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The Effect of Three Different Surface Sizes on Coated Sheet Properties

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by

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TABLE OF CONTENTS

INTRODUCTION

A literature search showed that although much work has been done on the mechanism of coating migration (1, 3, 5) and the influence of base sheet properties on migration (2, 8). No reports were found on the influence of different surface sizes on coating migration. The functions of a surface size in coating base stock is threefold. First, it is to resist excessive water penetration so that the sheet will retain sufficient strength for the coating operation. Second, the smoothness which it imparts is beneficial to further printing processes, especially in the case of offset. The third function of a surface size is to resist penetration of the base sheet by the coating binder. If excessive binder migration is present, a flaky coating can occur, resulting in dusting problems during printing. On the other hand, if little binder migration is present, the coating will be loosely held to the base sheet yielding a low pick resistance. This paper is designed to study the effects of three surface sizes, Penford Gum 280, polyvinylalcohol, and carboxymethylcellulose, with special emphasis on their effects to coated sheet properties.

HISTORICAL REVIEW

The interest in sizing as related to a coating requirement was shown as early as 1923 (4). At this time, while few methods were available to evaluate the degree of sizing or its effects, the coating process only called for a relatively low sized sheet. As methods improved and higher quality coatings were needed a closer look at the mechanics of coating was undertaken (2). It was then that the importance of coating or binder migration became apparent.

The definition of binder migration is simple the degree to which an adhesive in a coating color penetrates the sheet. The mechanism behind this action is rather complex. It can be roughly broken down into two basic areas; the tendency of the binder to enter the base sheet (3) and the effects of drying rate on the adhesive once it is in the sheet (5). Clark, Windle, and Beazly have shown that the initial penetration into the sheet on an inverted blade coater is caused by two distinct forces; the capillary action of the porous sheet structure and pressure migration, caused by nip clearances and viscosity of the coating. It was shown that the capillary migration could involve either the movement of the water and adhesive or just the water while pressure migration forces both the adhesive and water into the sheet together. They further indicated that the degree of sizing has a definite influence on the capillary action of the sheet, but had no effect on

penetration migration. They made no attempt to evaluate different surface sizes and their specific effects (5).

Eklund and Palsanen gave special attention to drying rates in relation to binder migration. It was shown that infra-red drying had no effect on migration because of the uniform heating obtained by it. Cylinder drying in the initial stage caused a migration to the outer free surface of the paper. The effect of hot air drying was the most pronounced and entirely dependent on the intensity during the first stage. A high temperature caused excessive migration to the surface of the coating and thereby lowering the ink receptivity. By allowing a longer dwell time between the blade and the initial drying stage, migration into the sheet was very noticable, thus increasing the ink receptivity of the coating (5).

The significance of coating penetration as related to printability has been shown by Fifi and Arendt (6). They concluded that as coating penetration into the sheet decreased, ink gloss M.A.N. smoothness, VanderCook print smoothness, and Smith Gravure print smoothness values all increased while the degree of calender blackening decreased, thus showing that a low degree of initial binder migration enhances the printability of the sheet (6).

MEASUREMENT OF PENETRATION

The measurement of binder penetration is varied and complex. The methods can be broken into five basic categories, physical, fluid spreading, electrical, ultrasonic, and optical.

Physical measurements involve actual separation of the sheet into layers for analysis of the binder. Sheet splitting and abrasion of the coating are common methods of isolating segments. In addition to the inaccuracy of segment isolation, the chemical processes for determining the amount of binder present are questionable. Slant sections are sometimes used, where a thin section at an angle of approximately one degree to the surface is removed and studied optically for penetration. This process is extremely tedious and distinctions of binder migration are often unclear (3).

When a liquid spreading method is utilized, it must be assumed that the binder penetration is related to the absorbancy of the coated surface. Various methods, including K & N ink holdout and Vanceometer, have been used, but are all only relative values and cannot be correlated to various base stock and coating combinations (3).

Electrical conductance and ultrasonic techniques are also relative indicators and cannot be correlated to various base stock and coating combinations. The time required for a specific value of electrical conductance while the opposite side of the sheet is in contact with a

conductive solution only measures the penetration rate of a fluid through an entire sheet (6). Likewise with an ultrasonic method. It assumes a reduction of the speed of sound through a sheet while the fibers are swelled during wetting. The test is variable with factors such as air entrapment and sheet density, and is not easily related to migration depth (3).

Optical properties have the advantages that they can be used under high pressure (to simulate penetration rate under coating conditions similar to those found in blade coating) and by application of the Kubelka-Monk theory, the actual depth of penetration can be calculated. The two major methods under this heading are reflectance change and backside reflectance. Reflectance change assumes that as the sheet is wetted by the coating the reflectance decreases and the transmission increases. This method has been used in various laboratory studies to evaluate penetration rate (3, 6). Backside reflectance is used to measure the total migration of the coating. A dye is used to obtain a dark coating and the penetration is calculated by use of equations obtained from the Kubelka-Monk theory. These equations are listed in the Appendix. Because of the direct calculation of penetration depth by this method, it shall be used in this study.

EXPERIMENTAL

Materials

A fifty pound (25 X 38 - 500) base stock used for surface sizing and subsequent coating was on hand in the Department of Paper Science and Engineering's pilot plant, as were the three sizing agents, Penford Gum 280, a medium viscosity polyvinyl-alcohol, and a medium viscosity carboxymethycellulose.

The coating consisted of a No. 2 clay, 12 parts Dow latex 620 adhesive and a 0.5% addition of a flourescent brightener (Calcoflour White) to assist in determining binder penetration. This color contained a 62% solids content.

Procedure

The paper was surface sized on a horizonal size press using the Louis Calder pilot papermachine at a speed of 200 f.p.m. The Penford Gum was applied at solids of approximately 10, 8, 6 and 4 per cent to obtain four levels of sizing. The PVA and CMC were both applied at about 2.0, 1.5, 1.0, and 0.5 per cent solids.

The coating was applied on the Louis Calder trailing blade pilot machine at a speed of 500 f.p.m. with a blade pressure of 3 3/4 psi. The three drying zones were held at a temperature of 250^{o}F during all runs. All samples were obtained at the completion of the coating run; therefore the sized samples were subjected

to the high drier temperature before testing.

Tests Performed

Calculations were made to determine size pickup and coat weight. The uncoated samples were tested for Cobb size (45 sec.), Gurley porosity, and Sheffield smoothness. The coated samples were evaluated by K & N ink holdout, Sheffield smoothness and coating penetration. Coating penetration was calculated by backside reflectance using the formulas given in the appendix.

Data

The data listed in Tables I and II is categorized with respect to uncoated and coated samples.

TABLE I

UNCOATED SHEET TEST RESULTS

		Size Pickup (#/ream*)	Cobb Size (^{gr}/100 sq.cm)	Sheffield Smoothness (units)	Gurley Porosity (sec/100 c.c.)
P.G. 280	10%	1.77	0.27	119	137
	8%	1.32	0.22	131	89
	6%	0.85	0.20	134	75
	4%	0.53	0.19	143	66
P.V.A.	2.0%	0.235	0.27	119	54
	1.5%	0.229	0.40	94	52
	1.0%	0.180	0.44	112	58
	0.5%	0.066	0.44	99	50
C.M.C.	2.0%	0.378	0.47	101	166
	1.5%	0.322	0.51	131	111
	1.0%	0.223	0.49	128	91
	0.5%	0.054	0.37	132	60

* 25 X 38 - 500 ream size

TABLE II

COATED SHEET TEST RESULTS

		Coat Weight (#/ream*)	Penetration (mils)	Sheffield Smoothness (units)	K & N Ink (% Red'n)
P.G. 280	10%	8.2	0.34	32	15.1
	8%	8.2	0.36	33	16.1
	6%	8.1	-	32	16.5
	4%	7.8	0.40	35	15.7
P.V.A.	2.0%	7.6	0.72	24	15.9
	1.5%	7.6	0.41	35	15.6
	1.0%	7.3	0.07	32	15.7
	0.5%	7.7	0.33	36	16.0
C.M.C.	2.0%	7.5	-	42	16.0
	1.5%	7.5	-	42	16.0
	1.0%	7.7	0.10	37	15.7
	0.5%	7.6	-	36	15.4

* 25 X 38 - 500 ream size

DISCUSSION OF RESULTS

In this study four factors may have led to sporatic data. The first is the raw stock used to prepare the samples. Variations in caliper and basis weight were noticed, although this does not appear to be a significant factor. However, the base stock had a Hercules size test value of approximately 80 sec. This value is somewhat high for a study of this nature. The second factor is that the blade pressure used was reset for each sample. This was done as accurately as the pilot facilities would allow. The third factor which perhaps affected size test results was that the uncoated samples were passed through the coater drying tunnel at its 250^{o}F temperature. This was necessary so that all samples could be run in the time available. A fourth factor, which is beyond the scope of this project, is the affect that the initial drying stage had on the binder migration.

The coat weights ranged from 7.3 to 8.2 lbs/ream. No distinct correlations could be made with any of the other variables studied, but these variations could be due to two main factors. The first is the blade pressure which is not considered to be significant. The second is the variation in basis weight of the base stock. Since coat weight was determined by weight difference as opposed to ash content, this could be considered the greatest source of error.

The results obtained for coating penetration is quite variable as seen by the data in Table II. Three factors may have contributed to these variations. The first is that the brightness meter used to obtain penetration depth, operates on a light source with a predominate wavelength of 457 mu. Fluourescent brighteners such as those used in this study are not as effective in this range as they are in lower wavelength ranges, therefore the sensitivity of this method was greatly reduced in this survey. The second factor is the variation in caliper in the base stock. This value is used in binder penetration depth calculations, however, this does not appear to be the most significant factor. The third factor which affects binder migration is the drying rate in the first drying stage. If this temperature was too high it may have caused a predominate migration of the binder to the surface of the coating, thus giving validity to some of the negative penetration values obtained (but not listed). An analysis of this factor is not considered in this paper, only the possibility of its influence. This same factor may be the cause for inconclusive K & N ink holdout values, which showed no correlations with any other property studied.

When size pickup was compared to smoothness (uncoated) and porosity, general trends were observable in the starch and CMC samples. As the size pickup increased, smoothness increased and porosity decreased, as expected. In the case of PVA, no correlations could be drawn. The

coated smoothness seemed to correlate with size pickup, but only in the case of CMC.

CONCLUSIONS

It is apparent that the backside reflectance technique for determining binder migration is not a suitable method when a fluorescent brightener is used as a tag for penetration. This method, however, has been used with good success when a pigmented tag is employed (6).

No significant differences are apparent between the coated samples with the three surface sizes used. It is possible, however, that further testing, including pick and print smoothness may show a inherent difference between these surface sizes as related to coated sheet properties. It is the opinion of this writer that further investigations in this area would be fruitless unless a study would be broken down in a number of categories and then compiled. The role of the base sheet, the tag for migration determination, and the effects of drying should all be investigated in depth before any further conclusions are drawn.

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APPENDIX

Equations used to determine the depth of coating penetration.

$$R_o = (R_t - R_b)/1 + R_t R_b - R_b \left(\frac{1}{R_i} + R_i\right) \qquad \text{EQ. 1}$$

$$SX = \ln\left[(R_o R_i - 1)(R_i / R_o - R_i)\right] / \left(\frac{1}{R_i} - R_i\right) \qquad \text{EQ. 2}$$

where: R_o = reflectance of sample with perfect black body.

R_t = reflectance of sample with dark background.

R_b = reflectance of dark background.

R_i = reflectance of infinity thick sample.

S = light scattering coefficient.

X = thickness of paper above dark background.

The depth of penetration is determined by:

$$D_p = X_i - X_c \qquad \text{EQ. 3}$$

where: D_p = depth of penetration

X_i = initial thickness of sheet

X_c = value obtained from equation 2