COATING FORMULATIONS FOR DIGITAL PRINTING; APPLICATIONS OF PHASE-CHANGE INKS

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Abstract

Hot melt/phase-change inks have gained popularity by imparting high print quality. As hot melt inks differ from other digital and conventional inks in terms of properties and mechanisms of transfer onto a substrate, there is need for developing low cost substrates compatible with these solid inks. As these inks solidify upon contact with the substrate, there is little absorption of the ink into the substrate. Thus, the print quality and associated color gamut are less sensitive to the substrate than that for aqueous ink jet printers.

It is well known that the surface properties that influence the print quality vary for different printing processes. Thus, the substrate-ink interactions must be well understood. Some of the important surface properties of a substrate include permeability, porosity, surface energy, roughness, opacity, brightness and gloss. These properties are known to influence final print quality and color gamut. Adhesion of ink on paper also plays a vital role. In addition, economics play a vital role. The paper specially formulated for phase-change inks sells for about 50 ¢ per sheet in comparison to 2-5 ¢ per sheet for water-based inkjet papers. Thus, there is a need for the development of lower cost substrates compatible with solid inks.

Introduction

The phase-change inks are solid at ambient temperature, liquefied at the time of printing and promptly solidify after reaching the substrate [1-16]. As soon as these inks reach the surface of the substrate, they solidify immediately from the molten state, which prevents the ink from spreading or penetrating into the printed surface and ensures good image quality.

The phase-change/ hot-melt ink formulation comprises of an ink binder including a wax with melting point ranging between 50-90^{0}C, which works as ink vehicle, resin, tackifier, adhesion promoters, pigment or dye functioning as colorant, and different additives, such as anti-scratch additives, surface additives, antioxidants, plasticizers, biocides and corrosion inhibitors [1-8].

The conventional hot-melt or phase-change inks have a high melting point ranging between 100 - 130^{0}C. These inks should possess good adhesion to various paper substrates as well as transparencies and good flexibility towards bending when printed on various flexible materials/substrates [1-3].

The drying phenomena for these inks (solidification) prevent the ink from migrating into the pores of the substrate and allow it to create better print density in solid areas with a thinner ink film. These inks exhibit reduced dot gain, enhanced color saturation and higher gloss values, due to lack of penetration/migration into the substrate.

This study includes determination of the factors governing the issues with digitally printing phase change inks in terms of various print attributes so as to develop a substrate that can impart better print quality and improve ink adhesion.

Ink-jet printing technology using phase change inks

In the first step, or beginning of the phase-change ink imaging process, a thin liquid is applied onto imaging surface/ drum. The hot-melt ink is maintained in liquid state in heated reservoir. The melting temperature of these inks ranges from 100-130^{0}C. These inks are formulated to provide low-viscosity at jetting temperatures (8-10cps at 130-150^{0}C) and high durability at room temperatures. The liquid ink flows through the manifolds of a specially designed print-head (having several rows of jets, each with different color) and is ejected from microscopic orifices using proprietary piezoelectric transducer (PZT) print-head technology [1,3,12-20], which employs accurately controlled duration and amplitude of electric pulse to apply repeatable and precise pressure pulses to the ink, resulting in the proper volume, velocity and trajectory of ejected ink droplets. These ink droplets are jetted onto the liquid layer present on imaging surface/drum, the imaging surface and liquid layer are maintained at a specific temperature so as to harden the ink droplets from liquid state to a ductile viscoelastic state.

Table 1. Different coating recipies with different pigment and binder ratios (the figures represents parts by dry weight)

Coating recipe no.	*GCC*	*No. 1 Clay*	*HS*	*Binder*
1	55	45	0	10
2	55	45	0	12
3	55	45	0	14
4	55	45	0	16
5	55	45	0	18
6	55	45	0	20
7	50	40	10	10
8	50	40	10	12
9	50	40	10	14
10	50	40	10	16
11	50	40	10	18
12	50	40	10	20

When the ink is deposited on imaging surface/drum, substrate/paper is heated by feeding it through a pre-heater and a nip formed between the imaging drum and pressure surface. A high-pressure nip is obtained by placing the pressure surface against the imaging surface/drum. The heated substrate is then pulled through the nip as the imaging surface/drum rotates, transferring the ink from imaging surface/drum onto the heated paper surface. The pressure surface compresses the heated printing substrate and ink together, due to which the ink droplets spread and fuse to the substrate. The ink droplets at the nip, receive heat from the preheated printing substrate, and becomes soft and tacky enough to adhere on the substrate [12-20].

Experiment

Different coating formulations (Table 1) were tested by varying the ratio of ingredients in the coating recipe so as to obtain coated papers with different surface properties and printed with phase-change inks so as to analyze the behavior of phase change inks in terms of various print attributes such, as ink adhesion and print gloss [22-31].

Various coating formulations were applied on basesheet using Cylindrical Lab Blade Coater at a speed of 3000 fpm so as to obtain a coat weight of 10.5±0.5 gsm on the coated sheets. The coated sheets were calendered using three different calendaring conditions. The coated samples were calendered at a temp. of 150°F using 2 nips and at three different pressure settings of 300, 600 and 1500 pli (quoted as calendaring conditions 1,2 and 3 respectively) so as to vary the surface properties of coated samples. After calendaring the samples, the surface properties [32-39] such as surface roughness and "porosity" (used to calculate permeability) were measured Parker Print Surf (PPS) at a clamp pressure of 1000 kPa and thereafter the apparent permeability was calculated using the PPS porosity and measuring caliper of coated sheet [33]. The surface roughness of coated sheet was measured at a clamp pressure of 1000kPa and using soft backing. The samples were printed with a solid black phase-change ink patch, using a Xerox 8550 printer. The delta gloss was calculated by print gloss and sheet gloss of the samples with Glossmeter at an angle of 60°. Tape adhesion test was conducted using Tesa AG 4651 and Spectape, by uniformly applying tape onto the phase-change ink printed sample and then peeling the tape off from the image area using Taber Friction/Peel tester which peels the tape off from the sample with constant force and at a constant angle of about 180°. Thereafter the ink adhesion [40-48] onto the substrate was determined by measuring the area coverage ratio of black ink after tape pull employing area analysis technique using ImageXpert.

The coating formulations include two different pigment systems; one including hollow sphere pigments and the other excluding hollow sphere pigments. Both pigment systems include Ground calcium carbonate and No. 1 clay. Hollow sphere pigments are used in coating formulations for various thermal printing [49] applications as they provide thermal insulation, which in turn drops the heat transfer to the other side of substrate and therefore imparts better ink adhesion and print quality. In both coating formulation SB-Latex was used as the binder with different levels so as to vary the surface properties of coated substrate. The formulations also include additives such as defoamer, dispersant, lubricant and rheology modifier. A basesheet of 82.96 gsm was coated with different coating recipies(1-12 as mentioned in Table.1) and thereafter calendered with calendaring conditions 1,2 and 3, so as to analyze the ink adhesion and print attributes of phase-change inks.

Results and Discussion

Fig. 1,2 and 3 represents the plot of measured values of permeability, PPS roughness and mean of area coverage ratio of black ink after conducting tape pull test using the two tapes for the samples coated using different coating recipies (1-12 as mentioned in Table 1.) and thereafter calendered using calendaring conditions 1,2 and 3 respectively.

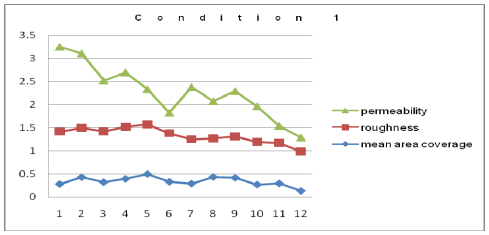

***Figure 1**. Permeability, roughness and mean area coverage of black ink as measured by image analysis on the image area after performing the tape adhesion test on calendering condition 1 samples.*

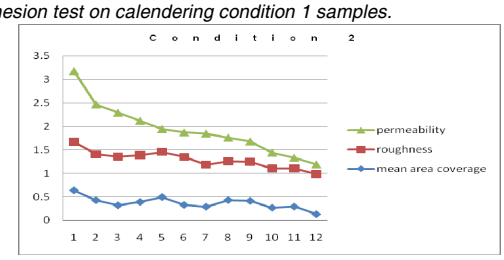

***Figure 2**. Permeability, roughness and mean area coverage of black ink as measured by image analysis on the image area after performing the tape adhesion test on calendering condition 2 samples.*

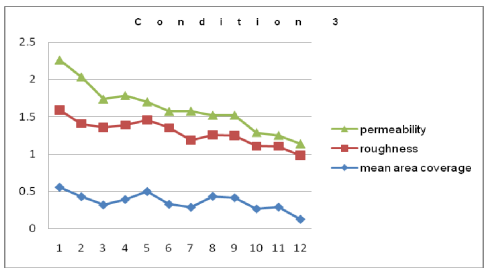

***Figure 3**. Permeability, roughness and mean area coverage of black ink as measured by image analysis on the image area after performing the tape adhesion test on calendering condition 3 samples.*

Fig. 4 represents the plot of delta gloss values calculated from measured print gloss and sheet gloss values for the samples coated with different coating recipies (1-12 as mentioned in Table 1) and calendered using calendaring condition 2. (Note: The measured

roughness values in fig.4 have been multiplied by 10 for better representation of data on the plot)

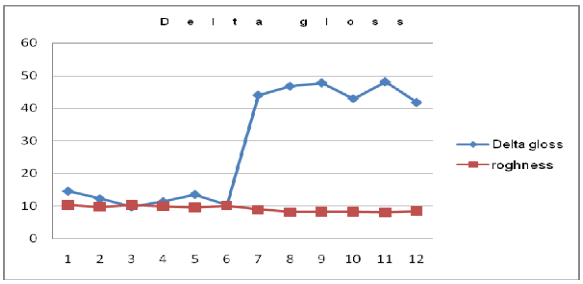

***Figure 4**. Delta gloss measurements of calendering condition 2 samples calculated from print gloss and sheet gloss measured at an angle of 60º.*

Fig. 5 represents the plot of roughness and mean area coverage ratio of black ink after tape pull test conducted on the coated samples and calendered with conditions 1,2 and 3

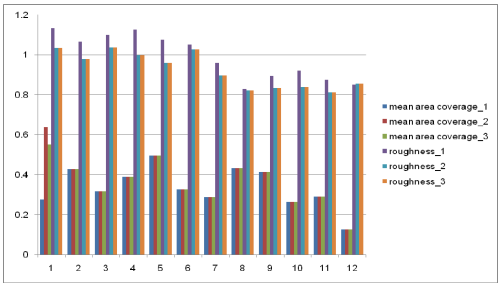

***Figure 5**. Roughness and mean area coverage ratio measurements of black ink after conducting tape pull test using both tapes for coated samples calendered with conditions 1,2 and 3.*

Fig. 1, 2 ,3 and 5 clearly represents the significance of surface PPS roughness on the ink adhesion of phase change inks, which is represented by the help of area coverage ratio of black ink after conducting the tape pull test.

Fig.4 represents that delta gloss depends on the surface PPS roughness of the coated sheet.

Conclusions

The results obtained from this study indicates that surface roughness of substrate to be printed plays a vital role in determining the ink adhesion and delta gloss of the samples printed digitally using phase-change inks. In phase-change ink applications, the ink-adhesion plays a significant role in obtaining acceptable print quality. The print attributes also depend on the delta gloss values, which can be estimated easily by measuring surface roughness, as it depends on the surface roughness of the substrate

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