

# The Influence of Kaolin Aspect Ratio on Offset Printability

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⊕ KAOLIN

⊕ GCC

⊕ PCC

# **The Influence of Kaolin Aspect Ratio on Offset Printability**

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## **ABSTRACT**

Maintaining quality in a cost focussed market is challenging, but for coated papers to have a future especially in the commercial printing and magazine sectors, they need to be able to maintain “quality” advantages over lower cost alternatives. Print quality and press runnability are especially important areas and issues here can really weaken a papers brand image. In this paper we show how different pigment concepts can influence printing, both in terms of quality and press related issues such as piling. Controlling porosity, topography and strength are critical to achieving good printability and in these studies we see that increasing pigment aspect ratio is powerful tool for influencing these parameters.

## **INTRODUCTION**

Producers of coated printing and writing papers in the mature markets of North America and Europe are facing very challenging times. Demand for these grades has fallen sharply in recent years for many reasons including competition from Asian producers, competition from other media, the global recession and of course substitution of coated grades with uncoated grades.

This puts ever increasing pressures on paper makers to reduce the costs of the coated grades. However, quality cannot be forgotten. For coated papers to have a future especially in the commercial printing and magazine sectors, they need to be able to maintain “quality” advantages over lower cost alternatives.

What constitutes quality is often debateable and it is questionable whether a unit or two in brightness or a few gloss points really bring a different quality feel to the end user. Publishers for example often use paper specifications as guidelines and rely more on the look and feel of the paper. While brightness can often be sought after, parameters such as opacity and image quality are perhaps more universal.

Printers mustn't be forgotten when discussing quality. For a printer, quality is really defined by press runnability rather than the traditional paper specifications. Factors such as stiffness, ink demand, ink piling and water adsorption etc become more crucial. These printability factors will be key to a paper's brand image. Papers which consistently cause problems are avoided by printers and there may be an increased charge for a given print run if a problem paper is chosen by a publisher.

For this reason maintaining good print quality and press performance is essential to the future of any coated paper grade and care must be taken when looking to reduce costs that these quality characteristics are not impacted.

There are many factors which can influence printability in coated grades. Fibre selection, application, grammage and formulation are all crucial factors. However, pigment selection is also a critical consideration in this respect. Coated graphic papers are mainly printed using offset and rotogravure processes. While these are different in nature and require different substrate characteristics the requirement to control porosity and topography are universal. For offset printing, surface strength and dimensional stability (especially in sheet fed presses) are also important.

Much work has been done over the years assessing different pigment types and mixtures and their impact on print quality. In particular the role of kaolin in affecting ink setting rates, ink transfer and ink holdout is well documented.

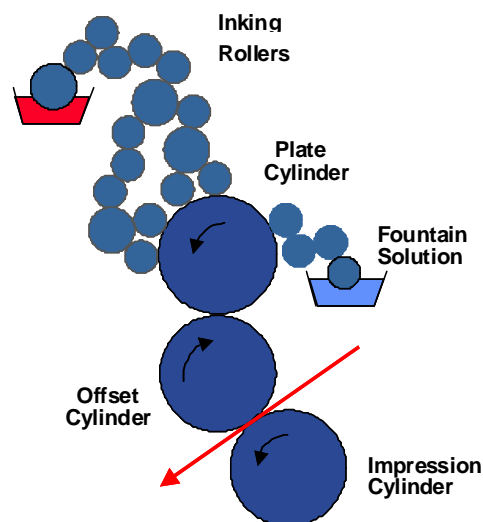
[1,2,3,4]. However, relatively little work has been done looking at how kaolin type and level in a pigment recipe effect printability and press runnability.

In this paper we focus on kaolin aspect ratio and review its impact in controlling porosity and print quality in offset applications. We also include new studies showing how kaolin aspect ratio can influence press runnability factors such as stiffness and ink piling.

## FACTORS AFFECTING OFFSET PRINT QUALITY AND PRESS RUNNABILITY

Offset lithography is the most common printing process used today and is set to remain so for the foreseeable future. A schematic of the process is shown in Figure 1, but in brief, it is a planographic (flat) printing process using aluminium plates which are treated to produce areas that are water accepting and areas that are water repelling. Water (fountain solution) is then applied, followed by the ink. These will adhere to the different areas of the plate to form the image. The image is then offset or transferred onto a rubber blanket before contact with the substrate. Colours then 'backtrap' onto the next printing blanket.

**Figure 1. Schematic of the Offset Litho Print Process**



Offset Lithography is a demanding process in terms of the requirements of the paper substrate. For example, high tack forces can be generated during printing requiring high paper strength if problems such as picking and ink piling are to be avoided. Good dimensional stability is needed to ensure print stays in register and for sheet fed grades to avoid paper jams, which can result in lost productivity and waste. Controlling surface topography and homogeneity are also important if high quality images are to be produced [5].

It is also apparent that as presses have developed the demands placed on the substrate become even more challenging. In today's high speed printing world, the water levels and balance can also become critical factors in waste creation. The water uptake and distribution will also impact the sheet registration and image stability, especially on perfecting sheet-fed presses (printing both sides simultaneously), where there may be up to 12 passes, before the paper can relax [6]. Likewise, as presses have developed, so have the aspirations for quality. Dot frequency and image resolution have improved, changing from 150 dpi to 300 dpi. This puts even greater demands on papers for surface homogeneity. These smaller dots (~2 $\mu$ m) are also far less forgiving to piling (build up of

deposits on press) and mottle. There is also more water associated with each tiny dot which means that many of the tiny dots may wash off onto the blankets increasing the blanket wash frequency thus impacting productivity and waste generation.

Paper structure, porosity and surface roughness will be key factors affecting all of the above. Porosity will impact the ink setting rate, ink tack build and water uptake [7,8]. Mottle tendency, picking and ink demand can also be linked to the porosity characteristics of the coating [9]. Paper topography (gloss and roughness) will affect the print gloss [10,11,12].

While many factors contribute to porosity and roughness of coated papers, it is clear that pigment selection can have a major part to play [13]. If the links between pigments and performance are to be understood then both pigments and coating structure need to be characterised in a rigorous way.

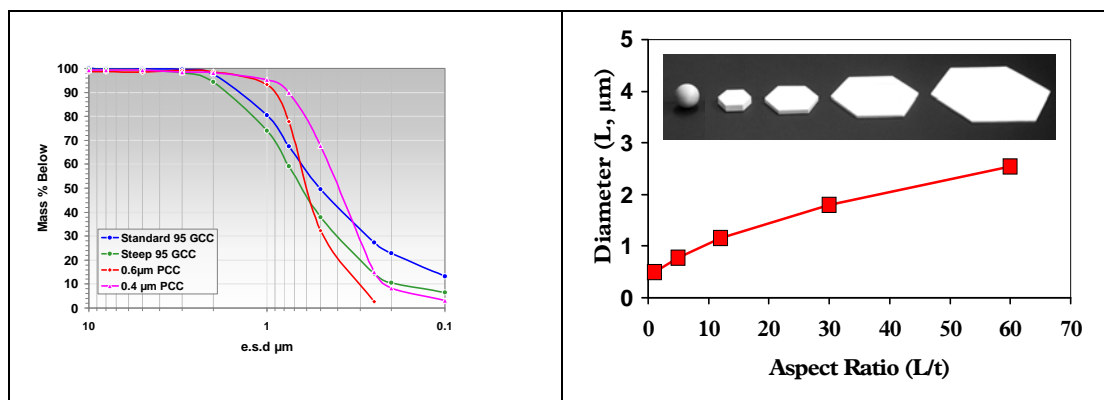
## CHARACTERISING PIGMENTS

There is a wide choice of pigments available to us differing dramatically in size and shape. All of these will clearly give very different coating structures and we need to understand what key pigment properties we need to characterise in order to predict coating structure.

In terms of using some simple measure to link to coating structure we have adopted the d50 for the average particle size and a ratio of the d30/d70 for the steepness [4].

A third variable in the case of kaolin is the shape, or aspect ratio, of the particle. This is more challenging for the pigment producer to control, but techniques are now in place to modify and control the shape factor of kaolins during production through a patented conductivity based measurement[14].

**Figure 2. Characterising Pigments**



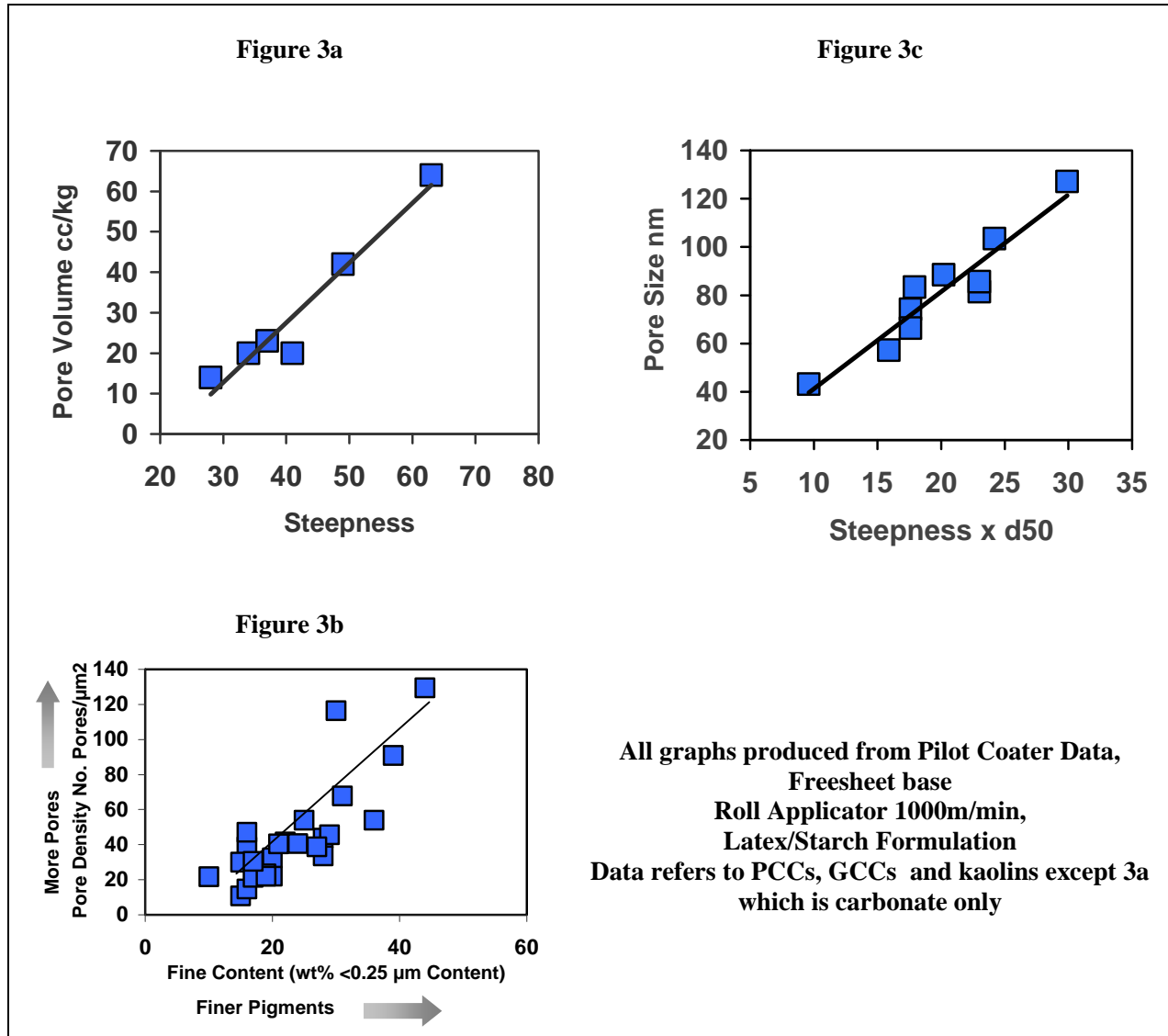
## EFFECT OF KAOLIN ASPECT RATIO ON PORE STRUCTURE AND POROSITY

The wide choice in pigments can lead to very different coating structures in terms of the balance between pore size, pore volume and number of pores. Through extensive pilot coating work and paper characterisation studies we have developed some rules for understanding the link between pigments and coating structure [2,15].

If we consider single component systems then the key relationships are firstly the steepness of the particle size distribution which affects the pore volume and bulk porosity (Fig 3a). The more monosize the distribution, the higher the pore volume will be. The fineness of the pigment particles will affect the number of pores in a coating

(Fig 3b) and the combination of fineness and steepness will affect the pore size. Finer and broader particle size distributions will give finer (and also broader) pore size distributions (Fig 3c)

**Figure 3. Pigment Effects on Coating Porosity**

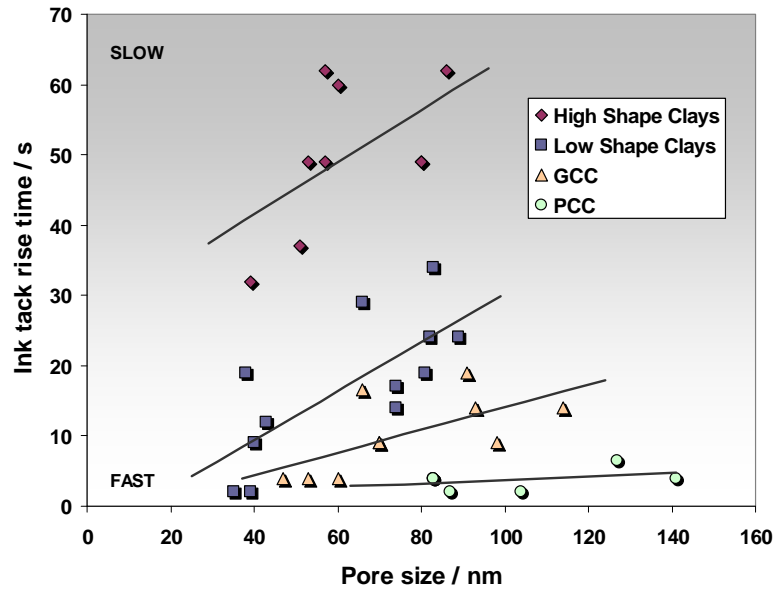


These pore structure effects have been shown by Preston et al [2,15] to be critical in governing the ink setting rate in offset printing, with large numbers of large pores giving the fastest ink setting rates. The model describing the link between coating structure and ink setting is adapted from the Lucas Washburn equation for capillary imbibition in cylindrical pores, but corrects for the viscous resistance to flow in drying inks and accounts for pore number effects. These studies have gone on to show that fast ink setting substrates can reduce print gloss development through macro-roughness effects coming from insufficient time for ink film levelling coupled with micro-roughness effects associated with resin depletion at the print surface [1,15].

However, in this work the role of shape in governing ink setting and print gloss development is less clearly defined as many of the correlations were inferred from measurements of bulk paper structure. When shape is introduced into

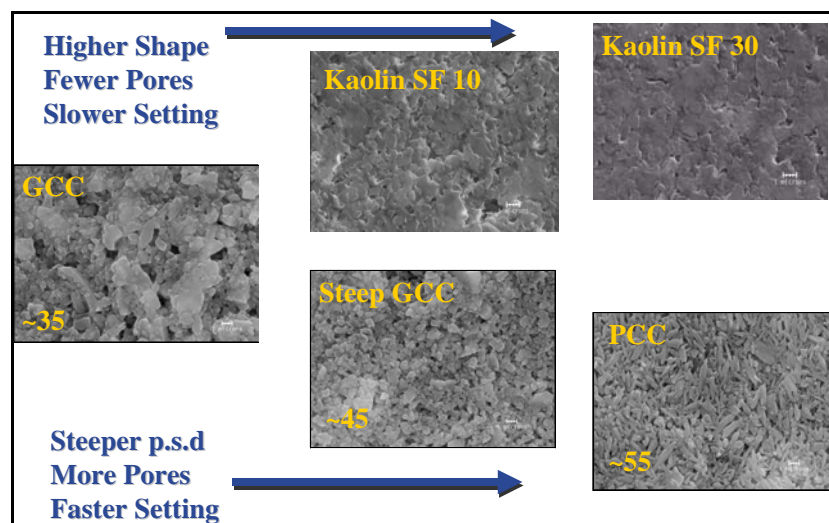
a coating then it becomes apparent that bulk and surface structure can become disconnected, especially after calendaring. Examples of this effect can be seen when the relationship between ink setting and pore size is determined for a range of different pigments coated onto a freesheet basepaper in a pilot coating application (Fig 4).

**Figure 4. Offset Ink Vehicle Absorption for a Wide Range of Pigments**



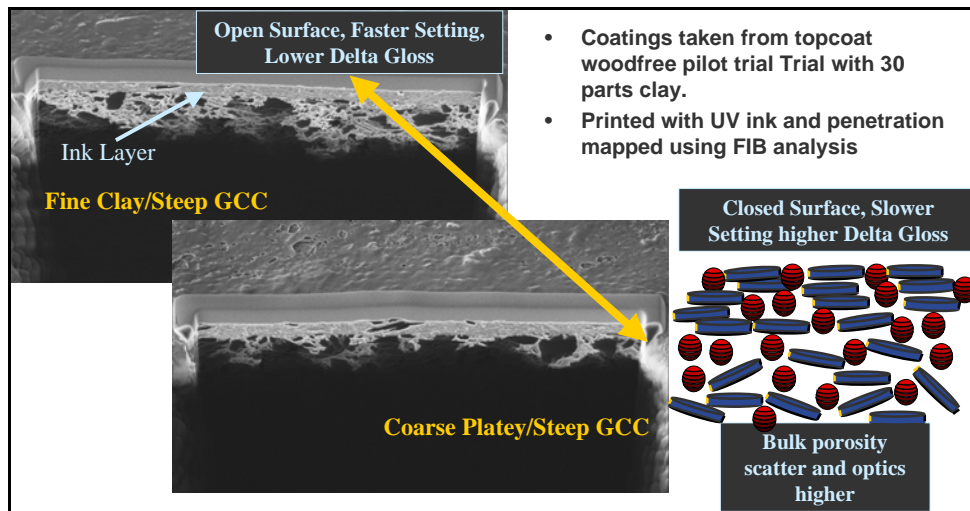
It is apparent that increasing the number of pores in the coating (in this example shown as finer pore sizes) increases the ink setting rate (measured as the ink tack rise by ISIT™ [16]). However, different pigments fall on different lines. Higher shape pigments will give slower ink setting for a given pore size or pore number. This relates to the ability of high aspect shape pigments to align on calendaring creating a more closed surface and a more tortuous path for fluid flow through the coating. Visually it is easy to understand these effects when we consider simple SEM pictures of paper surfaces coated with sole pigments (Fig 5).

**Figure 5. Effect of Pigments on Surface Porosity**



However, it is also evident that similar effects are seen in mixed component systems when high shape kaolins are used to partner carbonate. In the example below (Fig 6) the kaolin type is varied in a freesheet recipe based on 75 parts of narrow particle size distribution carbonate. The penetration of the fluid phase of the ink was then mapped using focussed Ion beam analysis [17, 18]. It was evident that the extent of penetration into the coated paper surface was much reduced when the conventional low shape fine kaolin was replaced with a kaolin with a larger plate diameter. The result was a marked improvement in delta gloss even though the kaolin amount in the recipe was relatively low.

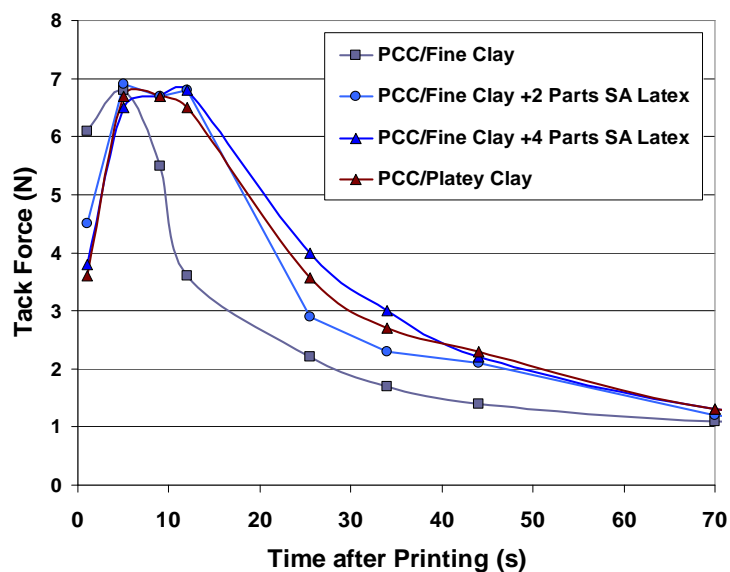
**Figure 6. Focussed Ion Beam Etching of Printed Paper**



A further example of this effect can be seen in studies based on PCC coatings. Here the influence of kaolin to control ink rate in a porous coating was measured against the ability of increasing binder level to close the surface. The results were surprising in that changing only 20 parts of the pigment recipe to a high aspect ratio kaolin had much the same impact on ink tack development as increasing binder by 2-4 parts or (22-44%).

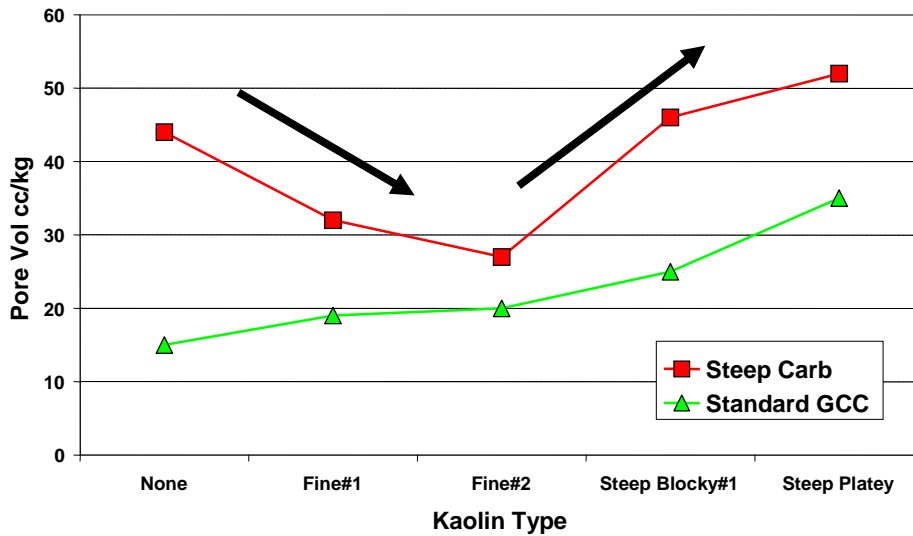
**Figure 7. Use of Platey kaolin to Control Ink Setting**

Topcoat Woodfree example  
80:20 PCC/Kaolin  
Reference binder level = 9 parts of a  
50:50 mixture of SB and SA latex



These studies have shown that high shape kaolin is very effective at reducing surface porosity, slowing down ink setting in otherwise fast setting systems and improving print gloss. However, while surface porosity can be reduced bulk structure in mixed systems is often increased, as the larger kaolin plates are not easily accommodated within the carbonate pore structure. In Figure 8 below we see the influence of kaolin type (shape) on the pore volume of coatings based on steep and standard carbonate. As before this data refers to pilot coated freesheet paper based on a latex-starch recipe (See Fig 3). In this case kaolin is mixed 50:50 with carbonate.

**Figure 8: Kaolin Effects on Bulk Structure**

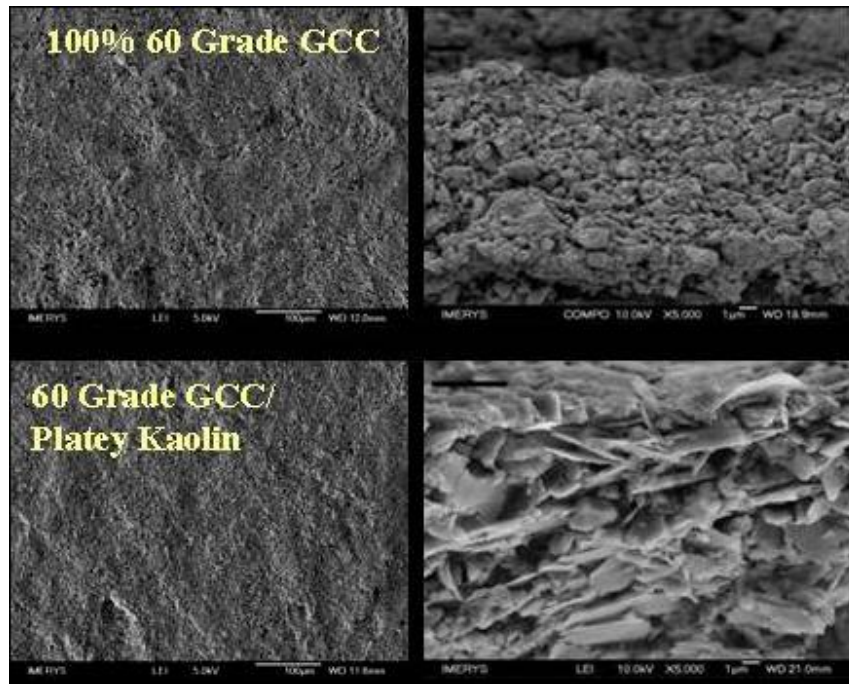


When fine standard carbonate is used with kaolin, all kaolins have a disrupting effect on bulk structure with the biggest effect being seen with the larger plate diameter kaolins. When narrow particle size carbonate is mixed with kaolin then the relationship is more complex. Finer kaolins can more readily be accommodated within the larger pore structure. The result is that these kaolins can reduce pore volume and bulk and hence reduce the value of the steep carbonate. In contrast larger plate diameter kaolins can continue to have a bulking effect in these systems.

These effects are critical in single coating or precoat applications particularly on rougher basestock where the ability of the pigment system to cover the paper is often critical in controlling paper and subsequent print performance. The combination of large plate diameters and a bulkier coating structure can give significant improvements in coverage (See Fig 9). The results can be improved smoothness and evenness (less mottle) from physical coverage coupled with reduced dewatering and fibre roughening effects. Fibre pick can also be improved helping runnability both in paper coating and on printing presses.

A previously unpublished example of the benefits of high aspect ratio kaolin in precoat is shown in Table I. In this case addition of 20 parts of coarse platey kaolin to the GCC based precoat gave benefits to coverage and smoothness which ultimately lead to 4 units increase in print gloss.

**Figure 9. SEM Micrographs Illustrating Coverage and Bulking Effects from Kaolin**



**Table I - Effects of Kaolin in Precoating**

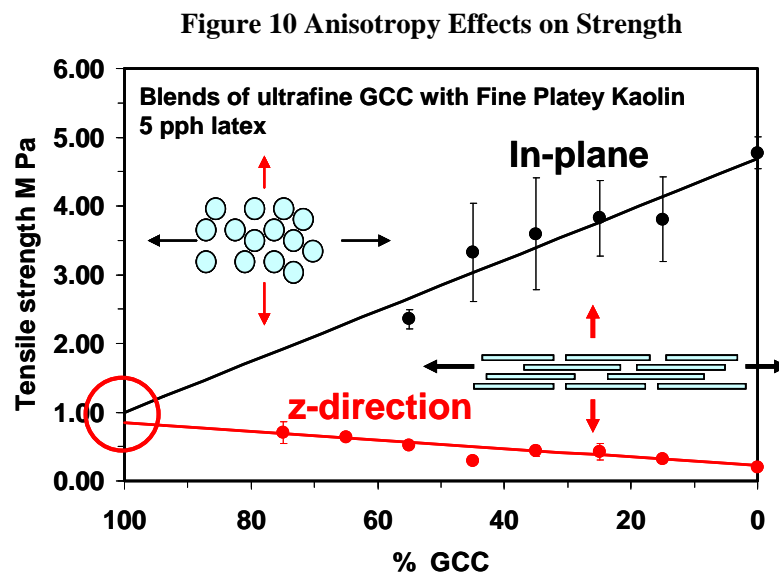
Precoat Properties	100% GCC 60	80:20 GCC60/ Coarse Platey Kaolin
Solids	67.5	66.3
Brightness No UV	75.1	75.6
Opacity	94.5	95.1
PPS WS	6.1	5.5
PPS FS	5.4	5.0
Topcoat Properties	70:30 GCC 95 Fine Clay	70:30 GCC 95 Fine Clay
Solids	61.8	61.8
Gloss	69	70
B'ness No UV	75.3	75.5
Opacity	95.0	95.3
PPS WS	1.2	1.1
PPS FS	1.0	0.9
Print Gloss	80	84

85 gsm Double Coated Fine Paper- 1500m/min 9 gsm precoat, 6 gsm topcoat

## EFFECT OF KAOLIN ASPECT RATIO ON COATING STRENGTH AND INK PILING

Achieving acceptable coating strength is critical to offset print press runnability. However, the binder demand of the pigment systems is also a careful consideration because of the impact on cost. Understanding how different pigment concepts affect coating strength as well as quality is essential in identifying formulations which give the best overall cost performance for a given application.

Much work has been done in the area of understanding the links between pigments and coating strength [19, 20, 21, 22] and we can cite some generally accepted rules. For example higher surface area pigments are known to have higher binder demand than low surface area pigments. Narrow particle size distribution pigments which yield more open coating structures tend to give inherently weaker structures. They also tend to give poorer water retention and hence binder retention during application which further adds to the binder demand of these systems. Typically we would expect a narrow particle size GCC or PCC to require 20% or more binder than a similarly sized broad particle size pigment. The role of aspect ratio in determining coating strength is, however, more complex. Work by Husband et al [22, 23] has shown that anisotropy in morphology will give anisotropy in strength. Higher shape pigments give a marked increase in-plane or tensile strength, but tend to give slightly lower out of plane strength than low aspect ratio pigments. In contrast, low aspect ratio pigments have the same strength response in both directions. These effects are shown in Figure 10 where the effect of shape is assessed by varying the kaolin content in the recipe.



The reason for this difference is not fully understood, but may relate to the larger z-directional surface area of aligned plates. However, it is clear that the reduction in z-directional strength with of coatings formulated with high shape is small compared to the benefits in tensile strength and paper stiffness. This is explored further in section 6

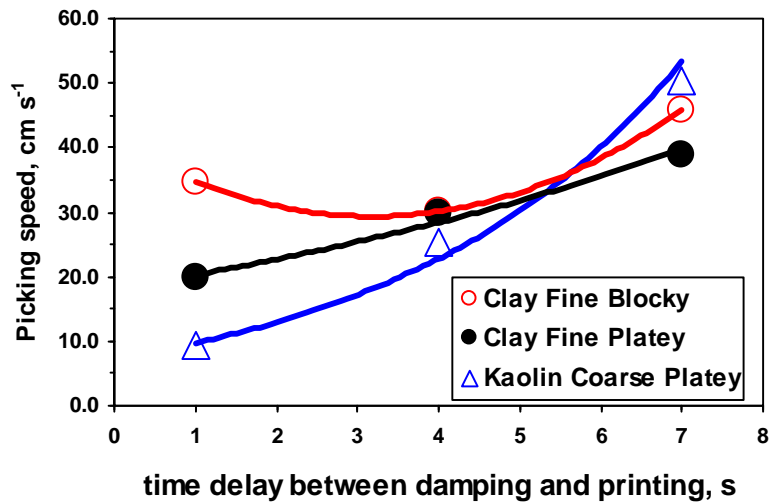
Fluid (fount) penetration and retention in the coating layer is also important in controlling strength during printing. Recent studies by Husband and Preston [24] have shown water has a pronounced, but transient, weakening effect on coating strength. When water is present in the coating layer, strength is reduced, but it will return to its original level once the coating is dry. Further studies in this area have indicated that the mechanism is linked to the ability of polar fluids to weaken the ionic bonding between the pigment particles and the latex binder causing failure. For coatings the key factor is the ability of coating to trap fount solution during the timescales relevant to the printing process. This in turn will be related to the coating structure (porosity) and hence pigment properties as discussed in Section 4.

The impact of fluid penetration on coating strength at longer timescales has been explored using wet pick tests on papers coated with kaolins varying in size and shape (Fig 11). This work showed that the strength of coatings

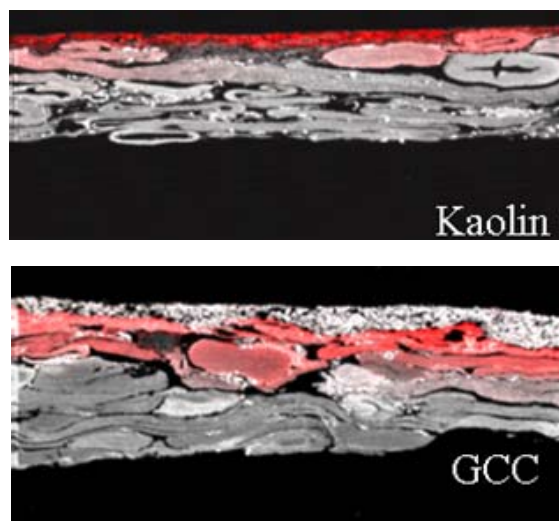
constructed using coarse platey clays showed a strong dependence on the interval between pre-damping the paper and printing. At shorter timescales this coating was weakest, but at longer timescales, when the fluid had sufficient time to penetrate all the way through the coating, it became the strongest. This effect while also evident with lower shape kaolins, was then much less pronounced.

The effect of coating structure was further explored by comparing coatings made with 100% GCC and 100% coarse platey kaolin using CsCl labelled fount solution and SIMS analysis (Fig 12. [25]). The results of these experiments clearly show that at longer time scales, higher shape coatings are more likely to retain fount solution. Than low shape coatings where the fount although rapidly absorbed passes quickly to the basepaper. The suggestion is that higher shape coatings may thus be more prone to fount weakening effects than low shape coatings. However, it must be remembered that these coatings tend to also have lower surface porosity as seen in Figures 5 and 6. On the short timescales relevant to the printing process it is possible that with high shape coatings much of the fount has yet to penetrate the coating and may remain emulsified in the ink.

**Figure 11 Wet Pick Strength Time Dependence**



**Figure 12 CsCl Mapping of Fount Solution**



Overall, the indication from these studies is that high shape pigments could require more binder to achieve acceptable printing strength than lower shape pigments. However, this is not the whole story and to some extent contradicts the experiences of printers with carbonate rich formulations which have tended to show increased piling tendency on press. While increasing shape may reduce Z-directional strength and perhaps increase the tendency for fount solution to be retained in the coating layer for longer, these effects can be offset by the ability of high shape coatings to slow down ink tack development thus generating less stress during printing. Likewise improved coverage of basepapers in single coating or precoating can also reduce the tendency for fibre pick in some cases.

In order to more fully understand pigment effects on coating strength and piling tendency a new study has been carried out. In this work, a systematic pilot coating program was put in place to benchmark range of formulation concepts in a single coated mechanical application. In this work the recipes were based on European LWC, but the findings are relevant to any single coating situation such as North American groundwood or single coated freesheet. The coating formulations are shown below in Table II and compare kaolin type and kaolin level effects.

**Table II - Pilot Coater Studies Assessing Ink Piling**

**Jet Coater 1500m/min 40gsm base, 10 gsm/side**

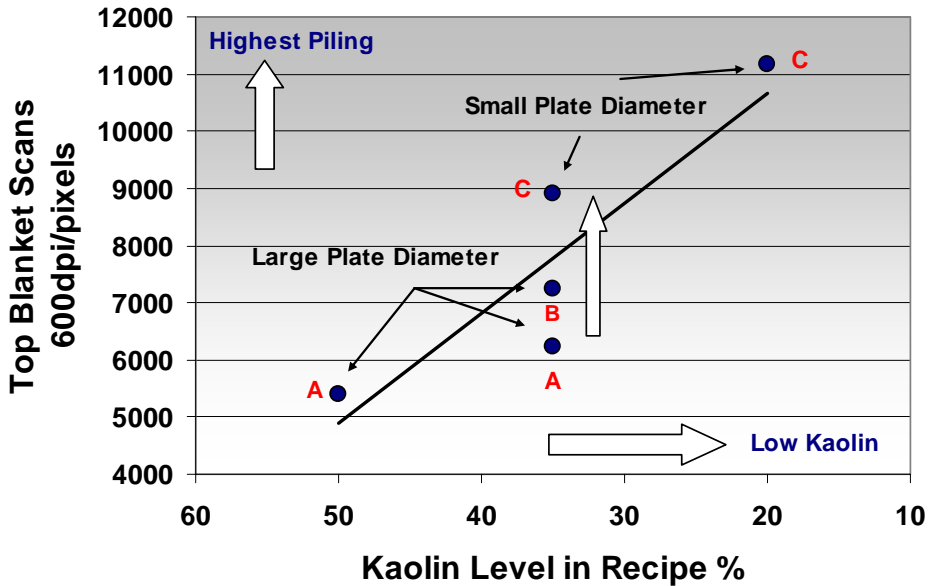
Colour	1	2	3	4	5
Brazilian Engineered Kaolin (A)	50	35			
Brazilian Engineered Kaolin (B)			35		
Ultrafine Glossing Kaolin (C)				35	20
Steep 95 GCC	50	65	65	65	80
Latex	7	7	7	7	7
Starch	4	4	4	4	4
OBA	1	1	1	1	1
CMC	0.3	0.3	0.3	0.3	0.3
Calcium Stearate	0.4	0.4	0.4	0.4	0.4
Running Solids %	63.1	63.6	63.2	63.5	64.0

Kaolin	A	B	C
-2µm	91	90	98
D50 (µm)	0.55	0.61	0.21
Plate Diameter (µm)	1.35	2.04	0.38

Printing was carried out on an Alberta Frankental Albert A101S HSWO press. Press conditions were carefully set up with respect to fount levels in order to show differences between formulations especially with respect to ink piling. Piling itself was determined from tape pulls from the upper printing blanket after printing of 27000 copies.

The results of this study (Fig 13) showed clear differences between the LWC formulations with the key differentiators being the kaolin level and kaolin type in the recipe. In general it was evident that engineered Brazilian kaolins with larger plate diameters gave lower ink piling than the ultrafine kaolin and that piling also reduced with increased kaolin in the recipe. Moreover, it was clear that the differences were significant with the extent of the build up doubling between the best and the worst recipes.

**Figure 13. Ink Piling Results**



In order to understand the causes of the piling differences further laboratory based measurements were also made to assess dry pick strength and ink tack development. Results are shown in Figures 14 & 15 and indicate that the coatings that gave the most piling also had lower intrinsic coating strength as shown by the dry pick results and gave the most rapid ink tack development. The combination of these two factors helps to explain the kaolin plate diameter effect on ink piling in that the fine blocky kaolin which clearly gave the worst piling also gave faster ink tack development and had lower strength. However, the effect of carbonate level on piling cannot be linked to these factors. In this case we can only speculate that the increased piling tendency with increased GCC in the recipe may be related to the effects of GCC solubility in acid fount solution.

**Figure 14. Dry Pick Strength**

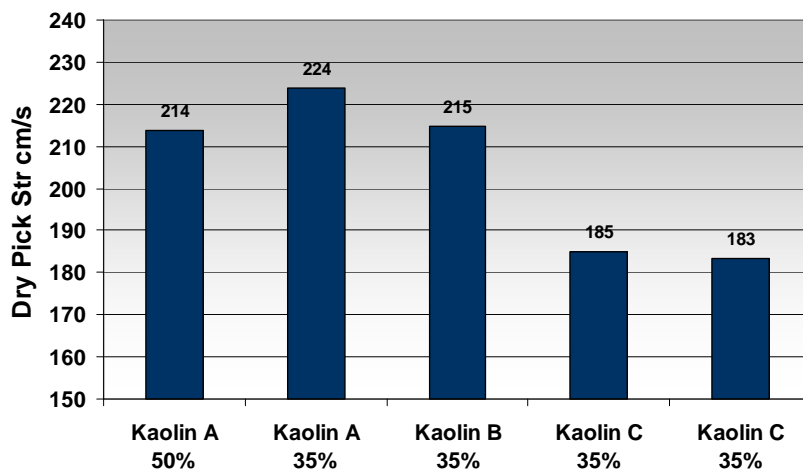
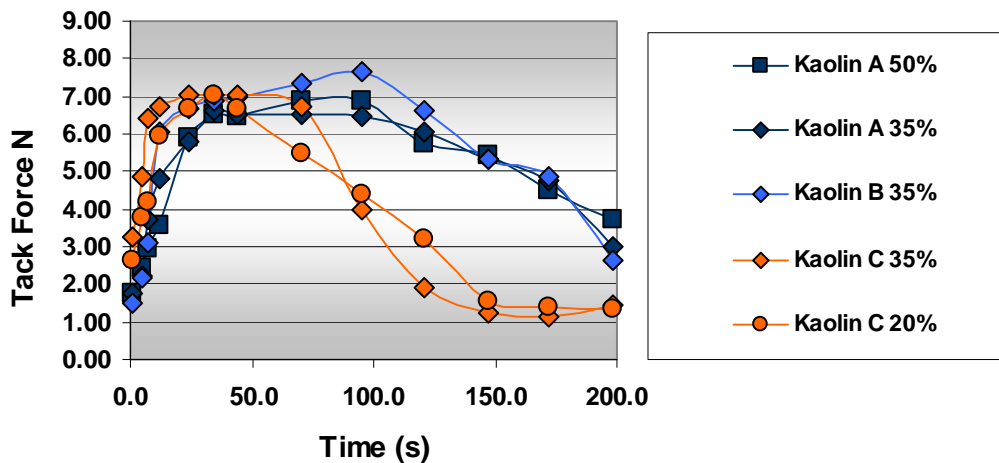


Figure 15. Ink Tack Development



So in summary it is evident that pigment type will affect coating strength and press issues related to strength in many ways. Fine pigments with high surface area have more surface to bind, requiring more binder and will set ink faster putting more stress in the printing process. Steep pigments give more open structures which are weaker and have poorer binder retention. While the role of shape is more complex we can still cite some general rules.

Higher shape gives:

- + Better binder retention
- + Slower ink setting (less stress in printing)
- + Reduced Piling tendency
- + Better coverage which can also help with fibre pick
- +/- Much better in plane strength, but slightly weaker Z-directional strength
- Increased likelihood of fount retention in coating layer, but reduced piling

In reality most coatings today are based on carbonate with kaolin used at lower levels. In this situation the benefits associated with high shape outweigh the negatives.

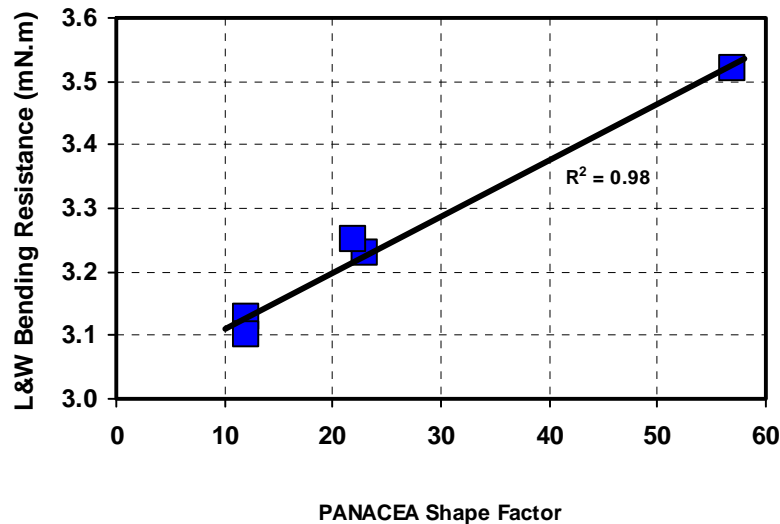
### EFFECT OF KAOLIN ASPECT RATIO ON COATED PAPER STIFFNESS

Stiffness is another important quality factor, not only for the feel of the paper, but also for press runnability, especially in sheet fed offset applications. There have been a number of published studies assessing how different pigment systems affect stiffness [26,27,28]. The results have shown that kaolins give higher coating modulus leading to higher stiffness than GCCs in coating applications and that kaolin level in the recipe is also important (see Fig 10).

Earlier studies by Husband et al [28] have shown that kaolin aspect ratio is also important in controlling stiffness. This has been mapped out more systematically in new laboratory coating experiments where a range of different aspect ratio kaolins were applied on to a 40 gsm LWC basepaper using a web coater. The kaolins selected, were all close to 90 wt% < 2µm and were evaluated in a recipe containing 30 parts of 95 grade GCC. The formulation was based on 7 parts of latex and 5 parts of starch. Coatweights of 10 g/m<sup>2</sup> per side were applied at ~10 m/min using the blade applicator. Laboratory calendering load was then adjusted to achieve a target 60 gloss level (Tappi 75°).

The measured bending stiffness is shown in Figure 16.

**Figure 16. Aspect Ratio Effects on Bending Stiffness**



The results showed a strong correlation between increasing aspect ratio and stiffness in the finished paper. In this work up to 13% improvement in stiffness was possible depending on kaolin selection.

## SUMMARY AND CONCLUSIONS

In this paper we have reviewed how different pigment concepts can influence printing, both in terms of quality and press related issues such as piling. Controlling porosity, topography and strength are critical to achieving good printability.

Kaolin shape will have a marked influence on both the bulk and surface structure of paper coatings even when used at low levels in a carbonate rich recipe. Larger plates tend to disrupt the bulk coating structure, but can still align at the surface after calendaring and effectively close down surface porosity and increase tortuosity for fluid flow through the coating. The anisotropy of kaolin also leads to anisotropy in strength which increases with increasing aspect ratio.

The benefits of these effects are widespread.

- + Greater bulk structure can improve coverage of rougher basestocks improving roughness and print gloss. Mottle tendency can also be reduced through improved coverage as can the tendency for fibre pick. These effects are especially important in single coating and precoat applications
- + Increased tortuosity and reduced surface porosity can slow down ink setting rates and reduce resin depletion from the surface resulting in better print gloss development. Slower ink setting can also help reduce press related issues such as piling resulting from too rapid an ink tack build. The increased tortuosity can also help improve binder retention in the coating layer which may improve strength. Likewise, increasing tortuosity in a precoat can also help topcoat binder retention.
- + Increased in plane or tensile strength is good for paper stiffness which can help press runnability in sheet fed printing.

In contrast the issues associated with high shape kaolins are less significant. While Z-directional (printing) strength is slightly reduced, the impact is small compared to the stiffness benefits and is moreover offset by improved binder retention, improved coverage and reduced ink tack build which all serve to reduce overall binder demand. Likewise the increased tendency to trap fount solution in the coating layer causing weakening may be relevant in long timescale laboratory studies, but does not appear to be relevant to the shorter timescales associated with commercial offset printing.

Overall, it is clear increasing the aspect ratio of kaolin is a powerful tool for improving print performance.

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