

Pigmented Latex System for Ink Jet Printing on Textile

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Abstract

The objective of work is to explore the application of small particle size polymer latex systems in ink jet printing on textile substrates. Pigments are incorporated in the latex to give colored inks. The routine of selecting microlatex and nanolatex polymer resins is set up. Particle sizes, surface tension, conductivity and viscosity of selected latices are measured and adjusted to meet the requirements of the printer. The Imaje Jaime 1000 S4 continuous ink jet (CIJ) printer is used to test these formulations. Cotton, silk and polyester/cotton are used as substrates. The printed substrates are evaluated in four aspects, colorfastness, hand, comfort and microstructure. The type of resin and ink formulation are optimized and used to develop a pigmented CMYK ink system.

Introduction

It has been generally recognized that digital textile printing offers improvements over the traditional textile printing with shorter lead time from design to production, variety of pattern design and production lot size, less space for archiving art, films, plates and screen. The results is lower product cost. However, current market for textile digital printing is limited to proofing, sampling and designing only. Most challenges for broadening this market are production speed, print quality and reliability, which could only be improved with printer firmware, software, printer head technology, image color profile, ink and media as an integrated solution.

As far as ink is concerned, reactive and acid inks are used predominately right now. These inks require pretreated fabric and a long process of post treatment, such as steaming, washing and drying. They are also limited to certain types of fabrics. For example, acid ink can only be used for protein fiber and polyamide fiber.

To develop an ink with a simple and short pre/post treatment process, and with a variety of fabric application would be a good direction to pursue. Encad TX ink is one of such example. This ink could be used to print coated fabrics such as cotton, polyester and silk with acceptable color gamut and color fastness can be obtained without post treatment.

This paper presents an example of using a pigmented latex system in textile ink jet printing. Pigment colorant does not have any reactive group to interact with fabrics. The printing resin forms a film when dried, which encloses the pigment and makes it adhere to the fabric. Hence the pigmented resin could be used for a wide range of fabrics, from natural fabrics, cotton and silk, to synthetic fabrics. The process of pigment printing is simple compared to printing with dyes. No pretreatment is necessarily required. Post-treatment is mostly a few minutes curing process.

There are many advantages to using polymer microlatex and nanolatex as resin. Firstly, both microlatex and nanolatex are small solid polymer particles distributed in a resin liquid. Their particle sizes meet the requirement of the printer. Secondly, they are water-based resins with good conductivity and relatively high surface tension. Thirdly, the process is simple. Resin film can be formed after a few minutes of curing. Since latex has been polymerized, no further polymerization reaction is needed. The purpose of curing is to evaporate water and form an integrated polymer film. Lastly, polymer latex is less costly and is easily available. Most microlatices used in this research are chosen from commercial screen printing binders.

Experimental

Resin Selection:

A number of microlatices which have been successfully used as adhesives and print binders in traditional screen printing are selected as candidates for resins in ink formulas. Six microlatices developed by Reichold Chem. Inc., TP6882, TP97767, TP68847, TP68837, TP5057 and TP68829 and three nanolatices developed by Rhone-Poulenc Inc., IU-103, IU-104 and IV-01 are investigated. Liquid resins are spread on a flat plate to make a film with controlled thickness, and cured using optimized procedures:

- Allow the film to set overnight
- Cure at 70 ^{0}Cfor 2 hours
- Cure at 140~150 ^{0}C for another 1 hour

The cured films are subjected to three tests: 1. Hand and yellowing of the cured film, 2. Mechanical properties, 3. The glass transition temperature (Tg).

An Instron Method 5567 is used for the mechanical testing. ASTM D822-95 (38) Standard--Test Method for Tensile Properties of Thin Plastic Sheeting (32) is followed to test film tensile properties. Load versus extension is recorded, and results including load at break, strain at break, stress at break, modulus and extension curves are obtained.

A Sieko Model 200 Dynamic Mechanical Analysis (DMS) unit instrument is used to measure the glass transition temperature of the resins. The scanning temperature range is from -100°C to around 90°C with a scanning rate of 3°C/minute.

Ink Formulation

Four fine particle pigments, C.I.Pigment black 7, C.I. pigment Red 184, C.I. pigment yellow 13, C.I. pigment blue B2G are used to make inks. These Hoechst Celanese Corp. pigments have a controlled particle size distribution less than 0.5 µm. The latex, pigment, solvent and humectant are mixed proportionally and grained in the mill to get the uniform ink. The particle size distribution is determined using Mastersizer Micro Plus Particle Size Analyzer. The viscosity of ink is measured using Brookfield DV-I+ Digital Viscometer, conductivity is measured with Omega Conductivity Meter CDH-37, and the dynamic surface tension is measured using KRUSS BP2 Bubble Pressure Tensiometer.

The pigmented latex inks are printed on a Jamie 1000 S4 continuous ink jet printer produced by Imaje.

Printed Fabric Evalutions

The printed samples are evaluated by colorfastness, hand, comfort and microstructure. The following properties are measured: ink pick-up, wet and dry crock fastness, flexural rigidity, air permeability, bending stiffness and hysteresis of bending moment. AATCC crockmeter, the cantilevel bending test, pure bending test and Kawabata Evaluation System (KES) are employed. Fabric comfort evaluation includes air permeability measurement and fabric thermal comfort test. Microstructure of substrates is measured using Scanning Electron Microscop (SEM).

Results and Discussion

Selection of Resin

One advantage of this research is to use existing textile screen-printing resin compositions. Textile apparel has strict requirements on hand, crock fastness and washing fastness, and the screen printing resin has been optimized for those purposes. The main component of the resin used in this work includes modified butadiene copolymer, nitrile-butadien copolymer, acrylonitrile-butadiene copolymer, modified acrylic polymer elumsion; The four parameters, resin emulsion particle size distribution, hand & yellowing, tensile properties and the glass transition temperature of the cured resin films, are used as criteria for pigmented ink resin selection.

For a microlatex of 10% - 20% solid content, the mean particle size is around 0.3 – 0.4 μm, with 99% of the particles smaller than 1 μm. The nanolatex is even smaller, around 0.1 – 0.2 μm. The yellowing of film is mostly resin component related. Resin containing styrene and butadiene is found to tend to yellow very easily. Table 1 lists some resins with their respective particle size, film hand and yellowing information. TP68837 and IV-01 could not be used as a resin because of yellowing and a stiff hand.

Table 1 Resin film yellowing and hand

Resin Name	Particle Size	Yellowing	Hand
TP5057	0.3~0.4 µm	Low	Very soft and elastic
TP68837	0.3~0.4 µm	High	Medium soft
TP68842	0.3~0.4 µm	Medium	Very soft and elastic
IU-103	<0.2 µm	Medium	Very soft and elastic
IV-01	<0.2 µm	Medium	Stiff hand

The cured resin film hand is found to be related to both film modulus and film glass transition temperature. Rubber-like extension curve with very low modulus, low stress and high strain at break is preferred. The recommended glass transition temperature (Tg) is below 0^0Cin order to obtain an acceptable hand. Table 2 lists five acceptable resins. TP68842 has a very high modulus which is expected to yield a stiff hand, but it has very soft hand instead. This suggests that modulus is not the only property of determining film hand. Other factors, such as Tg must be considered. The Tg of TP68842 is $–22^0$C, which is the main reason for its soft hand.

Table 2. Five acceptable resins with their mechanical properties and Tg

Resin Name	Strain (%) at break	Stress at break	Modulus	Tg of Storage modulus
TP5057	558.332	17.974	11.137	-42 ^{o}C
TP68842	129.17	118.44	8753.08	-22 ^{o}C
TP97769	198.217	89.947	73.180	-49 ^{o}C
IU-103	473.380	7.181	6.657	-14 ^{o}C
IU-104	288.629	48.672	133.902	13 ^{o}C

Properties of Ink

To evaluate an ink formula for ink jet printing, particle size, surface tension, viscosity and conductivity are monitored.

The benchmark values for the Imaje 1000 S4 printer are a mean particle size less than 0.5 μm and 100% of the particle size smaller than 1 μm. Particle size distribution should not change under high shear stress or at higher temperature. To get rid of larger particles, four filtration steps are used before and during printing.

The importance of surface tension, viscosity, and conductivity in jetting performance has been well recognized. The benchmark for surface tension is found to be 50-70dyne/cm, viscosity 2-4cp, conductivity above 0.75K Siemens.

The contents of resin and pigment affect ink physical properties and hence ink jetting performance. Table 3 lists ink jetting performance with different resin and pigment contents below. Performance, A indicates the extent of cartridge nozzle clogging; B indicates the extent of recycle gutter clogging; C indicates printed image quality. These performances are graded on a scale from 1 to 5, with 5 representing the best behavior and 1 the worst. A total of 1000ml ink is printed for each formula.

Table 3. Ink (TP5057 & Magenta) physics and performance

Ink formula (% by weight)			Visco./S.T/Condu.	Performance		
Resin	Pigment	Others	cp/(Dyne/cm)/K.Sie	A	B	C
15.0	0.0	85.0	1.86/65.9-70.2/2.8	5.0	4.5	5.0
20.0	0.0	80.0	2.40/60.0-64.7/3.5	5.0	4.5	4.5
15.0	2.0	83.5	1.86/58.2-64.8/2.4	5.0	4.5	5.0
20.0	2.0	78.0	3.02/55.7-62.0/3.6	5.0	4.0	4.5
15.0	4.0	81.0	2.34/55.7-64.0/2.7	5.0	4.5	5.0
20.0	4.0	76.0	3.30/54.0-62.0/3.2	5.0	4.0	4.5
15.0	6.0	79.0	2.30/53.2-63.8/2.4	4.5	4.0	4.5
20.0	6.0	74.0	3.96/53.0-63.6/2.9	4.5	3.5	4.5
15.0	8.0	77.0	2.80/51.0-61.5/2.5	1.0	1.0	1.0
20.0	8.0	72.0	4.04/53.4-63.5/3.1	1.0	1.0	1.0

From testing of different resin and pigment combinations, a total solid content up to 25% seemed to be the high limit to get good jetting performance. Ink with 15% resin has fewer clogging problems and better image quality than that with 20%. There is no serious problem in nozzle clogging when pigment content is less than 6%. Ink with 8% pigment has a very short breaking length with satellite droplets. Recycle gutter clogging is another problem.

Printed Fabric Properties and Microstructure Evaluation

Influence of Pigment on Printed Fabrics

The type of pigment in an ink formula might be a very important factor for the properties of printed fabrics. The tests for different pigments are performed with cotton as substrate. Five formulas have been checked:

a) 15% of TP5057 with 4% pigment Magenta
b) 15% of TP5057 with 4% pigment Yellow
c) 20% of TP5057 with 6% pigment Magenta
d) 20% of TP5057 with 6% pigment Yellow
e) 20% of TP5057 with 6% pigment Cyan

For a) and b), yellow pigment shows better crock fastness than the Magenta pigment in both wet and dry tests. For formulas c), d), and e), the yellow still shows the best crock fastness and magenta exhibits the worst crock fastness values. The differences are about 1 rating (AATCC Chromatic Transfer Scale and Gray Scale for staining) between the yellow and the Magenta. The bending and flexural rigidity properties of printing with different pigment do not show a clear difference. In other words, ink formulas with different pigment do not yield distinctly different hand properties. This is also true for air permeability. Since only limited pigments have been tested in this study, the conclusion may very when more pigment samples are investigated in the future.

Influence of Resins on the Printed Fabric

The properties for printed fabrics as different resins are applied in the ink formula. Three types of resins, microlatex TP5057, nanolatex IU-103 and nanolatex IU-104 are under investigation. Table 4 lists color fastness and hand data for these resins. The ink formula used here contains 15% resin and 4% yellow pigment. Ink pick-up is about 3%. For all three resins, the crockfastness values decrease when the ink pick-up increases. IU-104 shows the best crockfastness among them and TP5057 shows the lowest crockfastness. The highest is about 0.5-1 rating unit higher than the lowest, indicating that different resins have appreciable effects on the colorfastness of printed fabrics. Inks based on IU-103 displays the lowest change of B, 2HB and G values. In other words, it gives prints a soft hand. IU-104, on the contrary, yields a stiff hand. TP5057 based inks show a benefit over the other two in air permeability. In short, the measurements of colorfastness, hand and air permeability properties of prints from different resins clearly indicate that choosing different resins could make an obvious difference to the properties of printed fabrics.

Table 4. Hand and color fastness for different resin

Latex	dry/wet crock-fast	B Incre%	2HB Incre%	G Incre%	Air Perm Incre%
TP5057	4.5/3.5	16.7%	40.04%	25.1%	0.31%
IU-104	5.0/4.5	37.0%	49.1%	40.0%	7.60%
IU-103	5.0/4.0	14.8%	21.8%	5.8%	6.84%

Optimization of Ink and Resin Content

Formulations with less than 2% pigment do have good printing properties, hand and color fastness. But the color density is too low to be of interest for commercial usage. When pigment content is higher than 6%, ink exhibits some problems during printing, such as bad drop formation, clogging the nozzle and recycle gutter. With the concentration of latex fixed, the crock astness decreases with an increase in the amount of pigment. Using 15% and 20% microlatex in the ink formula does not change the observed crock fastness. The bending stiffness, bending hysteresis, and the flexural rigidity evaluation of images show a certain dependence on the content of resin and the dependence on pigment content is not obvious in our experiments. Ink with resin content higher than 25% experiences jetting problem. The dependence of air permeability on the amount of pigment and content of latex in the ink formula is very weak. Overall, the optimized pigment and resin content are 6% and 20% respectively.

Comparison of Ink Printing on Different Fabrics

A pigmented latex ink system has an outstanding advantage in that it can be applied to a wide range of fabrics. However, different fiber may show different properties due to various interactions between ink and substrates. Three fabrics, cotton, polyester/cotton blend, and silk are used to check the difference. Table 5 lists printed cotton color fastness and hand information of one of the ink formulations. 15% Nanolatex IU-104 and 4% of Black pigment are the main component of this formula. Ink pick-up is 5%.

Table 5. Printed fabric hand and colorfastness

fabrics	dry/wet crock-fast	B Incre%	2HB Incre%	G Incre%	Air Perm Incre%
Cotton	5.0/4.0	37.8%	49.1%	51.0%	7.62%
P/C blend	4.5/3.5	104.0%	72.1%	77.4%	6.26%
Silk	5.0/4.0	221.2%	150.0%	244.6%	-123.9%

Silk and cotton are better than the polyester/cotton blend with about 0.5 rating unit higher in wet crockfastness. For dry crockfastness, all three fabrics show good crockfastness with rating unit 4.5 – 5. For both formulas, silk shows the largest change in bending rigidity (B), bending hysteresis (2HB) and flexural rigidity (G) evaluation while cotton has the smallest change. This means the precious quality of silk-soft hand is lost when this kind of ink formula is applied. Air permeability of the two fabrics, cotton and polyester/cotton, changes slightly after printing for both formulas. Air permeability of silk, to our surprise, increases with the pick-up of ink on the textile. This is a good advantage of silk while the reason is not very clear.

Microstructure Evaluation

From the SEM photographs, it is noted that surface damage for cotton is the least in wet crocking. Only small pieces of resin film are peeled off. Cotton/polyester blend fibers are seriously marred after the wet crocking test. This happens not only to the resin film, but also to the fiber. When the resin film on the surface is rubbed, the fiber is delaminated into threads. The surfaces of the P/C blend are more hydrophobic than cotton. It may be easier for the water-based ink to spread and penetrate on cotton than that on P/C blend, which gives a more uniform and better adhesive film on cotton. This might be the reason for cotton's better crockfastness than P/C blend fabrics. As for silk, the surface damage is most severe after wet crocking. Fibers are seriously peeled, delaminated and some even broken. However, silk shows the same level of crockfastness as over cotton. Ink may be as readily spread over the silk surface as cotton. Though the silk fibers are damaged badly, the resin film will adhere to the fiber and not transfer to the crock cloth.

Conclusion

This work demonstrates that small particle size microlatex and nanolatex have promising properties in ink jet printing on textiles. To meet the requirement of textile marketing, the higher pigment content is needed to incorporated into the ink. In the meanwhile, formulation research is also expected to develop a latex with low viscosity, high solid content, low Tg, low modulus, as well as high thermal and mechanical stability. Such materials should be within the capabilities of existing emulsion polymerization technology and should be the very interesting candidates for an ink jet printing system.

References

1. Miles, Leslie W.C. "Textile Printing", 2nd editon, The Alden Press, Oxford, 1994
2. D.C. Patel, "Synthetic Binders for Pigment Printing", AATCC, Pigment Printing Handbook
3. Alan Johnson, "The Theory of coloration of Textile", second edition, Society of Dyers and Colourist
4. Wayne C. Tincher "Coloration Systems for Ink Jet Printing of Textiles", *IS&T NIP14*

Biography

Olivia Y. Tian received her M.S. in Textile Chemistry from Georgia Institute of Technology in 1998. This paper presented some of the work she had done at Georgia Tech, where she worked as research assistant with Dr. Wayne C. Tincher. Since 1998 she has worked in R&D, Encad Inc. in San Diego. Her work has primarily focused on the ink and media development. She is a member of the AATCC and SDC.