Study On Printability of Plastic Water-based Gravure Ink

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Abstract:

Plastic water-based gravure primary inks were prepared. The primary inks were diluted with resin solution which had good compatibility with primary inks. Isopropanol was added to improve the printability of the ink. Effects of pigment/binder ratio、dispersant、resin solution and isopropanol on printability of the inks were analyzed. The results showed that the pigment/binder ratio was 2:1, the content of dispersant of 750 was 0.7%, the content of dispersant of 760 was 0.7%, the formulation of mixed resin was 3808：1437：2640＝1：0：1, the content of isopropanol was 1%, printability of inks both on PET and BOPP was good.

Key words:

Plastic water-based gravure ink; Printability; Adhesion; Proofing density

1. Summary

With the enhanced awareness of environmental protection, as water-based ink did not contain volatile organic solvents, and was non-combustible and other advantages, it would be environment-friendly the printing ink with good future[1][2]. Substrate of water-based ink had developed from the single cardboard to various substrates and multicolor overlap. Water-based ink accounted for the plastic printing ink of United States 40%. Water-based ink was used more and more in plastic printing ink in Japan, Germany and France. The United Kingdom implemented legislation that prohibited the use of plastic printed by solvent-based inks in the food packaging. Water-based inks accounted for the flexible packaging ink 35% in China [3]. As plastic water-based gravure ink could not meet the requirements of printability in adherence, proofing density and dryness, the application of water-based ink on plastic had not been promoted.

The formulation of plastic water-based gravure ink sample was designed. Inks with proper viscosity and good dispersivity were prepared by changing pigment/binder ratio. The compatibility of different types of dispersant and ink was studied. Influence of formulation of mixed resin on printability was analysed by the method of formulation experiment. Addition of isopropanol improved printability of inks. Effects of pigment/binder ratio 、dispersant、resin solution and isopropanol on printability of plastic water-based gravure inks were analyzed.

2. EXPERIMENT

2.1 Materials

Pigment:Carbon Black(Cabot corporation)

Resins: AZR acrylic resin (ATOZ fine chemicals corporation); AZ-3808 acrylic emulsion (ATOZ fine chemicals corporation); 1437 acrylic resin (Cognis); 2640 acrylic resin (BASF)

Dispersants: 750 (TEGO); 760 (TEGO); 191 (BYK); 192 (BYK)

Defoamer: 810 (TEGO)

Wetting agent: 245 (TEGO)

Alcohols: isopropanol (Beijing Chemical Corporation)

2.2 Methods and Apparatuses of experiment

Preparation of primary inks: After mixing pigment、AZR resin and auxiliary by proper pigment/binder ratio, inks were predispersed by high-speed stirring mill and dispersed by milling equipment.

Dilution of primary inks: Primary inks were stirred by magnetic stirrer with the resin solution. The viscosity of the inks should satisfy the desire of gravure ink.

Formulation experiment: The method of the simple design of three components in the center of gravity was used to design experiment [4]. The maximal extremum and relevent formulation were gained by regressive equation and planning solving method.

Proofing trials and evaluation: Proof sample was proofed by printability tester of IGT, proofing density was measured by 528 densimeter, viscosity was tested by 3＃ viscosity cup, dispersivity was tested by laser particle size analyzer, adherence was measured by 3M adhesive tape, surface tension was measured by K100 surface tension apparatus, dryness was measured by fineness gauge, gloss was measured by glossometer.

3. RESULTS AND DISCUSSIONS

3.1 Effects of pigment/binder ratio on printability of the inks

Content of pigment and resin in the inks was determined by pigment/resin ratio. It also influenced dispersivity of inks. Main printability of inks was influenced by pigment/resin ratio such as viscosity and adherence.

Provided the pigment content accounting for total quantity of the primary inks 25%, preparing primary inks by different pigment/binder ratios. The viscosity and adherence of inks were discussed.

3.1.1 Effects of pigment/binder ratio on viscosity

With the increase of pigment/binder ratio, the viscosity of inks decreased because of the reduction of resin content, as shown in Figure 1. When the pigment/binder ratio was 1.5:1, the viscosity of primary ink was high, entire ink system was in over-saturated state, pigment dispersed unevenly and pileup, so the fluidity of inks went worse. When the pigment/binder ratio was more than 2:1, the viscosity of primary inks was less then 20 seconds, which didn't satisfy the desire of diluting ink. The optimal pigment/binder ratio for preparing inks was 2:1.

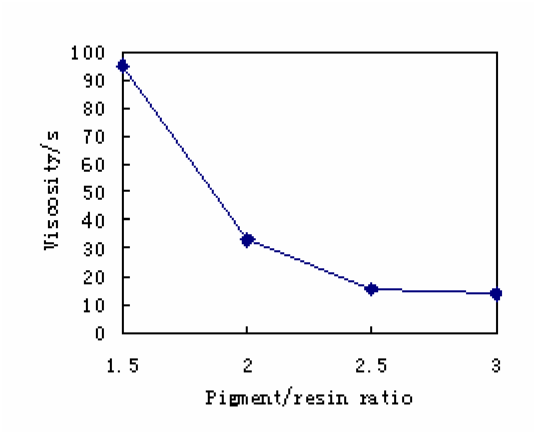

Figure1 *Effects of pigment/binder ratio on viscosity*

3.1.2 Effects of pigment/binder ratio on adherence

Inks were used for proofing both on PET and BOPP. Pintability of the inks was tested. The relation between the pigment/binder and the adherence was showed in Figure 2. When the pigment/resin ratio was 1.5:1, adherence of inks on PET was just 20%, when pigment/resin ratio was 2:1, adherence of inks on PET received 100%, when the pigment/resin ratio was more than 2:1, adherence retained constant. The situation was similar when proofed on BOPP.

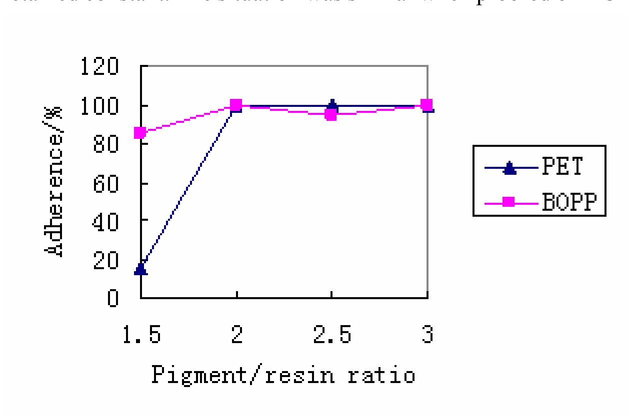

Figure2 Effects of pigment/binder ratio on adherence

Adherence of inks was influenced by dispersivity. Effects of pigment/resin ratio on dispersivity were shown in Figure 3. When the pigment/resin ratio was increased from 1.5:1 to 3:1, particle size of inks got smaller. Dispersivity of inks got better. Cohesion force was great between plastic and ink with good dispersivity. So adherence of inks proofed on both PET and BOPP appeared the change as in Figure 2.

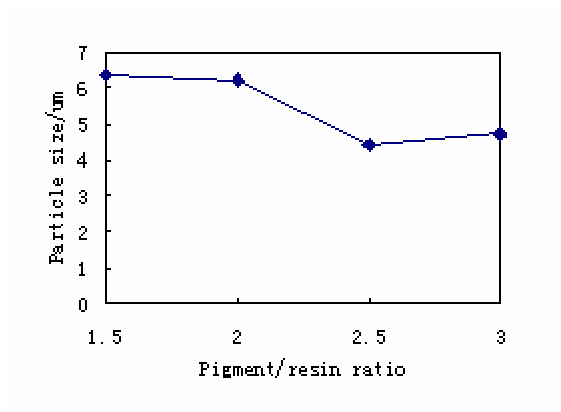

Figure3 *Effects of pigment/binder ratio on particle size*

3.2 Influence of dispersant on printability

Dispersant was surfactant that producing charge repulsion and space resistance. It prevented harmful sedimentation of pigments and brought the dispersed system to a stable state. In the system of plastic water-based gravure primary ink, compatibility of different types of dispersants and system were different which affected printability such as adherence and proofing density.

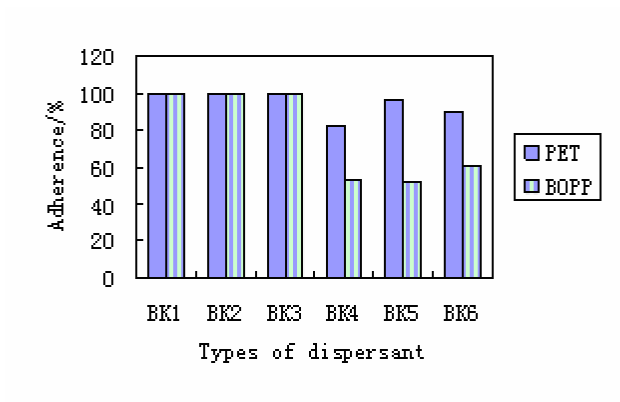

Figure4 *Effects of types of dispersants on adherence*

(Annotation: BK1, BK2, BK4, BK5 respectively denoted adding 1.4% of 750, 760, 191 and 192. BK3 denoted adding 0.7% of 750 and 0.7% of 760.BK6 denoted adding 0.7% of 191 and 0.7% of 192.)

Influence of different types of dispersants on adherence of inks was discussed when the content of dispersant was 1.4%. Figure 4 indicated that adherence of inks of BK1, BK2 and BK3 proofed both on PET and BOPP received 100%.And they were stable dispersed system. As compatibility of inks of BK4, BK5, BK6 and system was bad, dispersed stability of the inks was destroyed, and obvious sedimentation and sudden increase of viscosity appeared. So adherence of inks of BK4, BK5 and BK6 got worse.

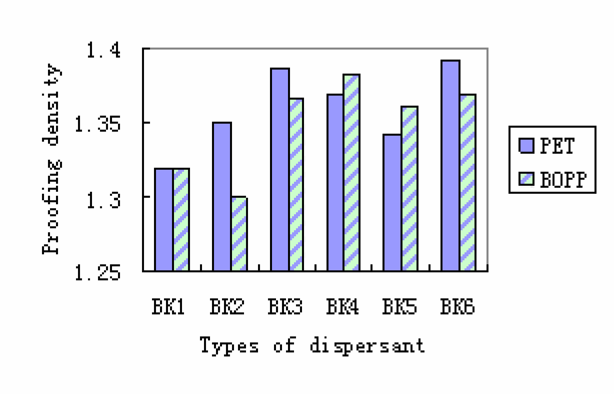

Figure5 *Effects of types of dispersants on proofing density*

The influence of different types of dispersants on proofing density of inks was showed in Figure 5. The proofing density of inks prepared by different types of dispersant varied between 1.3 and 1.4. The proofing density of BK3 both on PET and BOPP was highest during the three different types of formulations of BK1, BK2 and BK3 which adherence was 100%. So BK3 was the optical formulation. In the other words, printability was better when the content of dispersant of 750 is 0.7% and the content of dispersant of 760 is 0.7% both on PET and BOPP.

3.3 Influence of resin on printability

Inks prepared by single resin would not satisfy the desire of printability. In order to obtain inks with good printability, the method of mixing different types of resins was used. Glass transition temperature (Tg) was a key property when selecting the resins in the ink. A low Tg value resulted in better film formation and gave film properties such as water and grease resistance, flexibility and adhesion to non-porous substrates. With high Tg resins, hardness, gloss, drying speeed and heat resistance would be increased [5]. Three resins were selected to design experiment. The Tg of 3808 was between 40℃ and 50℃, the Tg of 1437 and 2640 were respectively 7℃ and -18℃. As there were three factors in experiment, the simple design of three components in the center of gravity was used to design formulation experiment. Seven different types of formulations were obtained.

As shown in Table 1, X1, X2 and X3 were respectively supposed as the proportions of 3808, 1437 and 2640 in the formulation of the mixed resins. The main printability of inks prepared by seven formulations on PET was also tested in Table 2.

Table1. Formulation experiment

NO	X1(3808)	X2(1437)	X3(2640)
1	1	0	0
2	0	1	0
3	0	0	1
4	1/2	1/2	0
5	1/2	0	1/2
6	0	1/2	1/2
7	1/3	1/3	1/3

Table2 The main printability of inks on PET prepared by different formulations

NO	Adherence (%)	Apparent situation	Proofing density	Rough Dryness (mm)
1	100	Grade 3	1.46	15
2	93	Grade 3	1.451	15
3	100	Grade 3	1.479	15
4	95	Grade 2	1.469	16
5	100	Grade 2	1.541	20
6	100	Grade 2	1.482	15
7	100	Grade 2	1.502	16
NO	Thorough Dryness (s)	Surface tention (mN/m)	Gloss	
1	95	33.776	9.3	
2	110.75	35.371	10.2	
3	95.64	35.694	10.5	
4	108.04	33.789	6.0	
5	83.03	33.905	6.3	
6	84.9	35.498	11.9	
7	94.46	34.108	7.7	

Experiment values of printability of inks prepared by seven different formulations were analyzed by integrated scoring process. The index score was achieved by membership grade, weight numbers of different index were gained according to difference of weightiness of index, and the overall score of index was gained by weighted sum.

The expressions of calculating index score and overall score on both PET and BOPP were as below:

Index score=（index value-the minimum index value）/（the maximal index value- the minimum index value）

Overall score=the index score of adherence×0.4+ the index score of apparent situation×0.25+ the index score of proofing density×0.15+ the index score of rough dryness ×0.05+ the index score of thorough dryness ×0.05 + the index score of surface tention×0.05+ the index score of gloss×0.05, the index score and overall score of different formulations on the PET were shown in Table 3.

Table3 The index score and overall score of printability of inks on PET

NO	Adherence	Apparent situation	Proofing density	Rough Dryness
1	1	0.6	0.060	0
2	1	0.6	0	0
3	1	0.6	0.188	0
4	1	0.4	0.121	0.2
5	1	0.4	0.604	1
6	1	0.4	0.208	0
7	1	0.4	0.342	0.2
NO	Thorough Dryness	Surface tention	Gloss	Overall score
1	0.844	1	0.114	0.657
2	0.640	0.622	0.145	0.62
3	0.836	0.546	0.155	0.655
4	0.675	0.997	0	0.612
5	1	0.970	0.010	0.74
6	0.976	0.592	0.203	0.62
7	0.852	0.921	0.059	0.653

The expression of regressive equation was:

$$y = b_1 x_1 + b_2 x_2 + b_2 x_3 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3 + b_{123} x_1 x_2 x_3$$

Overall score was expressed by parameter y. Replacing the parameters in regressive equation above with the data in Table3, regression coefficients were calculated and the regressive equation of printability of inks proofed on PET was achieved as below:

$$y = 0.657 x_1 + 0.62 x_2 + 0.655 x_3 - 0.106 x_1 x_2 + 0.336 x_1 x_3 - 0.07 x_2 x_3 - 0.237 x_1 x_2 x_3$$

The greater parameter y was, the better overall printability of ink was. Planning solving method was used in regressive equation to gain the maximal extremum. The maximal extremum of printability of inks proofed on PET was 0.74. And relevant formulation was 3808（x1）：1437（x2）：2640（x3）=1：0：1。

The main printability of inks prepared by seven formulations on BOPP was also tested in Table 4.

Table4 The main printability of inks on BOPP prepared by different formulations

NO	Adherence (%)	Apparent situation	Proofing density	Rough Dryness (mm)
1	100	Grade 3	1.449	15
2	100	Grade 3	1.438	15
3	100	Grade 3	1.454	15
4	100	Grade 3	1.44	16
5	98.9	Grade 3	1.435	20
6	93.3	Grade 3	1.465	15
7	100	Grade 3	1.475	16
NO	Thorough Dryness (s)	Surface tention (mN/m)	Gloss	
1	95	33.776	10.6	
2	110.75	35.371	10.5	
3	95.64	35.694	11.6	
4	108.04	33.789	6.9	
5	83.03	33.905	6.5	
6	84.9	35.498	11.1	
7	94.46	34.108	7.8	

The index score and overall score of main printability of inks on BOPP were achieved by the expressions of calculating index score and overall score:

Table5 The index score and overall score of printability of inks on BOPP

NO	Adherence	Apparent situation	Proofing density	Rough Dryness
1	1	0.6	0.085	0
2	1	0.6	0.018	0
3	1	0.6	0.115	0
4	1	0.6	0.030	0.2
5	1	0.6	0	1
6	1	0.6	0.182	0
7	1	0.6	0.242	0.2
NO	Thorough Dryness	Surface tention	Gloss	Overall score
1	0.844	1	0.144	0.662
2	0.640	0.622	0.140	0.623
3	0.836	0.546	0.179	0.645
4	0.675	0.997	0.014	0.65
5	1	0.970	0	0.698
6	0.976	0.592	0.161	0.664
7	0.852	0.921	0.046	0.687

Replacing the parameters in regressive equation above with the data in Table 5, the regressive equation of printability of inks proofed on BOPP was achieved as below:

$$y = 0.662x_1 + 0.623x_2 + 0.645x_3 + 0.03x_1x_2 + 0.178x_1x_3 + 0.12x_2x_3 + 0.195x_1x_2x_3$$

Planning solving method was used in regressive equation to gain the maximal extremum. The maximal extremum of printability of inks proofed on BOPP was 0.74. And relevant formulation was 3808（x1）：1437（x2）：2640（x3）=1：0：1。

3.4 Influence of isopropanol on printability

Ink film with good leveling performance was gained by addition of isopropanol. Inks were used for proofing both on PET and BOPP after addition of isopropanol. Pintability of the inks was tested. Addition of isopropanol in the inks not only did not influence adherence but also improved proofing density. Apparent situation of inks were improved at the same time .When the content of isopropyl increased from 0 to 5%, the adhesion of ink both on PET and BOPP was 100%. The apparent situation on PET was Grade 3. The apparent situation on BOPP was Grade 4. The relation between isopropanol and proofing density was shown in Figure 6.

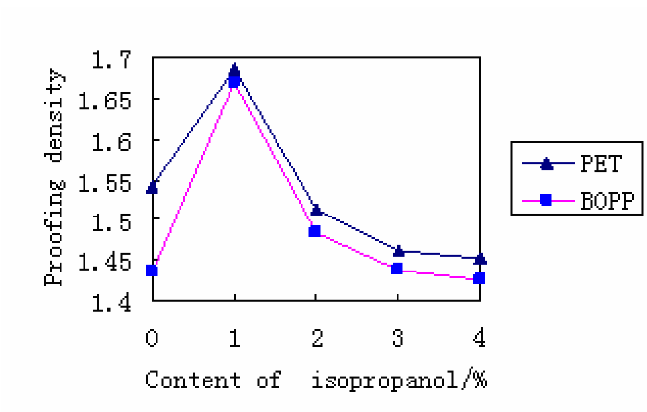

Figure 6 Effects of content of isopropanol on proofing density

When the content of isopropanol was less than 1%, proofing density of inks both on PET and BOPP increased with the increase of content of isopropanol. This was because the surface tension of isopropanol was less than that of water. Addition of isopropanol in the inks would reduce surface energy of system, making the inks level much easily, proofing density of inks increased. When the content of isopropanol was 1%, the proofing density of inks both on PET and BOPP reached the highest value. When the content of isopropanol was more than 1%, the proofing density of inks both on PET and BOPP decreased instead. This was because isopropanol was micromolecule, excessive eaddition of isopropanol did not benefit transfer of inks, the proofing density decreased accordingly.

4. Conclusion

1) Pigment/binder ratios influenced the viscosity and adherence of the inks. Inks had good printability both on PET and BOPP when the pigment/binder ratio was 2:1.

2) Inks had good printability both on PET and BOPP when adding 0.7% of dispersant of 750 and 0.7% of dispersant of 760.

3) Inks prepared by single resin would not satisfy the desire of printability. In order to get the better overall performance of inks, the method of mixing different resins was used. The optical formulation of mixed resin both on the PET and BOPP was 3808：1437：2640=1：0：1.

4) Addition of isopropanol in the inks would increase the proofing density. Inks had good printability on both PET and BOPP when the dosage of isopropanol was 1%.

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