Thermally Stable Aqueous Pigmented Inks for Printing on Vinyl

Dheya Alfekri
Encad, Inc. A Kodak Company
San Diego, California

Abstract

Direct to vinyl digital printing using solvent-based inks is very well known in a piezo inkjet print head for durable outdoor signage. Due to the high cost of piezo heads, the printers are too costly for small volume printing jobs in small shop environments.

To fulfill the need for an affordable printer that prints directly on vinyl and still offers a competitive cost per print, a low cost wide format printer with thermal inkjet head is suggested.

The challenge in building such system is heavily dependent on development of an ink that is required to be aqueous, can jet reliably through a thermal inkjet head and still meet the requirements for outdoor performance.

For this purpose we have developed an inkjet ink that is composed of pigment, aqueous vehicle, and a sufficient amount of polymeric binder that is capable of jetting reliably in thermal inkjet head with consistent image quality and no kogation. The aqueous ink can print directly on uncoated or untreated vinyl with excellent adhesion and lighfast durability.

The printer and the printing process have been specifically modified to suit the special ink needs.

This paper will address the steps, requirements, and conditions taken to achieve the objective application.

Introduction

There have been many water based ink compositions disclosed as containing polymeric binders.[4-6] So far, these binders are added to the ink composition in very low concentrations when jetted in thermal inkjet heads. The main objective is to enhance drop ejection properties and/or enhance image quality. For low viscosity inks that are suitable for thermal in jet heads, there has been great difficulty in jetting water based pigmented inks directly to non-porous, uncoated hydrophobic substrates like vinyl. In thermal inkjet, an ink drop is heated to as high as 300C for a very short time.[1,3] This normally leads to kogation and nozzle malfunction. The industry is challenged to produce inkjet ink compositions that can adhere to uncoated vinyl and can jet through thermal heads while maintaining high reliability at high temperature. In addition, the pigmented ink is required to be water-based ink, which is more difficult to wet and adhere on vinyl than the solvent inks.

Therefore, there is a need to develop a low viscosity, low cost, aqueous pigmented ink that is suitable for use in low cost thermal inkjet heads.

The challenge is heavily related to ink viscosity and rheology. The analogy we use is to develop an ink analogous to a flexographic ink[3] composition and yet jets reliability in thermal inkjet head. This requires the use of enough binder concentration which normally raises the ink viscosity. Also, the use of high pigment concentration to get the proper color density may complicate the dispersion stability and the adhesion. In comparison to any piezo ink, and especially solvent ink, the following table lists some properties of the ink and head used in thermal inkjet and piezo heads:

Table 1. Thermal vs. Piezo Ink/Head

	Thermal	Piezo
Ink Viscosity	1-3 cps	3-10 cps or >
Ink/Binder Formulation	Limited	More Options
Head Temperature	Sensitive	No heat
Air Sensitivity/ Ink	Moderate	Critical
Cost / Nozzle	\$ 0.1-0.20	\$0.5 -3
Cost /Printer	\$10K-\$15K	\$20-\$100K

Experimental

The ink is designed to be water based and adheres to vinyl. We started by looking at various highly concentrated pigment dispersion and various binder systems. The other main variable was the vehicle to carry both the binder and the pigments. As a result we selected one concentrated pigment dispersion system that has the best surfactant package for low surface tension.[2] The binder was also screened based on two important factors. Reliability and compatibility with the thermal inkjet head.

Accordingly, the best candidate for the ink formulations was selected:

- Pigment — Highly concentrated
- Vehicle — Reliability and sit time
- Surfactant — Wetting on vinyl
- Binder — Adhesion with 3 years durability

The next step was to optimize the formula for maximum jetting reliability, best image quality and lowest cost per print. The goal was to achieve 300ml of ink reliability with no compromise in image quality. In addition the ink viscosity during printing was the main factor to control.

The next challenge was to optimize the binder concentration in the ink for the best adhesion and still maintain the viscosity level within the norm for thermal inkjet. Our approach was to incorporate the binder to a minimum level where it gives best performance regardless the viscosity obtained at that optimum level of binder. The viscosity was then lowered by other mean in the printing process. With this approach it was possible to incorporate enough binder and vehicle that leads to higher ink viscosity for thermal inkjet. The ink density is also higher. The printing of this ink was tested in an elevated heating environments during printing. These conditions lower the ink viscosity back to standard thermal inkjet ink. The heating techniques are outlined in the printing process below.

Printing Process

The water based thermal outdoor printing ink (TOPI) was evaluated in an Encad printer with a Lexmark thermal inkjet head. The head has 208 nozzles and prints in 600dpi resolution. The ink was developed in four colors: cyan, magenta, yellow, and black. The Encad 36 inch printer platform with bulk ink supply system was selected for the best end user cost saving.

The thermal inkjet cartridge was filled and primed according to Encad filling method.[7]

The printer platen has been equipped with a heating element embedded at the inside wall of the platen on front and backside. The vinyl entering the print zone is preheated by the backside of platen up to 50C and heated up to 60C in the printing zone. The printer is also equipped with an InfraRed (IR) heating element to evaporate the ink aqueous vehicle and concurrently cures the ink on vinyl. Under those conditions the ink viscosity drops by 0.3 – 0.7 cps during printing. The cartridge body temperature could reach as high as 40C due to the platen and the IR heat sources.

The other method for lowering the ink viscosity is to utilize the preheat feature in the inkjet head. The head is equipped with two blocks on opposite side of the ink via, or wells, to preheat the bulk ink in the vicinity of the nozzle (Figure 2). Encad has utilized this preheat feature to maintain the ink temperature during printing. In this case, with new ink, it has been utilized to further lower the ink viscosity and to maintain it during printing. Another advantage of heating the ink is that it provides better wetting properties and higher color density.

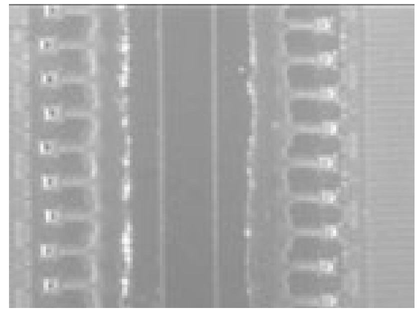

Figure 1. Ink Channels and Nozzle, Thermal ink Jet Head

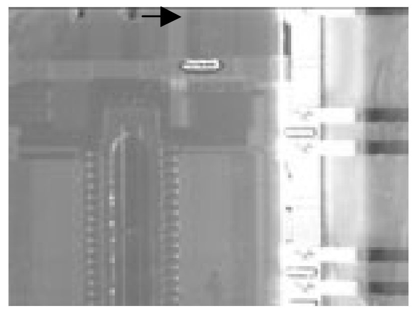

Figure 2. Ink Preheater in Thermal Ink Jet Head

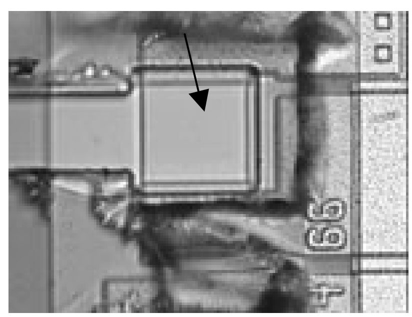

Figure 3. Jet Heater in Thermal Ink Jet Head

Results and Discussion

Several attempts were made to optimize the vehicle for best cartridge decaps time (non-printing state) and jettability. The ink in the cartridge was fired for at least 100ml and the sit time was examined at periods of 1 to 7 days. The ink was still printing under the printer's standard conditions. Then the jettability testing continued to 500ml and image quality was assessed every 50 ml of printing. The following chart (Figure 4) shows the ink performance as function of ink volume jetted.

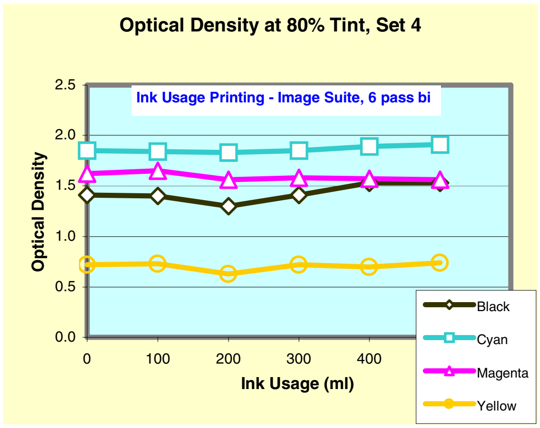

Figure 4. Ink O.D. Change vs. Jetting Reliability

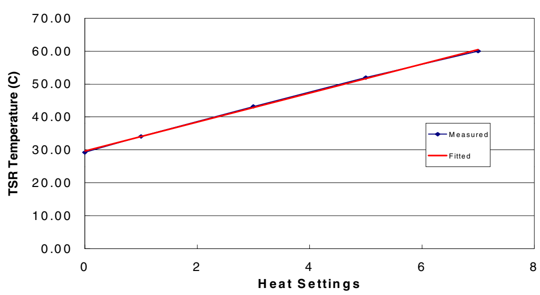

Figure 5. Ink Temperature vs. Ink Preheat for the Standard Ink

The above Figure 4 shows the ink optical density to be practically consistent through out the printing cycle of up to 500ml.

The actual ink temperature inside the cartridge and in the vicinity of the ink channels was measured during printing using a range of ink preheat. This temperature was compared to temperature profile of a standard, dye based, thermal inkjet ink (Figure 5) without binder and standard low viscosity (1.8 cps). The new ink shows slightly above normal operating temperature between 50-75C (Figure 6). The standard ink operates at 40-65C, Figure 5.

The two graphs Figures 5, 6 show the thermal ink heat behavior. Figure 6 shows the new ink operates at higher temperature than standard ink. In spite of the higher heat in the new ink (Figure 6), the reliability and compatibility of this ink is not adversely affected. The preheat keeps the new ink at a set level that reduces the viscosity. The ink is highly resistant to temperature inside the cartridge for that short firing time period.

Due to this property, the ink rheology fit perfectly the optimized jetting parameter for the ultimate performance.

The image quality of this ink was studied in relation to number of missing or clogged nozzles. Figure 8 shows the present ink behavior when a multiple of 16 nozzles were intentionally clogged and not compensated. The color loss is much less at higher ink density and is still much less than the standard ink. The standard ink, Figure 7, tends to show image defects easier as missing nozzles increased. The new ink property maintains a consistent large dot size enable it to perform more reliably than standard ink in image quality. Missing nozzles result in lower optical density change in new ink than standard ink. The measured values of Delta E were used to compare the color loss for both inks.

The new ink has demonstrated the consistency of its color throughout the jetting life cycle due to the ink's high dot gain as the color density increases.

The ink reliability is attributed to its binder high shear resistance and Newtonian property and fine pigment particles in a very highly stabilized vehicle.

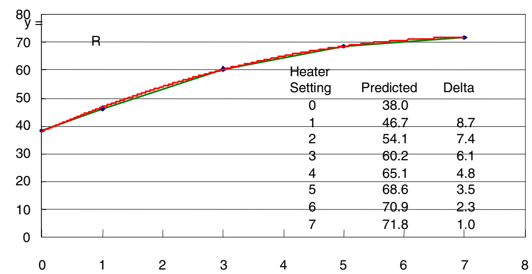

Figure 6. Ink Temperature vs. Ink Preheat for the New Ink

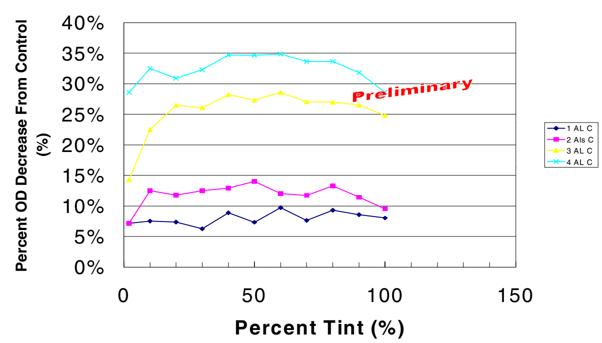

Figure 7. Image Quality as a Function of Missing Nozzles for the Standard Ink

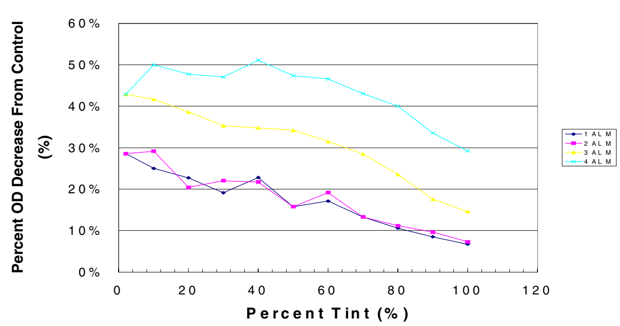

Figure 8. Image Quality as a Function of Missing Nozzles for the New Ink

Conclusion

In this study it was possible to formulate water based pigmented ink that can jet reliably in a thermal inkjet cartridge without degradation or kogation. The ink has high color gamut comparable to a dye base ink and good image quality throughout the life of the jetting cycle of 300ml-500ml per cartridge. In addition the printing system allows to directly print on vinyl with low overall cost to end-user.

References

1. US patent 5,085,698.Dupont (1992).
2. US patent 5,852,075 Dupont (1998).
3. US patent 6,284,816-Sunchemical (2001).
4. US patent 6,239,193 Xerox (2001).
5. US patent 5,364.462 Graphic Utilities (1994).
6. US patent 5,133,803 Hewlett-Packard (1992).
7. Encad Proprietary ink fill and prime method.

Biography

Dheya Alfekri received his Ph.D. in Physical Organic Chemistry from the University of Florida, Gainesville, Florida (USA) in 1985. He joined E.I. DuPont de Nemours and Co. ,the fluorinated surfactants division in 1985. Since 1997, he has worked in the Encad Imaging System & Product group in San Diego, California. His work is mainly concentrated in ink formulation and developments for outdoor digital printing applications. Previous work included formulating specialty coating in thermal and UV curing technology for the coating and laminating of flexible substrates in the display and packaging application with Material Sciences Corporation (MSC).