The role of pore density in the setting of offset printing ink on coated paper

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ABSTRACT: One of the critical features that determine the appeal of the printed page is that the printed areas should have a higher gloss than the unprinted paper, in other words a positive "snap." Coating pigment can be a critical factor, with very fine pigments, which generate high paper gloss, often giving poor or even negative values of snap [1, 2].

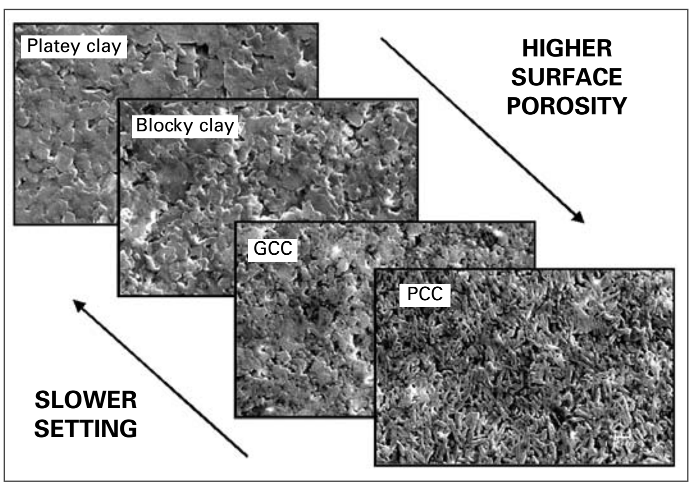
Coatings containing ultrafine pigments also give a rapid tack buildup leading to press problems such as back trapping and piling. Some research attributes this fast ink setting behavior to the presence of very fine pores [1-4]. One report suggests that when the ink sets too quickly, there is not enough time for the ink film to level after printing, reducing smoothness [5].

For a wide range of commercial coating pigments, the most important factors determining offset ink setting rate are the number of pores per unit area of coating (pore density) and their size. For coatings of equal pore density, larger pores set ink faster. Compared at equal pore volume (which is a function of size and pore density), coatings with smaller pores set ink faster because of the larger number.

Application: A paper designed to give good print quality is very desirable. Knowing which factors govern ink setting rate is a valuable tool in designing new grades of coated paper which have improved press runnability and ink gloss. This new way of interpreting coating porosity should help paper mills work with pigment and binder suppliers to engineer coating structures to achieve those qualities.

MEASURING PORE DENSITY

We used conventional mercury intrusion porosimetry to determine the mean pore diameter and pore volume of pilot coated papers prepared using a wide range of commercial pigments under carefully controlled conditions. We used these results to obtain comparative values for the bulk pore density of the coatings. These were in qualitative agreement with visual estimates of the surface pore density obtained from electron micrographs. We found that coatings with ultrafine pigments, both kaolin and calcium carbonate, had more pores in a given area of paper than coatings with engineered or platey grades of clay (**Fig. 1**).



1. Surface electron micrographs of coated papers revealing effect of coating pigment on surface pore density.

NORMALIZING THE INK SETTING RATE FOR PORE NUMBER

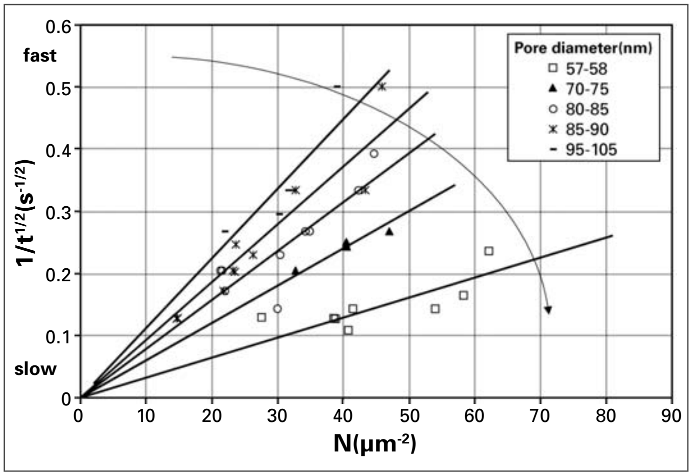
We studied the ink setting rate using an ink surface interaction tester (ISIT). This equipment samples the tack force of the drying ink film as a function of time [6]. The rate of ink tack build varied monotonically with the volume of vehicle removed from the ink.

We were then able to plot the rate of ink tack rise ($1/t^{1/2}$) as a function of the number of pores for coatings grouped according to their average pore size (**Fig. 2**). The curved arrow shows that as the average pore size decreases, the ink sets more slowly *if the coatings have the same number of pores.* When we plotted the data in the conventional way, as setting time against pore radius for constant pore volume (**Fig. 3**), we found that as pores become finer, ink setting rate becomes faster, in agreement with previous studies. We have determined that this effect is not a direct consequence of the finer pore size, but of the increasing number of pores present as their size becomes finer.

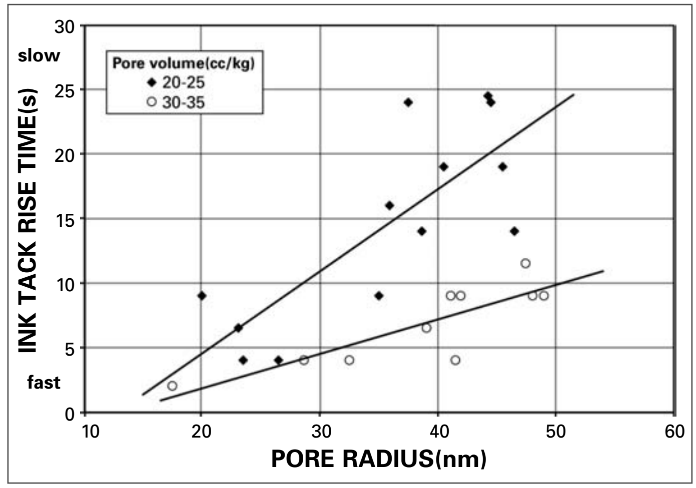
CONCLUSIONS

The capillary imbibition model of Lucas-Washburn predicts that ink setting rate should increase as pore size increases [7]. However, this equation applies to a single pore and therefore paper coatings should be compared at equal pore density. Taking this into account, our proposed model shows that the volume of distillate removed from the ink by the coating varies as $k\,N\,R^{3/2}\,t^{1/2}$, where N = the number of pores per unit area, R = the pore radius, and k = a constant. The Lucas-Washburn model predicts $k\,N\,R^{5/2}\,t^{1/2}$, which differs from our model by $1/R$.

Our model shows that by normalizing ink setting rate for a constant number of pores per unit area of coating, larger pores will give faster ink setting. However, if compared at equal pore volume, coatings having more numerous



2. Ink setting rate as a function of number of pores, showing retarding effect of reducing pore size.



3. Conventional plot of ink setting rate against pore radius at constant pore volume.

smaller pores will set ink faster, as normally observed. In practice, ultrafine pigments, which give very fine pores, set ink very fast because the large number of pores has a greater influence than their size. This principle has general applicability to most clay and calcium carbonate coatings used in gloss papers today. **TJ**

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INSIGHTS FROM THE AUTHORS

Our company supplies a significant quantity of minerals for coated paper grades used in offset lithography. A fundamental understanding of the coated paper properties achieved by using these minerals and the effect on offset print quality is vital to achieve optimal printability. This understanding then helps us design better pigments for our customers in the paper mills, and indirectly to the printers.

Significant work in recent years has focused on the link between coating structure and ink setting rate and the link between this and print gloss. Many of these studies use capillary imbibition theory to describe the flow of ink oils from the ink into the paper coating. This theory (Lucas-Washburn) is valid for a single capillary or pore, but the effect of the number of pores per unit area near to the surface of the coating is often ignored. In this work, we considered the number of pores per unit area as well as the size. The fastest ink setting rate occurs with coatings that have a large number of pores per unit area, and larger pores. This analysis was found to hold true for a range of different mineral types [precipitated calcium carbonate (PCC), ground calcium carbonate (GCC), and kaolins], which were combined with a typical offset color formulation and applied with a pilot coater to a freesheet base paper. This work has extended the work of others by applying findings to a wider range of minerals and by showing the influence of both the number of pores per unit area and the pore size.

The most difficult challenge in this study was finding an accurate measure of the pore density. This was particularly difficult with kaolins of high aspect ratio. Two methods were used, the first involved visual estimation and counting of pores present at the surface of the coating layer using SEM micrographs and image analysis. This method proved too subjective, as it was difficult to see what was a pore and what was surface roughness. Determining where one pore stopped and another one started was also difficult. Owing to the subjective nature of the above method, we eventually used mercury porosimetry to obtain a measure of the "bulk pore density" within the coating.

This work was carried out as part of a PhD thesis, and many interesting findings were made during the three years study. The most interesting point to me was that very different mineral pigments (PCC and GCC and platey kaolins), which produced very different coating structures, all showed similar ink setting behavior when the ink setting rate was normalized for a single pore. This implies that consideration of the pore density as well as the pore size is vital in understanding ink setting.

Our next step has been to use surface analysis techniques such as SIMS and XPS to obtain more information on the chemical composition of the ink film at the surface, and enable us to investigate how the pigment influences this.

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