Binder distribution and mass distribution of the coating layer – cause and consequence

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1. ABSTRACT

Three base papers having different fiber furnishes and different degrees of sizing were blade coated in a pilot coater with two clay-based coating colours with different binder systems. The experimental variable in the pilot coater trials was the drying strategy. The coated material was printed in lithographic offset and the print mottle was evaluated. The mass distribution of the coating layer and the binder distribution in the surface of the coated material were also evaluated.

The aim of the trial was 1) to investigate how the mottle in the offset print on the coated material was affected by the drying strategy, 2) to produce a coated material of general character and to investigate the relations between the mottle in the offset print, the binder distribution in the coating surface and the mass distribution of the coating layer.

The results showed that the mottle in the offset print, the binder distribution in the coating surface and the mass distribution of the coating layer were all affected in the same manner by the drying strategy, but at different levels.

The mottle in the offset print decreased when the evaporation rate in the hot-air dryer was increased. IR-drying increased the mottle.

The binder in the coating surface was more evenly distributed in materials dried with a high rather than a low evaporation rate in the hot-air dryer. The binder was also more evenly distributed when the binder content in the coating surface was higher.

A positive correlation was observed between the binder distribution in the coating surface and the mass distribution of the coating layer. This was also true of the mottle in the offset print and the binder distribution in the coating surface. The relationships were at different levels depending on the type of base paper and coating colour used, which indicates that the mottle in the offset print is not solely determined by the binder distribution in the coating surface.

2. INTRODUCTION

Paper is coated in order to obtain a good printing surface, which means only that the print quality on a coated paper is generally superior to that on achieved on an uncoated paper. It does not imply that print quality problems are absent on coated paper. They exist and one of the most common, as well as most serious, problems is mottle in an offset print [1,2].

The quality and the mottle of the offset print are the result of a complicated interaction in which the base paper [3,4], the coating colour [5,6] and the coating process [7,8,9] are involved. During the printing, the ink, the fountain solution and the type of printing press are of course, also factors of importance [10,11,12].

It has often been suggested that a mottled offset print is due to binder migration accompanied by an uneven binder distribution in the coating surface, which is the result of an incorrect drying strategy, e.g. too severe evaporation. In spite of great attention this problem, e.g. refs. [1-3,6-9], systematic and direct studies are lacking. A positive correlation between the mottle in an offset print and the binder distribution has, however been reported for materials of a model character [13]. Another factor which may affect the mottle in the offset print is the mass distribution of the coating layer.

In this work the aim has been to investigate 1) the relation between the mottle in the offset print and the strategy adopted when drying the coating, 2) the relation between the mottle in the offset print and the binder distribution in the coating surface, 3) the relation between the binder distribution in the coating surface and the mass distribution of the coating layer. The investigation was performed on a coated material of general character, produced for this purpose in a pilot coater trial, with the type of base paper, the coating colour and the drying strategy as experimental variables. Direct techniques were used to evaluate the mottle in the offset print, the binder distribution in the coating surface and the mass distribution of the coating layer.

3. BACKGROUND

During the process of consolidation of the coating layer on the base paper, the binder in the layer is redistributed. The binder is transported towards the surface together with the water which is evaporated in the dryer and away from the surface together with the water which is sorbed by the base paper. The binder distribution in the dry coating is determined by these two competitive processes [15,16,17, 18].

An attempt is here made to derive an expression which may be used to discuss how the binder distribution in the coating surface may be influenced. The derivation is of a phenomenological nature.

If it is assumed that the surface profile of the base paper is sinusoidal and that the coating surface is completely flat, Figure 1, then the coat weight profile of the coating layer can be described by an expression of the type

$$W(x) = a - A \sin x \qquad (1)$$

where $W(x)$ = coat weight in position x
a = mean coat weight
A = amplitude of the coat weight profile
x = a position coordinate

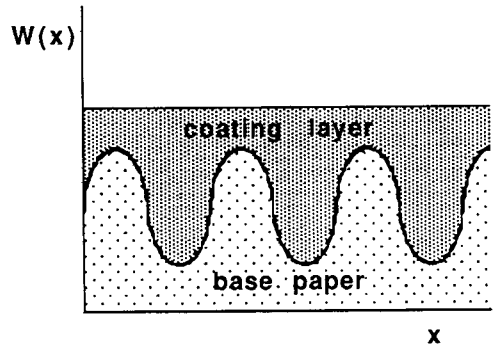


Figure 1 Schematic illustration of coat weight profile of the coating layer.

If it is further assumed that the transport of binder inwards and outwards is related respectively to the local coat weight and to the transport of water in the coating layer during its process of consolidation, then the distribution of binder can be written

$$T_i(x) = V_i(a - A \sin x), \quad (i = d \text{ and } e) \qquad (2)$$

where $T_d(x)$ and $T_e(x)$ denote the total amount of binder transported away from the surface and towards the surface respectively. $V_d$and V_e are dimensionless factors proportional to the respective transport rates. V_e is determined by the evaporation rate in the dryer and may be considered to be a constant. In contrast, V_d is not a constant but varies in the plane in the same way as the water sorption rate in the base paper surface. In principle, it can be related to the base paper topography in two ways being 1) higher in the valleys than on the hills, or 2) vice versa. It is also possible that the water sorption rate is not related to the topography of the base paper. How the water sorption rate varies is determined by whether the sorption into the base paper is governed by diffusion or by capillary flow [19,20, 21].

The density of the paper can be assumed to vary in the same manner as its surface profile [22,23], the valleys being of lower density and more porous than the hills. It follows that the sorption of water is higher in the valleys than in the hills if the sorption behaviour is determined by capillary flow. If the sorption of water is instead determined by diffusion, then most of the water is sorbed by the hills since the material density is highest there. Consequently $V_d(x)$ can be written:

$$V_d(x) = b \pm B \sin x \qquad (3)$$

where the minus sign is valid for capillary sorption and the plus sign for diffusion-controlled water sorption in the base paper. B is the amplitude of the water sorption rate and b is a dimensionless water sorption rate.

It may now be assumed that the enrichment of binder in the coating surface can be described by the difference between the transport of binder inwards and outwards, i.e.:

$$C(x) = (a - A \sin x)[V_e - (b \pm \sin x)] \qquad (4)$$

where the minus sign is, as before, valid for capillary sorption and the plus sign for diffusion- controlled water sorption in the base paper.

The mean value and standard deviation of C(x), calculated over one period, are measures of the binder content and binder distribution respectively in the coating surface. The latter is obtained by integrating the square of the deviation from the mean over one period divided by the length of the period. The following expression for the standard deviation in C(x) is then obtained:

$$S = \{\frac{(AB)^2}{2}\{[(\frac{b - V_e}{B}) \pm \frac{a}{A}]^2 + \frac{1}{4}\}\}^{0.5} \qquad (5)$$

where the plus sign is valid for capillary sorption and the minus sign for diffusion-controlled water sorption in the base paper.

Equation 5 shows that the standard deviation of the binder content in the coating surface increases with increasing A and B, i.e. when the mass distribution of the coating layer and the water sorption of the base paper are more uneven, which is in agreement with what is to be expected intuitively.

It is also evident in eq. (5) that the standard deviation of the binder content in the coating surface is affected in an identical manner by changes in b and V_e via the mass distribution of the coating layer. The uneveness in water sorption in eq. (5) is taking into consideration via the coat weight. It is interesting to note that the standard deviation of the binder content in the coating surface can in fact be both enhanced and supressed by the transport of binder away from the surface depending on the mechanism of water sorption of the base paper. If the water is sorbed by diffusion, then the transport enhances the standard deviation of the binder content. If the water is instead sorbed by capillary action, then the binder distribution is evened out.

4. EXPERIMENTAL

4.1 Pilot coating

In order to obtain a coated material of general character to evaluate the mottle in the offset print, the binder content and binder distribution in the coating surface and the mass distribution of the coating layer, a series of blade coating trials was performed with an Autoblade ^{R} -unit at Valmet Paper Machinery Inc., Järvenpää, Finland. The machine speed was 1000 m/min and 11 g/m2 of coating (dry) was applied to the wire side of the base paper. The blade thickness was 0.381 mm, the blade length 84 mm and the blade angle 40 °. The speed of the applicator roll was 20 per cent of the machine speed.

4.1.1 Base paper

Three base papers were coated, one base paper for LWC and two base papers for coated free sheets. One of the two latter was internally and surface sized as is custom for this type of base paper. The other was neither internally nor surface sized. Some data for the base papers are given in Table 1.

Table 1 Data for the base papers.

	Base paper		
	LWC	Free sheet sized	Free sheet unsized
Pulp	50 % mech. 50 % chem.	chemical	chemical
Filler		calc. carb.	clay
Internal sizing		ketene dimer	
Surface sizing		starch	
Grammage, g/m2	41	79	72
Surface roughness, PPS-10, µm			
ws	5.7	6.4	5.5
fs	4.5	5.5	4.6
$Cobb_{30}$, g/m2	saturated	17	saturated
Formation, var. koeff., % (Beta radiography)	11.4	10.9	10.8

The base paper for LWC was supplied by Kymmene Kaukas in Finland and the base papers for the coated free sheets by MoDo Husum in Sweden.

4.1.2 Coating colours

Each base paper was coated with two clay-based coating colours. The binder system in one of these was CMC (carboxymethylcellulose) and SB(styrene-butadiene)-latex and in the other starch and SB- latex. Coating formulations and some data for the coating colours are given in Table 2. The coating colours were prepared in a conventional manner.

Table 2 Coating colour formulation and data.

Coating colour	1	2
Clay	100	100
Starch		7
CMC	1	
SB-latex	12	5
Curing agent	0.5	0.7
Stearate	0.4	0.6
Optical brightener	0.5	0.5
Solids, %	59.0	58.0
Viscosity (Brookfield 100 rpm), mPas	580	820
pH	7.2	7.0
Temperature °C	29	29

Product names and suppliers of the raw materials were: Clay, SPS from ECC, England; starch, H-30 from Raisio, Finland; CMC, Finnfix FF5 from Metsä-Serla, Finland; SB-latex, DL-526 from Dow Chemical, Switzerland; curing agent, Glyoxal T from BASF, Germany; stearate Nopcote 104 from Nopco, USA and optical brightener, Blankophor P from Ciba-Geigy, Switzerland.

4.1.3 Drying strategies

The pilot coater used in this work was equipped with four hot-air hoods for air-borne webs and two IR-dryers, E and D_{1+2}. The hot- air hoods were heated with gas and the IR-dryers with electricity. The effect of IR-dryer E was 225 kW and its length was 1 m. The corresponding data for IR-dryer D_{1+2} were 250 kW and 2 m. The length of each of the hot-air hoods was 4 m. A schematic picture of the pilot coater including the dryers is shown in Figure 2.

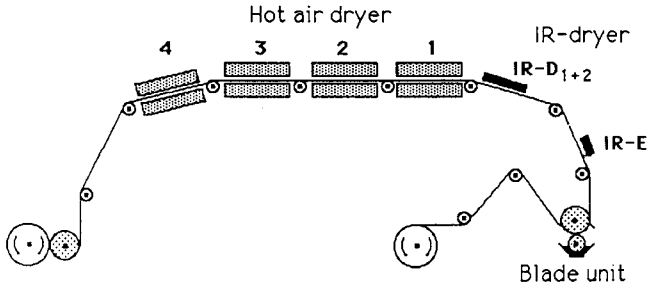


Figure 2 The pilot coater. The distance from the blade unit to IR-E is 1 m, to IR-D_{1+2} 4 m, and to the first hot-air hood 8 m.

Each combination of base paper and coating colour was dryed in the same series of different strategies, including hot-air drying and combinations of hot-air and IR-drying. A detailed plan of the drying strategies is given in Table 3.

Table 3 Drying strategies.

Base paper	IR-dryer E	IR-dryer D_{1+2}	Hot-air dryer Hood 1 Evap.rate kg/m2•h	Hood 1 Temp/vel °C/m/s	Hood 2 Evap.rate kg/m2•h	Hood 2 Temp/vel °C/m/s
LWC and sized free sheet			20	180/20	20	180/20
			40	240/40	20	180/20
			60	240/60	20	180/20
			20	180/20	40	240/40
			40	240/40	40	240/40
			60	240/60	40	240/40
	X		20	180/20	20	180/20
	X	X	20	180/20	20	180/20
		X	20	180/20	20	180/20
	X		40	240/40	40	240/40
	X	X	40	240/40	40	240/40
		X	40	240/40	40	240/40
Unsized free sheet			20	180/20	20	180/20
			60	240/60	20	180/20
			20	180/20	40	240/40
			60	240/60	40	240/40
	X		20	180/20	20	180/20
	X	X	20	180/20	20	180/20
		X	20	180/20	20	180/20
	X		40	240/40	40	240/40
	X	X	40	240/40	40	240/40
		X	40	240/40	40	240/40

X = dryer switched on

The conditions in hot-air hoods Nos 3 and 4 varied and were set to obtain a final moisture content of 6.0 % in the coated paper.

4.1.4 *Supercalendering*

Before the printing and further evaluation of the coated papers, they were supercalendered in a 12-roll pilot calender, under a line pressure of 300 kN/m and at a speed of 450 m/min. The temperatures of the rolls were 70, 100, 100, 130, 130 and 70 °C counted from the bottom and upwards.

4.2 Test printing

The supercalendered papers were cut to 400 x 570 mm2 (short side in MD) and then printed in a sheet-fed Roland Favorit RVT offset press [25]. Four rectangles, 64 x 133 mm2, with screen dot densities of 20, 40, 70 and 100 % were printed in each printing unit. To simplify the evaluation of the print mottle, the same printing ink was used in all four printing units. The ink was a cyan from Wintner (Irolite-serie). The fountain solution contained 10 % isopropanol and 2 % of a surfactant. The press was run at a speed of 5000 copies per hour.

The mottle in the print was evaluated using image analysis [26,27] and is here reported as the standard deviation in grey value (print reflectance). With the method used the standard deviation was obtained in a frequency analysed form.

4.3 Binder migration and binder distribution in the coating surface

Most of the material coated with coating colour No 1, i.e. the colour containing CMC and SB-latex, was evaluated with reference to content and distribution of SB-latex in the coating surface using a UV-technique. The principle of this technique was to scan the coating surface with a narrow beam of UV-radiation perpendicular to the paper surface and then measure the reflection at 45° at wavelengths of 220 and 260 nm. This provides the basis for the calculation of the UV-absorption of the coating layer. Since the absorption was not calibrated against known contents of SB-latex, it is here expressed in relative units, as is the standard deviation which is a measure of the SB-latex distribution in the coating surface. A detailed description of the technique is given in refs [28,29].

The binder content and the binder distribution in the surface of the material coated with coating colour No 2, i.e. the colour containing starch and SB-latex, were determined with help of an ESCA- technique, using a X-ray probe spectrometer from Surface Science Instruments [8,13,18,30]. Only a small but representative amount of the material was evaluated with this technique. The principle of this method was to scan a line, 15 mm in length, in steps of 1 mm and for each step to measure the binder content. The diameter of the measuring area was 0.6 mm. The atomic ratio $N_C/N_{Al}+ N_{Si}$ was calculated from the intensity peaks for C(1s), Al(2s) and Si(2s) in the ESCA-spectrum. The average of the 15 measurements provided a measure of the binder content, and the standard deviation gave a measure of the binder distribution in the coating surface.

4.4 Mass distribution of the coating layer

The mass distribution of the base paper and of the coated paper was determined by X-ray radiography [14,31]. The mass distribution of the coating layer was then calculated by a subtraction procedure described in ref [32].

The radiograms were evaluated by image analysis. The procedure was identical to that used for determining the mottle in the offset print.

The material evaluated with reference to the mass distribution of the coating layer was identical with that evaluated with reference to the binder distribution. The mass distribution of the coating layer is here reported as the standard deviation in coat weight.

5. INFLUENCE OF DRYING STRATEGY ON THE MOTTLE IN THE OFFSET PRINT

5.1 Hot-air drying

The effect on the mottle in the offset print of the evaporation rate in the first hot-air hood is shown in Figures 3a-f for all the combinations of base papers and coating colours. Although the level of mottle was dependent on the base paper and coating colour, the mottle clearly decreased when the evaporation rate was increased in all cases.

Most mottled was the LWC sample, but the fact that the least mottled was the print on the coated unsized free sheet indicates that it was probably not the absence of internal and surface sizing that made the print on the LWC the most mottled. Coatings on LWC were also more sensitive to the changes in the evaporation rate than the coatings on either of the papers for coated free sheets.

Least mottled was the material coated with the coating which contained CMC and SB-latex. More mottled was the material coated with the coating which contained starch and SB-latex [5]. The difference in mottle between the coating colours was less on LWC than on the coated free sheets. The effect of both base paper and coating colour on the mottle was more pronounced at low than at high evaporation rates.

Not only the evaporation rate in the first air-hood but also that in the second air-hood affected the mottle in the offset print. In both cases, it was more favourable to dry with a high evaporation rate. The effect of the evaporation rate in the second hot-air hood was more pronounced for all combinations of papers and coating colours when the evaporation rate was low in the first hot air hood.

The reduction of mottle in the offset print with increasing evaporation rate has been reported earlier, e.g. refs [7,8], but these authors also claimed that a high evaporation rate in the first hot-air hood should be followed by a conditioning phase, with as low an evaporation rate as possible in the second hot-air hood. This is not a general conclusion of the present work.

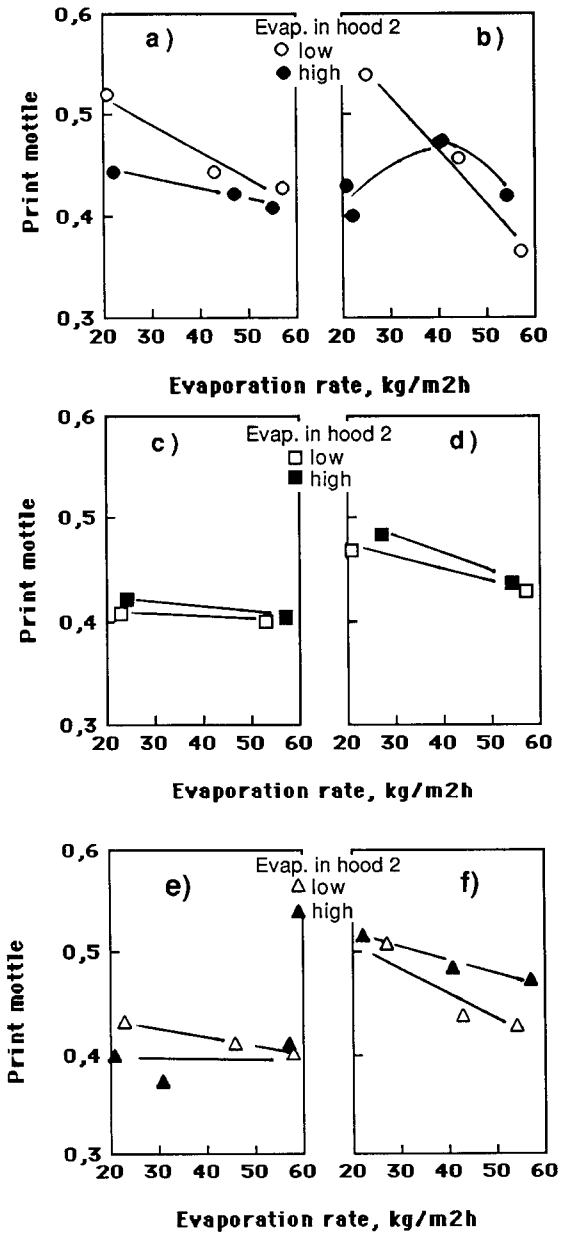


Figure 3 *The mottle in the offset print, evaluated by image analysis, as a function of the evaporation rate in the first hot-air hood, for both low and high evaporation rates in the second hot air hood.*

a) LWC coated with colour No 1
b) LWC coated with colour No 2
c) unsized free sheet coated with colour No 1
d) unsized free sheet coated with colour No 2
e) sized free sheet coated with colour No 1 and
f) sized free sheet coated with colour No 2

5.2 IR-drying

In general IR-drying is said to have a positive effect on the printing properties of coated paper, resulting in a less mottled offset print [9].

In the present study, the effect of the IR-drying on the offset mottle was not however unambiguous. Table 4, in which the results are summarized, indicates nevertheless that the mottle in the offset print increased in more cases than it decreased.

The properties of the base paper may vary across the web. Since the base paper rolls were taken from different positions across the web, the mottle in the offset print may vary on different rolls coated in the same way. Since the reference coating, dried with hot-air, and the test coating dried with IR were performed on different base paper rolls, the effect of the IR-drying on the mottle in the offset print may be merely the effect of variations in the base paper.

The levels of the offset mottle on the different combinations of base paper and coating colour were rated in the same order as for the hot-air-dried material.

Table 4 *Effect of IR-drying on mottle in offset print: (-) denotes more mottled, (+) less mottledand (o) unchanged, relative to hot-air-drying.*

Base paper and coating colour	Hot-air dryer Evap.rate hood 1	IR-dryer E	IR-dryer $E+D_{1+2}$	IR-dryer D_{1+2}
Colour No 1				
LWC	low	+	0	
	high	-	-	-
Unsized	low	-	-	+
free sheet	high	-	-	-
Sized	low	-	-	-
free sheet	high	-	-	-
Colour No 2				
LWC	low	-	-	-
	high	-	-	-
Unsized	low	-	-	-
free sheet	high	-	+	+
Sized	low	+	0	+
free sheet	high	-	0	0

6 EFFECT OF DRYING STRATEGY ON THE BINDER CONTENT AND THE BINDER DISTRIBUTION IN THE COATING SURFACE

6.1 Binder content

Figure 4, in which the SB-latex content in the coating surfaces is plotted vs the evaporation rate in the hot-air dryer (hoods Nos 1 and 2), shows that the evaporation rate had only a marginal influence on the SB-latex content in the coating surface compared with the effect of the type of base paper [8]. The highest SB-latex content was found in the coating surface of the unsized free sheet. The lowest SB-latex content was found in the LWC surface.

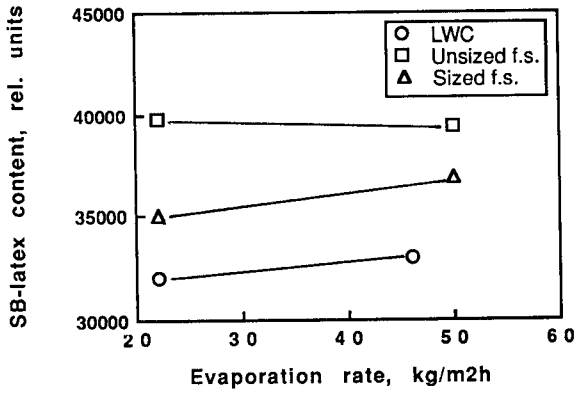


Figure 4 *The SB-latex content in the coating surface as a function of the evaporation rate in the first and second hot-air hoods on material coated with colour No 1.*

In the coating experiments on the pilot coater, the dewatering of the coating and the disappearance of the water mirror from the coating surface between the blade-unit and the first hot-air hood was studied visually. The dewatering rate was approximately the same for the base paper for LWC and for the unsized base paper for coated free sheet, but the dewatering rate on the sized base paper for coated free sheet was substantially lower.

Equation (4) suggests that the binder content in the coating surface depends on the rate of the water sorption of the base paper and decreases when that increases, but this was not wholly the case in this work. Instead, the content of SB-latex in the coating surface seems to be determined by the type of fiber in the base paper, a high content of SB-latex being observed when the base paper was based on chemical pulp and a low content when it was based on mechanical pulp.

If the water is sorbed by capillary flow, the base paper takes up the whole aqueous phase of the coating layer, i.e. water + binder and the coating layer loses its binder to the base paper as indicated by eq. (4). If instead the water is sorbed by diffusion, the base paper takes up the water from the coating layer selectively and no binder migrates into it. The fact that water sorption by diffusion is more pronounced in chemical than in mechanical fibers [21,33], the content of SB-latex in the coating surface was therefore higher on the two coated free sheet grades than on LWC. At a given water sorption rate, it is expected that b is greater if the water sorption of the base paper is capillary-controlled than if it is diffusion-controlled.

The evaporation rate in the hot-air dryer (hoods Nos 1 and 2) was here varied within a wide interval from approximately 20 to 60 kg/m2h. When the drying strategy was varied within these reasonable limits, the SB-latex content in the coating surface was only marginally affected, but a small increase with increasing evaporation rate was observed for the coated sized free sheet and for LWC [16,34]. For the coated sized free sheet, an increase in the content of SB-latex in the coating surface was also observed when the IR-dryers were applied.

The influence of the type of base paper and of the drying strategy on the binder content in the coating surface was the same with both coating colours, Figure 5. On material coated with coating colour No 2, it was however observed that the content of SB-latex in the coating surface was higher than the starch content, although the starch content was higher than the content of SB-latex in the coating colour. Similar results are reported in ref [13].

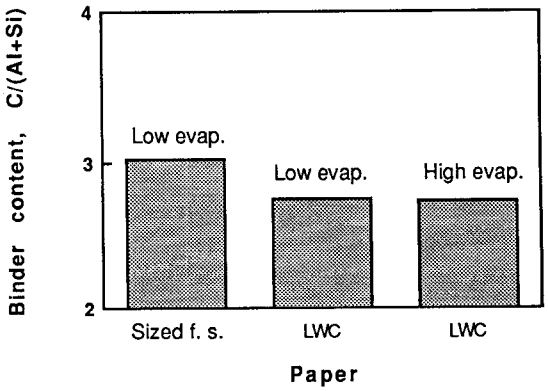


Figure 5 *The binder content in the coating surface on LWC and coated sized free sheet coated with colour No 2.*

6.2 Binder distribution

The standard deviation of the SB-latex content in the surface of the material coated with colour No 1 decreased when the evaporation rate in the hot-air dryer (hoods Nos 1 and 2) increased, but the level was dependent on the type of base paper, Figure 6. The SB-binder distribution was most uneven in the surface of the coated sized free sheet. It was more even on LWC and most even on the coated unsized free sheet. This is the rating expected from eq. (5) considering the relative magnitude of b for the respective base papers. Figure 6 also shows that the SB-binder was more evenly distributed in the coating surface after drying at a high than at a low evaporation rate. Similar results were obtained for materials coated with coating colour No 2, Figure 7.

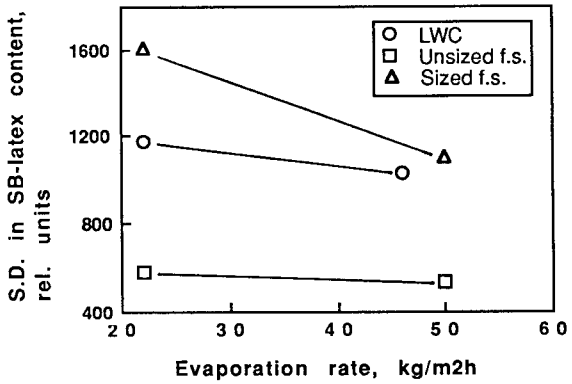


Figure 6 *The standard deviation in SB-latex content in the coating surface as a function of the evaporation rate in the first and second hot-air hoods on material coated with colour No 1.*

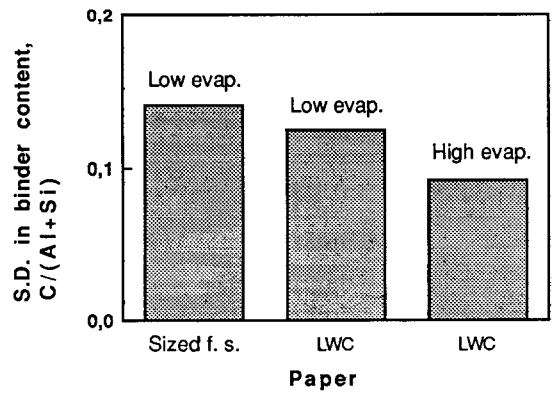


Figure 7 *The standard deviation in binder content in the coating surface on LWC and coated sized free sheet coated with colour No 2.*

Although it has usually been agreed that an enrichment of binder in the coating surface implies an uneven distribution, no experimental verification of the correctness of this opinion has been reported in literature. Figure 8 indicates however that the higher the content of SB-latex in the coating surface (colour No. 1) the more evenly was it distributed.

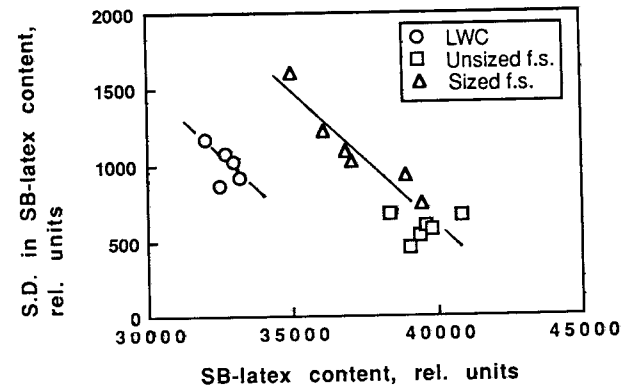


Figure 8 *The standard deviation in SB-latex content in the coating surface as a function of the SB-latex content for material coated with colour No 1.*

7 CAUSES OF MOTTLE IN AN OFFSET PRINT

7.1 Binder distribution in the coating surface

In Figure 9, the offset mottle is plotted vs the standard deviation of the SB-latex content in the surface of material coated with coating colour No 1. Three relations at different levels, all with a positive correlation, can be identified, indicating that the mottle in the offset print is not determined solely by the standard deviation in SB-latex content. Other factors are also involved. Further, the significant difference in level and slope of the relations for LWC and the coated sized free sheet indicates that these other factors were probably more important.

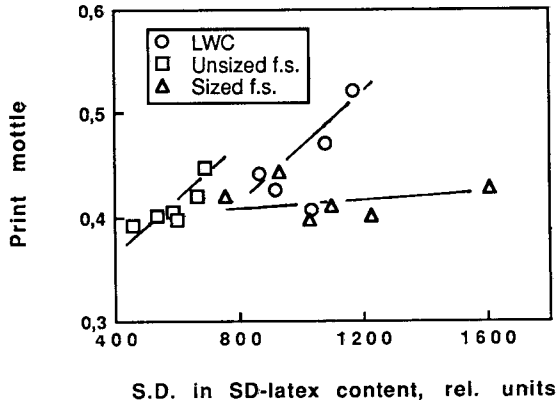


Figure 9 *The mottle in the offset print as a function of the standard deviation in SB-latex content in the coating surface on material coated with colour No 1.*

7.2 Mass distribution of the coating layer

The binder distribution in the coating surface and the mass distribution of the coating layer can be assumed to be positively correlated, since more binder is transported to the coating surface at higher than at lower coat weights [8, 15]:

A good estimate of the mass distribution of the coating layer on the coated paper is obtained if the standard deviation in grammage of the coated paper is subtracted from that of the base paper [32] i.e.

$$S_y = S_x - S_{x+y} \qquad (6)$$

where S is the mass distribution expressed as standard deviation in grammage or coat weight. The suffixes x, y and x+y denote base paper, coating layer and coated paper respectively.

Figure 10 shows for the material coated with coating colour No 1. there is a tendency towards a positive correlation between the standard deviation in SB-latex content in the coating surface and the standard deviation in coat weight, but at different levels depending on the type of base paper, being higher for LWC.

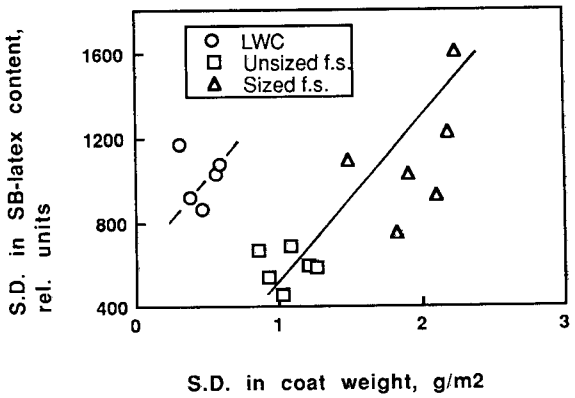


Figure 10 *The standard deviation in SB-latex content in the coating surface as a function of the standard deviation in coat weight on material coated with coating colour No 1.*

This indicates that the SB-latex content in the surfaces of the two coated free sheets was affected in the same way by changes in the coat weight. This is expected since b in eq. (5) has been stated to be the same for these two base papers and higher for LWC. In contrast, the variation in SB-content in the coating surface of LWC was relatively greater then suggested by the standard deviation in coat weight. This means that there are other factors that determine the standard deviation in SB-latex content and that these factors had a greater influence on LWC than on the coated free sheets. Since b in eq. (5) is more important for LWC than for the coated free sheets, it appears that these factors are related to the base paper and to the binder transport towards the base paper.

Since there was a positive correlation between the offset mottle and the standard deviation in SB-latex content in the coating surface, Figure 9, and between this standard deviation in SB- latex content and the standard deviation in coat weight, a positive correlation is expected between the mottle in the offset print and the standard deviation in coat weight. This is illustrated in Figure 11 for the sized free sheet coated with coating colour No 1. Since the figure is based on material with different drying strategies as the only variable, it is evident that the mass of the coating layer is redistributed during its consolidation process. Identical results are presented in ref [14].

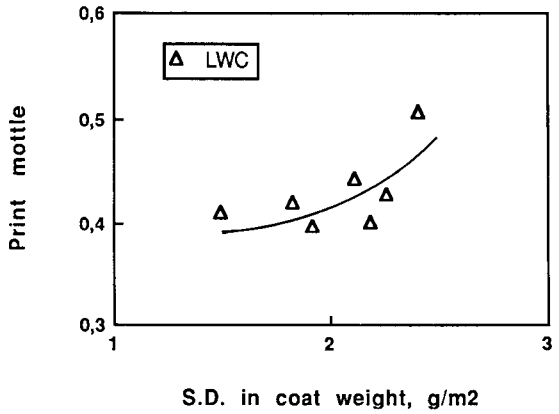


Figure 11 The mottle in the offset print as a function of the standard deviation in coat weight on the coated sized free sheet coated with colour No 1.

The standard deviation in coat weight on LWC and on the coated unsized free sheet was less than that on the coated sized free sheet. Since both these papers sorbed more water between the application of the coating colour and the blade and hence were more plasticized, it can be assumed that they were also more compressed under the blade tip. The compression smoothens out the irregularities in the base paper surface which affects the thickness profile or the mass profile of the coating layer at the time of forming the coating layer under the blade tip. High compression gives a coating layer with more uniform thickness than low compression [35]. This hypothesis explains the rating in standard deviation in coat weight on the coated materials in this investigation.

8 FINAL REMARKS

This work has shown that offset mottle, the binder content and the binder distribution in the coating surface were all affected in the same manner by the drying strategy, but at different levels depending on the combination of base paper and coating colour.

The effect of the conditions in the hot-air dryer on the offset mottle was consistent, the mottle decreasing with increasing evaporation rate. The effect of IR-drying was not as consistent but in most cases the offset mottle increased.

The mottling was greatest on LWC. The print on the coated sized free sheet was less mottled and that on the coated unsized free sheet was least mottled. This rating suggests that the mottle is not higher on LWC because this paper is unsized. It is probably due more to the type of fiber in that paper.

As expected the offset print on material coated with the colour containing starch and SB-latex was more mottled than that on material coated with the colour that contained CMC and SB-latex.

The SB-latex content in the coating surface was only slightly affected of the drying strategy. The type of base paper had a greater effect. The highest SB-latex content was observed in the coating surface on the unsized free sheet. The content was slightly less in the surface of the coated sized free sheet and least in LWC. The SB-binder was more evenly distributed in the surface of the coated unsized free sheet than in the LWC. It was most unevenly distributed on the coated sized free sheet. The SB-binder was also more evenly distributed when the evaporation rate was high in the hot-air dryer.

When the standard deviation in SB-latex content in the coating surface was plotted against the SB-latex content, two relations were observed at different levels, one for LWC and one for both the coated free sheets. This disproves the notion that an enrichment of binder in the coating surface implies an uneven distribution.

Two relations at different levels were also found when the standard deviation in coat weight was plotted against the standard deviation in SB-latex content in the coating surface, one for LWC and one for the coated free sheets, which suggests that the standard deviation in SB-latex content in the coating surface on both the coated free sheets was determined in the same way by the standard deviation in coat weight and that the standard deviation in coat weight was less important in the case of LWC. In the case of LWC, the effect of the base paper was more pronounced.

The relation between the mottle in an offset print and the standard deviation of the SB-latex content was also found to differ depending on the type of base paper. Different relationships were found for each base paper, all with a positive correlation. Consequently the offset mottle was not solely determined by the standard deviation in SB-latex content in the coating surface.

The offset mottle also correlated positively with the standard deviation in coat weight.

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