Influence of Coating Paper Properties on Sharpness of Ink-jet Printing Image

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Abstract

Surface properties of several ink-jet papers were measured, and coating layer structure properties (including pore size, pore size distribution, pigment particle size and shape, etc.) was analyzed through Scanning Electron Microscope (SEM). A testing image composed of a series of lines and dots was designed and got printing image on four ink-jet papers by Epson printer. The printing dot and line quality, which could reflect the sharpness of image, were measured by image analytical method with QEA Image Analyzer. Dot quality (diameter and circularity) is influenced by paper coating structure, ink absorption and contact angle. With the increasing of the printing resolution, the line quality (width and edge roughness) is less influenced by paper properties. For all ink-jet papers, 2#paper (De Ying RC) and 3#paper (Epson half glossy EP313) has better printing sharpness.

Introduction

To get high quality ink-jet printing image, professional ink-jet paper is necessary. Now, ink-jet paper is almost high quality coating paper. They have fine and smooth coating layer and special micro porous structure or certain resin coating, which gives them fast ink absorption, high color density and wide-gamut. Ink-jet paper should not only ensure good color rendering, but also high image sharpness. The behavior of ink spreading on coating layer and permeating in coating layer could effect on the sharpness of printing image. This paper studied the relationship between ink-jet paper properties and printing image sharpness by image analytical method [1].

Experimental

Material and Apparatus

The investigations were performed using following ink-jet paper: De-Ying FT190 (1#), coated paper; De-Ying RC180 (2#), Europe standard photographic paper; EP313 (3#), Epson half glossy ink-jet paper; De-Ying RC190 (4#), glossy ink-jet paper. Epson Stylus Pro 788C ink-jet printer (Japan); Epson Ultrachrome K3 VM ink (Japan); ME-113 Bendtsen roughness tester (Messmer, USA); ZZ-100 Cobb absorption tester (China); JC2000A static contact angle tester (China); SEM S-3700N (Hitachi, Japan); ATR-FTIR Vector 33 (Bruker, Germen); Image Analyzer PIAS-Ⅱ (QEA, USA).

Experiment

The quality of printing dot and line is important parameter to evaluate the sharpness of printing image. Some control strips were selected as testing image (Figure 1.) from GATF standard image. There are dots, horizontal lines (H-line), vertical lines (V-line) and 45°diagonal lines (45°D-line) in testing image, and lines have positive and negative types. Testing image was printed on 4 papers under 720*720dpi, 1440*720dpi, and 2880*1440dpi respectively.

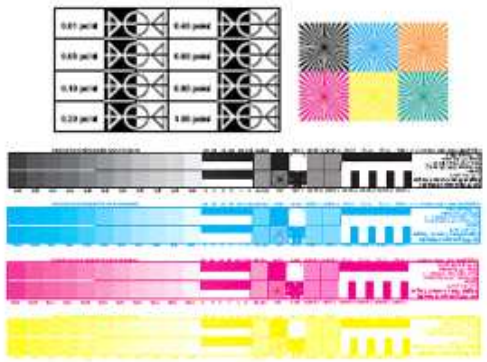


Figure.1 *testing image*

Quality of Printing Dot

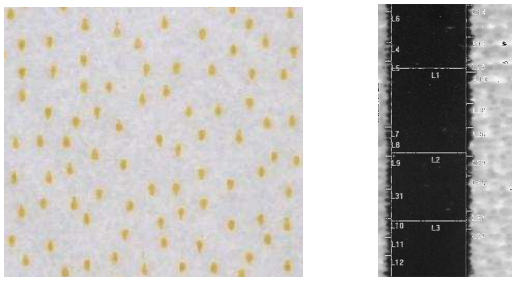
When it comes to quality of printing dot, diameter and circularity could be got through QEA image acquisition and analyze system. Epson Stylus Pro 7880C is piezoelectric ink-jet printer with minimum ink droplet of 3.5pl. Epson Ultrachrome K3 VM ink is water-based pigment ink and pigment particle diameter is less than 0.5μm. Then, we believe that the theoretical diameter of printing dot is 26μm (3.5pl=0.5×10-6πr2). Circularity(C) of printing dot should close to 1, which shows best quality of dot and coating paper. If C value is less than 1, the printing dot is not complete. If C value is greater than 1, the printing dot spreads [2]. The definition formulas of dot circularity see Eq.1.

$$C=P2/4\pi A \quad (1)$$

Among Eq.1, P represents perimeter of dot, and A represents area of dot.

Quality of Printing Line

The loss of sharpness of printing line is evaluated by measuring the average width and edge roughness of lines. The roughness is the average deviation between actual edge and optimal edge, see Figure.2. Through QEA image analytical system, we could get data of the average width of H-line, V-line and 45°D-line, top/bottom edge roughness of H-line and 45°D-line, and left/right edge roughness of V-line[3]. The theoretical width of lines on testing image is 1 point, i.e. 0.35mm. The average width of printing lines should be close to 0.35mm.



(a) (b)

Figure.2 *Testing image of printing line*

Result and Discussion

Physical Properties of Ink-jet Paper

Physical properties of ink-jet paper are listed in Table.1.

Table. 1 Physical properties of 4 samples.

Paper samples	1#	2#	3#	4#
Cobb value	50.69	28.02	33.92	106.67
Contact angle (degree)	56.37	42.04	32.69	52.56
roughness ml/min	14.3	16	7.8	28
ISO brightness(%)	98.82	92.23	95.12	107.58

As the property of ink-jet ink is similar to water, we substitute Cobb value of paper for ink absorption of ink-jet paper. The ink absorption is not the bigger the better for ink-jet paper. The optical Cobb value is 20~60g/m2 [4]. Moreover, the contact angle of water on paper could characterize ink absorption from another angle. The contact angle is smaller, the wetting between ink and ink-jet paper is better, and paper absorbs ink easer. And the roughness of paper surface to some extent reflects the pigment particle size, the degree of pigment conglomeration, and the size and distribution of micro pore in coating layer. Little roughness means the uniformity of coating surface construction. It could be seen from Table.1 that overall surface properties of paper samples is in order of 3#>2#> 1# > 4#.

The Coating Layer Structure of Ink-jet Paper

The coating layer structure could be observed through SEM image (Figure 3). The ideal coating layer structure is that the amount of micro pore is large, the pore size is small and diameter range is narrow and uniform, and the quality of coating layer is uniform and stable. It could be seen from Figure.3 that under the magnification of 20,000~30,000 coating layer surface presents uneven porous structure, and the pigment on coating layer surface of 1#, 2# and 4# paper is silicon dioxide whose particle diameter is less than 1μm. Among them, 1#paper has a lot of micro pores of diameter varying from 1μm to several microns, distributing evenly with a few fine crack; 2#paper's pore diameter mainly concentrates in less than 1μm, distributing evenly with a few pore of 1μm~2μm and fine crack; to 4#paper, pore diameter is polarization, i.e. there are predominantly pore diameter under 1μm and a few pores of several microns. But 3#paper has no distinct SEM image, and observed under microscope, a resin layer is found on the paper surface. Being scatter evenly, and middle size pore is few. The quality of coating layer of paper samples is in order of 2#>4# >1#. This resin layer is found out to be PVA (Poly Vinyl Alcohol) by fourier infrared spectral analysis (see Figure.4) [5]. Then, 3#paper is resinous type characterized by a swellable coating, which commonly has good color rendering and slow ink dry speed. But 3#paper's overall surface properties are best among the four paper samples.

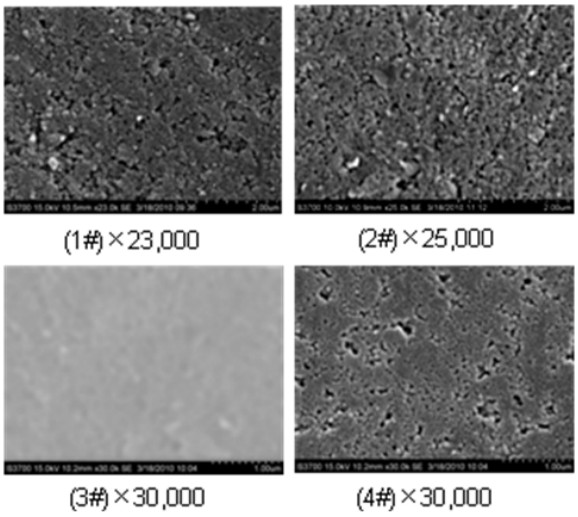


Figure 3. *SEM images of ink-jet paper coating surface*

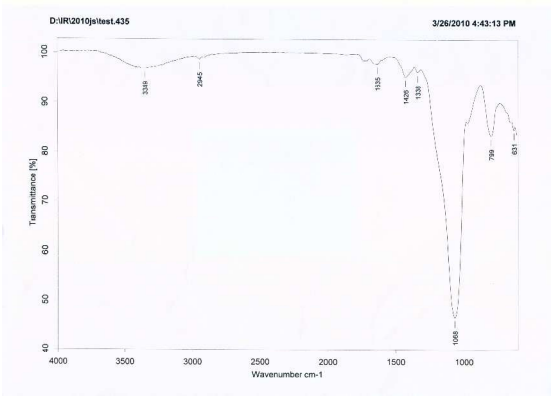


Figure 4 . *Infrared spectra of the 3# sample's coating surface*

Printing Quality Analysis

Figure.5 is of size of printing dot on four paper samples, and Figure.6 is of circularity of printing dot on four paper samples.

From Figure.5 and Figure.6, it is found that the size and circularity of printing dots on all ink-jet paper are on the whole identically, and the measured diameters were all larger than the theoretical value (see the horizontal line in Figure.5), whereas, the

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measured circularities were all close to ideal value, i.e. 1. It may because the ink droplet of the printer is enlarged under lower printing resolution. Under resolution of 1440*720dpi and 2880*1440dpi, the size of printing dot on 2# and 3# paper was close to theoretical value, while the circularity decreased; whereas, the diameter of printing dot on 1# and 4# paper decreased, but was still larger than theoretical value and the circularity was also close to 1. 2# and 3# paper have good construction uniformity of coating layer and proper ink absorption, so they all have good dot quality. 1# and 4# paper have some bigger pores and cracks and their cobb value and contact angle are all bigger than 2# and 3# paper, then printing dot is larger than theoretical value, meanwhile, circularities is better.

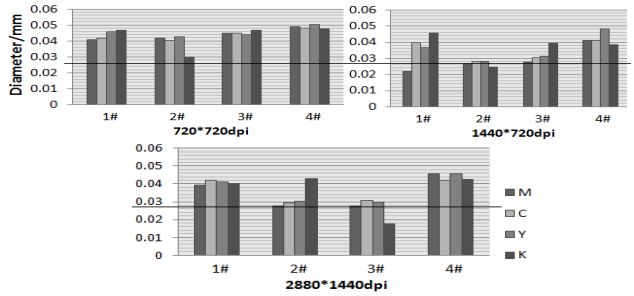

Figure.5 *Size of printing dot on 4 paper samples*

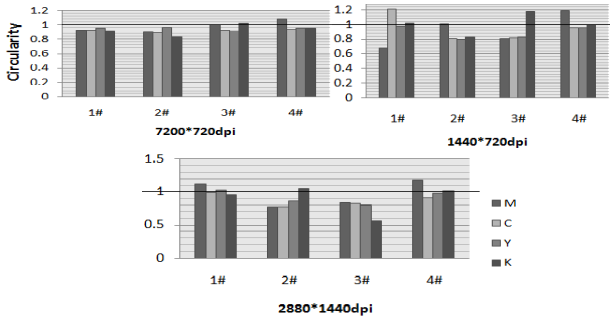

Figure.6 *Circularity of printing dot on 4 paper samples*

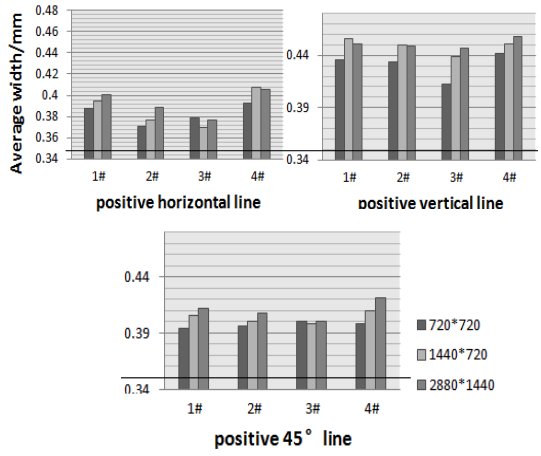

Figure.7 *Average width of printing positive lines on samples*

Figure.7 shows that to all ink-jet paper, the average width of printing positive lines is bigger than theoretical value, and size deviation ratio is listed from small to big: H-line (8.1%~14.8%),45°D-line (14.4%~17.2%) and V-line (23.5%~28.5%). It is the result of properties difference between horizontal and vertical direction of ink-jet paper due to manufacture process. In the case of one paper sample, with the increasing resolution, the average width of all lines increased slightly. And the difference between 4 paper samples is little: 2# and 3# paper is almost equal and better than 1# and 4# paper.

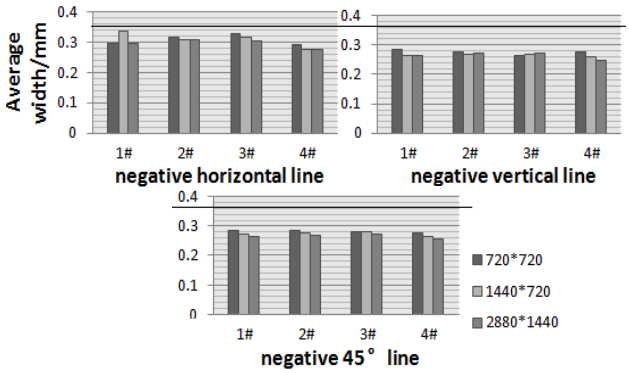

Figure.8 *Average width of printing negative lines on samples*

It is consistent to ink-jet paper's surface properties and coating quality. But as shown in Figure.9, with the increasing resolution, the average width of printing lines has lower sensitivity to surface properties and coating quality.

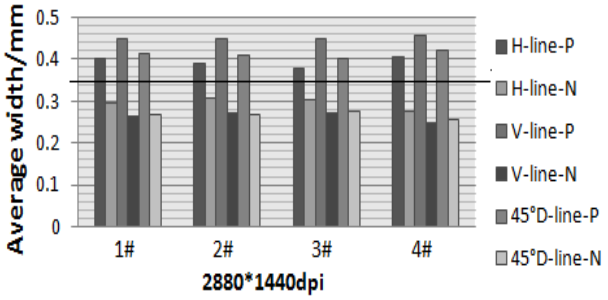

Figure.9 *Average width of resolution - 2880*1440dpi*

The negative lines have the same trend with positive lines (see Figure.8), just V-line (22.1%~25.4%) and 45°D-line (20.3%~23.9%) are alike, while the widening ratio of H-line was 8.1% to 14.8%.

Under different printing resolution, the edge roughness of positive H-line and V-line see Table.2. The edge roughness appears in pairs. As can be seen from Table 2, in 720 * 720dpi resolution, 1 # and 4 # paper have similar roughness of H-line and V-line, meanwhile, roughness of V-line is obviously bigger than H-line, especially 3#paper.

This may be caused by the differences of coating properties between vertical and horizontal, that is the differences on the arrangement of pigment particles and the slits oriented in both directions, which due to production process. But because the scanning area is too small, there is no obvious proof in the electron

Tab. 2 Edge roughness of printed horizontal&vertical positive lines on samples under 3 resolutions

Resolution	paper	H-line			V-line		
720 *720	1#	0.007/0.002	0.006/0.002	0.005/0.003	0.005/0.006	0.006/0.006	0.005/0.006
	2#	0.003/0.002	0.003/0.001	0.002/0.002	0.005/0.007	0.005/0.006	0.004/0.006
	3#	0.004/0.003	0.003/0.004	0.003/0.005	0.010/0.012	0.011/0.012	0.010/0.013
	4#	0.006/0.008	0.006/0.008	0.005/0.007	0.007/0.005	0.006/0.005	0.006/0.006
1440 *720	1#	0.007/0.002	0.008/0.002	0.008/0.004	0.007/0.008	0.006/0.007	0.006/0.007
	2#	0.006/0.002	0.006/0.002	0.005/0.002	0.007/0.005	0.006/0.004	0.006/0.005
	3#	0.002/0.002	0.002/0.005	0.003/0.002	0.005/0.007	0.005/0.006	0.004/0.007
	4#	0.004/0.005	0.004/0.006	0.005/0.007	0.007/0.007	0.007/0.004	0.006/0.006
2880 *1440	1#	0.004/0.004	0.004/0.004	0.003/0.004	0.003/0.003	0.004/0.003	0.003/0.004
	2#	0.002/0.003	0.002/0.003	0.002/0.003	0.004/0.004	0.002/0.004	0.003/0.004
	3#	0.002/0.002	0.002/0.003	0.002/0.002	0.003/0.004	0.003/0.004	0.003/0.004
	4#	0.003/0.004	0.004/0.004	0.003/0.003	0.004/0.004	0.004/0.004	0.004/0.005

micrographs in Figure 3. electron micrographs. In addition, 1 # and 2 # paper at low resolution, the edge roughness between up and down both sides of the H-line are quite different. That is due to the ink droplet fall on the paper make a certain orientation blot (see Figure 2 - (a)), caused by the relative movement between ink droplets and the paper, combined with different absorbent of paper coating. Comparing the surface properties and coating structure of these four paper patterns, coating absorption is too large or too small, will lead to the obvious dots orientation. In addition, the feeding paper speed is related to resolution. The greater the resolution, then the smaller the feeding rate, which has been confirmed from the situation of edge roughness of H-line (see Table 2). It needs further specific test to get reliable conclusions on the impact of the relative motion between the paper and ink jet on quality of dots and lines.

Overall, as the resolution increased, all roughness decreases, and tends to be equal. High printing resolution is good for obtaining high quality printing lines. Comparing roughness of different ink-jet paper, to H-line, 2# and 3# paper are better than 1# and 4# paper; to V-line, under low resolution, 1# and 4# paper is superior to2# and 3# paper, but all paper samples having no difference as resolution increased. So 2# and 3# paper have good printing line quality and sharpness relatively.

Summary

The uniformity of coating layer structure has great effect on printing quality of dot and line. 2#paper is of both minimum size pore and good uniformity of distribution, and 3# paper has high quality resin coating layer and proper ink absorption, then, 2# and 3# paper perform better in printing dot size, the average width of printing line and the edge roughness of printing line. Moreover, the increasing printing resolution is benefit to obtain high quality printing lines. And under high printing resolution, to some extent, the quality of ink-jet paper have little effect on printing sharpness.

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