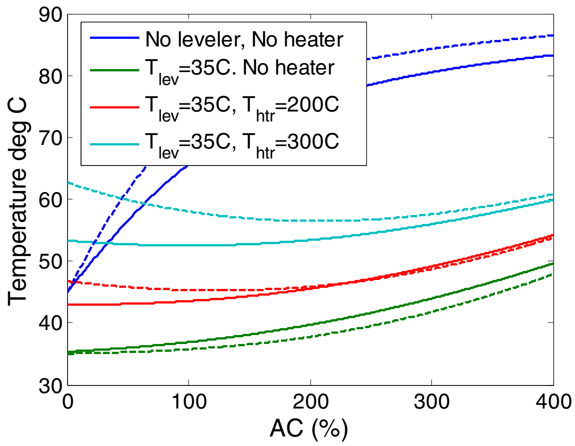

Fig. 7 Effect of ceramic heater on web temperature,Solid line 500fpm, Dashed line 325fpm

Heat Removal and Thermal Leveling of Ink Temperatures

The cooler roll works in conjunction with the ceramic heater to remove heat and collapse the temperature delta between the ink and paper as well as bring the paper and ink temperature to the target spread value.

The requirement to remove heat from the ink quickly is managed by the cooling roll where the warm ink comes into direct contact with the metal roller. The cooler roll runs about 35C and is the primary mechanism for removing the heat from the ink. Figure 6 shows the difference of the ink and paper temperatures with and without the cooler roll. Note how the temperature delta between paper and ink is greatly reduced but not completely collapsed and the paper temperature is well below the target temperature of 55C.

To complete the paper and ink temperature collapse and bring both paper and ink temperatures to the desired target, the ceramic heater applies uniform heat. Figure 7 shows how this process of applying a uniform heat flux to the paper and ink results in different increases in temperature for paper and ink depending on the area coverage. The blank paper increases the most since it has lower heat capacity than regions with ink. Therefore, the more ink on the paper, the less of a temperature increase from the ceramic heater. This completes the thermal leveling of paper and ink temperatures while adjusting the temperature to the target prior to spreading.

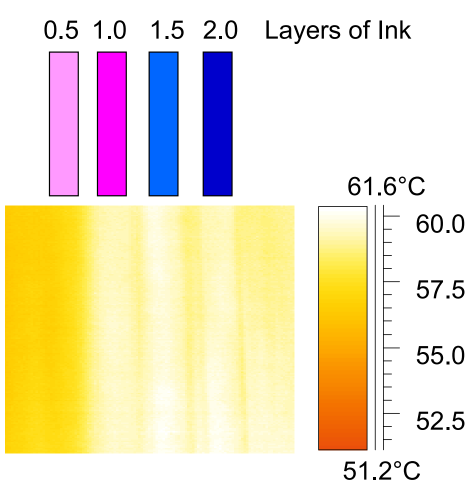

Figure 8 – Thermal image of paper with ink prior to spreader.

Figure 8 shows a thermal image of the final ink and paper temperature prior to entering the pressure zone in the spreader. Note how the ink and paper temperatures are now within a few degrees and largely independent of area coverage. This enables controlled ink spread without show through.

To enable multiple process speeds for the direct to paper we note that the maximum amount of ink depends on the process speed. Therefore as the system slows down for higher image quality and a larger gamut, both the cooling roll and ceramic heater dwell times increase inversely to the process speed difference. This leads naturally to a flexible print process enabling the tradeoff between speed and image quality as shown in figure 7 comparing the solid line data for 500 fpm to the dashed line data for the 325 fpm.

Conclusions

In conclusion, both the offset and high speed direct to paper architecture enable the phase change ink printing process. The key to this printing process is leveling and controlling the ink temperature prior to mechanical spreading. This occurs naturally for the offset printing process using a heated metal drum while in the high speed direct to paper process this is accomplished through the functions of the cooling roll and ceramic heater.

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