Effects of Surface-Size Treatment on Performance of Plain Paper in Non-Impact Printing

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Abstract

Polymeric surface sizes, applied from the size press during the paper-making process, can be used to modify the chemistry of a plain paper surface to improve performance in different printing environments. For inkjet printing with water-based inks, a moderately hydrophobic surface controls lateral spreading and aids holdout of the ink. With polymeric toners in electrographic printing, surface wetting is again important. Compatiblity of the surface treatment polymer also appears to affect the toner adhesion.

In this investigation, alkaline sheets treated with commercial surface sizes were evaluated in terms of wetting and absorptivity, measured by contact angle, ink penetration and Bristow Wheel. These parameters were then correlated with Ink-jet print quality measured by image analysis techniques. Paper treated with the same surface sizes was tested in an office copying machine. Toner adhesion, measured by several techniques, was related to dose and chemistry of the surface treatments.

Introduction

With increasing use of inkjet printers in the office environment it is important that standard plain paper should provide good image quality with inkjet printing as well as with laser printing or copying[1]. To improve the sharpness of inkjet printed characters the paper surface can be modified at the size press with a polymeric surface agent that has partly hydrophobic character. This treatment prevents the rapid capillary flow (wicking) through the paper fibers and can much improve inkjet print quality[2]. Moreover, polymers with certain structures, as well as improving the paper surface for inkjet printing, are found to improve toner adhesion to paper in electrographic and xerographic printing.

In order to obtain an objective and quantitative measure of print quality, image analysis was used to measure letter areas of typical printed text. This tech-

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nique proved to be a practical method to measure the letter spreading and was used to determine the effectiveness of the polymeric agents with dose, and to relate print quality to performance of the treated paper in sizing tests. Image analysis was also used in evaluating toner adhesion by a tape test..

Experimental

Sheets cut from 50 lb basis weight paper (pilot machine) were tub-sized using 3% of a standard size press starch with surface treatment polymers added at a dose of 0.025 - 0. 15% on paper. A number of equivalent sheets were prepared at each concentration. The surface treatments are designated as follows:

- S/AR a commercial styrene-acrylic resin
- SMA a commercial styrene-maleic resin
- UR a commercial urethane resin

Print tests were performed using a Hewlett-Packard DeskJet 500 ink-jet printer. Areas of 6 CS Courier 9-point letters (e, o, j, m, v, d) were measured using an Olympus® Corporation Cue-2 image analysis system with morphometry application, and a stereo zoom microscope with CCD camera and ring fiber optic illumination. A correction for background illumination was applied, and control measurements (letter area measurements of a standard sheet) were performed at intervals to check uniformity of response. A standard grey level threshold was used for binarization of all character images from all sheets.

The ink penetration test was based on Tappi method T530, using 12.5 g/L of Napthol Green B dye in water buffered at pH 7.0, omitting formic acid. Values represent the mean of six measurements.

A modified Bristow Wheel test was performed with a Paprican Bristow Tester from Noram Quality Control and Research Equipment Ltd operated at one speed only. Using 50 µL of ink in the headbox, ink track lengths were determined for each of 3 paper strips from each test sheet. For all experiments a 1 m wheel was set at 0.5 mm/sec, with a contact time of 2 sec.

Contact angles (left and right hand side) of 4 water drops on each of 4 samples from each test sheet were measured using a Krüss U.S.A. automatic contact angle goniometer and the mean of the 16 values calculated

Toner adhesion was measured in two ways:

1. Treated paper was printed with black rectangles in a Xerox 1090® brand xerographic copier. Scotchs 810 brand cellophane tape was smoothed into contact by light rubbing with a pencil eraser. Olympus densitometric image analysis was then used to calculate percent toner remaining after rapid removal of the tape.

2. Treated sheets were printed with a uniform pattern of E's with a Xerox® 1090 copier. Mounted samples were abraded for 30 cycles with a Taber® Abraser fitted with a CS 10F abrasive wheel. The abraded samples were rated visually on a scale 1 (total removal of image) to 10 (image not affected by abrasion).

Results and Discussion

Image Analysis and Letter Area Measurement

A major cause of deterioration of an ink-jet printed character is the spreading or wicking of the inked area. Therefore, measurement of the image area provides an important measure of image quality. Image areas of each of the six characters were summed to give a "total letter area". These results are related graphically to surface treatment dosage in Figure 1 and a listing of the numerical data for this and other tests is summarized in Table 1.

Table 1. Data from Image Analysis Ink Penetration, Bristow and Contact Angle Tests

Resin Code	Dose (lbs/t)	Letter Area (mm2)	Bristow Track (mm)	IPT (secs)	Contact 0 secs (º)	Angle 60secs (º)
none	0.0	9.8	44	2.4	58	0
SMA	0.5	8.80	95	29.5	84	16
	1.0	8.51	121	42.6	86	52
	1.5	8.32	139	45.6	112	93
	2.0	8.24	143	33.9	91	80
	3.0	8.42	163	32.0	106	99
S/AR	0.5	8.08	153	40.4	98	60
	1.0	7.94	169	63.3	111	100
	1.5	7.60	173	84.9	108	103
	2.0	7.76	184	121.0	106	97
	3.0	7.76	194	155.0	110	96
UR	0.5	8.61	101	21.7	86	5
	1.0	8.00	128	43.3	91	70
	1.5	8.20	152	71.0	96	81
	2.0	8.26	168	90.0	98	89
	3.0	7.88	186	119.0	98	81

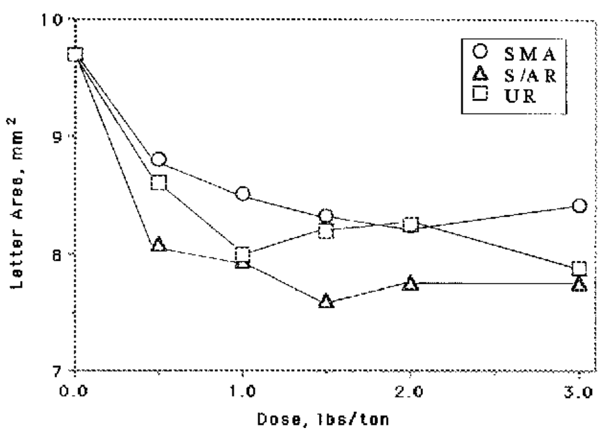

Figure 1. Dependence of Letter Area on Chemistry and Dose of Surface Treatment.

In general a smaller letter area corresponds to less spreading and irregularity so that a more precise letter image (better print quality) results. At some point there would be an optimum value, below which erosion of the letter profile would be measured but this was not observed with our samples. The results show large differences of image area between the untreated (starch-coated) control sheet, and treated sheets. There are apparently also significant differences between the surface treatments, with the S/AR polymer providing smaller letter areas.

Ink Penetration Test

The dependence of green-water ink penetration times on surface treatment is shown in Figure 2. For the S/AR and UR treatments, progressive increase of ink penetration is observed whereas the SMA polymer shows low penetration times even at higher doses. Ink penetration times do not appear to have a well defined relationship to print area. The correlation coefficient for a straight-line fit of ink penetration and print area was 0.57.

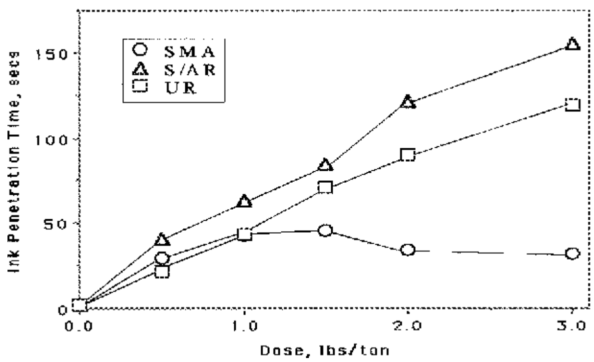

Figure 2. Dependence of Ink Penetration Time on Surface Treatment.

Modified Bristow Wheel Test

The Bristow absorption test provides a measure of the dynamic absorption process which occurs when liquid is transferred to apaper surface (3). The track length (which was measured with a paper ink contact time of 2 sec) is related to dosage in Figure 3 . It can be seen that the test distulguishes between the different surface treatments. It also correlates fairly well with letter area (correlation coefficient 0.78).

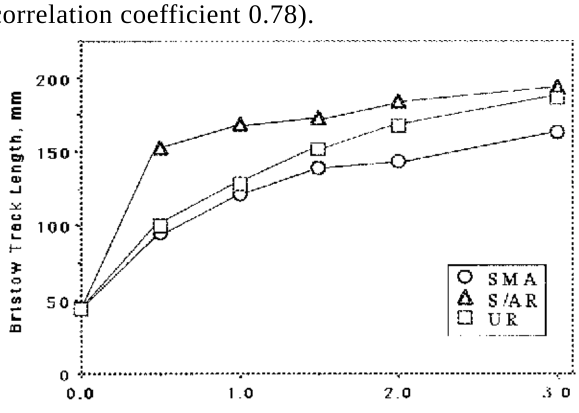

Figure 3. Dependence of Bristow Track Length on Surface Treatment.

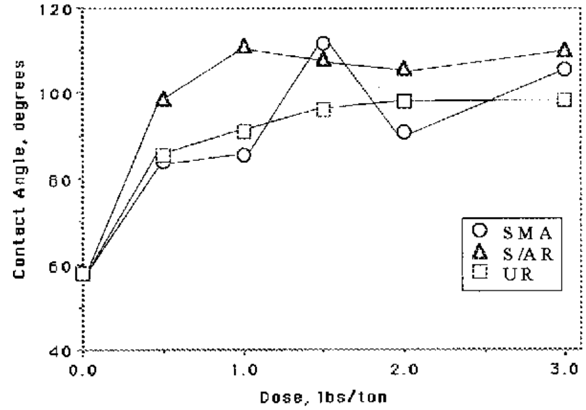

Figure 4. Dependence of Initial Contact Angle on Surface Treatment.

Contact Angle Measurements

Contact angle measurements are performed in order to measure the wettability of a paper surface. In these experiments,contact angles were first measured immediately after formation ofthe drop, and then 60 seconds later. A lower value for the latter measurement results from drop spreading or from loss of drop volume by penetration into the surface. The contact angle dose profiles for each resin are shown in Figures 4 and 5. Highest contact angles, and best holdout, were obtained at the higher doses of the S/AR resin. A correlation coefficient of 0.73 was obtained from a straight line fit of the contact angle versus letter area and for a fit of contact angle versus Bristow track length the correlation coefficient of 0.78 was obtained. Good correlation is expected because capillary absorption is governed by the contact angle. Scatter in the contact angle results could be due to local surface differences as well as sheet to sheet variation.

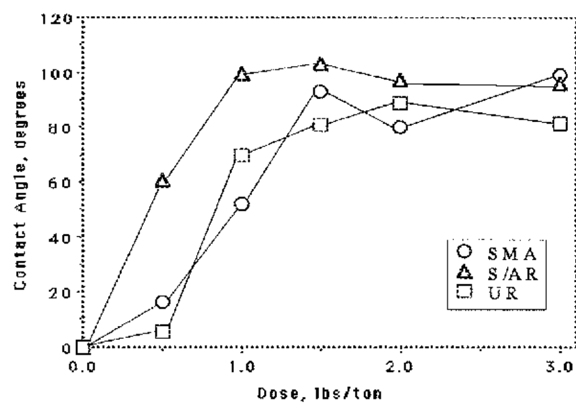

Figure 5. Dependence of Contact Angle at 60° on Surface Treatment.

Toner Adhesion

Experiments measuring toner adhesion by the tape test are illustrated by the graph in Figure 6. The effect of two of the surface treatments is to increase the adhesion beyond the level provided by starch alone. The third treattnent, however, has a deleterous effect. An explanation of this difference may lie in the chemical compatibility of toner resin (based on a styreneacrylic resin] and the styrene copolymer sizing agents.

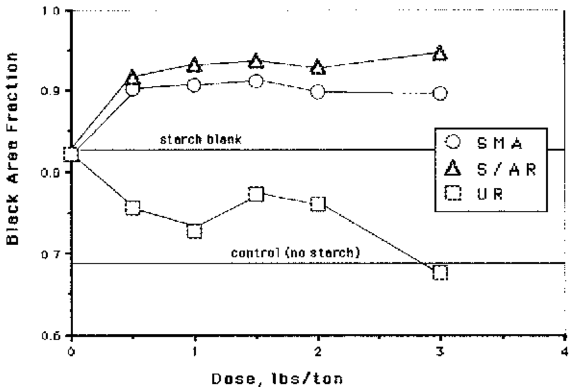

Figure 6. Dependence of Toner Adhesion on Surface Treatment.

The Taber Abraser test was used to evaluate machinemade paper treated with two levels of S/AR resin. Results, shown in Table 2 below, show that abrasion resistance is enhanced by the treatment, which is consistent with increased adhesion.

Conclusions

Letter spread measured by image analysis provided a means to establish the relationships between print quality and typical sizing measurements for plain paper surfaces treated with polymeric surface sizing agents. The surface treatments reduced the amount of image area spread. Performance of surface treatments was also compared in tests of toner adhesion in Xerographic printing. In general, a styrene-acrylic resin demonstrated improved performance over other commercial resins, both for mkjet printing and for toner adhesion.

Table 2. Abrasion Resistance of S/AR Treated Paper Measared with the Taber Abraser

Resin Code	Dose lbs/t	Side	Abrasion Resistance Ratings 1-10	Mean Rating	Std DEV
None	0.0	top	5,5,5,4,3,4	4.3	0.8
“	“	bottom	5,4,3,3,3,3	3.5	0.8
S/AR	1.5	top	8,7,6,5,4,3	5.5	1.9
“	“	botton	7,5,5,5,5,5	5.3	0.8
S/AR	3.0	top	8,7,7,6,5,4	6.2	1.5
“	“	bottom	7,6,6,6,5,5,4	5.6	1.0

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