# Evaluation of the Pigment Dispersion of UV-Curable Inkjet Ink Using UV Absorption Spectrum

*Wei Xian-fu, Wang Na, Wang Xiao-fang, Yan Yan-ni, Huang Bei-qing ;School of Printing & Packaging Engineering, Beijing Institute of Graphic Communication; Beijing, China*

## Abstract

*With the formulation experiment to design the UV inkjet ink of different pigment/binder ratios, UV inkjet ink samples of different dispersions are prepared. The size and distribution of pigment particles and UV absorption spectrum of the samples are then tested. The result indicates that: the pigment/binder ratio has a great impact on the dispersion of the UV inkjet ink, when the ratio is 2:1, the ink sample can obtain good dispersion; dispersion of the pigment particles affects the intensity of UV absorption of the ink system. The absorption spectrum has a strong dependence with the dispersion of ink. With the decreasing of the pigment particle size, the UV absorption intensity of the ink system increases. The main innovation of this study lies in the establishment of evaluating particle's dispersion according to the change of UV absorption spectrum of the ink system.*

***Key words**: UV inkjet ink, dispersion, UV absorption spectrum, pigment/binder ratio*

## Introduction

Digital inkjet printing has been widely applied in many fields, is one of the important developing directions of digital printing. Currently used water-based and solvent-based inks for ink-jet printing have some special requirements of the printed material. Especially the dye-based inkjet ink's poor light-fastness has limited the area of application of inkjet printing. UV pigment-based inkjet inks has some advantages, for example low VOC, fast drying, variety of printed material, and will not block the nozzles, stable, and high printing quality, so it has gained widespread attention in the field, and become the research hotspot in recent years[1].

UV pigment-based inkjet ink consists of pigment, pre-polymers, monomers and additives, is a typical dispersion system. Pigment dispersion (particle size and distribution) directly affects the ink's printing performance and quality [2-3]. The dispersion of pigment particles and the dispersing state of the UV inkjet ink are evaluated by the methods which are observation by eyes, observation by microscope, the testing of the size and the distribution of the particles, the absorption spectrum， the test of the rheological parameter and other methods [3-4], different evaluation tools as a result of their different processes, conditions and the changing angle of observation, there are certain advantages and disadvantages. With the formulation experiment to design the UV inkjet ink, UV inkjet ink samples are obtained by some dispersing devices. According to the different pigment agglomeration size and distribution state, light scattering and absorption of the dispersion systems varied. Through the test of ink's absorption spectra of UV light, the dispersion of pigment particles is evaluated according to diversity in spectral absorption intensity.

## 1. Experiment

### 1.1 Materials

Pigment: RT-355-D (Ciba, Switzerland)
Pre-polymer: Viajet100 (UCB, Belgian)
Monomers: EOEOEA, NPGDA, TMPTA (Tianjiao, China)
Dispersant: BYK9077 (BYK, Germany).

### 1.2 Equipments

YM-I milling machine (self-made);
SBM-T ball mill (Beijing);
Niro Soavi high pressure homogenizer (Italy);
Microtrac S3500 Laser particle seizer (U.S.A);
UV-2501PC spectrophotometer (Shimadzu, Japan)

### 1.3 Sample preparation

According to the results of preliminary study, the UV ink-jet ink samples with different pigment particle size and distribution are dispersed by milling devices and high pressure homogenizer at pigment/binder ratios of 1:1,2:1,3:1 and 4:1[5-6]. **Table 1** shows the four formulations of UV inkjet ink at four pigment/binder ratios.

**Table 1 the four formulations of UV inkjet ink at different pigment/binder ratios**

| Pigment/Binder Ratio \ Component | Pigment/g | Pre-polymer/g | Mixed monomers/g | Dispersant/g |
|---|---|---|---|---|
| 1:1 | 1.2 | 1.2 | 4.08 | 0.12 |
| 2:1 | 1.2 | 0.6 | 4.08 | 0.12 |
| 3:1 | 1.2 | 0.4 | 4.08 | 0.12 |
| 4:1 | 1.2 | 0.3 | 4.08 | 0.12 |

## 2. Results and Analysis

### 2.1 Particle size and distribution of UV inkjet ink samples

With the formula of samples of UV Inkjet ink designed by **Table 1** to disperse samples to test and count all the particles sizes and distribution of the samples , by YM-I milling machine, SBM-T ball mill, as well as Niro Soavi-High pressure homogenizer .

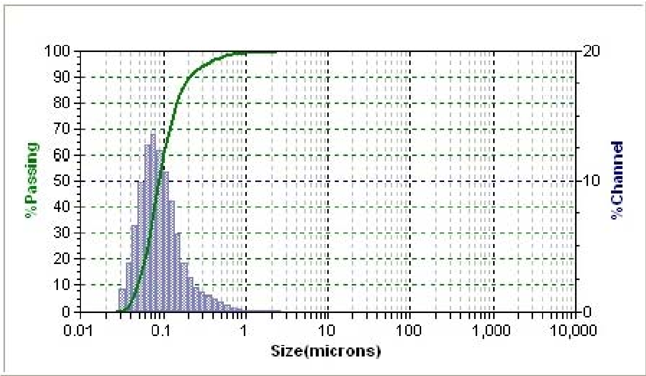


*Figure 1. Particle size and distribution of UV inkjet ink sample at pigment/binder ratio of 2:1*

**Figure 1** shows the particle size distribution by milling for 30 minutes using SBM-T ball mill, when sample is at the pigment/binder ratio of 2:1. We can obtain results of the size and distribution of pigment particles .The testing results of **Figure 1** reflect that the particle size is 0.1μm, which sample of ink was milled for 30 minutes using SBM-T ball mill. **Table 2** shows the pigment size and distribution of 4 ink samples at different pigment/binder ratio by milling for 24h using YM-I milling machine.

**Table 2 the size distribution of the pigments at different pigment-polymer ratio**

| Pigment/binder Ratio / Size/μm / Distribution/% | 1:1 | 2:1 | 3:1 | 4:1 |
|---|---|---|---|---|
| 10 | 0.80 | 0.72 | 0.74 | 1.05 |
| 20 | 1.03 | 0.92 | 1.00 | 1.37 |
| 30 | 1.30 | 1.15 | 1.29 | 1.65 |
| 40 | 1.58 | 1.40 | 1.60 | 1.92 |
| 50 | 1.88 | 1.67 | 1.91 | 2.23 |
| 60 | 2.22 | 1.97 | 2.27 | 2.61 |
| 70 | 2.61 | 2.32 | 2.69 | 3.14 |
| 80 | 3.16 | 2.81 | 3.25 | 3.99 |
| 90 | 4.12 | 3.69 | 4.22 | 5.75 |
| 95 | 5.17 | 4.70 | 5.26 | 8.03 |

From **Table 1**, the size of pigment tends to increase after decreasing with the increasing of the pigment/binder ratio, which reflects that the pigment at different pigment/binder ratio has a great impact on the dispersion of UV inkjet ink samples. And it relates to the viscosity of the system and wetting on the surface of pigments. In general, dispersion of the pigment particles includes three procedures: the wetting on the surface of particles, abrasive dispersing and stabilizing. The viscosity of the continuous phase in system is the maximum and has impact on the spreading and the wetting of the particles at the pigment/binder ratio of 1:1. And the particles can't achieve the best dispersion. At the ratio of 2:1, the binder can wet the pigment well. The pigment particle has the optimal dispersion state and it shows that the particle size is the smallest and has the uniform distribution. The viscosity of the system reduces when the pigment/binder ratio increase to 3:1 and 4:1. And the size of the pigment agglomeration increases because the spreading of the particles that is dispersed and milled is so intense that particles tend to become cluster after shearing stops.

### 2.2 Light absorption and scattering of Dispersion

Light intensity that passing through the dispersion is $I_0$, the transmitted light intensity $I$ can be expressed by the formula (1)[9].

$$\ln \frac{I}{I_0} = (\varepsilon + \tau)L \tag{1}$$

In the formula, $\varepsilon$——absorption coefficient; $\tau$——turbidity; $L$——optical path. When $\varepsilon$=0, formula (1) is Tyndall Formula; when $\tau$=0, formula (1) is Lambert's Law. If $a$ on behalf of particle radius and $N$ is particle number, absorption coefficient and turbidity can be expressed by formula (2) and formula (3).

$$\varepsilon = \pi N a^2 Q_{abc} \tag{2}$$

$$\varepsilon = \pi N a^2 Q_{sca} \tag{3}$$

$Q_{abs}$——absorption factor; $Q_{sca}$——scattering factor.

$Q_{abs}$ and $Q_{sca}$ are the function of α (α=$2\pi a/\lambda$ (λ expresses the wavelength of incident light)), $n$(index of refraction) and $k$ (absorbance). **Figure 2** shows the results between absorption factor $Q_{abs}$ and scattering factor $Q_{sca}$ and α, when $n=2.00$ and $n=1.28$, $nk=1.37$. When λ has no change, in direct proportion to the relationship between particle radius $a$ and α. The bigger the particle radius $a$, the bigger the α. On the contrary, the smaller the particle radius a, the smaller the α.

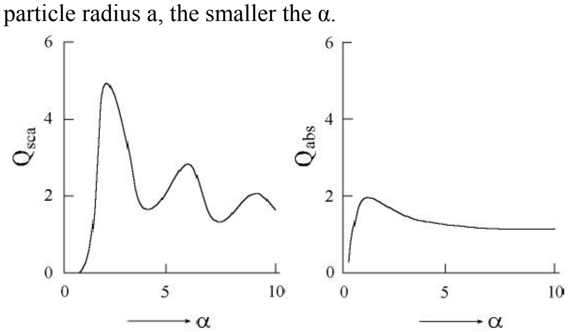


*Figure 2. The relationship between α, $Q_{abs}$ and $Q_{sca}$*

From **Figure 2**, scattering factor $Q_{sca}$ changes as α increases and amplitude reduces gradually; absorption factor $Q_{abs}$ increases with α increases in the scale of the small particle size. When particle size gets to a certain value, absorption factor $Q_{abs}$ will reach the maximum, and then reduces when α increases. In other words, the absorption intensity of the system is connected to the dispersing particle size.

### *2.3 Reproducibility of UV absorption spectrum of the dispersion system*

Firstly, do some tests of the reproducibility of UV absorption spectrum in the same system, for discussing the evaluation of the pigment dispersion by using the UV absorption spectrum. Choosing the magenta sample at the pigment/binder ratio of 1:1, the sample to be tested is prepared by milling for 24h using YM-I milling machine. And to place for some time, the UV absorption spectrum is tested. The results are showed in **Figure 3**. Two curves almost coincide that means the curve of UV absorption spectrum has reproducibility with good distribution and stability of the distribution system.

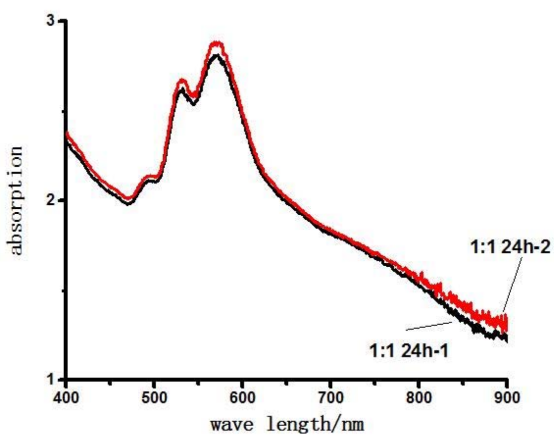


***Figure 3**. UV absorption spectrums of magenta ink samples*

### *2.4 UV absorption spectrums of the cyan-blue ink samples in different milling time*

**Figure 4** shows the samples that milling for 5min, 30min, 1h, 1.5h and 2h of the cyan-blue ink. The UV absorption spectrum has more absorption at red-band and green-band because using cyan-blue pigment. From **Figure 4**, absorption intensity is different at different milling time, and the absorption peak is different. The sample by milling for 5min has weak absorption of UV light; absorption peak is low and absorption intensity increases with the milling time, and the absorption peak increases.

In generally, the dispersion of the pigment particle depends on the milling time for the distribution of UV inkjet ink. The longer time for grinding, the smaller the pigment particle size is. From the results of the particle size tested by laser particle seizer, the particle size of samples by milling at different time is from 0.31μm to 0.80μm. In **Figure 3**, when α reaches a certain value, absorption factor $Q_{abs}$ reduces with α increases, for in direct proportion to the relationship between α and pigment particle size, the better dispersing particle and the smaller the particle size, the stronger the absorption of UV light and larger the absorption peak.

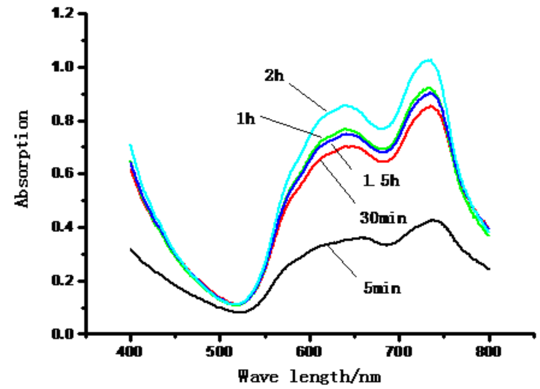


***Figure 4**. UV absorption spectrum of the cyan-blue ink sample in different milling time*

### *2.5 UV absorption spectrums of UV inkjet ink samples prepared by different dispersing methods*

For equipment, process and force generated on the samples varied in different dispersing methods, so the dispersion effect is different too by using YM-I, SBM-T and Niro Soavi homogenizer.

UV inkjet ink samples, whose particle size and distribution is measured by Microtrac S3500. The test result of 95% particle size is as shown in **Table 3**.

**Table 3 95% particle size of ink samples obtained by three dispersion methods**

| Dispersion condition | SBM-T mill-6 hours | SBM-T mill-12 hours | YM-I mill-1hour | Homoge-nizer-1hour |
|---|---|---|---|---|
| size(μm) | 0.907 | 0.770 | 0.310 | 0.259 |

From the test results shown in **Table 3** we can see that the SBM-T milling for 6 hours has the largest pigment particle size (0.907 μm), followed by the SBM-T milling for 12 hours (0.770μm), and the YM-I milling sample's particle size (0.310μm) is much smaller than the SBM-T milling ones. And with the homogeneous dispersion the smallest size (0.259μm) is obtained. **Figure 5** are the UV absorption spectrum of ink samples above-mentioned. From **Figure 5**, we can see that UV absorption spectrum is basically the same curve, but the intensity of light absorption is different, the absorption peaks are also different. Homogeneous dispersion can get the smallest pigment particles size, with the largest absorption peak, YM-I milling dispersed particle size to be followed either is the absorption peak weaker than homogeneous dispersion. The particle size of sample with 6 hours SBM-T milling is greater than that of the 12 hours', the absorption peak is also smaller. The test results shows that the smaller the dispersed particle size, the more intensive the UV absorption spectrum.

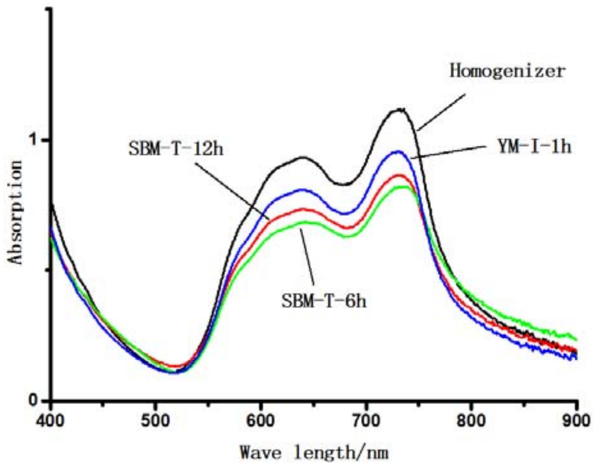


***Figure 5**. UV absorption spectrums of UV inkjet ink samples prepared by different dispersing methods*

## 3. Conclusion

To design and optimize the UV inkjet ink formulation with the formulation experiments, through milling devices and high-pressure homogenizer, UV inkjet ink samples of different dispersions are prepared. The pigment particle size, distribution and UV absorption spectrum of the samples are tested. We can draw the following conclusions:

(1) Made by SBM-T-milling, YM-I milling and high-pressure homogenizer, UV ink-jet ink has a relatively small sample size with the use of high-pressure homogenizer, the extension of dispersing time can obtain smaller pigment particle size of the UV ink-jet ink.

(2) The UV absorption spectrum can be used to evaluate the pigment particle dispersion of UV ink system. The smaller the pigment particles and the better evenly distributed, that is, the greater the characteristic peak of UV absorption spectrum. The study has proved that using UV absorption spectrum can evaluate the dispersion of pigment particles.

## References


[1] CHEN Yonglie. Radiation-curable material and its application [M]. Beijing: Chemical Industry Press, 2003

[2] Xiang Yang, WANG Jiexian. Printing materials and printability [M]. Beijing: Printing Industry Press, 2000

[3] Li Xingrong. Ink (the last part) [M]. Beijing: Printing Industry Press, 1986.

[4] Shi Hongmei, Wei Jie. Progress of UV inkjet inks [J]. packaging engineering, 2007(10):45-47

[5] Zhang Wan, Huang Bei-qing, WEI Xian-Fu. Effect of Monomer on curing rate of UV-curable Inkjet Ink [J]. Packaging Engineering, 2007 (10) :45-47.

[6] Zhang Wan, Huang Bei-qing, WEI Xian-Fu. Effect of Monomer on performance of UV-curable Inkjet Ink [J].Journal of Beijing Institute of Graphic Communication, 2007,6 (15) :4-6

[7] Zhao Xuehui. Influence of Acylate Monomer Structure on Color Reccurence and Rheological Properties of UV Ink [D]. Beijing: Beijing Institute of Graphic Communication, 2006

[8] Li Yuanyuan. Study on the Solvent/pigment Ink Jet Using for the Color Digital Prepress Proof [D]. Beijing: Beijing Institute of Graphic Communication, 2006.

[9] Kitahara bumio. Solution and Application Technology of dispersing System [M]. Tokyo: Thecnosystem, 1995.


## About the author


*WEI Xian-fu, professor of Beijing Institute of Graphic Communication, works on the teaching and researching of printing inks, printing technologies, as well as rheology of dispersion system.*

*Email: weixianfu@bigc.edu.cn,*

*Tel & Fax: 86 (10) 60261094*