

Environmentally friendly digital printing on cotton using, synthesized pigmented inkjet inks and comparison of their properties

DOI: 10.35530/IT.073.05.202181

HAYAT MUHAMMAD AKHTAR
GULZAR TAHSIN

HUSSAIN TANVEER
FAROOQ TAHIR

ABSTRACT – REZUMAT

Environmentally friendly digital printing on cotton using, synthesized pigmented inkjet inks and comparison of their properties

The “top-down” approach was adopted to manufacture nano inkjet inks. Pigment Black 7 and Pigment Red 122 both 100% dried powders were used. The premix of these two pigments was subjected to bead milling to reduce the particle size to the nano-scale. The inkjet inks prepared were characterized for their particle size, zeta potential, purity, viscosity, surface tension, foaming properties, and pH using required analysis and spectroscopy techniques. Both inkjet inks were applied digitally on pre-treated cotton. The printing was performed on a Monna Lisa Evo Tre printer (EPSON). The printed samples were evaluated for colour fastness to light, rubbing, washing, and laundering using relevant AATCC and ISO methods. The powders of the same colour index numbers were kneaded and emulsified by a traditional ball milling method. Emulsions prepared were characterized and applied on singed, desized, scoured, bleached, and pre-treated pure cotton through a traditional rotary screen-printing method. The printed samples were evaluated for their application fastness properties for comparative studies. It was concluded that by promoting the use of green chemistry and nanotechnology, the digitally printed fabric samples displayed better print quality, increased application fastness properties and good colour gamut as compared to traditionally printed fabric samples. Moreover, the new digital printing process resulted in reduced chemical, energy and water consumption along with socio-economic, environmentally friendly effectiveness, with almost zero waste production as compared to the traditional printing method.

Keywords: bead mill, cotton, digital particle size analyser, inkjet inks, Monna Lisa Evo TRE printer, pigments

Imprimare digitală ecologică pe bumbac folosind cerneluri inkjet pigmentate sintetizate și compararea proprietăților acestora

Abordarea „de sus în jos” a fost adoptată pentru a produce cerneluri nano inkjet. S-au folosit Pigment Black 7 și Pigment Red 122, ambele pulberi uscate 100%. Preamestecul acestor doi pigmenți a fost supus frezării cu bile pentru a reduce dimensiunea particulelor la scară nanometrică. Cernelurile inkjet preparate au fost caracterizate prin dimensiunea particulelor, potențialul zeta, puritatea, viscozitatea, tensiunea superficială, proprietățile de spumare, pH-ul, utilizând tehnicile necesare de analiză și spectroscopie. Ambele cerneluri inkjet au fost aplicate digital pe bumbac pretratată. Imprimarea a fost efectuată pe imprimanta Monna Lisa Evo Tre (EPSON). Probele imprimate au fost evaluate pentru rezistența culorii la lumină, frecare, spălare, clătire folosind metode relevante AATCC și ISO. Pulberile cu aceleași numere de index de culoare au fost frământate și emulsionate printr-o metodă tradițională de frezare cu bile. Emulsiile preparate au fost caracterizate și aplicate pe bumbac pur părilit, descleiat, spălat, albit, pretratată printr-o metodă tradițională de serigrafie rotativă. Probele imprimate au fost evaluate pentru proprietățile de rezistență a culorii la aplicare pentru studii comparative. S-a ajuns la concluzia că, prin promovarea utilizării chimiei ecologice și a nanotehnologiei, mostrele de țesături imprimate digital au prezentat o calitate mai bună a imprimării, proprietăți superioare de rezistență a culorii la aplicare și o gamă corespunzătoare de culori în comparație cu mostrele de țesături imprimate în mod tradițional. În plus, noul proces de imprimare digitală a rezultat cu un consum redus de substanțe chimice, energie și apă, împreună cu o eficiență socio-economică, ecologică, cu producție aproape zero deșeuri în comparație cu metoda tradițională de imprimare.

Cuvinte-cheie: frezare cu bile, bumbac, analizor digital de dimensiunea particulelor, cerneluri inkjet, imprimanta Monna Lisa Evo TRE, pigmenți

INTRODUCTION

Digital textile printing is a green and eco-friendly method of textile printing. This is cost-effective overall and economical for short production runs as compared to the traditional textile printing method. The synthesis of pigment-based nano inkjet inks for digital textile printing is a revolutionary step in the developmental path of the textile printing industry. The use

of inkjet inks in digital textile printing resulted in a significant decrease in water, energy, colour, and chemical consumption with reduced waste production to almost zero [1, 2].

The art of textile printing is probably as old as mankind or civilization itself. Over the years, there are significant developments in textile printing. The digital inkjet inks implementation in textile printing is

the latest trend, adopted by the industry for its survival. Recent developments in inkjet ink textile printing techniques are not only suitable for short production runs but also for an on-demand rapid market response and the incorporation of unique and diverse designs description to fulfil the requirement for mass customization trend [3].

With the formation of the International Textile Machinery Association (ITMA in 2003), several commercial textile production inkjet ink printers were launched in the marketplace. Digital textile printing has gained popularity as the preferred production technology. Today it is formed a niche part of digital textile printing. The low cost made it competitive for short runs. In addition, the fact that its waste production is almost zero has made this textile printing method socio-economic and environmentally friendly [4, 5].

The digital textile printing technique is interlinked, with the design software, printer, printing environment, fabric pre-treatment, post-treatment methods, and the operator. As digital technology is reaching new horizons, digital textile printing with the use of pigmented nano inkjet inks represents the future development direction in the textile printing industry. The new customer demands are only possible by the use of this new printing technique [5, 6].

This new technology is becoming a popular tool by replacing the traditional textile rotary screen-printing technique. As a result, this sector is encountered significant investments. Because of the combined efforts of inkjet ink manufacturers, printer manufacturers, and designers, inkjet-ink-based digital textile printing has gained popularity worldwide. The output of digitally printed fabric was grown by 300% since 2005 which was approximately 1% of the global market for printed fabrics. Water-based pigmented inkjet inks are especially popular because of their better application and weather fastness properties [7].

The use of pigment-based nano inkjet inks in digital textile printing has gained importance because of the following reasons: high-speed textile processing technology is less complicated, compatibility of pigmented inkjet inks with almost all types of fabric substrates, lowest possible (almost zero) waste production has made it green processing, the possibility of short-run processing, design diversity, with good quality prints, cheap as it is based on computer-aided technology [8].

MATERIALS

Pigment Black 7 Imported from NINGBO F.T.Z. HONGDA CHEMICALS INDUSTRIAL CO., LTD 535 QINGSHUIQIAO ROAD 11TH FLOOR OFFICE PARK BUILDING NINGBO HI-TECH PARK 315040 CHINA. Pigment Red 122, Imported from HANGZHOU DIMA COLOR IMPORT and EXPORT CO., LTD. ZHEJIANG, CHINA, Co-solvent (deionized water and ethylene glycol), surfactant (Scaural CA, Daico Chemical Industry Egypt), biocide (SPX Thor), buffer (Dytek[®] HMI, Inveta), chelating agent (EDTA, China),

defoamer (no foam SE Sybron-Tenatex.), dispersing agent (styrene-maleic anhydride copolymer) tailored with ammonium dimethyl quinacridone (Am DMQA), emulsifier (N-methyl-N-Oleoyltaurate or OMT, Parchem Fine), dispersing agent (acrylic copolymer, Clariant), anionic surfactant (SDS), and yttrium-stabilized zirconium beads (China).

Method

The top-down Method of nano-technology was adopted to proceed with the particle size reduction of the pigments. Kneader machine and nano design bead mill were used to reduce the particle size to < 50 nm.

Synthesis of inkjet ink A (Pigment Black 7)

The pigment-based inkjet ink A concentrate was prepared, using 100 g of the powder of the Pigment Black 7. N-Methyl-N-Oleoyltaurate (OMT) dispersing agent. 50 g and 140 g of diethylene glycol were added in a kneader machine and mixed for 3 h to form a slightly hard semi-dispersed paste with a partially reduced particle size. This paste was then offloaded to a wooden box. It was gradually added to a 1.5 l stainless steel turbo mixer which contains 650 g of deionized water, 10 g of diethylene glycol and 5 g of the dispersing agent. This mixture was agitated slowly using a frequency inverter. The agitation speed was increased slowly to 600 rpm within 15 min. The agitation was performed for another 3.5 h to obtain a smooth liquid (premix). Stirring was performed using the turbo mixer (input) to bead mill that contained 70% yttrium stabilized zirconium beads (1 mm) through a continuous pass system. The bead mill was equipped with a master sizer 2000 laser diffraction particle size analyser to measure the particle size distribution during the milling of the inkjet ink. The inkjet ink premix was stirred in the bead mill at a flow rate of 191 g/h (5 h) for the first pass to complete. The efficiency of size reduction was proportional to the efficiency of energy conversion [9,10]. The temperature was controlled by continuously supplying chilled water (35°C) through the jacket of the bead mill.

An inkjet ink sample was taken out from the sample outlet and its particle size distribution was evaluated offline using a digital particle size analyser to verify the results obtained on the laser diffraction particle size analyser. It was found that only 88% of the particles were in the 0.2–0.3 µm particle size range, the same results were shown by the master sizer 2000 system. At this stage, the remaining 45 g of deionized water was added. The concentration of the inkjet ink was become 10 wt.%. High-speed agitation was performed in the bead mill by adjusting the flow rate to 110 g/h. The material was run for a period of 9 h through a pass system which connected the bead mill, 1.5 L turbo mixer and stainless-steel vessel. The temperature of the inkjet ink circulating in the bead mill at 4000 rpm was controlled through its jacket system. After 9 h the agitation was slowed down and the sample was taken out and its particle size distribution

was analysed by a digital particle size analyser. At this stage, 96.5% of the particles had attained a particle size < 95 nm while the master sizer 2000 showed that 86% of the particles were in particle size range < 90 nm. Agitation was resumed again by adjusting the flow rate to 90 g/h and the inkjet ink was run for 11.11 h and the third pass was completed.

The speed of the bead mill was again reduced and a sample was taken out and analysed to evaluate the particle size distribution. It was found that 99.6% of the particles were in the size range < 50 nm. This was in keeping with the results obtained using the master sizer 2000 system. The milling and stabilization processes continued until the energy transfer between the grinding beads and the pigment particles reached its limiting value. At this point, the particles were reduced to the size range < 50 nm [11]. Initially, there was a rapid decrease in particle size because of the breakdown of the loosely agglomerated particles. As the milling progressed, the rate of decrease in the particle size was reduced because, at this stage, the milling was breaking the large primary particles. The laser diffraction analyser successfully tracked the milling process over time. Particles of the desired particle size < 50 were obtained after 25.11 h of high-speed milling.

The inkjet ink was filtered through a nano sieve and transferred into a turbo mixer. Agitation was performed at 200 rpm; 100 g of a defoamer and 0.1% of a biocide were added to the inkjet ink during this process stage. The agitation process was stopped once when all the foam was finished. The inkjet ink was collected in a 1.5 L glass bottle with an airtight stopper and was labelled as Inkjet Ink A. Modified structure of carbon black is shown in figure 1.

Synthesis of inkjet ink B (Pigment Red 122)

The pigment-based inkjet ink B concentrate was prepared and charged 110 g of the powder of Pigment Red 122 in the kneader machine. Dispersing agent styrene-maleic anhydride copolymer tailored with AmDMQA 90 g and 125 g of diethylene glycol were also added. The kneader machine was operated for 4 h with a temperature of less than 35°C. The kneading process yielded a slightly hard semi-dispersed paste, that was offloaded in a wooden box. This paste was gradually added to a high-speed turbo mixer that contained 600 g of deionized water, 25 g of diethylene glycol and 10 g of a dispersing agent. The agitation process was started slowly, speed was increased to 600 rpm within 15 min and agitation was performed for 4 h to obtain a smooth liquid (premix). Stirring was resumed using the turbo mixer to the bead mill containing 70% yttrium-stabilized zirconium beads (1 mm). For output and receiving 1.5 l, stainless steel tank was connected to the bead mill. The flow rate was adjusted to 160 g/h in the output tank. The inkjet ink B was stirred for 6 h first pass was completed. The particle size distribution of the premix during milling was measured with the master sizer 2000 system. The temperature was controlled by continuously supplying chilled water maintained at 35°C through the jacket of the bead mill. After 6 h of stirring, the speed was slowed down.

The sample was taken out and analysed offline, used the digital particle size analyser to determine the particle size distribution. The results obtained were verified using the master sizer 2000 system. It was found that only 73% of the particles were in the 0.2–0.5 µm size range. The remaining 40 g of the deionized water was added to the pigment and now the concentration

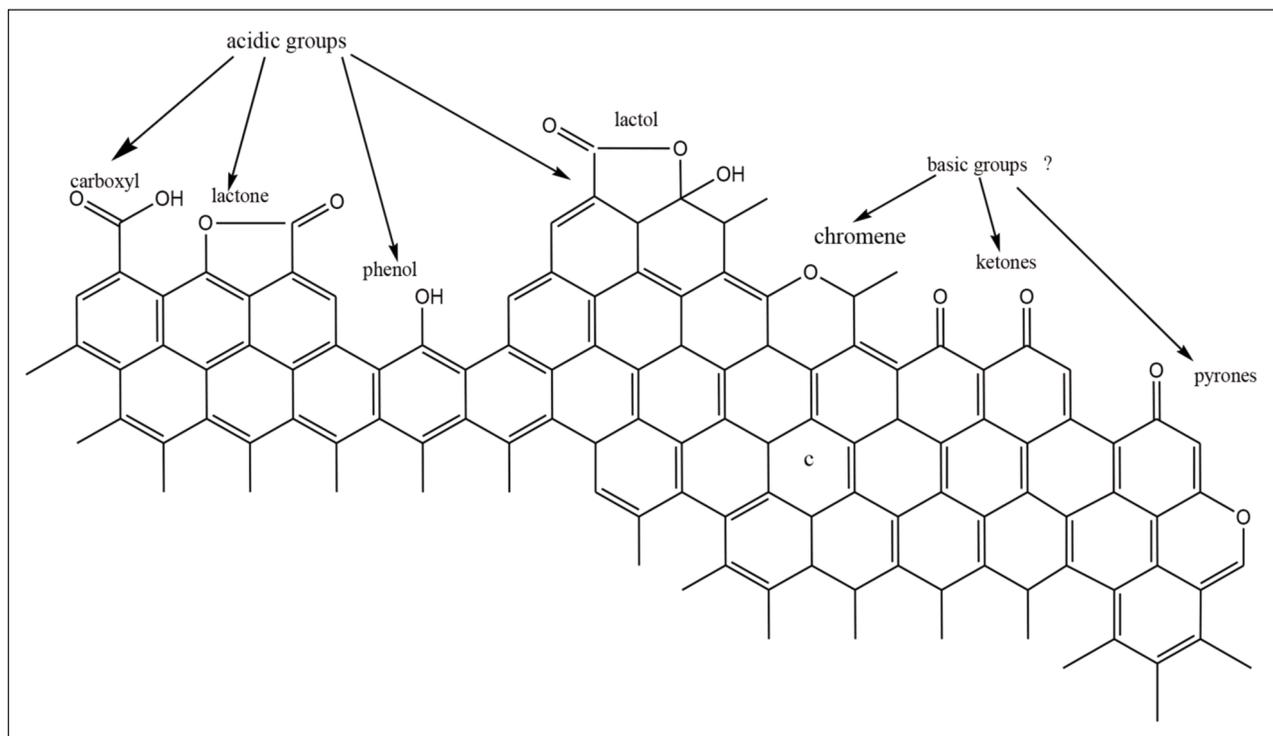


Fig. 1. Structure of carbon black showing different functional groups

in the inkjet ink became 12 wt.%. High-speed agitation was performed in the bead mill via pass system, the flow rate was adjusted at 110 g/h and the inkjet ink was agitated for 9 h; in this way, the second pass was completed. After 9 h, the agitation was slowed down. A sample was taken out and analysed to determine the particle size distribution using the digital particle size analyser. Only 87% of the particles were in the size range < 100 nm. The master sizer 2000 system indicated that 86% of the particles were in particle size range < 95 nm. Agitation was performed again and the flow rate was adjusted to 100 g/h. The inkjet ink was agitated for another 10 h; the third pass was completed.

The speed of the bead mill was reduced and a sample was taken out and its particle size was evaluated. It was found that 97% of particles attained a particle size distribution < 50 nm; the same particle size distribution was noted on master sizer 2000. The agitation was resumed and the flow rate was adjusted at 99 g/h output. The inkjet ink material was run for 10.1 h and the fourth pass was completed. The speed was slowed down. At this point, the particle size was reduced to a range of < 50 nm. The sample was taken out and particle size was evaluated. It was concluded that 99.7% of particles were in a size distribution range < 50 nm. The results demonstrated the ability of laser diffraction to track the milling process as a function of time. A consistent fine particle size distribution was attained after approximately 35.1 h of high-speed bead milling. The inkjet ink was filtered through a nano-tech sieve using a vacuum system and transferred into a turbo mixer. The turbo mixer was operated at a speed of 200 rpms/h. During the stirring, 101 g of defoamer and 0.12% biocide were

added; agitation was stopped after the complete foam was finished. The inkjet ink was collected in a 1.5 l glass bottle, which was closed with an airtight stopper and labelled as inkjet ink B. Modified structure of red 122 is shown in figure 2.

Powders of the same colour index numbers were kneaded, premixed and performed their traditional ball milling to emulsify them. The emulsions were characterized and applied on the same cotton for purpose of comparative application studies.

CHARACTERIZATION

The inkjet inks and emulsions were characterized for their purity, particle size, viscosity, surface tension, pH and shelf life (engineering stability) to meet operational requirements [12, 13].

Particle size

First, a diluted sample of inkjet ink A was placed in the measurement chamber of the particle size analyser, three successive measurements were performed and the mean of the three measurements was calculated. It was found that 99.9% of the particles were in the size range of < 50 nm. The chamber of (PSA) was calibrated and a sample of inkjet ink B was placed in the measurement chamber and three successive measurements were performed as described above. It was found again that 99.9% of the particles were in the size range of < 50 nm.

A digital particle size analyser was used to measure the particle sizes of emulsion samples A and B. It was found that 99% of the particles were in the particle size range of 0.2–0.5 μm [14].

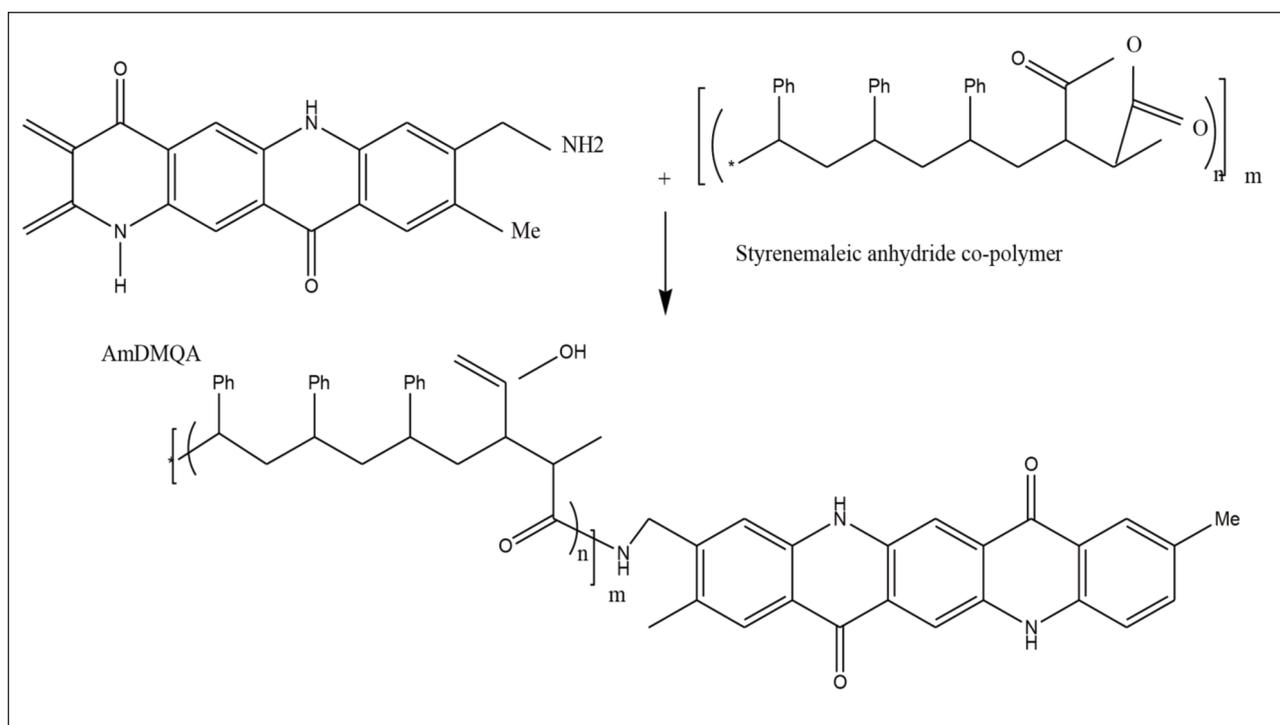


Fig. 2. Modified structure of Red 122

Purity

The total trace metal contents of inkjet ink samples A&B and both of the emulsion samples were analysed by inductively coupled plasma atomic emission spectroscopy. The samples for the analysis were digested in a mixture of sulfuric acid and nitric acid. The digested material was dried in ash in a muffle furnace. The dried residue was dissolved in hydrochloric acid and nitric acid. The resultant solution was used to measure the trace metal contents present and the results were compared with pure standards for quality assessment. Toxic heavy metals (Hg, As, Cd, Pb, and Cr IV) were present in amounts lower than the permitted limits of the Okeo-Tex® Standard 100 [15, 16].

Results are shown in tables 1 and 2 in section results and discussion.

Ink viscosity

The polymeric additive was added at a concentration of 0.16% and the viscosities of the inkjet inks A & B were adjusted to 10–12 cps at 25°C. The viscosity was measured under conditions similar to those that were during the application of the inkjet inks at the print head. Modern printers were generally operated at shear rates as high as 105–106 s⁻¹. Thus, microfluidic rheometry, a relatively new technique, was used to measure the high-shear viscosity. The viscosity of inkjet ink samples was measured by using an “m-VROCI microfluidic rheometer” at an ultra-high shear rate of 30,000 S⁻¹ temperatures 20 to 40°C. The viscosities of both emulsion samples were adjusted to 53 maps. It was evaluated and verified by using “the digital rotary viscometer model SNB-1 (OLD technique). This viscosity ranges of emulsions were 53 maps at 25°C. These were within the applicable limit of the rotary screen-printing method [17].

Surface tension

The surface tensions of inkjet inks sample A and B were adjusted using a non-ionic surfactant to 25–60

dynes/cm. The surface tensions were measured using a stalagmometer. The choice of solvent used was another important factor for controlling the surface tension within the permitted operational limits [18].

Foam

A common problem encountered during the use of inkjet ink was the formation of foam on the inkjet ink surface. This problem was solved by using a defoamer (0.01%), which was stable enough during the inkjet ink storage period.

pH

The pH was also an important factor to maintain, especially in the case of water-based inkjet inks. The zeta potentials of the pigment-based inkjet ink sample A and B were maintained within the required limits to ensure that the inkjet inks were stable. A buffer solution with pH = 7 was used to make the inkjet inks inert or less vulnerable to the effects of changes in the pH.

Ink storage and stability

All the parameters of pigment-based inkjet nano inks, including the pH, surface tension, particle size and viscosity, remained constant over prolonged periods (i.e., the “shelf life” of the inks). The shelf life for good quality inkjet inks at room temperature is almost two years.

RESULTS AND DISCUSSION (PROPERTIES OF PRINTED FABRICS)

The volume percentage of the inkjet ink changed into fine particle size distribution < 50 nm concerning cumulative volume (%) changed with time as shown in figures 3 and 4.

Toxic heavy metals (Hg, As, Cd, Pb, and Cr IV) were present in amounts lower than the permitted limits of the Okeo-Tex® Standard 100. Tables 1 and 2 are listed the detected limits, which are lower than the permitted limits as per a previous literature survey [19].

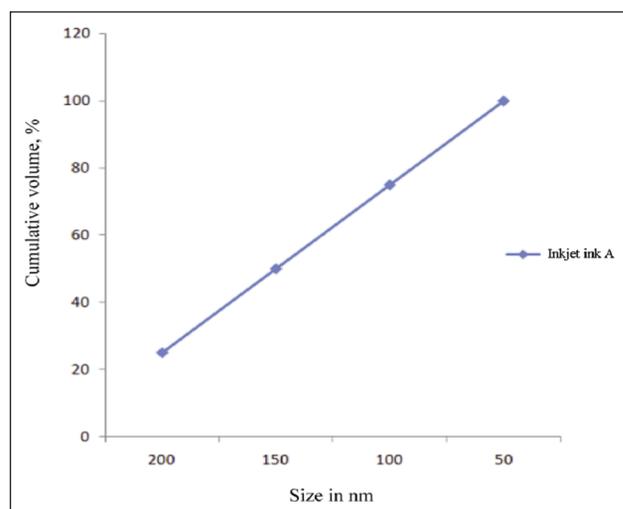


Fig. 3. Change in cumulative volume % age of inkjet ink A as function of particle size reduction

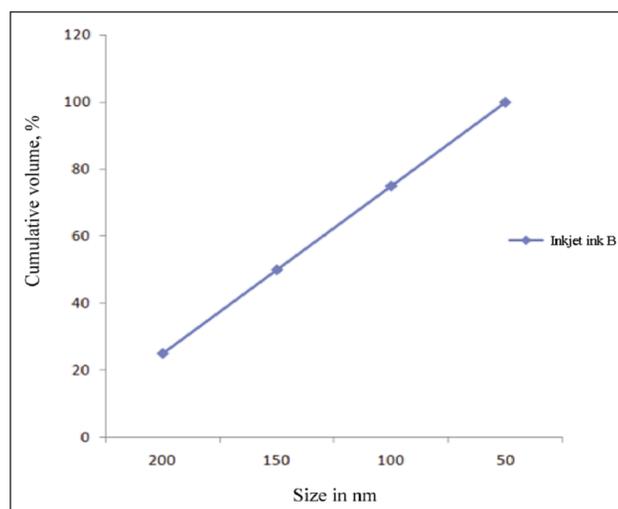


Fig. 4. Change in cumulative volume % age of inkjet ink B as function of particle size reduction

Table 1

METALS CONTENTS IN INK A				
Heavy metals in sample A	Body contact	Skin contact	Non-skin contact	Decomposed metal
Cd	0.09 (PL 0.1)	0.089(PL0.1)	0.098(PL0.1)	0.99(PL0.1)
Cu	16(PL 25.0)	14.9(PL50.0)	17(PL50.0)	20(PL50.0)
Pb	13(PL90.0)	11.9(PL90.0)	14(PL90.0)	21(PL90.0)
ZN	Not detected	Not detected	Not detected	Not detected
Fe	Not detected	Not detected	Not detected	Not detected

Table 2

METAL CONTENTS DETECTED IN INK B				
Heavy metals in sample B	Body contact	Skin contact	Non-skin contact	Decomposed metal
Cd	0.092(PL 0.1)	0.091(PL0.1)	0.099(PL0.1)	0.1(PL0.1)
Cu	16.3(PL25.0)	15.1(PL50.0)	17.2(PL50.0)	20.4(PL50.0)
Pb	13.1(PL90.0)	12.1(PL90.0)	14.3(PL90.0)	21.2(PL90.0)
ZN	Not detected	Not detected	Not detected	Not detected
Fe	Not detected	Not detected	Not detected	Not detected

The results in the graphs are indicating that the viscosities of both inkjet ink samples decreased with an increase in the temperature and shear rate, by results that are reported in a previous literature survey. The effects of the temperature and shear rate on the viscosity are shown in figures 5 to 8, respectively [20]. The most common problem in pigmented inkjet inks is an aggregation of pigment particles due to the inherent stability of the most common dispersion systems. When pigment particles approach each other, Vander walls interaction takes place, causing the particles to aggregate and eventually reached minimum potential energy as shown in figure 9. If the pigment is hydrophobic, it will tend to form a large aggregate in water. To avoid this aggregation, a mechanism to overcome attraction was required. To prevent the

phenomenon of aggregation, an anionic surfactant was used. The surfactant SDS was adsorbed onto the surfaces of the pigment particles, where it imparted a negative charge. Thus, when the particles approached each other, they were repulsed electrically, as shown in figure 9 [20]. According to Derjaguin-Landau-Verwey-Overbeek theory (DLVO theory), if the repulsion overcomes the attraction, an energy barrier will exist and prevent the aggregation of particles as shown in figure 9. Thus, the prepared inkjet inks exhibited good storage stability.

Colour fastness to rubbing

A digital crock meter (KTS) 500×500 was used to perform dry and wet rubbing fastness tests. The AATCC-08 method was used in both cases. For the wet rubbing

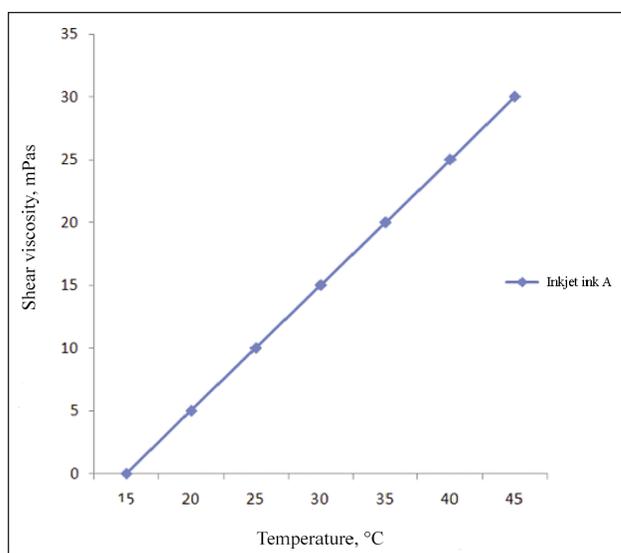


Fig. 5. Effect of temperature on shear viscosity for inkjet ink A

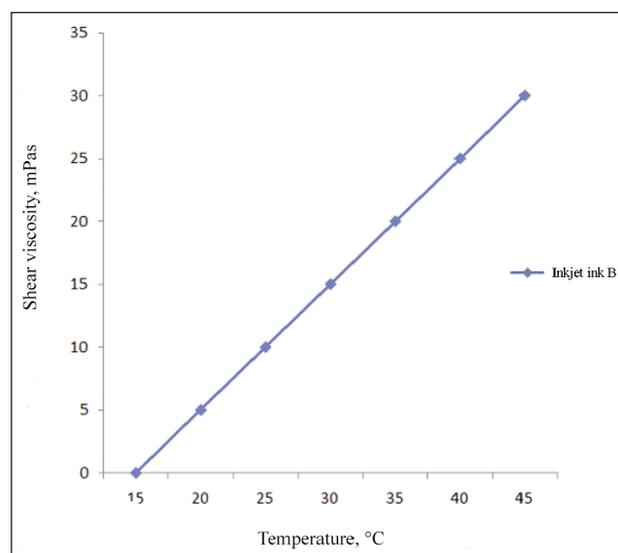


Fig. 6. Effect of temperature on shear viscosity for inkjet ink B

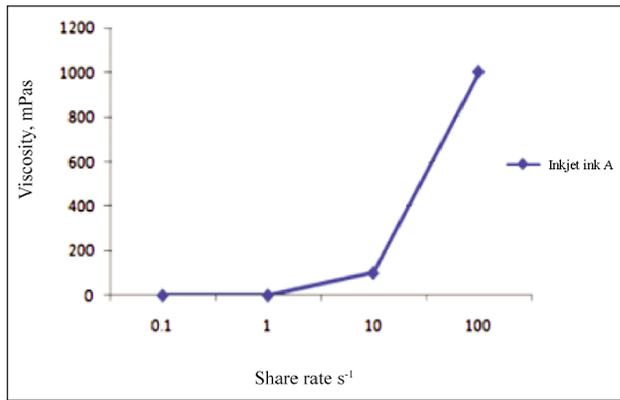


Fig. 7. Effect of shear rate on viscosity for inkjet ink A

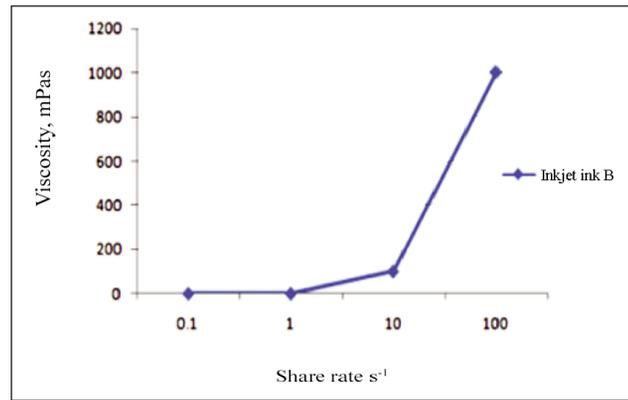


Fig. 8. Effect of shear rate on viscosity for inkjet ink B

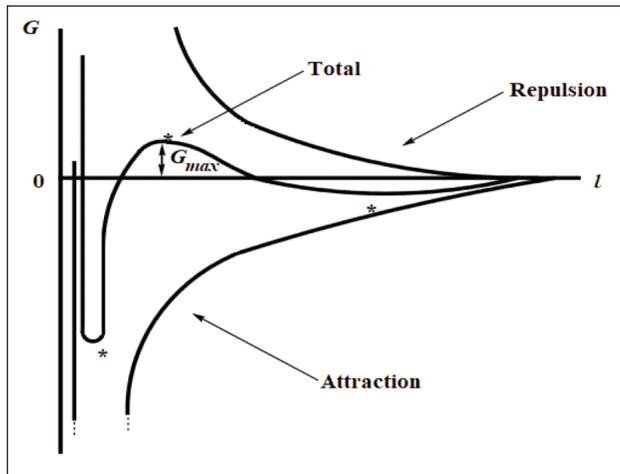


Fig. 9. Mechanism underlying ink stability during storage

test, the rubbing cloth used was 65% wet while for the dry rubbing test, it was 100% dry. The test was performed for dry and wet rubbing turn by turn for digital textile printed fabric samples and traditionally printed fabric samples. It was found that the digitally printed fabric samples exhibited better dry and wet rubbing fastness properties as compared with those of the traditionally printed fabric samples. Images are shown in figures 10 and 11. The quantitative rating of results is listed in table 3.

Colour fastness to washing

The ISO 105 C06 test method was adopted to evaluate the washing fastness of the traditionally and digitally printed fabric samples. Specimens with dimensions of 4×10 cm² (ISO) were cut from the traditionally



Fig. 10. Rubbing fastness of traditionally printed fabrics

Table 3

RATING OF DRY AND WET RUBBING OF TRADITIONALLY AND DIGITALLY PRINTED SAMPLES A AND B				
Fastness property	Ink A traditionally printed	Ink A digitally printed	Ink B traditionally printed	Ink B digitally printed
Rubbing Dry	4-5	5	4-5	5
Rubbing wet	3-4	4-5	3-4	4-5



Fig. 11. Rubbing fastness of digitally printed fabric



Fig. 12. Washing fastness of traditionally printed fabric



Fig. 13. Washing fastness of digitally printed fabric

and digitally printed fabric samples. A multi-fibre swatch was attached to each specimen. All the colours of the samples were covered during the cutting process. A wash liquor was prepared using Grade 3 water and the required amount of Sand pan[®] DTC (Clariant). Steel balls were used in the HT machine, which was run for 30 min at room temperature. The washed specimens were removed, rinsed and dried in still air at a temperature not exceeding 60°C. Once the specimens were dried and conditioned, they were evaluated. It was found that the washing fastness of the digitally printed fabrics was better than that of the traditionally printed fabrics. The rating of results is listed in table 4 and images are shown in figures 12 and 13.

Colour fastness to dry cleaning

The ISO 105-DO1 method was adopted to test the dry-cleaning fastness of the traditionally and digitally printed fabric samples. Specimens with dimensions of 40×40 mm² were cut from the samples with care and placed along with white cotton fabric and non-corrodible steel discs (diameter = 30 ± 2 mm, thickness 3 ± 0.5 mm, smooth and free from rough edges, mass = 20 ± 2 g) in a bag with inner dimensions of 100×100 mm². The bag was sealed and put in the steel glass of the wash wheel and added perchloroethylene (10 ml/l) and a water-based detergent (0.6 ml/l). All the materials were agitated in the wash wheel for 30 min at 30°C. The specimens were removed from the bag, placed between absorbent paper and squeezed to remove the surplus solvent. They were then dried in air at a temperature not exceeding 60°C and evaluated changes in their shades using the grayscale proposed by the AATCC. It was found that the digitally printed samples exhibited better dry-cleaning fastness as compared to the traditionally printed samples as shown below. The images are shown in figures 14 and 15 and the rating of the results is in table 5.

Table 4

WASHING FASTNESS RATINGS OF TRADITIONALLY AND DIGITALLY PRINTED FABRIC SAMPLES			
Ink A traditionally printed	Ink A digitally printed	Ink B traditionally printed	Ink B digitally printed
4	5	4	5



Fig. 14. Dry cleaning results for digitally printed samples



Fig. 15. Dry cleaning results for the traditionally printed sample

Table 5

DRY CLEANING FASTNESS RATING OF TRADITIONALLY AND DIGITALLY PRINTED FABRICS			
Ink A traditionally printed	Ink A digitally printed	Ink B traditionally printed	Ink B digitally printed
4	5	4	5

Colour fastness after light exposure

The ISO 105/BO2 test method, which is widely accepted in the industry, was used to evaluate the colour fastness after exposure to light. A xenon arc lamp was used as the artificial light source as it was representative of natural daylight.

The specimens were cut carefully and exposed to moderate effective humidity. Light fluorescence (L F) of humidity test control was 5. The maximum black standard temperature was kept at 45 °C. Irradiance was performed at 300–400 nm. The specimens were exposed until a contrast corresponding to grey scale grade 4 and later to greyscale 3 was visible on the test sample, but at most until the blue wool reference was shown a contrast corresponding to grey scale grade 4 AATCC. The specimens were assessed using blue wool as a reference; images are shown in figures 16 and 17 and the rating of results is listed in table 6.



Fig. 16. Results of light fastness tests for traditionally printed fabrics

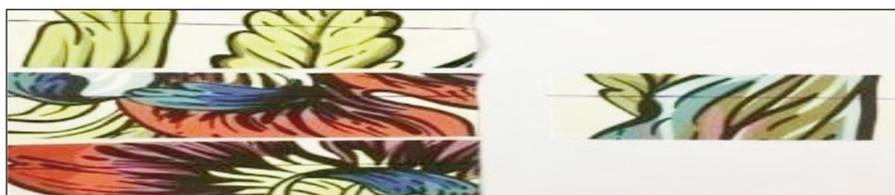


Fig. 17. Results of light fastness tests of digitally printed fabric

Table 6

LIGHT FASTNESS RATING OF TRADITIONALLY AND DIGITALLY PRINTED FABRIC				
Fastness property	Ink A traditionally printed	Ink A digitally printed	Ink B traditionally printed	Ink B digitally printed
Light Fastness	5-6	7-8	5-6	7-8

CONCLUSIONS

Inkjet nano inks and emulsions were synthesized, characterized and applied on the same pre-treated cotton fabrics. Their fastness properties, such as rubbing, washing, dry cleaning and light fastness were evaluated using ISO and AATCC methods. It was concluded that all the fastness properties of the digitally printed fabric samples were better as compared to traditionally printed fabric samples. Secondly, the colourants used have the same colour index numbers but the weather fastness properties were better in nanoparticle size as compared to micron particle

size. Furthermore, digital inkjet ink printing and traditional rotary screen-printing methods were compared and were concluded that the digital textile printing method was a better printing method for quality printing, socio-economic and environmentally friendly as compared to the traditional rotary screen-printing method.

ACKNOWLEDGEMENT

All authors are highly thankful to the department of applied chemistry, NTU & Kausar Processing Industry for providing the necessary facilities. This work is part of the Ph.D. study of M. Akhtar Hayat.

REFERENCES

- [1] Daplyn, S., Lin, L., *Evaluation of pigmented ink formulations for jet printing on to the textile fabrics*, In: Pigm. Resin Technol., 2003, 32, 307–318, <https://doi.org/10.1108/03699420310497454>
- [2] Magdassi, S., *Chemistry of inkjet inks*, Singapore world scientific publishing Co. Pvt. Ltd., 2010
- [3] Dehghani, A., Jahanshah, F., Bormann, D., Dennis, K., Wang, J., *Design and engineering challenges for digital ink-jet printing on textiles*, In: Int. J. Clothing Sci. Technol., 2004, 16, 262–273, <https://doi.org/10.1108/09556220410520531>
- [4] Provost, J., *Inkjet ink printing on textile*, In: Surface Coatings International, 1994, 77, 36–41
- [5] Ding, Y., *Color Gamut Comparison Methodology and Evaluation for textile Inkjet Printing (Raleigh, NC: North Carolina State University)*, 2016
- [6] Schulz, G., *Preparation and characterization curable inkjet inks*, In: Melland Textile berichte, 2003, 83, 154
- [7] Schulz, G., *Textile chemistry of digital printing*, In: Melli t-Textilberichte/Int. Text rep. Eng. ed., 2007
- [8] Hakeem, O.A., Daib, H.A., Adams, J., *Preparation and characterization of UV curable-encapsulated phthalocyanine blue pigment*, In: Prog. Org. Coat., 2015, 84, 70–78, <https://doi.org/10.1016/j.porgcoat.2015.02.007>
- [9] Magdassi, S., *Chemistry of inkjet inks*, Singapore world scientific publishing Co. Pvt. Ltd. 2010
- [10] American Association of Textile Chemists and Colourists, *Evaluation procedure 1Gray scale for color change*, in AATCC technical manual 2013, 2-2-2-AATCC (NC: Research Triangle Park), 407–402
- [11] Dehghani, A., Jahanshah, F., Bormann, D., Dennis, K., Wang, J., *Design and engineering challenges for digital ink-jet printing on textiles*, In: Int. J. Clothing Sci. Technol., 2004, 16, 262–273, <https://doi.org/10.1108/09556220410520531>
- [12] H-Ujiiie and Clark, D., *Applications of digital ink-jet printing on textiles*, In: AATCC Rev., 2003, 3, 14–16
- [13] Bowles, M., Isaac, C., *Digital textile design*, London: Laurence king publishing Ltd, 2009
- [14] Kochenberger, G., Glover, F., Alidaee, B., Rego, C., *Solving combinatorial optimization problems via reformulation and adaptive memory metaheuristics*, In: Frontiers of evolutionary computation, ed. A. Menon, Genetic Algorithms and Evolutionary Computation Series, Kluwer Academic Publishers, Springer, 2004, 11, 103–113
- [15] Fu, S., Du, C., Zhang, K., Wang, C., *Colloidal properties of copolymer-encapsulated and surface modified pigment dispersion and its application in inkjet printing inks*, In: J. Colloid Interface Sci., 2011, 334, 42–49
- [16] Australia RMIT Momin, N.H., *Chitosan and improved pigment ink printing on textiles in School of Fashion and Textile Design and Social Context*, 2008
- [17] Fu, S., Du, C., Zhang, K., Wang, C., *Colloidal properties of copolymer-encapsulated and surface modified pigment dispersion and its application in inkjet printing inks*, In: J. Colloid Interface Sci., 2011, 334, 42–49
- [18] Fukai, J., Ishizuka, H., Sakai, Y., Kaneda, M., Atchara, A., *Effects of droplet size and solute concentration on drying process of polymer solution droplets deposited on homogeneous surfaces*, In: International Journal of Heat and Mass transfer, 2006, 49, 3561–3567
- [19] Kondo, A., *Ink composition and method of inkjet printing*, US20030149130A1, Nov. 7, 2007
- [20] Shlomo M., *The Chemistry of Inkjet inks*, World Scientific Publishing Co. Pte Ltd. 1st ed., 2009, 23–356
- [21] Kang, H.R., *Water-based Ink-Jet Ink, parts I, II and III*, In: J. Imaging Sci., 1991, 35, 179–201

Authors:

HAYAT MUHAMMAD AKHTAR¹, GULZAR TAHSIN¹, HUSSAIN TANVEER²,
FAROOQ TAHIR¹

¹Department of Applied Chemistry, Government College University, 38000, Faisalabad, Pakistan
e-mail: tahsingulzar1@yahoo.com, tahirfarooqfsd@gmail.com

²Textile Engineering Rector, National Textile University, Sheikhpura Road, 37610, Faisalabad, Pakistan
e-mail: tanveer@ntu.edu.pk

Corresponding author:

HAYAT MUHAMMAD AKHTAR
e-mail: chemicals@kausar.com