Ink-Coating Adhesion:
factors affecting deposits on the CIC in "satellite" type CSWO presses when using VAC papers

C.J. Ridgway
Senior Scientist, Omya AG

E. Kalela
Manager, R&D and Technical Service, UPM-Kymmene/Stracel Mill

P.A.C. Gane
Vice President Research & Development, Omya AG

Abstract:

Enhancement of image quality and reduction in print-through can be achieved by printing on so-called Value Added Coldset (VAC) papers. Independent absorption tests, model coatings, commercial ink and paper samples, together with commercial printing trials, are used to illustrate the effect of pore structure and size distribution on the rate of absorption and the relative permeability of papers and coatings on the deposit build-up tendency. This work shows that runnability of specific ink and paper combinations is not a simple function of tack rate but rather a function of ink component penetration properties, specific for different surfaces, and its effect on ink adhesion in relation to permeability of the coating to fountain solution. This relates to the ability of the ink to be compatible with the fountain solution being used and the role of the basepaper in absorbing and retaining fountain solution. By developing a special tack measurement technique for coldset web offset (CSWO) ink and VAC paper coatings, using the Ink-Surface Interaction Tester (ISIT[1]), it has been possible to show that by changing the composition of CSWO ink the penetration phenomenon on the VAC paper surface can be changed. This has been further illustrated by two different CSWO inks and two different VAC paper surfaces using a chromatographic GPC technique. By analysing the retained print density in the pull-off areas of the ISIT test, differences in ink-coating adhesion as demonstrated by the two inks are illustrated.

Keywords: *Newspaper publishing, VAC papers, coldset web offset printing, ink tack, ink-coating adhesion, printability, ink absorption, ink setting, ink chromatography, CSWO inks, negative CIC build-up*

[1]ISIT is a product name of SeGan Ltd., Perrose, Lostwithiel, Cornwall, PL22 0JJ, U.K.

Introduction

The research activity in the area of Value Added Coldset papers (VAC) is driven by the needs of newspaper publishers who are obliged to create new business designs in order to be able to compete successfully in tomorrow's media world. To remain competitive, big improvements in print quality are targeted. VAC paper grades are proving to give the right type of print quality improvements when used with the latest printing technology developments in the satellite and four-high-tower coldset web offset (CSWO) printing machine configurations. Simultaneous with quality improvements, some limitations have arisen in runnability in the satellite press configuration. The operating window at the satellite presses is smaller than when printing with conventional machine finished MFS or newsprint paper grades. Current runnability levels achieved at satellite presses reach about 200,000 copies being printed without washing and stopping the press.

VAC papers are typically produced by creating a suitable basesheet from mechanical fibres and/or recycled fibres and fresh fillers. Subsequently, a thin coating layer may be applied on both sides. Coating consists typically of the basic raw materials; pigment, binders and some additives. The paper grammage range is typically between 48 and 60 gm^{-2}, and the applied total coat weights vary between 6 and 16 gm^{-2}. One of the problems identified, when printing such papers in CSWO satellite type presses, is that deposits of ink, especially black, appear on the common impression cylinder (CIC) of the second satellite unit. The phenomenon appears across the cylinder in both image and non-image areas. Little or no trapping of the deposit is seen back onto the printed paper. Surface coatings made from typical mineral pigments do not have the same absorption-porosity relationship as uncoated newsprint and it is shown that standard newsprint has a different form of deposit build-up tendency on the CIC from that of VAC paper.

During the first phase of the development work, controlled and repeatable printing trial procedures were developed at a commercial Wifag OF 970 printing machine. After creating a number of hypotheses for reasons why build-up sometimes occurs on satellite type presses, it was clearly seen that lacking suitable analysis techniques, particularly in the area of absorption and penetration of ink components and fountain solution, research work was being severely hampered. The correlation between measurements of conventional paper properties and CIC build-up tendency was not sufficient to replace printing trials as the evaluation tool of runnability.

Researchers in the industry are quickly responding to the needs concerning analytical techniques. The characteristics of ink vehicle absorption into porous structures has formed the basis of a number of recent detailed studies. Gane and Ridgway (1) showed that the formation of a filter-cake and entrapment of water-soluble polymer controlled the imbibition characteristics of a flexographic ink on a coated substrate. Investigation of highly viscous offset inks, on the contrary, showed a continuous viscous build-up during tackification rather than a distinct filtercake formation (2). The studies published here centre on the absorption mechanisms of coated coldset VAC paper grades, which have been printed using the CSWO process.

Defining the Problem

The printing of VAC papers differs somewhat from the printing of uncoated CSWO paper grades. Particularly in satellite press configurations (Wifag OF 7, with 9 cylinders or Wifag OF 790 with 10 cylinders, for example) the operating window for a printer is narrower than for uncoated paper grades. It has been reported that different build-up problems occurred on the CIC surface during printing (3). The formation of deposits happens in the second satellite, where the second side of the paper web becomes printed with four colours. Figure 1 illustrates a heavy build-up on the CIC surface after printing 150,000 copies of VAC paper. Figure 2 illustrates the schematic run path of the paper web for 4 + 4 colours printed on the Wifag OF 790. The arrow in Figure 2 points to the place in the printing machine where the deposit in Figure 1 has been photographed. The deposit can be more specifically divided into two different types: negative and positive build-up.

- Negative build-up, which Figure 1 illustrates, can be found on the non-image areas of the first printed side of the web as seen against the first CIC of the second satellite unit. The delay between the first and second satellite units is typically around 1 second or slightly less. The deposit is being observed just after the first colour on the verso side of the paper web has been printed down. When negative build-up is formed, no trapping of the deposit is seen back onto the non-image areas of printed, final product. Negative build-up is very seldom to be found on the surface of the second CIC in the second satellite unit.

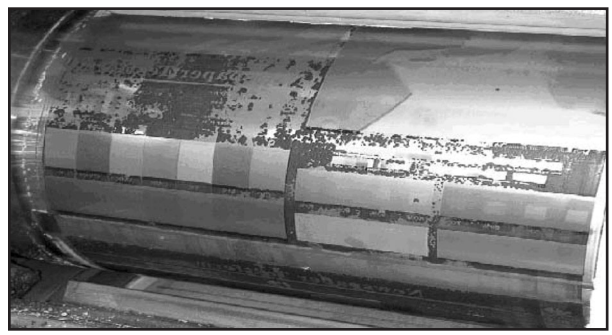

Figure 1. Heavy negative build-up on the first CIC of second satellite unit on Wifag OF 790. The squares on the left edge of the cylinder represent places where image areas of the first printed side of the web have been in contact with this CIC, but not formed any deposit.

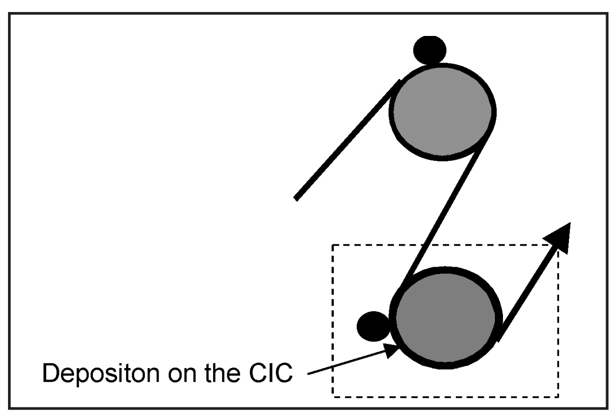

Figure 2. Defining the problem—disposition at the delayed second nip.

- Positive build-up is formed on the first CIC surface of the second satellite unit in places where image areas of the first printed side of the web are in contact with the cylinder surface. In Figure 3, positive build-up can be seen on the surface of the first CIC of the second satellite unit (printed text from first printed side of the web). Unlike negative build-up, positive build-up can be found either at the surface of the first or second CIC of the second satellite unit.

Figure 3. Example of positive build-up on the surface of the first CIC of the second satellite unit in Wifag OF 790 printing machine.

In the case of uncoated papers, positive and negative build-up on the CIC of the second satellite are only rarely observed, and then generally only with highly filled grades, arising from, say, high contents of recycled fibre in the raw material.

Proposed Mechanisms Behind the Build-Up Phenomena

Before defining the proposed mechanisms in respect to the overall physics of the problem it must be recognised that the relationship between the ink and the paper surface is not only related to the paper surface itself but clearly also to the formulation of the ink, its pigmentation characteristics, resin suspension and flow properties, as well as press settings, such as fountain solution quantity, type, temperature etc. The work presented in this paper focuses on the observations made for a limited series of inks chosen to illustrate good and bad properties in respect to build-up on a satellite type press and is described in terms of the analytical techniques used to probe the ink-surface interactions rather than defining the inks or probing the press variables themselves.

It is suspected that when black ink is applied as the last colour on the last printing nip of the first satellite unit, one or both of the following thereafter occur(s):

1. Water absorbed by the paper in the previous printing nips creates an hydraulic pressure under the action of the subsequent nip, such that the coating structure and part of the fibre structure effectively 'explodes'. This further leads to a situation that there are loose pigment particles on both surfaces, i.e. on the printed and opposite sides. At the same time, after hydraulic expulsion, water is in excess at the ink-coating interface, and therefore acts to reduce ink adhesion to the coating on that surface.
2. The black ink starts to penetrate into the coating structure of the printed side. This phenomenon is time dependent and some phase separation between original components of the black ink (pigment, binder, vehicle) occurs. If this separation is either too fast or the binder and vehicle pass together into the sheet (particularly likely in the case of low coat weights and poor coverage), the ink cannot bind properly to the surface. This in turn also affects adhesion.

These hypotheses focus the attention on the permeability of the coating in respect to fountain solution and in the absorptive power of the coating. The possibility to obtain proof that binder is or is not separating from the vehicle as it penetrates into the sheet is, therefore, a crucial step in understanding the phenomenon.

The potential ink adhesion-fountain solution retention imbalance is illustrated by the schematic in Figure 4, where it can be seen that fountain solution applied before and at the first printing nip on the second satellite unit completes the loosening of the ink and coating pigment particles on the verso side, leading to their direct deposition to the CIC surface (positive build-up) or ink flotation into the fountain solution via an aquaplaning effect (negative build-up).

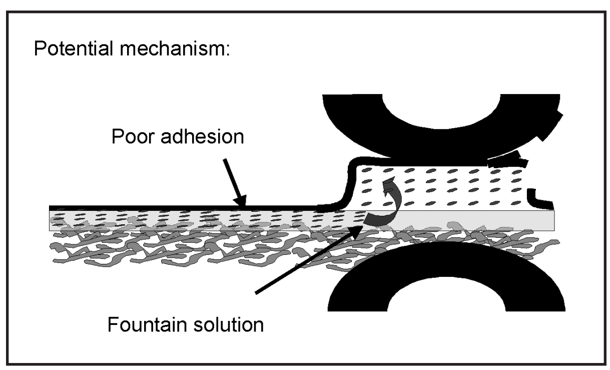

Figure 4. Proposed mechanism of hydraulic expulsion of fountain solution acting to remove ink that is poorly adhering to the coating in the first printing nip of the second satellite unit. This model is supported by the absorption, porosity and permeability data obtained in this study.

Experimental Design

Independent laboratory absorption tests, using model coatings of compressed (calendered) pigmented coating formulations of measured porosity, are used to illustrate the effect of pore size distribution on the rate of absorption, and in particular the permeability of the coatings. Comparison with standard newsprint shows that surface coatings made from typical mineral pigments do not have the same absorption-porosity relationship as uncoated newsprint.

Penetration of CSWO ink components and the phase separation taking place after the printing nip are studied by chromatographic methods developed by KCL, Finland, (4). With results from this test it can be shown that there is a correlation between penetration properties of ink binder and vehicle and CIC build-up tendency (positive build-up).

A special test was developed by Omya AG using the principles of Gane *et al.* (5), (6) for CSWO inks on coatings by studying techniques of tack cycle analysis and correlation with adhesion, i.e. observing print density on the pull-off areas using the Ink-Surface Interaction Tester (ISIT[1]). With this technique it is possible to link the deposition phenomenon to poor ink-coating adhesion. This has been demonstrated by using two inks—one ink showing good resistance to common impression cylinder deposition and one bad ink in this respect[2]. To achieve sufficient separation force to make an adhesion assessment in this way using realistic print densities it was necessary to adopt a new approach by applying the coating layer to an artificial macrosmooth substrate, Synteape[3], as newsprint paper is too rough to achieve sufficient contact area with the test blanket under standard testing conditions.

Methods for Independent Study of Absorption, Porosity and Permeability of Papers and Coatings

Three methods have been used to study the effective pore capillary radius of papers and coatings. Each method samples the structure under different conditions to identify the factors of absorption, porosity and permeability independently. The initial contact dynamic of ink and fountain solution is absorption driven, the capacity of the coating and paper for fluid is defined by the interconnected porosity. As seen in the schematic of Figure 2, the dynamic in a subsequent time-delayed nip depends most probably on the permeability characteristics of the paper, i.e. the ease or otherwise for liquid to flow through the porous structures under the application of external pressure and compression of the basepaper, acting effectively as a compressed liquid-filled sponge.

Mercury Porosimetry

A Micromeritics Autopore III mercury porosimeter was used to measure the percolation characteristics of the coating and paper samples. The mercury intrusion measurements were corrected using the software Pore-Comp[4] (7). Further newly-developed corrections are used to account for mercury occlusion in respect to surface features of fibrous and laminate samples and to normalise the porosity, Ridgway and Gane (8). The corrected volume of mercury intruded at the maximum pressure can be used to calculate the porosity of the sample.

Absorption

The rate of fluid uptake into both coated and uncoated paper sheets (measured in the machine direction) was determined using an automated microbalance, following the methodology of Gane, Schoelkopf *et al.,* (9), (10).

Permeability

The permeability of papers (coated and uncoated) was studied using liquid permeation under pressure through a saturated sample, using a methodology designed by Schoelkopf *et al.* for macroscopic pigment tablets (11), (12), (13). It was necessary to develop the methodology further for determining the permeability of sheet paper samples to liquid in the cross-section (z) direction, whereby a stack of laminar sheet samples are mounted surrounded by resin (this method is discussed in more detail in (12)). A PC samples the liquid throughput from the balance data using the same software as developed for the imbibition experimentation described above.

Methods for Studying Component Penetration and Ink-Surface Adhesion

Measurement of Ink Component Penetration on Coated Coldset Paper

The printed samples were progressively ground/sliced from the top surface with the surface grinding machine (4), removing layers of controlled thickness as determined by measuring the paper thickness before and after grinding (0–15 µm). The ground samples were then extracted with an organic solvent and analysed by gas and gel permeation chromatography to reveal the amount of ink components left in the paper. Unprinted paper samples were also ground and the contribution of binders in the paper itself could be subtracted from the total signal intensities to obtain the concentration of ink components. Three parallel printing, grinding and analysis series were produced from each sample to determine the reproducibility.

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[2]Inks provided by Sun Chemical, U.K.

[3]Synteape is a product name of Arjo Wiggins

[4]Pore-Comp is a software program developed by the Environmental and Fluids Modelling Group, University of Plymouth, PL4 8AA, U.K.

Direct Measurement of Ink Vehicle Absorption and Ink-Surface Adhesion

The dynamic of ink vehicle absorption, ink setting and adhesion of ink to the surface of coatings were studied using the ISIT (5), (6). A contact disc is pressed against the print on the sample platen by an electromagnetic force acting on a solenoid. This action applies an extensional force on a coil spring mounted in parallel with the solenoid. Contact time and force can be varied by electronic controls to optimise adhesion between contact disc and print. At cessation of the electromagnetic force the contact disc is retracted from the print by the strain force of the extended coil spring controlled by a ramp-down of the solenoid force. Under small extensions, the coil spring provides a constant acceleration during the retraction of the disc. This is a unique feature of this static test procedure. The strain gauge, fixed between contact disc and coil spring, generates a load-dependent signal which is recorded as the force during separation as a function of time. The build-up of the tensile force required to achieve each individual separation is recorded with time (pull-off curve) and can be analysed through specifically designed software.

The basic physics behind the tack force measurement has been previously described (5), (6) and a typical tack curve and test strip after testing are illustrated in Figure 5. The interpretation, involving both optical (and instrumental) examination of the pull-off areas on the printed paper stripe and the tack force curve over time, proposes a rupture at the weakest point of the adhesion/cohesion chain, (5), (6), i.e. either between ink and paper or between ink and blanket, or within the cohesive layer of the ink itself. Once a tack cycle is generated it is possible to evaluate the remaining print density in the ISIT pull-off areas and relate this to the adhesion of the ink to the surface via the transmitted separation force at maximum tack[5].

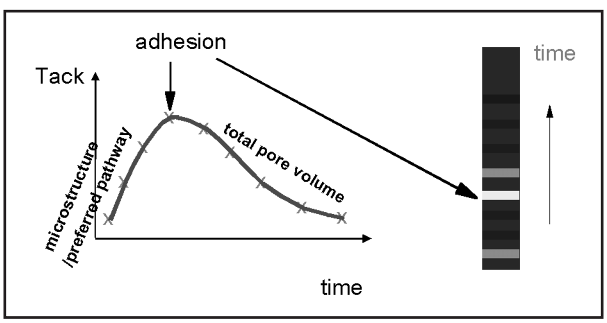

Figure 5. Schematic of a typical tack cycle curve and test strip showing the residual print density after "pull-off".

[5]The print density is measured with a spectrophotometer, Techkon SP810 Lambda. Techkon SP810 Lambda is a product name of Techkon GmbH, Wiesbadener Strasse 27, D-61462 Königstein / Ts, Germany

Coldset offset inks produce tack levels as low as half that of a typical sheet offset ink, and the surface of newsprint is considerably rougher than gloss coated papers. It is possible, however, by adjusting the ISIT parameters to identify differences in ink tack development of CSWO inks on realistic VAC coated paper surfaces. First the key variables affecting the tack measurement were identified by performing an L18 Taguchi matrix experiment with chosen variables (14). Table 1 shows the chosen variables used for the parameter optimisation. As can be seen, contact ramp-in force and ink amount were shown to be the most critical parameters in this measurement. Clearly this indicates that surface roughness is the controlling parameter of the measurement, i.e. the contact area is strongly roughness related.

Whilst changing the ramp-in force and ink quantity allows for tack rise measurement, the excess pressure and amount of ink tends to saturate the sample under compression and no information can be obtained regarding ink tack decay. For standard ramp-in force conditions, using realistic amounts of CSWO ink, it is necessary to reduce the surface roughness component. This is achieved by using the model substrate, as previously described, and provides the basis for the ink-surface adhesion measurement technique.

Table 1. Variables used for developing the ISIT test for coated CSWO papers and their optimal settings on the ISIT device. Last column chows the relative significance of the variable for the measurement (noise level is 0.5).

	Applied Parameter	Matrix Weighting
Ink Type (CSWO)	B	0.6
Ink Amount	0.5 ml	2.3
Printing Speed	0.5 ms^{-1}	1.7
Nip Pressure	300 N	1.3
Ramp-In Force Parameter	8	4.8
Hold Time	1.5 s	1.2
Ramp-Down Speed	4	0.0

Results and Discussion

Porosity, Absorption Characteristics and Permeability of Coated and Uncoated Mechanical Papers

Three newsprint papers were analysed for the three properties of porosity, absorption and permeability, an uncoated standard newsprint paper, an uncoated highly filled paper made from de-inked pulp and a coated and filled VAC paper. The surface coating of the latter is produced with ground calcium carbonate (Omya AG) as pigment and has a matt finish. The coated paper is calendered and has a high brightness, 78 (D65) in comparison with 55 for the standard newsprint paper (D65).

Table 2. Paper properties of analysed coldset papers.

Paper	Furnish	Basis Weight /gm^{-2}	Total Ash Content / %w/w
Standard Newsprint (uncoated)	Mechanical Pulp + DIP	36	7.7
Uncoated and Filled (recycled)	100% DIP	52	18.4
Coated and Filled	100% Mechanical Pulp	54	25.5

Mercury Porosimetry of Coated and Uncoated Mechanical Cold Set Paper Grades

The three papers were analysed using mercury porosimetry with a novel sample preparation technique (8). The samples are prepared in such a way as to minimise the paper overlap in the sample chamber (penetrometer) which otherwise causes differences between repeated measurements. The data otherwise are corrected for mercury compression and penetrometer expansion, and also for the compression of the solid phase of the sample using the software program Pore-Comp (7). Differences occur between repeated measurements of the same sample due to fibres which do not lie flat with the paper and cause additional void volume to be included in the bulk volume of the sample—this effect is defined by Ridgway and Gane as mercury occlusion (8). To overcome this problem the total intrudable volume was measured independently by saturation with hexadecane (a liquid chosen to be inert in respect to fibre swelling, debonding etc.) and the mercury intrusion data after the Pore-Comp correction was then adjusted to this value. The skeletal volume was also measured independently using the hexadecane saturated sample immersed in a known volume of hexadecane by Archimedes using a pycnometer, and these values were used to calculate the porosity of samples (8).

The mercury intrusion data, after all these corrections have been applied, are shown in Table 3.

Table 3. Intruded volume, skeletal volume and porostiy values for examined papers.

Sample	Intruded Volume / cm^{3}g^{-1}	Skeletal Volume / cm^{3}g^{-1}	Porosity / %
Coated and filled	0.633	0.722	46.6
Uncoated and filled	0.596	0.725	45.3
Standard newsprint	0.549	0.821	40.1

The standard newsprint has the lowest porosity but contains the largest pores. Porosity values are higher for the filled paper and yet higher for the coated and filled grade. These papers have a fundamentally coarse fibre mat structure and the addition of filler or coating introduces more void volume in the small pore range.

Mercury porosimetry in the region of interest associated mostly with pore level structure shows that the coated filled paper is of similar total porosity as the uncoated filled paper, these however differ significantly from the low ash containing standard newsprint paper.

Absorption of Real Ink into Coated and Uncoated Mechanical Coldset Paper Grades

The absorption of an actual ink into the three paper samples was studied, Figure 6. The standard coldset ink used consisted of carbon black pigment, resin compound as binder and a mixture of mineral and vegetable oil as vehicle.

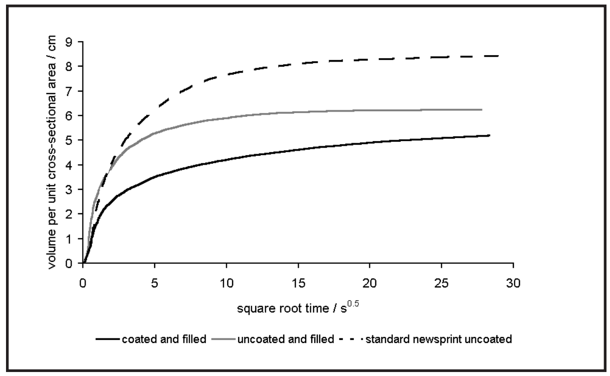

Figure 6. Absorption curves into paper sample(s) machine direction using standard coldset ink.

With an actual ink it can be seen that the absorption into the low ash content standard newsprint paper is faster than the other papers over the longest timescale. This is consistent with the finer pore structures of the filled and the coated and filled papers which rapidly become blocked by the ink pigments and resins, when no pressure pulse is used to push the ink compounds deeper into the paper structure, despite their overall higher porosity. This highlights the difference between permeability of a paper and its porosity.

Permeability—Direct Measurement in Z Direction

The data above from absorption suggest that, in practice, the permeability of all the papers in the press in the presence of ink on the paper surface is most likely controlled by the larger pores when accessible. When inaccessible, the fine pores of a coating control the permeability. The permeability of light weight coated paper under pressure is determined strongly by the basepaper which remains exposed in areas of poor coverage.

In this work 125 sheets of each sample were embedded in a resin block as previously described. By using such a stack of so many sheets the effect of pinholes or variable coating coverage dominating the results was avoided. Application of the Poiseuille equation [1] provides a relationship between permeation rate, d(V(t)/A)/dt, defined as the volume flow rate per unit cross-sectional area, and the equivalent permeation radius for this cross-section, r_{perm},

$$\frac{\mathrm{d}(V(t)/A)}{\mathrm{d}t} = \frac{\pi r_{perm}^{4} \delta P}{8\eta l} \quad [1]$$

where δP is the applied pressure difference across the sample, η is the viscosity and l is the length of the sample. The Poiseuille equivalent permeation radii are shown in Figure 7.

The coated and filled paper is confirmed to have somewhat lower permeability. The uncoated filled paper is more permeable than either the coated and filled or uncoated standard newsprint. This permeability of pure fluid (hexadecane) differs from the absorption data for ink, and confirms the suspicion above that the ink components block the finest pores. Permeation is therefore confirmed to be restricted by the coating layer leading to higher permeation pressures within and below the coating. Since the basepaper under the coating is filled it can be expected to have a permeability similar to that of the uncoated filled paper. There is, therefore, a dramatic contrast in permeability between the coating and its filled basepaper.

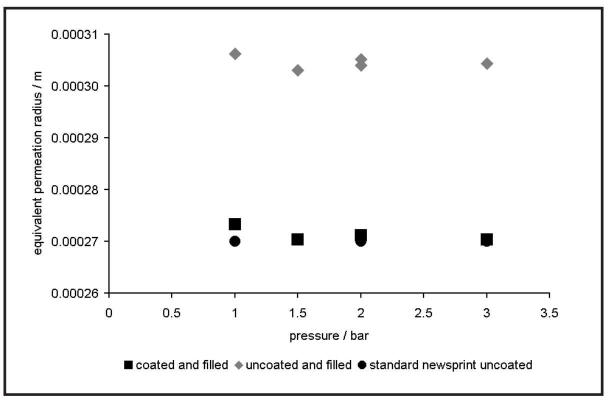

Figure 7. Permeation results showing consistency of Poiseuille equivalent permeation radius as a function of applied pressure differential.

Possible Role of Basepaper in the CIC Build-Up Phenomenon

In respect to volume uptake of fluid, we can conclude that the basepaper is expected to play a dominant role in terms of the amount of fluid, especially fountain solution that will be taken up in a printing nip under a pressure pulse. The mechanism of wetting the fibre network is different from that of the coating layer. The permeability in the z-direction then relates to how easily an absorbed liquid can be forced out again under pressure. The coated sample shows resistance to flow most strongly in the coating network with relatively little resistance in the basepaper network itself. The model proposed in Figure 4 in respect to the basepaper function is strongly supported by these data, in that the coated sheet displays the greatest back-pressure of fountain solution through the coating, because: 1) the basepaper has a high permeability, 2) the numerous fine pores in the coating structure become blocked by ink components in the printing nip and 3) the swellability of certain furnishes in contact with water makes them increasingly compressible. The excess fountain solution will try to escape through those areas of poor coverage via the larger pores as the nip pressure is encountered. This effect can greatly stress the adhesion of ink on the coated paper surface. A suitable basepaper optimisation, therefore, should be to form a relatively incompressible sheet, consisting of relatively fine pores, achieved, for example, by using a suitable fine filler pigment that is non-orientable (blocky), be porous but with a tortuous structure such that the permeability is low.

Results of Ink Penetration Studies of Coated Coldset Papers

In the next steps of the study we investigate how coldset inks penetrate and how the ink compounds separate on the coated paper surface. For this, different inks are applied on the surfaces of different coated mechanical papers under the application of printing nip pressure.

As a last step, in order to demonstrate the effect of ink adhesion to the coating layer, model coatings are tested with two inks which were shown to be good and bad in respect to CIC build-up.

Ink Penetration and Component Separation

Two coated VAC paper samples were printed with a laboratory scale printing machine IGT AIC2-5. The target was set to have a constant ink amount of 2.0 ± 0.05 gm^{-2}, which corresponds to print density values of approximately 12 (immediately after printing) and 10 (after 24 hours). The two papers (indicated as 1200111 and 1111584) do not significantly differ in respect to their standard paper technical characteristics, but they show significant difference in respect to the ink component penetration. The analyses were performed using two different commercial coldset inks (P and U). The inks have different rheological properties and chemical composition. As Figure 8 shows, the inks differ mainly in mineral oil concentration, with ink U having the higher level. It can be seen that mineral oil concentration in the paper for ink U remains on a high level but falls in relative concentration faster than that of ink P.

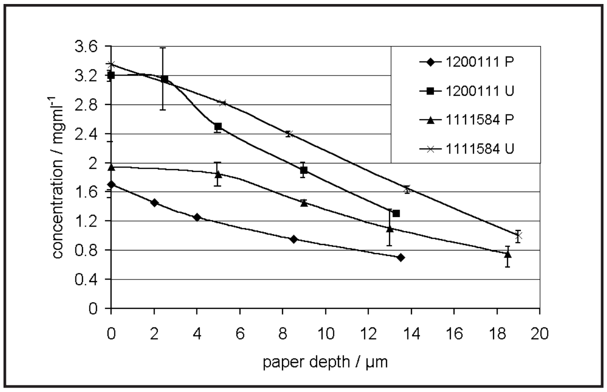

Figure 8. Mineral oil concentration in paper depth profile with inks P and U and two coated coldset paper samples. Ink U creates high mineral oil concentration at the surface but falls more rapidly than ink P as it penetrates deeper into the paper profile. [The subtraction process has succeeded quite well, because the initial points at 0 µm correspond to the original composition of the inks.]

The ink resin measurement has weaker signal intensities. The error, however, seems to be smaller for the samples printed with ink U. It can be seen already that the signal is decreasing most rapidly with sample 1200111 using P ink, (Figure 9).

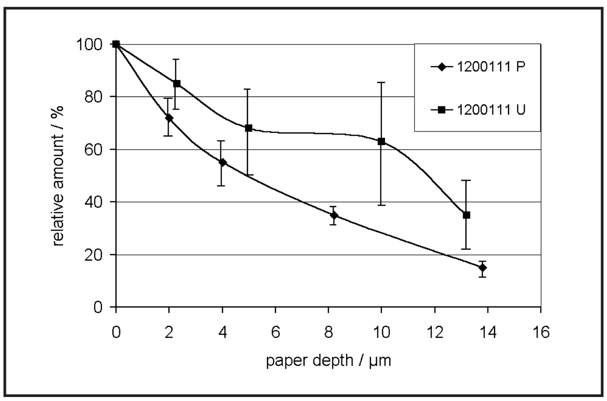

Figure 9. Relative resin amount as function of paper depth, coated mechanical paper and two commercial coldset inks.

Based on these results it can be concluded that resin separation from mineral oil is not taking place so strongly on the coating layer of the coated paper sample (1200111) when using ink U, i.e. more resin is carried into the paper. This means that the ink is expected to have incomplete setting as the resin passes into the paper at the printing nip and immediately after. According to the hypothesis, this will lead to weak adhesion of ink onto the coating, causing quick formation of build-up at the first CIC of the second satellite unit. During a commercial trial, ink P (good) could run over 200,000 copies without cleaning of the CIC, whereas at the same press and with the same printing conditions ink U (bad) could run only 40,000 copies. At this point the positive build-up was so thick that it started to damage blankets at the first printing nip of the second satellite.

Differentiation of Ink Vehicle Absorption for Different Coated Coldset Paper Structures, Characterised by Tack Development Analysis (ISIT)

As Figure 10 shows, the tack curves obtained from a series of paper samples can be easily distinguished. The four different coated coldset papers tested here have been produced with different coating pigments and different basepapers. According to the hypothesis it is expected that lower measured maximum tack force means less absorption of ink vehicle into the coated surface at a given surface roughness, being sufficient only to maintain the ink on the paper surface. The hypothesis is shown to be correct with correlation analyses performed between the maximum tack force of each sample shown in Figure 10 and their respective positive build-up tendency.

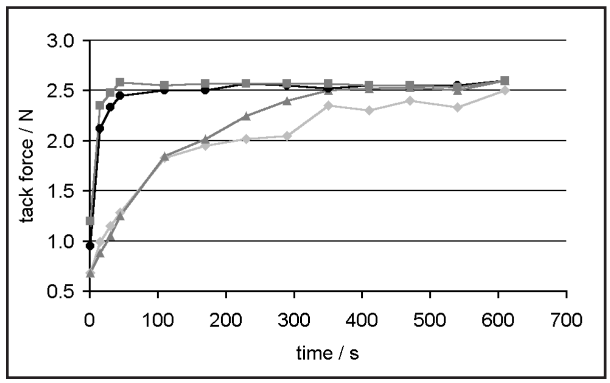

Figure 10. ISIT curves from four different coated coldset paper samples. Measurement performed with optimised settings (Table 1). Curves with lower slope on the tack rise part of the curve and lower maximum tack are less critical in forming positive build-up at the printing machine.

Tack development is seen here to fit the classical picture for positive build-up, i.e. the interface between ink and surface and coating and basepaper are adversly stressed by high tack values. The case for build-up at similar tack values and for the impact of fountain solution in negative build-up relies, however, on the study of ink adhesion.

Ink-Coating Adhesion — Direct Results

A model coating formulation was made that consisted of a fine ground dispersed calcium carbonate (gcc) with 98 %w/w < 2 µm and 90 %w/w < 1 µm, 12 parts latex, Acronal S360D[6], and 0.1 part CMC based on 100 parts of pigment.

[6]Acronal is a product name of BASF, Ludwigshafen, Germany

Enhancing the adhesion of ink to a coated surface was first discussed as a way of resisting offset blanket piling by Gane and Seyler (5), (6). They proposed that the remaining print density after stressing a drying ink layer under static film split conditions could be related to the affinity of the ink for, and its adhesion to, the coated surface. Later, this principle was applied by Haenen (15) showing that rapid ink setting was not a prerequisite for piling as long as sufficient adhesion was maintained between the ink and the coating surface and that the coating and basepaper were both strong and well bonded.

By coating the formulation onto the smooth plastic substrate, described previously, it was possible to analyse the coating structures independently of the basepaper in respect to ink interaction for the two inks previously studied, P and U (good and bad, respectively). Although some caution is needed in the interpretation of the results, since the compressibility (and hence the behaviour in the printing nip) of such plastic substrates is not the same as a real paper substrate, the intrinsic adhesional properties of ink to the coating can be determined. The sample was measured in a calendered state as this provided the greatest differentiation.

Studying the strips visually after the ISIT test made on the gcc, it is clear to see that the residual print density is low for the bad ink U and there is a lot higher ink density left on the surface when the good ink P is used, Figure 11. In this test, the volume of ink applied is constant, and so the higher remaining ink density is due purely to a greater adhesion of the ink to the coating surface. The adhesion to the surface is much lower for the bad ink U than for the good ink P.

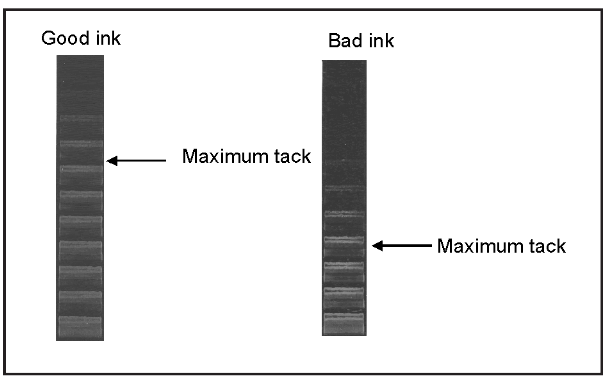

Figure 11. ISIT strips for good and bad inks (P and U) on the gcc coating—the remaining print density in the "pull-off" areas is lower for the bad ink despite the overall higher print density of the bad ink, indicating poor ink-surface adhesion.

It can be speculated here that the negative CIC build-up phenomenon is probably strongly related to a competitive adhesion phenomenon and its relation to fountain solution behaviour: 1) with the ink and 2) with the paper. Also, the thickness of the ink film transferred to the paper surface plays a role. Once again, the schematic mechanism proposed in Figure 4 is supported by these ink adhesion observations.

To go further in maximising ink adhesion to the coating requires that the effective adhesion and stress on that adhesion be quantified. This is achieved by considering not only the remaining print density but also the maximum tack—if there is high remaining print density then the adhesion is high but the stress (maximum tack) on that adhesion also needs to be considered. If the tack value is high, the remaining print density is driven lower, therefore a combination of the two values is the key to understanding the build-up phenomena. The maximum tack value is therefore incorporating an adhesion property and is not dependent on the rate of absorption alone.

Conclusions

Coated mechanical coldset paper is a new challenge for the operating and printing in satellite type coldset offset presses. The paper design needs to account for both basepaper and coating structural effects, especially in cases of imperfect coating coverage. The study here has shown that the runnability properties of the sheet in respect to ink deposits, especially manifest in build-up on the first common impression cylinder of the second satellite unit, depend on a number of measurable parameters. These include, porosity, permeability, rate of absorption and compressibility, ink component separation at the paper surface, ink tack development and importantly the adhesion of the ink to the coating surface in relation to the fountain solution, its flow and position within and upon the coating and basepaper structure.

The basepaper needs to be constructed such that permeability is low whilst maintaining sufficient absorbency on the short timescale and sufficient porosity to accept the fountain solution. The basepaper should also be somewhat incompressible. Both these actions prevent the expulsion of fountain solution under hydraulic pressure during exposure to the secondary nip. In practice this could be achieved by creating a fine pore structure using a relatively stiff fibre mat, incorporating fines and particularly focusing on the potential advantages of using a non-orientable (blocky or aggregated) relatively fine pigment filler. Addition of speciality highly porous fillers may also be advantageous.

The coating needs to have a maximum absorption capacity/porosity and be highly permeable. This target involves minimising the localised back-pressure created by the fountain solution held within the basepaper at the exit of the last printing nip of the first satellite unit, as it becomes extruded under the action of the pressure pulse of the first printing nip in the second satellite unit. Maximum adhesion of the ink in competition to the fountain solution should also be targeted.

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Appendix

Running Conditions for the Full-Scale Print Trials

The press used was a WIFAG OF 790, stacked nine cylinder satellite (page 1 reel outside) over a ten cylinder satellite (page 2)—four backing two, as shown in the example Figure 2. Distance between satellite 1 and 2 was 6.5 m. Fountain solution was at pH 4.9, conductivity 1,300 μScm^{-1} and temperature 16.3 °C, with an additive Sun classic fount 4; 3%, no alcohol.

Deposits were examined on the first CIC of the second satellite unit, always after a constant number of printed copies. Printing was always performed using the same, specially designed, test form (16).

C.J. Ridgway, Senior Scientist, Omya AG CH-4665 Oftringen, Switzerland

E. Kalela, Manager, R&D and Technical Service, UPM-Kymmene/Stracel Mill, B.P. 79, F-67016 Strasbourg cedex, France

P.A.C. Gane, Vice President Research & Development, Omya AG, CH-4665 Oftringen, Switzerland