Overview of Next Generation Phase Change Ink

Jule W. Thomas, Jr.
Xerox Corporation, Office Printing Business Unit
Wilsonville, Oregon, USA

Abstract

Color printers based on solid ink (or phase change ink) employing piezo electric printheads have enjoyed wide spread acceptance in several diverse markets with very strong and sustained acceptance in the color office work group printer market. Work continues to further develop and refine this technology to enhance its strengths and mitigate or remove any deficiencies as compared to other technologies in the office market space, especially xerographic color printers.

This paper gives a short overview of the color solid ink print process as used in the Xerox Phaser® 8xx series printers. A new generation of solid ink was introduced in June 2001 with the introduction of the Phaser® 860. This paper looks at three key ink attributes, ink viscosity, color gamut and ink coefficient of friction. The performance of the new Phaser® 860 solid ink is compared to previous solid ink printers and xerographic printers.

Introduction

Color printers based on solid phase change ink, or hot melt ink as it is sometimes referred to, were first introduced a little over 10 years ago. Solid ink printers have enjoyed success in many different market applications including, graphic arts, general office[1], medical imaging[2,3,4], packaging, 3D models, and wide format printing to name a few. Printer architectures based on solid ink have included both shuttling heads printing direct to the media and offset processes that involve jetting to an intermediate drum with subsequent transfer to the final media.

Within the networked color office printer market solid ink printers generally compete against xerographic printers and to a lesser degree aqueous based thermal and piezo ink jet printers. Solid ink generally enjoys customer acceptance due to perceived high image quality, vibrant colors, fast print speeds, ease of use (lower number of consumables and ease of replacing consumables especially when compared to color xerographic printers) and the ability to print on a wide range of media. However, as with any technology, there are areas where solid ink is often considered disadvantaged, especially when compared to xerography, and these include a waxy feel and inferior durability.

Xerox has recently introduced a new solid ink printer, the Phaser® 860, that is based on an entirely new ink formulation platform, Color Stix II. This paper will investigate some of the technical advances brought by this new ink set.

Phaser® 8xx Family Architecture

An overview of the Phaser® 8xx family of printers is shown in figures 1 through 3. Figure 1 shows a simplified side view of the ink deliver system, the printhead and the transfer drum. Solid ink is melted in the ink loading system and flows to a reservoir in the top of the printhead (shown in figure 2). Here the ink is typically heated to 120°C to 140°C with a nominal viscosity in the range of 10 to 13 cPs. The ink is then routed through a system of ink manifolds to the piezo electric ink jets where it is jetted on the heated rotating aluminum drum. Prior to jetting, the transfer drum has been prepared with a release oil. Depending on the formulation, the drum is kept between 50°C and 70°C. At this temperature the ink solidifies into an elastic, rubbery solid.

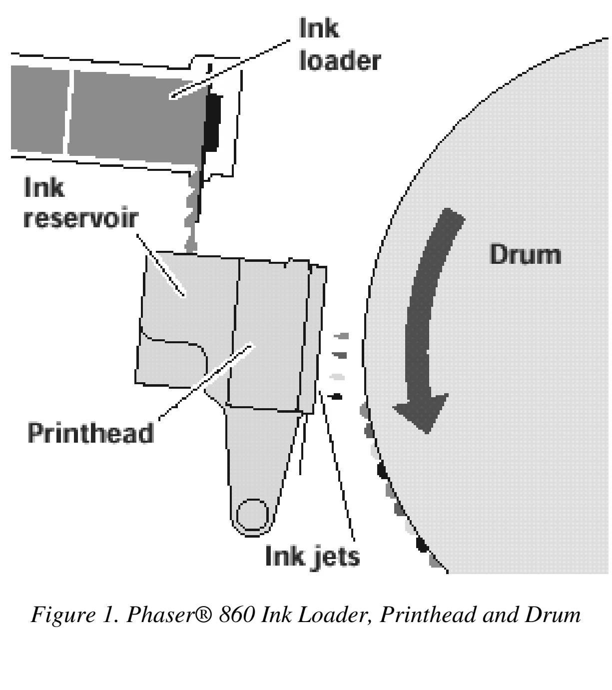

Figure 1. Phaser® 860 Ink Loader, Printhead and Drum

In the Phaser® 860 the full width head containing 448 jets paints the full image onto the drum after many revolutions of the drum (see figure 2). After the image is completely written to the drum, the print media is transported through a preheater into the high-pressure nip between the transfer drum and the transfix roller (see figure 3). Complete image transfer to the print media is achieved.

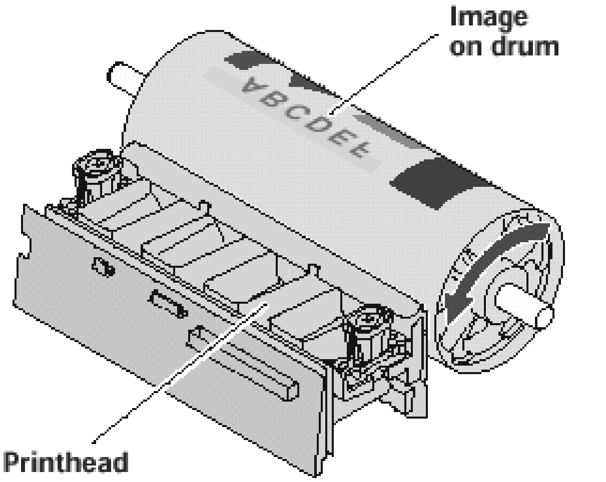

Figure 2. Detail of the printhead and imaging drum

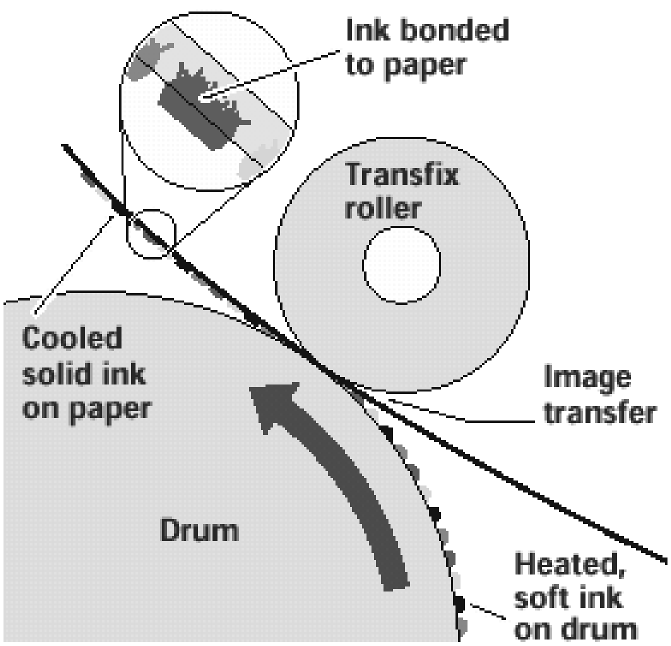

Figure 3. Phaser® 860 Transfix Process

Ink Design Goals

Solid ink has a very difficult set of design requirements based on physical performance in three different temperature regimes[5]. Properties in the melt must be carefully tailored to meet jetting requirements of the printhead. Secondly, the ink must have the correct viscoelastic behavior at the drum/transfix temperature and lastly, it must have excellent physical properties at room temperature.

The design goals of the next generation of solid ink were to keep the excellent performance of the Phaser® 850 solid ink and lower the surface coefficient of friction (COF) for better performance in auto document feeders (ADF) and a less waxy feel. Also, it was desired for the new formulation to have a lower viscosity at jetting temperature so higher jet firing rate could be used to improve the overall print speed of the printer.

Measured Ink Properties

Viscosity

Figure 4 shows the temperature versus viscosity profile for a representative ink from the Phaser® 850 and Phaser® 860. In each case all of the colors are designed to have very similar viscosity profiles. The lower viscosity of the Phaser® 860 ink at elevated temperature as compared to the Phaser® 850 ink can be exploited in one of two ways. First, the Phaser® 860 ink, at equivalent jetting properties, could be jetting at a lower operating temperature, thus lowering energy requirements and possibly extending printhead component life. Or, at the same operating temperature, the Phaser® 860 printhead could be operated at a higher firing rate, thus improving overall system productivity. The latter scenario was followed in the Phaser® 860 printer with the standard print quality mode firing rate going from 33 kHz to 36 kHz. This effectively takes the standard print mode from 8 ppm to 10 ppm and the fast color mode from 14 ppm to 16 ppm.

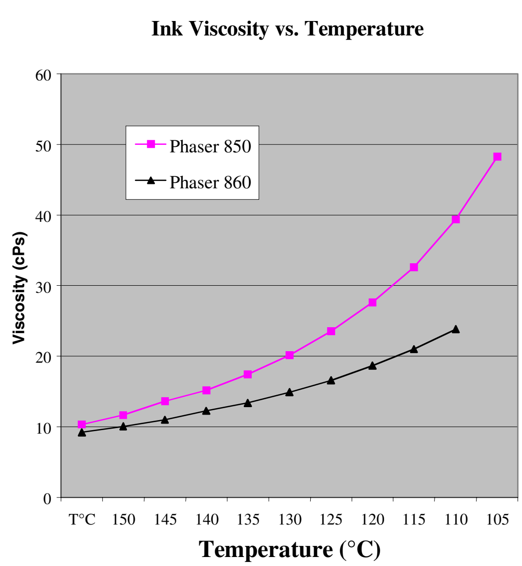

Figure 4. Ink Viscosity vs. Temperature

Color Gamut

Over all color gamut is an important facet of print performance for a color printer. Color gamut is affected by many factors including the ink formulation; print process (including fusing and finishing), media, and print dither or lay down techniques.

The ink itself contributes to color gamut in two primary ways. First, the choice of colorants greatly affects the color palette. Colorants broadly fall into two different families, dyes and pigments. All Xerox/Tektronix solid inks have used dye based colorants. These dye based systems have given bright vibrant colors, especially when compared to xerographic pigment based systems. While dye systems are generally not as light fast as pigment systems, for the office market the better color gamut meets most customers needs better.

Second, the choice of base materials can also greatly affect the color gamut. In solid ink systems the base ink vehicle must be as colorless as possible and able to transmit light efficiently (low haze). Care must be taken to control the crystallinity of the ink vehicle to keep haze low and thus deliver bright vibrant colors.

Figures 5 & 6 show the color gamut comparison of the Phaser® 860 and several printers that compete in the color network printer market. Two of the printers are xerographic printers (Phaser® 1235 and HP 4500) and the other (Phaser® 850 and Phaser® 860) are solid ink based. All prints were made using Hammermill LaserPrint paper and the default standard print mode. CIE L*a*b* color measurements were made on the primaries and secondaries using a ACS Spectro – Sensor II colorimeter.

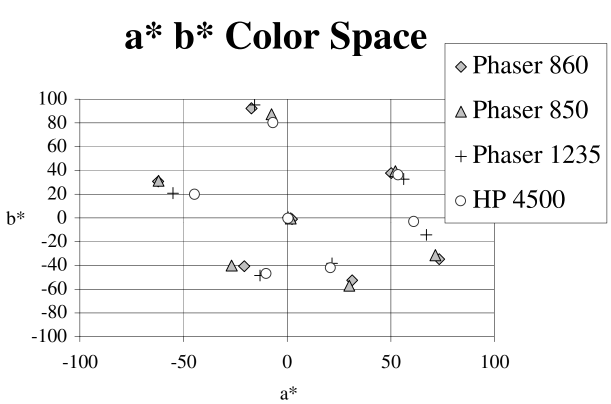

Figure 5. Color Gamuts of Solid Ink and Xerographic Printers. Projection of primaries and secondaries onto the a, b* plane.*

Figure 5 shows the projection onto the a*, b* plane. In almost all cases the solid ink printers out perform the xerographic based printers. And, the Phaser® 860 is very close to the Phaser® 850.

Figure 6 shows the L* values for each of the primaries and secondaries. Again, in almost all cases the solid ink printers out perform the xerographic printers. While there is no clear leader between the Phaser® 850 and Phaser® 860. Thus, the quantitative colorimetric measurements suggest that the Phaser® 860 color gamut performance will meet or exceed the previous solid ink products.

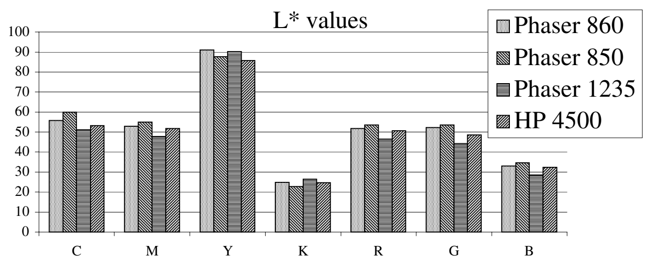

Figure 6. L of Solid Ink and Xerographic Printers. Phaser® 850 and 860 are solid ink, Phaser® 1235 and HP 4500 are xerographic printers. C = Cyan, M = Magenta, Y = Yellow, K =Black, R = Red, G = Green, B = Blue*

Coefficient of Friction

While solid ink has enjoyed many positive attributes that have given it a strong place in the market, the relatively high coefficient of friction (COF) of the ink surface has caused problems in some automatic document feeding systems. Also, some users do not like the "waxy" feel of the prints where there is high ink coverage. The subject of how to relate the measured COF to a quantitative measure that is more in line with customer experience is covered in the paper, "Measurement and Improvement of Automatic Document Feed Performance of Solid Ink Printers" in this proceedings. For the sake of this paper, I will focus on the design goal to lower the coefficient of friction of the ink and leave the broader discussion of how that relates to customer experience to the referenced paper.

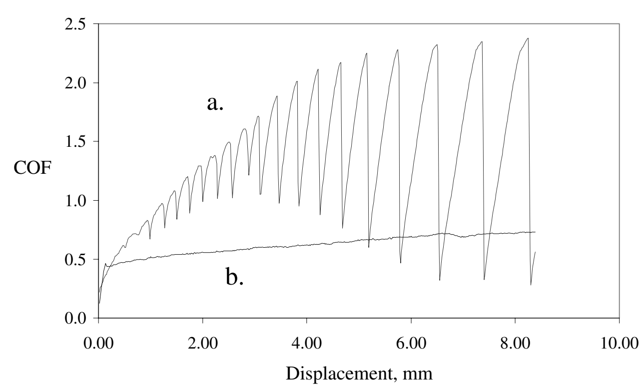

Figure 7. COF versus displacement in a horizontal sled arrangement with ink against glass, a. Phaser® 850 ink, b. Phaser® 860 ink.

Static and kinetic COF can be measured by a variety of ASTM approved methods[6,7,8]. An easy method employed for ink is to measure the COF of ink (a printed sample) with a weighted sled being pulled on a clean horizontal glass surface. When you try to make these measurements on Phaser® 850 ink you cannot get reproducible results because of the "stick slip" behavior of the ink. As the weighted sled is pulled the static COF is overcome and the sled will start to move only to jump to a new position and stick until the static COF is again overcome. This behavior is shown in Figure 7, curve a. In this case the static COF is greater than the kinetic COF and the machine is unable to reliably measure the COF due to the stick slip behavior.

However, the new Phaser® 860 ink shows a totally different behavior as is also seen in Figure 7, curve b. Here the Phaser® 860 ink does not show the stick slip behavior and reliable measurements in the range of 0.5 to 0.6 for the COF are made. Clearly, the Phaser® 860 ink has a much lower COF than the Phaser® 850 ink.

Conclusion

The next generation solid ink in the Phaser® 860 shows major improvements over previous solid inks in terms of a decreased COF and in lower viscosity at jetting temperature. Both of these attributes are translated in improved print system performance for the user. The Phaser® 860 ink also continues the excellent tradition of excellent color gamut when compared to xerographic printers. Though not discussed in this paper, these advances have been made without degrading other excellent physical properties of solid ink. As solid ink technology continues to mature, progress must be made to improve the weaknesses of solid ink while keeping its inherent strengths.

Acknowledgement

I want to thank Everett Ness for the color gamut data, Dr. Wolfgang Wedler for the COF data, and Dr. Michael B. Meinhardt for the viscosity data, all of Xerox Corp., OPB, Wilsonville, OR, USA.

References

1. R.L. Adams, " The Printing Technology of the Tektronix Phaser® 340" Recent Progress in Ink Jet Technologies, 1996, pg. 117(1996).
2. C.W. Jaeger, J.W. Thomas, Jr., M.H. Tennant, B.A. Apple, "Dry Digital Medical Imaging with Phase Change Ink Jet" IS&T's NIP 13, pg. 725(1997).
3. B.A. Apple, M.H. Tennant, J.W. Thomas, Jr., "Review of Hard Copy Systems for Digital Medical Imaging" Proc. SPIE 2658, pg. 85(1996).
4. B.A. Apple, M.H. Tennant, J.W. Thomas, Jr., "Novel Hard Copy System for Digital Medical Imaging" Proc. SPIE 3018, pg. 348(1997).
5. L. Bui, H. Frame, D. Titterington, W. Jaeger, "Rheological, Thermo-Mechanical and Viscoelastic Requirements of a Phase Change Ink for and Offset Ink Jet Printing Process" Recent Progress in Ink Jet Technologies 1996, pg. 233(1996).
6. Standard Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting, ASTM Standard D1894.
7. Standard Test Methods for Measuring Static Friction of Coating Surfaces, ASTM Standard D4518.
8. Standard Guide for Measuring and Reporting Friction Coefficients, ASTM Standard G115.

Biography

Dr. Jule "Jay" W. Thomas, Jr. is Manager, Advanced Development Ink R&D for the Office Printing Business of Xerox. Dr. Thomas joined Xerox (Wilsonville, OR) in January of 2000. Dr. Thomas' group is developing future generation solid inks for use in Xerox products. For the five years previous to joining Xerox, Dr. Thomas led the technical effort to develop and commercialize a printer for diagnostic medical applications using the Xerox (formerly Tektronix) solid ink inkjet technology for the medical businesses of E.I. DuPont, Sterling Diagnostic Imaging and Agfa. Dr. Thomas holds four US patents related to the development of the medical printer. From 1984 to 1995 Dr. Thomas was involved in research and development in polyester film for the Photo Products and Medical Imaging departments of E.I. DuPont (Brevard, NC). He received a B.S. Degree in Chemistry and Chemical Engineering, cum laude, from Rice University (Houston, TX) and his M.S. and Ph.D. in Chemical Engineering from Stanford University (Palo Alto, CA).