

INK-COATING ADHESION: the importance of pore size and pigment surface chemistry

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ABSTRACT

The characteristics of ink vehicle absorption into porous structures has formed the basis of a number of recent studies. Kalela, Ridgway and Gane (*11th International Printing and Graphic Arts Conference*, Bordeaux, 2002) considered an example of common impression cylinder deposits as a result of poor coldset ink adhesion especially in the presence of excess fountain solution. These studies centre on the absorption mechanisms of pigmented coatings and how these can be adjusted to enhance ink coating adhesion. By developing 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), it has been possible to assess ink-coating adhesion. To enhance the adhesion properties of inks, two strategies for coating designs are discussed. The first is to increase the number of ultrafine pores and to increase simultaneously the pigment surface area to enable a capillary-driven separation of oils from solved resins and to provide higher adsorptive power for resins. This was tested by the inclusion of a novel surface-structured calcium carbonate. The second is to introduce an oleophilic species into the coating structure, achieved by the inclusion of hydrophobic talc via a costructure between talc and hydrophilic dispersed calcium carbonate (Gane, P.A.C., Buri, M. and Blum, R., *International Symposium on Paper Coating Coverage*, Finland 1999). Mercury porosimetry measurements of model coatings using these pigment combinations are used to illustrate their effect on coating structure. These structures are modelled using a computer network simulator, an absorption algorithm is applied to generate the absorption dynamic for each structure. The differences in wetting front are illustrated. It is seen that only at the shortest timescales is there any difference in the absorption dynamic (ignoring any surface chemistry effects). It can therefore be concluded that the observed improvements in this study of ink adhesion are related to adsorptive mechanisms, and absorption rate governs the dwell time over which this adsorption can occur.

Keywords: ink tack, ink adhesion, printability, ink absorption, ink setting

INTRODUCTION

The attraction of ink for the surface of a substrate, be it non-permeable, e.g. metal, plastic, or porous, such as paper and especially coated paper, is of prime importance for the successful transfer of an image onto that substrate. The offset process is particularly sensitive to the running balance between ink uptake on the printing blanket and its subsequent transfer to the printing medium. However, all printing processes require an affinity between ink and the surface to which it is applied. Normally, this affinity is provided by the initial wetting of the surface by the fluid ink, or by the adhesion directly of dry toner. However, subsequent changes in the ink during drying, especially when associated with further mechanical interactions with the process, such as further film splitting or rubbing/contact against ancillary equipment, transfers large strains from the originally fluid ink to the interface between a setting ink and the substrate surface. The typical example of such a strain transfer occurs when an offset ink is losing the solvating and suspending fluid phase, typically oil, into the permeable porous network structure of a coated paper. The solids increase of the ink results in an observable increase in viscosity or tack. This tackification progressively acts to resist film splitting within the ink layer and, rather, transfers the ever present adhesion to the printing blanket in the wet state to the interface between the ink and the surface of the coating. This adhesional strain is a maximum when the tack is at a maximum or rising towards it.

The rate of absorption of ink fluid into paper coatings has been extensively studied by Schoelkopf *et al.* [1-3]. It is shown that the fractional decrease in fluid content is linear as a function of time in the first regime of tack rise. This finding indicates that the absorption dynamic is controlled predominantly by interconnecting fine pores and not in respect to porosity per se. The permeability of porous networks was shown by Schoelkopf *et al.* [4] to determine the access to the finest pores at the wetting front as the fluid is being absorbed. The important parameters are, therefore, pore size distribution and permeability, which are interlinked by the connectivity of the pore network structure, Ridgway and Gane [5]. It is this latter finding that challenges the traditional view of a porous medium acting as a bundle of capillaries, each of these capillaries absorbing under a Lucas-Washburn dynamic. Instead, the network must be viewed as consisting of a number of interconnected discrete pores, each separated by a throat-like feature. The discrete changes in pore diameter and length determine the wetting dynamic. Pore geometry can act to speed up or slow down the imbibition, Ridgway *et al.* [6]. Furthermore, the short length of the finest pores (assuming isotropy) means that inertial wetting can occur which is linearly proportional to time, Ridgway *et al.* [7]. The overall dynamic is still observed as proportional to the square root of time, due to the access control by the permeability, which is itself viscosity related, but the parameters of surface energy and contact angle are inconsistently determined as porosity changes, Schoelkopf *et al.* [8], confirming the divergence from Lucas-Washburn absorption.

The wetting of the fluid on the surface and within the porous network structure is a function of the relative surface energies of the solid skeletal material and that of the fluid itself. Paper coatings are made up of a number of different species, typically dispersed minerals, binders and additives. Each contributes its own micro environment of surface energy as presented to the molecules of the imbibing fluid. Furthermore, inks consist of solvents and suspensions in a variety of oils and oil mixtures. The coating network surface provides for adsorption and desorption phenomena, effectively creating chromatographic separation of components, Rousu *et al.* [9-11]. The separation is enhanced when interpolymer diffusion can occur, which is observed strongly for polar oils and many paper coating latices, Rousu *et al.* [12]. The situation becomes further complicated when highly polar species are present such as hygroscopic dispersants and wetting agents. In the presence of fountain solution, Kalela *et al.* [13], competition between the ink fluids and the water-based fountain solution can occur.

The absorption behaviour determines the concentration gradient within a setting ink layer, Gane and Ridgway [14]. The concentrating ink resins which are filtered out on the surface of the paper, Rousu *et al.* [9], begin to polymerise and adhere to the surface. Furthermore, the retreat of liquid through the ink layer results in free menisci forming at the ink surface and a concentrating effect occurs there also. This strength of ink adhesion in relation to the adhesive competition between blanket and the paper surface depends on the presence or otherwise of species which either assist or block adsorption to the paper surface materials. The surface chemistry of the porous medium and the ink formulation play the major roles in this adhesional effect in respect to all the fluids and species present.

This paper first of all reviews a novel method for determining ink-surface adhesion by studying the residual print density remaining in the so-called ISIT¹ pull-off area at maximum tack and applies this method to illustrate how the responsibility for good press runnability and image quality lies with the ink formulator and the paper maker in equal measure. Solutions are proposed, including the choice of paper coating mineral surface chemistry and the design of specialised structures of high surface area to assist in controlling both absorption dynamic and adhesion behaviour, Kalela *et al.* [13] and Ridgway and Gane [15]. Using model coatings of pigmented coating formulations, independent laboratory tests are performed to measure porosity and absorption properties which are used to illustrate the effect of pore size distribution, pigment morphology and surface chemistry on the rate of absorption, and in particular the permeability of the coatings. The pore structures are modelled using the pore and throat network simulator Pore-Cor². By applying a wetting algorithm based on the Bosanquet equation [16, 17] the absorption rate of liquid into the structure can be predicted. Comparison is made between porosity, absorption dynamic and the ink surface adhesion.

INK-SURFACE ADHESION: A NOVEL MEASUREMENT TECHNIQUE

Ink tack on paper has been a topic for study for many years. It is well known that the tack of an ink once applied to a porous substrate rapidly changes from the well-defined film split value delivered by the ink maker. This is due to the progressive loss of ink vehicle (suspending and solvating fluid) into the porous network. Many techniques have been proposed to measure ink tack, most of them relying on subsequent film splitting of the

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

² Pore-Cor is a software product name of the Fluid Interactions Group, University of Plymouth, U.K. PL4 8AA

printed layer. Unfortunately, these methods provide no information about the adhesion of the ink layer to the surface, as either the paper is destroyed during realistic tack level determination [18, 19] or because the test is especially designed to limit the strain applied to the interface³. An exception is the method of Gane and Seyler [20, 21] following the concept of Swan and Terry, and Franklin [22-24], which applies an extensional force to the printed film in a single spot measurement, a fresh spot being taken for each tack measurement as a function of time.

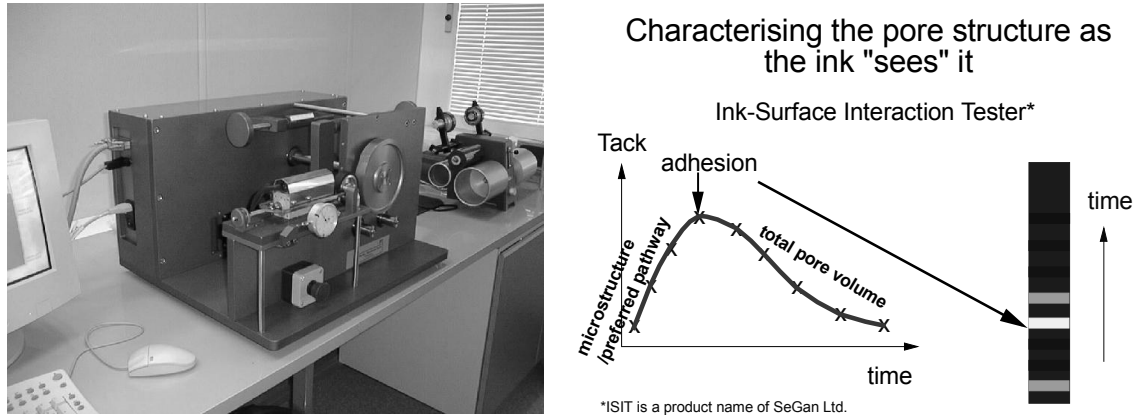


Fig. 1 Ink-Surface Interaction Tester: the apparatus and the measurement of adhesion at maximum tack.

The separation process using the ISIT, Fig. 1, relies on the adhesion of the ink surface to layer at a given time after printing. This is achieved by a tack wheel which has the blanket material attached to its surface. The tack wheel is rolled into contact with the ink layer, held stationary and then removed under a controlled force (constant acceleration). The maximum force required to remove the tack wheel is recorded as the tack force. During the separation, the force is continuously recorded as a function of the time during separation. The force maps out the mechanism of separation, which consists of a breakage of the surface film, followed by a retreat of the newly formed menisci to form a central lamellar filament.

Mechanism of Separation

The tack wheel separation from the thin printed ink layer is a two-step action. First of all, the compression of the rubber blanket-like material creates a virtual parallel plate contact with the deformable paper substrate.

As the ramp-down in contact force begins, its form chosen by the user and controlled by the ISIT software, the separating spring, Gane and Seyler [20, 21], acts to perform the separation of the tack wheel either through the ink film (at low tack) or from the ink film surface (after maximum tack). The initial separation occurs by the breakage of the film and retreat of the newly formed menisci toward the centre of the pull-off area (Fig. 2). This action records the maximum tack force as would be seen by the separation of a printing blanket creating the free meniscus at the film split.

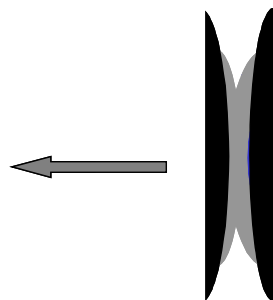


Fig. 2 Initial breakage of the film and formation of the free meniscus under extension is recorded as part of the the tack pull-off curve.

³ Method used by Deltack: a product name of Prüfbau Print Testing Equipment

After the retraction of the menisci to form a central planar (lamellar) filament, Fig. 3, the ink is further extended until finally the filament breaks. The pull-off area clearly shows the traces of the final lamellar filamentation either as a central line of higher print density or as a line of adhesion failure or sometimes pick.

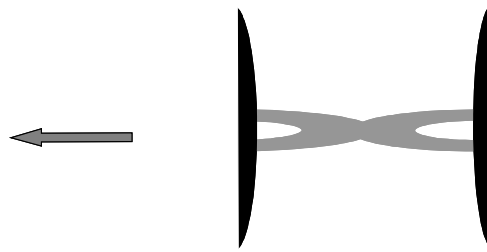


Fig. 3 Retreat of the menisci toward the centre and the formation of the lamellar filament.

At maximum tack, adhesion failure may occur next to the paper, post tack adhesion should fail next to the blanket, if not then poor print rub properties can be suspected.

The two regimes are shown in Fig. 4, which shows a record taken from a high speed camera image of the distance travelled by the tack wheel as a function of time (left axis). Superposed on this distance-time plot are the actual recorded force data. The initial rate of change of position undergoes a slight vibration as the film is broken. The meniscus formation and rapid retreat is then determined as the separation time, T_s , as starting from this initiating vibration. The transition between the two conditions occurs and is seen as a dip in the force as the measurement progresses to the maximum tack for the given pull-off point.

The constant acceleration of the separation within these regimes means that the mechanism can be expressed as an extensional measurement in rheology with a defined rate of change of strain, Schoelkopf *et al.* [2, 3].

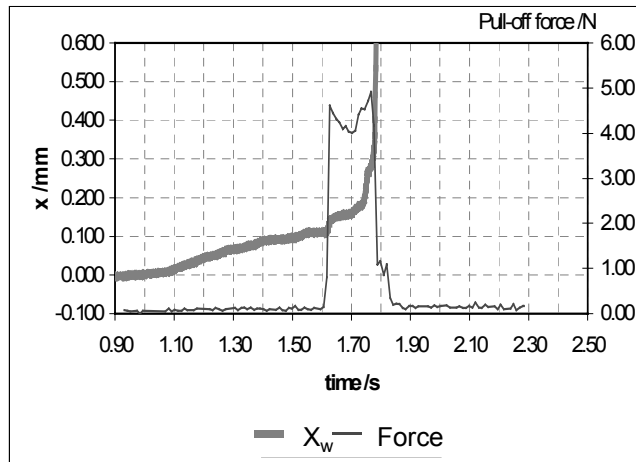


Fig. 4 One to one correspondence of the observed tack wheel displacement (thick line) and the recorded force data (thin line). [Picture reproduced from Schoelkopf *et al.* [3]]

The correspondence between the separation time on the individual force-time pull-off curves and the separation times as shown by the physical tack wheel motion is exceptionally good and supports the two-step mechanism described above. Furthermore, the force data collection continues to record the forces during the filament extension, and they are seen to fall once again to zero at an effective infinite extension.

The interpretation, involving both visual and instrumental examination of the pull-off areas to determine remaining print density on the printed paper strip as a function of the tack force curve over time, proposes a rupture at the weakest point of the adhesion/cohesion chain, Gane and Seyler [20, 21], i.e. either between ink and paper or between ink and blanket, or within the cohesive layer of the ink itself. This is illustrated in Fig. 5, and was used also by Haenen [25] to describe the impact of adhesion on mottling of multi-coated woodfree papers.

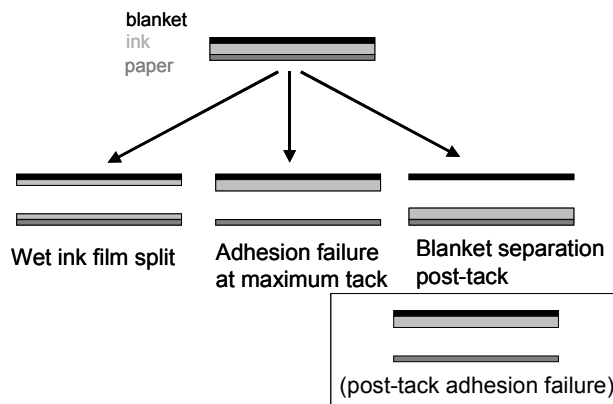


Fig. 5 Separation of a trilayer at the weakest point.

Implications for fountain solution

The impact of fountain solution is seen as a diluent to the ink when a stable emulsion is present. If an ink fails to support emulsification of fountain solution then the liquids separate. This effect, illustrated schematically in Fig. 6, can be particularly important when a delay is present between subsequent nips on a press, as is the case, for example, in a satellite coldset offset press.

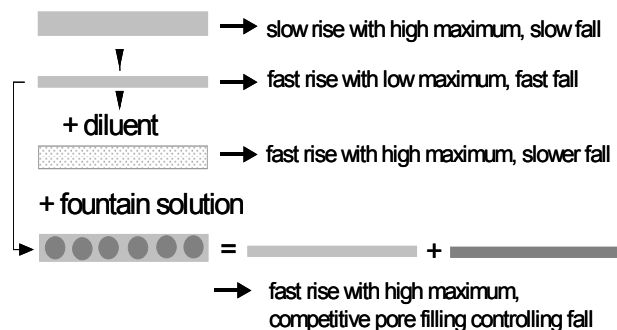


Fig. 6 The impact of ink amount and the emulsification of fountain solution on the tack cycle (rise and fall) characteristics.

In extreme cases, the fountain solution can either remain on the surface or be forced back to the surface under pressure. In the latter case, the hydraulic expulsion of fountain solution from the basepaper through, say, a thin layer of coating can lead to an effect similar to aquaplaning which acts to remove ink that poorly adheres to the coating. Such a mechanism is shown schematically in Fig. 7.

Potential mechanism:

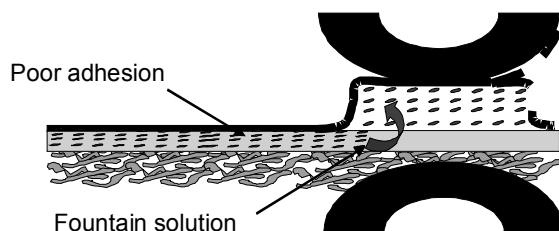


Fig. 7 Proposed mechanism of hydraulic expulsion of fountain solution acting to remove ink that is poorly adhering to the coating - this model is supported by the absorption, porosity and permeability data obtained later in this study. [Schematic taken from Kalela *et al.* [13]].

Since the adhesion measurement principle relies on the contact and removal of a blanket-like material covering a tack wheel on a previously printed sheet, the contact area is strongly roughness related. Since some inks, such as coldset offset inks produce tack levels as low as half that of a typical sheet offset ink, and the surface of some papers, such as newsprint, can be considerably rougher than gloss coated papers, it may be necessary to make model coatings on a controlled microroughness substrate, such as the synthetic plastic laminate paper Synteape⁴, in order to record effective tack measurement of some ink-coating combinations. Such a method also allows the independent study of the coating pore structure effect on ink tack without the impact of the underlying basepaper pore structure. The method, therefore, has potential for wider application beyond the confines of this study.

⁴ Synteape is a product name of Arjo Wiggins

Practical example: high and low adhesion inks

Fine ground calcium carbonate

A standard coating formulation was made that consisted of Setacarb⁵ (gcc), which is a fine ground dispersed calcium carbonate with 98 %w/w < 2 µm and 90 %w/w < 1 µm, 12 parts latex, Acronal S360D⁶, and 0.1 part CMC based on 100 parts of pigment.

Fig. 8 shows an example of two test strips made on this simple 100 % calcium carbonate coating. They show the adhesion of two inks, one with high adhesion and the other with low adhesion. The inks were compared in a study of value-added-coated newsprint (VAC paper) on a coldset web offset press (Kalela *et al.* [13]), where the ink with low adhesion was shown to give significant build-up on the second satellite unit.

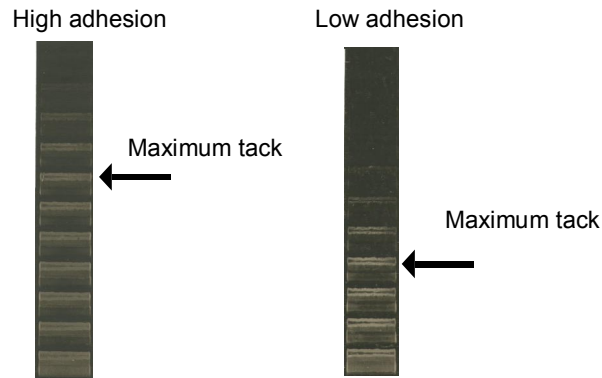


Fig. 8 ISIT strips for high and low adhesion inks on 100 % gcc coating - the remaining print density in the "pull-off" areas is lower for the low adhesion ink despite the overall higher print density of this ink at constant application weight.

The high adhesion ink in this study has a slower tack cycle, visible as observable pull-off points over a longer cycle time (further along the strip), indicative of either a higher viscosity oil or significantly higher volume of oil. Since the print density is low it can be concluded that the oil volume is the parameter here as it is known that other components were kept constant. Such an ink, however, would be considered too weak in print density and having "low mileage" in respect to ink consumption. However, if the emulsion stability with fountain solution is maintained or improved by such an oil dilution, the mechanism of good runnability can be promoted by the application of a thicker ink layer whilst maintaining print density. A further possible disadvantage though is that the high adhesion ink is slow setting and could lead to set-off problems during further handling. The low adhesion ink shows a more rapid tack cycle and traditionally could be expected to show "chalking". Both of these test inks are of generally low overall tack. This is especially the case for the low adhesion ink. So, it can be readily concluded that build-up phenomena which might occur on the press are not driven in this case by high tack values nor by high rates of tack rise, in fact to the contrary.

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 needed. The print density is therefore also inversely related to the maximum tack. The maximum tack value is therefore incorporating an adhesion property and is not dependent on the rate of absorption alone. The function to be maximised for the best effective adhesion is therefore proposed to be related to the ratio of the remaining print density: maximum tack value.

Clearly, the solution lies at least in part in ink formulation and this, in turn, lies in the hands of the ink maker.

⁵ Setacarb is a product name of Omya AG, CH 4665 Oftringen, Switzerland

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

MODIFYING COATING PIGMENTS

The addition of two other specially designed pigments to the host ground carbonate is illustrated in respect of ink adhesion. These pigments consist of a novel high surface area calcium carbonate (10 parts), having the form best described as a porous "golfball", and a costructure between hydrophobic talc and hydrophilic dispersed calcium carbonate, respectively.

Golfballs

This pigment⁷ is highly porous with a surface area in the region of 70-80 m²g⁻¹ and a relatively uniform particle size of 15-20 μm. A schematic representation of a coating including such a pigment is shown in Fig. 9. The bulky particles with internal void structure are able to absorb fluids rapidly due to the pore size design and maintain the openness (permeability) of the coating, Ridgway and Gane [15]. They act effectively as an absorption sink while maintaining the bulk of the coating. This action assists in retaining fountain solution under external pressure and also provides a highly active adsorptive surface for ink resins and toners in general.

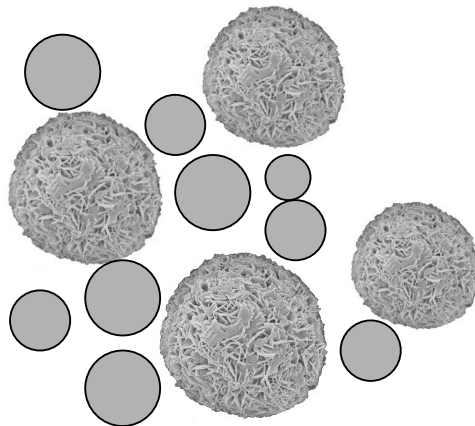


Fig. 9 Addition of golfball pigment to a coating colour containing fine ground carbonate.

Costructure of talc and CaCO₃

Talc particles have a high aspect ratio and so increase the coating coverage but reduce the porosity and permeability of the coating, Fig. 10. Talc is hydrophobic and remains so in this costructure, (Gane *et al.*, [26]). Due to the hydrophobicity, the permeability will be reduced in respect to the fountain solution. As non-polar oils, such as aliphatic mineral oil, are adsorbed to the talc, so polar components such as vegetable oils and solved resins can adsorb onto the dispersed polar calcium carbonate surface such that the adhesion of the ink should be improved.

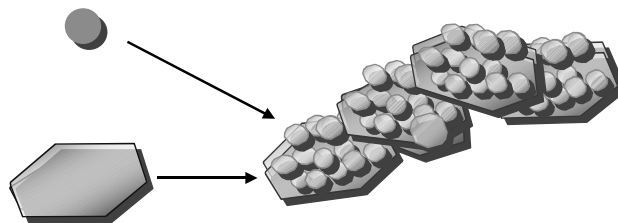


Fig. 10 Costructure of talc and CaCO₃

⁷ It forms just one of a family of newly developed surface modified pigments of various particle size and surface area.

The three formulations of standard gcc and the the mixes of gcc plus the two additive pigments, respectively, were coated onto aluminium foil for mercury porosimetric analysis, and coated onto the plastic substrate for ink adhesion analysis (ISIT).

MERCURY POROSIMETRY

A Micromeritics Autopore III mercury porosimeter was used to measure the percolation characteristics of the coating samples. The maximum applied pressure of mercury was 414 MPa, equivalent to a Laplace throat diameter of 0.004 μm . The equilibration time at each of the increasing applied pressures of mercury was set to 60 seconds. The mercury intrusion measurements were corrected using the software Pore-Comp⁸ for the compression of mercury, expansion of the glass sample chamber or 'penetrometer' and compressibility of the solid phase of the sample, which adopts the following equation from Gane *et al.* [27]:

$$V_{\text{int}} = V_{\text{obs}} - \delta V_{\text{blank}} + \left[0.175(V_{\text{bulk}}^1) \log_{10} \left(1 + \frac{P}{1820} \right) \right] - V_{\text{bulk}}^1 (1 - \Phi^1) \left(1 - \exp \left[\frac{(P^1 - P)}{M_{\text{ss}}} \right] \right) \quad [1]$$

V_{int} is the volume of intrusion into the sample, V_{obs} the intruded mercury volume reading, δV_{blank} the change in the blank run volume reading, V_{bulk}^1 the sample bulk volume at atmospheric pressure, P the applied pressure, Φ^1 the porosity at atmospheric pressure, P^1 the atmospheric pressure and M_{ss} the bulk modulus of the solid sample. The volume of mercury intruded at the maximum pressure, once corrected for sample compression effects, can be used to calculate the porosity of the sample.

The three coating formulations were analysed as coated onto aluminium foil. A strip of uncoated aluminium foil was first analysed in the mercury porosimeter such that its compression behaviour could be determined. A strip of coated foil was then measured for each coating formulation. The intruded volume of the coating is achieved by extrapolating the initial part of the mercury intrusion curve which is representative of the foil, Fig. 11.

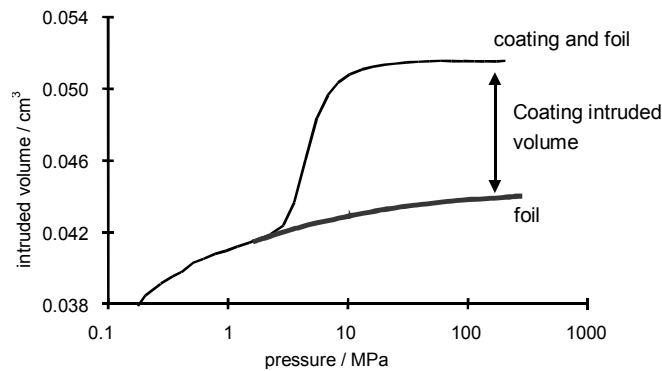


Fig. 11 Mercury porosimetry for coating formulation on aluminium foil after corrections [27].

The mercury intrusion curves into the coating alone is calculated by subtracting the extrapolated foil intrusion curve from the intrusion curve for the coating on the foil. Fig. 12.

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

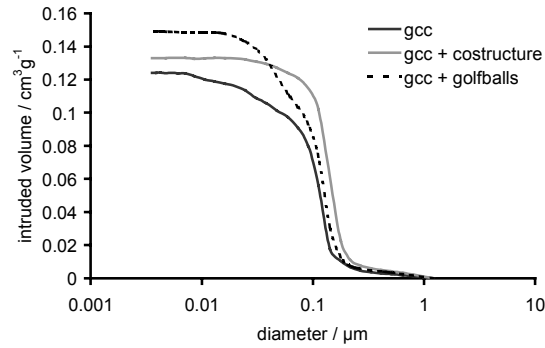


Fig. 12 Mercury intrusion curves for coatings as volume intruded per gram of coating

The addition of the golfball pigment has introduced a lot more fine pores as can be seen in Fig. 12. The pore volume has also been increased. The addition of the platy costructure has also increased the pore volume and also the diameter at the point of inflection is increased.

The porosity values for the coatings were determined independently and the porosities for the three coatings are 22.01 % for the gcc, 23.68 % for the gcc and costructure and 27.61 % for the gcc and golfballs.

The mercury porosimetry data and measured porosities are used to develop simulated pore structure networks which match the percolation and porosity of the measured samples.

THE NETWORK SIMULATOR

The network simulator is a computer model that simulates the void-space structure of porous materials. It has been used to model the structures of a wide range of porous materials including sandstones [28], medicinal tablets [29] and soil [30]. It uses a unit cell with 1 000 cubic pores in a 10x10x10 array, connected by up to 3 000 throats, i.e. one connected to each cube face. The structures are optimised such that the simulated intrusion curves match as closely as possible the experimental curves and the experimental porosity is accurately reproduced.

The unit cell for the gcc coating, for example, is shown below in Fig 13.

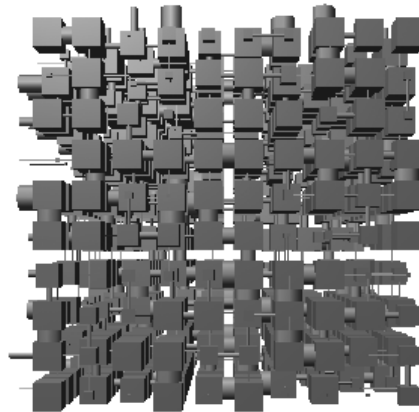


Fig. 13. Pore-Cor unit cell for gcc structure, unit cell size 17.33 μm

Implementing the wetting algorithm

Details of the application of the wetting algorithm have been previously published [17]. The Bosanquet equation [16] is used to calculate the wetting flux into each pore as defined by the entry throat(s) in the void network. A mass balance control is used to ensure that a pore, once full, delivers only the network permeability limited flux into the next exiting throat(s).

The dynamic absorption into the gcc and gcc plus speciality pigment structures was modelled using the fluid properties of hexadecane, an apolar liquid which has a similar wetting relationship to the coating surface as a typical mineral oil as used in ink formulations. Such aliphatic alkanes and show a readiness to wet a freshly ground (and dispersant-treated) calcium carbonate surface [31].

Fig. 14 shows the unit cells for the three comparative coatings modelled using a grid structure so that the depth of the wetting fluid in the structures at a chosen time can be seen. The top row shows the fluid position in the unit cells after 50 μs and the bottom row shows the position after 500 μs . The first column is the gcc sample the second column the gcc with the costructure and the final column is the gcc with the golfballs.

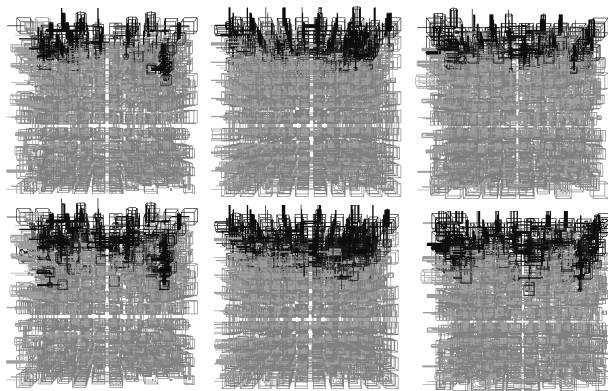


Fig. 14 Unit cells for gcc (unit cell size 17.33 μm), gcc with the costructure (unit cell size 17.91 μm) and gcc with the golfballs (unit cell size 14.99 μm) showing oil absorption at 50 μs and 500 μs .

These unit cells show that after 50 μs the unit cells incorporating the co-structure and the golfballs have a more even fluid front, i.e. less preferred pathway flow, however after 500 μs there is very little difference between the absorption depths.

The absorption curves for the unit cells in Fig. 14 are shown in Fig. 15. Previously it has been shown that at very short times the absorption rate of a fluid is linear with time [32]. The absorption rates at very short times have been magnified to show the fitting of linear trendlines, all of which have an R^2 value of above 0.98. The equations next to the legend show the equations of these lines and it can be seen that the effect of the costructure is to increase the initial absorption rate slightly in comparison to the carbonate alone, and the golfball pigment has increased the absorption rate further. This is at times of only a few microseconds, at longer times the absorption rate between the three structures becomes even less differentiated.

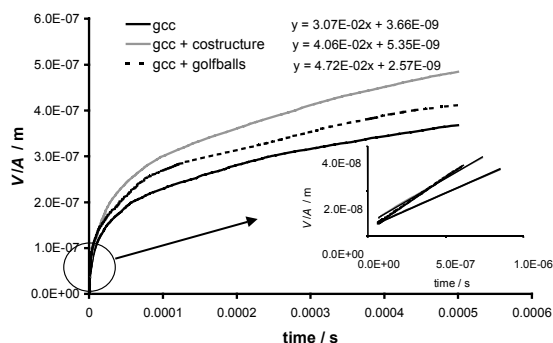


Fig. 15. Network model absorption curves for hexadecane (volume uptake, V , per unit cross-sectional area of the sample A , against time) together with the linear fits at the shortest timescales.

As we shall see later, the small differences in absorption dynamic cannot be responsible for the differences that will be seen in respect to ink-surface adhesion. This means that the adhesion of the ink is not a strong function of the absorption rate of the ink vehicle but is likely to be dependent on the differential adsorption of the ink and its components onto the various surfaces within the coating structure, depending on surface area available and the surface chemistry involved.

The absorption model takes account of pore structure only and does not differentiate between multiple surface chemistries as are introduced for example using the talc-carbonate costructure. These surface chemistry effects will undoubtedly play a role for this particular additive.

OBSERVED EFFECTS ON INK ADHESION

The three formulations were coated onto the plastic substrate for ink adhesion analysis (ISIT) as previously described.

The effects of the additive pigments are clearly seen (Fig. 16). As we saw in Fig. 12, the addition of the golfball pigment has introduced a lot more fine pores, the result of which is that the initial tack rise is greater as the ink vehicle is absorbed faster. The pore volume is also increased. The addition of the platy costructure has the effect of reducing the tack rise rate and lengthening the tack cycle, thus both reducing permeability and pore volume. These interpretations of the curves are supported fully by the porosimetry of the coatings. The addition of the platy costructure particles reduces the permeability and the absorption rate, and this is evidence that the coating is more closed. The addition of the golfballs speeds up the absorption and increases the permeability as there are more micro pores and also an increased pore volume. Both of the additive pigments improve the remaining print density at the maximum tack pull-off point, Fig. 15. These effects parallel those seen in the simulation at short times which confirms the importance of the finest pores in determining the tack rise of an offset ink.

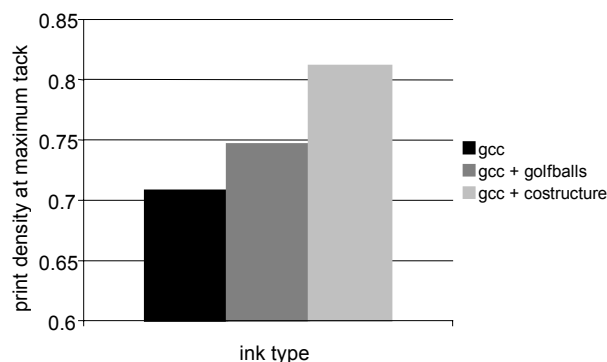


Fig. 16 Remaining print density at maximum tack for the low adhesion ink on the three coating formulations.

The addition of these pigments has also reduced the maximum tack value and in combination, therefore, with the increased remaining print density show an improvement in ink adhesion, Fig. 17.

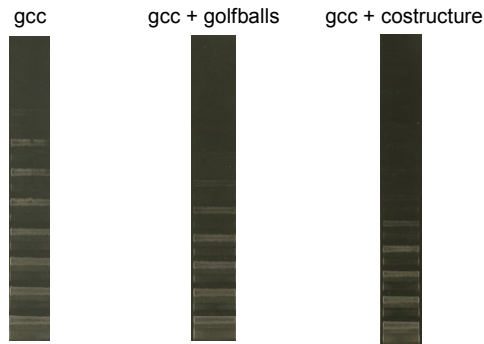


Fig. 17 Improved ink-coating adhesion by the inclusion of golfballs and costructure as seen by increased remaining print density in the "pull-off" regions.

Ink adhesion / fountain solution balance in practice

Build-up in a printing press can be reduced by reducing the competitive action between fountain solution interference and ink adhesion to the coating surface. It is essential, therefore, not only to increase the intrinsic adhesion of the ink to the coating but also to balance porosity and permeability to account for the uptake and distribution of fountain solution, especially between coating and basepaper. It is for this reason that the two extremes of coating permeability are illustrated above, both of which improve ink-coating adhesion, but each of which provide a different absorption and permeability dynamic. Only print trials can now be used to show which strategy is suitable for which coating-basepaper combination. This will depend on basepaper furnish, permeability, porosity and wettability as well as coat weight, the binder formulation employed and the way it is applied.

The solution, therefore, lies partly also with the choice of coating pigment and formulation and therefore lies in equal part in the hands of the papermaker.

CONCLUSIONS

Studying ink-coating adhesion is a new challenge for the runnability of printing papers. The paper design needs to account for both basepaper and coating structural effects, especially at low coat weight applications.

The controlling parameters from the viewpoint of the paper include, porosity, permeability, rate of absorption and compressibility, and importantly the adhesion of the ink to the coating surface in relation to the fountain solution flow and position within and upon the coating and basepaper structure.

The absorption rate properties for liquid imbibing into the structures have been studied both experimentally and by modelling. The correlation of absorption rates between experiment and the model system shows that the fine capillaries control the ink tack rise.

Maximum adhesion of the ink in competition to the fountain solution should be targeted. This factor has been exemplified by both the selective design of the ink, having a high volume and maintaining a good fountain solution emulsion, and by incorporating speciality highly ab- and adsorbing pigments, with high and low permeability respectively. By comparing the adhesional changes observed for the different coatings and their absorption properties it can be seen that adhesion in these cases is strongly related to surface chemistry and the surface area properties of the coatings, while the absorption rate determines the residence time over which the selective adsorption can take place.

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