

Ink Jet Resin-Pigment Printing of Silk Fabrics

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Abstract

Silk fabric printing is expected to be an early production application of ink jet technology. A variety of silk fabrics have been printed with a TOXOT continuous ink jet printer using a pigmented ink with sub-micron particle size polymer latex resins. Inks with pigment loading of 5-9% and resin content of 15-20% could be successfully jetted. Printed samples were thermally cured and were tested with no wet post processing. Bending rigidity, air permeability and fastness properties were obtained on all printed samples. Acrylic resins with glass transition temperatures of -10 to -20 degrees C gave good fabric hand and acceptable wet and dry crockfastness properties. Pigmented polymer latices with sub-micron particle size appear to be a promising and cost effective approach to ink jet printing of a wide variety of textile substrates.

Introduction

Resin-pigment systems are used in over 50% of the printing on textile substrates worldwide and are the most rapidly growing area of textile printing. These coloration systems have significant advantages in that only a simple thermal cure is required after printing and good stability properties can be achieved without steaming or post washing. Costs of printing are, therefore, significantly lower than with dye based printing systems. Resin-pigment prints suffer from the disadvantage that fabrics may be stiffer after printing due to the resin binder used to hold the pigments on the fabric surface. Resins must be carefully chosen to achieve the required stability properties of the printed fabric with minimum change in stiffness ("fabric hand").

Resin-pigment printing represents a special challenge for ink jet printing due to the fact that neither resins nor pigments are soluble in water or organic solvents. These two phase systems are subject to problems with high viscosity, particle size instability, agglomeration, shear instability and phase separation. Despite these problems, resin-pigment systems can be formulated which meet requirements for delivery by ink jet engines and give very acceptable properties on printed fabrics.

Two Phase Ink Systems

Recent developments in emulsion polymerization can be employed to produce latices with very small polymer particles suspended in water. Particle sizes in the nanometer range are possible with low viscosities even at 50% solids in the latex. Polymer structures in these latices can be varied over a wide range of compositions to give the desired properties of the cured resin on the substrate.

Based on previous work on two phase ink systems [1], two polymer compositions were selected for the present study on silk fabrics. The polymer latices were prepared by Vinings Industries of Atlenta, GA, by a proprietary process known to give a stable latex with particle sizes in the nanometer range. The latex particles were acrylate copolymers with different ratios of butyl acrylate to methylmethacrylate to control the polymer glass transition temperature (T_G). Previous studies had shown that fabric hand properties[2] are related to the polymer T_G with resins with T_G's near -10 degrees C giving good fabric hand. The two resins prepared for studies on silk fabrics had T_G's of -10 (Resin IV-82) and -21 (Resin IV-83) degrees C. Viscosities of the latices were in the range of 12-13 cps at approximately 30% solids.

C.I. Pigment Red 184 (Hostafine Rubine F6B) was used for most of the studies on silk. In earlier studies,[1] the pigment color had little effect on printed fabric properties except that C.I. Pigment Red 184 was more sensitive to crockfastness tests.

Samples were printed on a TOXOT Jamine™ 1000 S4 continuous ink jet printer. Two phase inks perform well on this printer except for the clogging of the recycle line on high solids inks. This clogging apparently occurs because the vacuum used to draw unused droplets into the recycle line causes sufficient water evaporation to plug the line. To circumvent this problem, several strong hydrogen bonding agents were investigated to reduce the rate of water evaporation in the recycle line. The addition of approximately 2.5% urea to the ink formulation was found to significantly reduce the clogging problem. This additive also improved the jetting characteristics of the ink formulation in the high solids compositions. No other additives were used in the formulations.

Fabric Printing

Four types of silk fabric were used in printing studies. These fabrics were selected to give a range of fabric styles and weights. The fabrics are described in Table 1. Fabrics were printed as received with no pretreatment. The TOXOT Jamine™ 1000 S4 was used to print all samples. Samples were printed at essentially 100% coverage. The volume of ink delivered to the fabric samples was controlled by changing the number of passes through the printer. Most samples were printed with 1, 2 and 4 passes. The actual deposit of pigment and resin on the fabric samples was determined gravimetrically after curing and ranged from approximately 3% to 15% by weight depending on the solids content of the ink and the number of passes through the printer.

Table 1. Fabrics Used in Printing Studies

Fabric Type	Fabric Weight (g/m^2)
Habutai	35.6
Twill	41.1
Crepe de Chine	67.4
Charmeuse	80.6

Table 2. Properties of Two Phase Ink Formulations

Resin (%)	Pigment (%)	Viscosity (cp)	Surf. Ten. (nM/m)
15	5	3.11	60.0
15	7	3.77	59.5
15	9	5.01	59.0
17	5	4.58	58.0
17	7	5.65	58.0
17	9	6.12	60.0
19	5	5.92	58.5
19	7	6.06	59.5
19	9	6.23	60.0

Observations and assessments of printing performance were made with all ink formulations. Drop formation characteristics, jetting characteristics and clogging problems were noted. As expected, the performance of the printer deteriorated with ink formulations at high total solids (>30%). Most studies were performed at ink total solids of 26% or less. Properties of some typical ink formulations with Resin IV-82 and Hostafine Rubine F6B are shown in Table 2. It is apparent that increase in either resin or pigment has little effect on surface tension. However, increasing either pigment content or resin content increases the viscosity. The resin increase has a greater effect than the pigment increase in raising the viscosity. The sample with 28% total solids could be successfully jetted but this represented about the upper limit in viscosity for good performance with the TOXOT printer. Although no long term studies were conducted, the formulations in Table 2 could be jetted for periods of hours without problems.

Several formulations similar to those in Table 2 were selected for printing on the silk fabrics and properties of the printed fabrics were evaluated.

Effect of Ink Formulation

The effects of a number of factors in ink formulation on printed fabric properties have been evaluated. Properties of interest in the study were fabric stiffness (assessed by the Cantilever Bending Test, ASTM Standard D1388-64) and crockfastness (Standard for Colorfastness to Crocking, AATCC Test Method 8-1995). The effect of resin on these properties is shown in Table 3. Although both resins give printed fabrics with acceptable hand, Resin IV-82 is a somewhat stiffer resin (T_G = -10 C) than Resin IV-83 (T_G = -21 C) and this resin clearly causes a greater increase in fabric stiffness. However, with the softer resin somewhat poorer crockfastness is observed. Resin IV-83 probably represents the lower limit in resin softness that would be acceptable for ink jet printed fabrics. It is interesting to note that with these silk fabrics, the dry crockfastness values are lower than the wet crockfastness values. This is the reverse of the usual order of these values on other fabrics.

Table 3. Effect of Resin on Fabric Properties

Resin/Fabric	Bending Length (% Inc.)	Crockfastness (Dry/Wet)
IV-82/Charmeuse	+18	4.5/5.0
IV-83/Charmeuse	+11	4.0/4.5
IV-82/Twill	+27	3.5/4.5
IV-83/Twill	+10	3.5/4.0

The effect of the ratio of pigment to resin in the formulation that will give acceptable properties is of interest since the highest possible colorant concentrations are desirable in inks for fabric printing. Properties of printed fabrics with increasing pigment concentration in the formulation are shown in Table 4. For these samples Resin IV-82 was held constant in the ink formulation at 15% and Hostafine Rubine F6B was increased from 5 to 9 %. One very interesting result shown in Table 4 is the clear indication in all 4 fabrics that the stiffness of the fabric as measured by the bending length decreases as the pigment level increases. This was not expected and probably indicates that the pigment particles interrupt the resin film formation process during the curing of the latex. The crockfastness data follow the expected pattern of lowered values as the pigment content increases at fixed resin content. These samples also show better wet than dry crockfastness. At the 9% pigment level, two of the fabrics (Twill and Charmeuse) have already reached acceptable limits for crockfastness. The 15% resin, 7% pigment formulation gave good properties on all of the silk fabrics.

The effect of pigment to resin ratio on fabric properties was investigated further by varying the ratio of Resin IV-82 and Hostafine Rubine F6B in an ink formulation at 26% total solids. Fabrics were printed at an average total solids pick-up of 13%, which gave very heavy coverage of the fabric. These samples were tested as described above and the results are shown in Table 5. As indicated in Table 5, this print formulation is probably the limit in resin and dye concentration and that can be successfully printed on these silk fabrics. The change in stiffness of the Crepe de Chine at this resin/pigment concentration and 13% pick-up is undoubtedly higher than acceptable limits for this fabric.

Table 4. Effect of Pigment Level on Fabric Properties

Fabric	Ink Comp. (R%/P%)	Bending Inc (%)	Crockfast. (Dry/Wet)
Crepe de Ch.	15/5	14.3	5.0/5.0
Crepe de Ch.	15/7	14.3	4.5/5.0
Crepe de Ch.	15/9	4.2	4.0/4.5
Charmeuse	15/5	10.5	5.0/5.0
Charmeuse	15/7	4.4	4.5/4.5
Charmeuse	15/9	5.3	3.5/4.0
Twill	15/5	24.4	5.0/5.0
Twill	15/7	10.9	4.5/4.5
Twill	15/9	7.3	3.5/4.5
Habutai	15/5	12.2	4.0/4.5
Habutai	15/7	4.9	4.0/4.5
Habutai	15/9	-7.3	4.0/4.5

Table 5. Fabric Properties at High Resin/Pigment Level

Fabric	Ink Comp. (R%/P%)	Bending Inc (%)	Crockfast. (Dry/Wet)
Charmeuse	20/6	21.1	3.5/4.5
Charmeuse	18/8	18.4	3.0/4.0
Crepe de Ch.	20/6	50.0	4.0/4.0
Crepe de Ch.	18/8	54.2	3.5/4.0

The very high pigment loading (31%) in the 18/8 formulation is unacceptable in crockfastness on the Charmeuse and marginal on the Crepe de Chine. For these samples at high fabric add-on, it appears that a resin to pigment ratio of 2.5 or above is required for acceptable crocking performance.

Conclusions

Very fine particle latices prepared by microemulsion polymerization of acrylate monomers and containing very finely ground and well dispersed pigments are a promising system for use in ink jet printing of textiles. Surprisingly high solids levels can be successfully ink jetted. Increase in viscosity appears to be the limiting factor in solids level for good drop formation. The use of a good hydrogen bonding, additive, in this case urea, reduces viscosity and decreases the clogging problem in the continuous ink jet recycle line.

Good hand and crocking properties were obtained on silk fabrics in a wide range of fabric styles and weights. Inks containing up to 20% solids with resin to pigment ratios of 2.5 or better gave acceptable printed fabric performance. Resins with T_G's near -15 degrees C would appear to be best for a good balance between hand and crockfastness for use in silk fabric printing.

It is anticipated that latices with mixed particle sizes may be capable of giving lower viscosities at higher solids levels. The performance of the printing formulation might also be improved by availability of smaller particle size pigments or pigments with a different particle size distribution.

Pigmented nanometer particle latices appear to be a very promising, low cost system for ink jet printing of a wide range of textile substrates.

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References

1. Wayne C. Tincher, et. al., *Proceedings of IS&T NIP14: International Conference on Digital Printing Technologies*, Springfield, VA, 1998, pg. 243.
2. Yingnan Tian, Pigmented and Solvent Dyed Latex Systems for Ink Jet Printing on Textiles, M.S. Thesis, Georgia Institute of Technology, Atlanta, GA, 1998.

Biography

Dr. Wayne Tincher received his B.A. degree in Chemistry from David Lipscomb University in 1956 and his PhD degree in physical chemistry from Vanderbilt University in 1960. He is currently a Professor in the School of Textile and Fiber Engineering at Georgia Tech. His research interests are in the areas of textile dyeing, printing and finishing processes. Dr. Tincher was awarded the Olney Medal by the American Association of Textile Chemists and Colorists in 1996 for "outstanding achievement in textile and polymer chemistry."