Effect of Pigment Particle Size on Color Properties of Inkjet Printing Inks

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Abstract

The waterborne pigment red 122 dispersions with different particle size were prepared by phase separation technique, and follow prepared the inkjet printing inks. The effects of particle size on absorbance and the crystal of pigment were measured, and also the color properties of textile which printing using these inks. The results showed that the absorbance was the lowest and printing performance the pigmented ink with particle size 110.8nm was the best among these three pigmented inks. The K/S values of printing cotton fabrics showed that the pigmented ink with small particle size could import cotton fabrics much higher color depth. The rubbing fastness of cotton fabrics printed by the pigmented ink with particle size 110.8nm was superior to the other pigmented inks.

Introduction

Color performance of pigmented ink is mainly determined by molecular structure, crystal structure, particle size and its distribution. Commonly, in the traditional pigment printing, the smaller particle size and the narrower distribution of pigment particles, the higher color depth, more brilliant and purer color was [1,2].

At present, more and more people paid their attention on the color performance of pigmented ink with development of pigment processing technology. Samantha L. Pugh has proved that pigment with small particle size shows an excellent light fastness and tinct strength [3]. Alexandra D. investigated the color performance of pigment with diameter 100nm and 50nm respectively, the results show that the printing paper with diameter 50nm was more brilliant and distinct [4]. In our previous work, the printing impact with pigment yellow which diameter were 90nm and 350nm respectively was investigated, the results show that the color performance of printing with nanoscale particle size is obviously superior to that of printing with sub-nanoscale particle size [5].

In this paper, the pigmented inks with different particle size were prepared by phase separation technique. The color performance of pigmented ink and its printing production, printing performance of the pigmented inks with different particle size were investigated.

Methods and experiments

Preparation of pigmented ink

Preparation of the dispersion with different particle size

The waterborne pigment red 122 dispersions were prepared by the method described in Fu's work [6]. A certain amount of styrene-maleic acid copolymers (PSMA, the molar content of maleic acid in copolymer was 0.43, number molecular weight was 18000, measured by GPC) were dissolved in media, and a corresponding amount powder of pigment 122 (Jiangsu Wucai specialty chemicals co., Ltd) were added into the solution under stirring at 500r/min. The mixed slurry was transferred to an Ultra Turrax IKA T18 Basic (IKA Instruments Ltd) and dispersed for different time. The mixture was filtered and dried, and then modified pigments were obtained. 10g modified pigments and corresponding weight of demonized water were mixed together, and then pH value was adjusted by solution of sodium hydroxide (1%) to 8. The above slurry were stirred by blender at 45℃ for 30 min, and prepared the pigment dispersion with 10% pigment weight fractions.

Preparation of the pigmented ink

Table1. Formulation of inks for inkjet printing

Component	Weight content (%)	Component	Weight content (%)
Dispersion	50	Urea	2.0
Glycerol	15	Tween-80	1.2
Ethylene glycol monomethyl ether	10	Distilled water	21.8

Inkjet pigmented inks with different particle size were prepared from the prepared dispersions. The pigmented ink formulation based on weight is given in Table 1. The pigmented ink components were mixed together under stirring at 300r/min until a homogeneous dispersion was obtained. After filtered through a 500nm pore filtering sieve, the pigmented inks were loaded for inkjet printing.

Absorbance of pigmented inks

The particle size of the pigmented ink was measured by Nano-ZS90 (Malvern Instruments Ltd). The pigmented inks with different particle size were diluted to 2000 times respectively and the absorbance was measured using UV-2100 spectrophotometer.

X-ray diffraction of the modified pigment

The relationship between diffraction angle and diffraction intensity of modified pigment with different particle size were determined by XRD (ARL-X TRA) using CuKa as radiation at a wavelength of λ=1.54183Å respectively. The generator settings were 40 kV and 35mÅ. The diffraction data were collected over a 15min range of 5º–45º, with a step width of 0.02º and a counting time of 5s per step.

Printing performance of pigmented inks

The printing performances of the pigmented inks prepared from pigment dispersions were tested on an inkjet printing machine (Mimaki JV4-180, Japan, pizeo-electric inkjet printer, the diameter of nozzle about 50000nm). The clogging nozzle rate was calculated according to Eq. (1):

$$B = \frac{C_1}{S} \times 100\% \qquad (1)$$

Where C_1 is the amount of clogged nozzle, S is the sum of the whole nozzle on the print head. The greater B, the poorer printing performance of ink is.

Color performance of printing products

K/S values of printing product were measured with xrite-8400 colorimeter under illuminant D65 using the 10 standard observer. The rubbing fastness and washing fastness were tested according to AATCC standard 8-2001, 61.

Results and discussions

Particle size distribution of pigmented ink

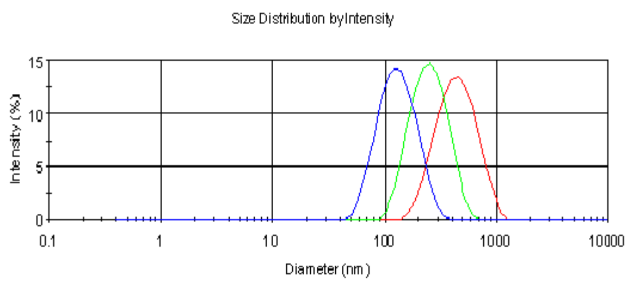

Figure1. Particle size distribution of pigmented ink, blue-average particle size 110.8nm, green-average particle size 243.5nm, red average particle size - 380.0nm

Figure1 revealed that the particle size of three pigmented ink represented the normal distribution, the smallest particle size was about 40nm, and the largest particle size was about 1050nm.

Absorbance of pigmented ink

The absorbance of pigmented ink with different particle size was measured. The results were shown in Figure2.

Figure2 revealed that the smaller particle size, the smaller absorbance at the same wavelength of pigmented ink was, especially in glow and blueness area. It may due to that the light was easy to round away when the particle was small, especially when the particle size was smaller than that half of wavelength.

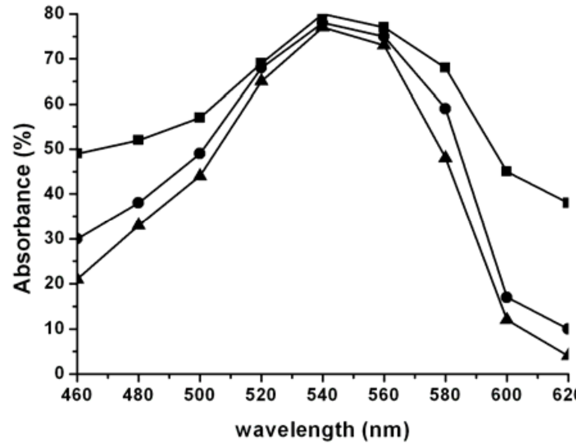

Figure2. Effect of particle size on absorbance of pigmented ink, ■-110.8nm, ●-243.5nm, ▲-380.0nm

X-ray diffraction of pigment with different particle size

The diffraction intensity of pigment with different particle size as a function of diffraction angle was shown in Figure3.

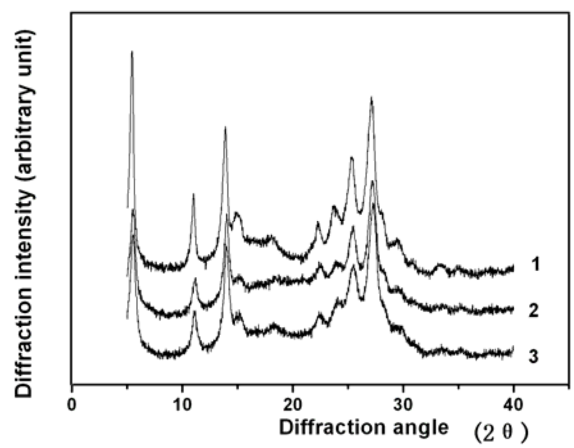

Figure3. Effect of pigment red 122 size on XRD, 1-particle size 380.0nm; 2-particle size 243.5nm; 3- particle size 110.8nm

The diffraction is a special behavior when the X-ray is scattered by the crystal. The direction of diffraction is different when the crystal of pigment is changed [6]. It is well known that the color performances of pigmented ink were determined by the molecular structure, and were also greatly affected by crystal structure, particle size and its distribution. Generally, the hue would be changed if the pigment had different crystal structure [7]. Figure3 revealed that the diffraction curve of pigment with different diameter was similar, and the peaks appear almost at the same position which told us that the crystal structure was not unchanged.

Physical properties of pigmented inks and their printing performance

Table2 shows the physical properties of the pigmented inks with different particle size. It was noted that the smaller particle size, the lower apparent viscosity and the higher surface tension was, which indicated that the particle size can greatly influence the physical properties of the pigmented ink. As a consequence, the pigmented ink with particle size 110.8nm exhibited better printing performance as presented in Figure4.

Table2. Physical properties of the pigmented inks with different particle size

Pigmented ink with different particle size (nm)	Apparent viscosity (mpa.s)	Surface tension (mNm^{-1})
110.8	4.72	29.7
243.5	5.24	28.4
380.0	6.08	28.2

Compared with the three pigmented inks, we may conclude that the smaller particle size of the pigmented ink, the better printing performance was. The difference of printing performance may be ascribed to that the larger particle size, the easier clogging the nozzle of print head was, moreover, the higher apparent viscosity might also lead to poorer printing performance.

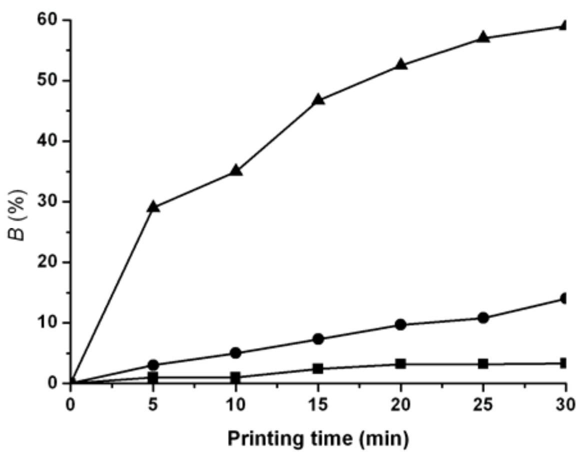

Figure4. *Printing performance of pigmented ink with different particle size, ■-110.8nm, ●-243.5nm, ▲-380.0nm*

Color performance of printing product

The K/S value of cotton fabrics which were printing by pigmented ink with different particle size was measured, the results was shown in Figure5.

Figure5 revealed that under the same printing conditions, the K/S value of cotton fabrics was the highest when the particle size was 110.8nm. This phenomenon indicated that pigment with small particle size was easy to absorb onto the surface of fabrics. The smaller particle size, and the more pigment particles could produce, and then the more surface area would create, which results in improving the pigment covering performance.

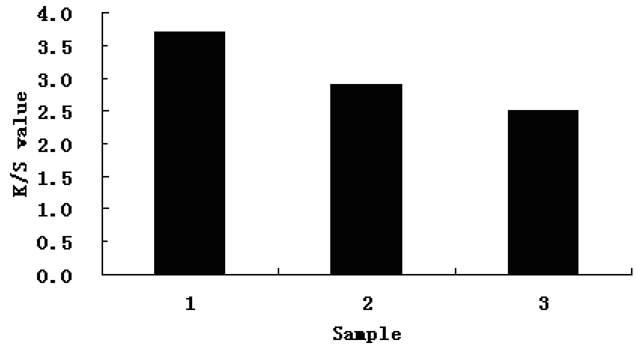

Figure5. *Effect of particle size on K/S value of cotton fabrics*

The particle size could also affect the fastness of printing cotton fabrics, in this experiment, the fastness of cotton fabrics were tested. The results were listed in table 3.

Table3. Effect of particle size on fastness of dyeing cotton fabrics [a]

D(nm)	washing fastness (grade)	rubbing fastness(grade)	
		dry	wet
110.8	2	3	2
243.5	1-2	2-3	1-2
380.0	1	1-2	1

[a] the fastness of dyed cotton was measured according to AATCC standard.

Table3 indicated that the rubbing fastness and washing fastness of printing cotton fabrics with small pigment particles was superior to that of printing with large pigment particles, and the smaller particle size, the higher fastness was. The reason might be explained as follows: (1) the smaller particle size, the higher surface energy was, which could produce higher forces between pigments and fabric surface. (2) The smaller particle size, the better penetrability and fluidity were which the pigment particle could easier move and entry into inner fabrics. (3) The smaller particle size, the more smooth cover layer can be formed.

Conclusions

From analyzing above, it is concluded that the pigment crystal structure was not changed with altering the particle size of pigmented ink. The smaller particle size, the lower absorbance of pigmented ink was, especially in glow and blueness area. The printing performance was excellent when the particle size was small. The pigmented ink with smaller particle size can import the cotton fabric much higher color depth, and the K/S value of printing cotton fabrics was highest when the particle size was 110.8nm. Rubbing fastness and washing fastness of printing cotton fabrics with small pigment particles is superior to that of large pigment particles, and the smaller particle size, the higher fastness was.

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