WGCC Rich Coating Formulations

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Abstract :

Calcium carbonate is now the dominant mineral used in paper and Board coating. However, wide variations in the extent of its use exist even within the same type of paper or board.

Typically topcoat formulations contain a proportion of ultrafine kaolin to improve the gloss of the finished paper or board. However the cost of the kaolin is significantly higher than the cost of the ground calcium carbonate, which is the main constituent in the coating. The kaolin has lower brightness and a yellower shade than the carbonate and this has an impact on the finished appearance.

Imerys has developed a ground calcium carbonate pigment which can be used in topcoat formulations without kaolin. This removes the need for kaolin makedown in the mill and reduces costs. The kaolin-free coating colour runs without problems and gives good fibre coverage. Without kaolin the finished brightness and shade is improved whilst the gloss, opacity and printing characteristics are unchanged.

Some of these differences are due to issues of local mineral availability and logistics but others are due to the experience and sensitivities of individual mills.

In coated wood free grades, especially in Europe, it is not uncommon to be completely clay free. However, learning to run clay free has required a re-think on the control of coating solids, drying profiles and coating application.

Some board mills also run totally clay free, and in general where clay is used, it is used for its specific functionalities of physical coverage of a very rough base, for high uncalendered gloss and for improved activation of laser marking due to its specific beneficial impact on laser energy absorption.

This presentation first introduces some typical formulations that are used in coated board and paper throughout the different regions of the world, and then explores the different ways in which an increased amount of CaCO3 can generate maximum benefits.

Calcium carbonates can be produced with a wide range of brightness, particle size and particle size distribution.

In many cases, the increased use of CaCO3 will significantly increase final sheet whiteness (blue shade), as well as lowering the cost of production, however, the use of 100% CaCO3 formulations often also requires a total system approach.

In most cases formulations containing high levels of CaCO3 need to be run at high coating colour solids in order to maximise paper and print gloss and physical coverage. The lower aspect ratio of CaCO3 particles will facilitate coating colour rheology and on machine runnability, but the poorer intrinsic water retention means that binders and thickeners must also be reviewed. Higher solids coating requires stable operating conditions and therefore also can lead to modifications to machine operating conditions such as application configurations and coatweight distributions.

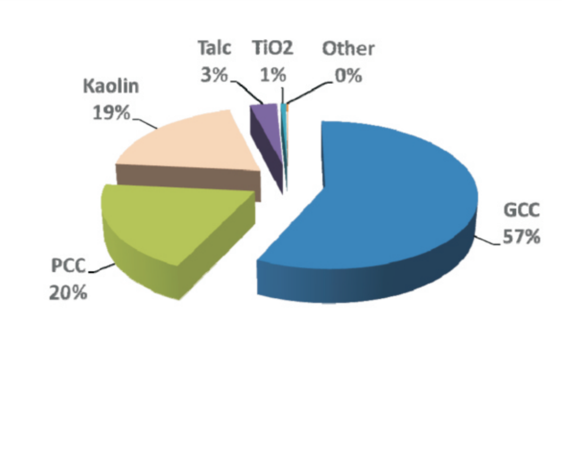
Highest levels of gloss can be achieved with ultrafine carbonates coated at high solids, combined with a reduction in binder levels due to the higher intrinsic pick strength of 100% CaCO3 formulations.

In coating of low brightness board, due to the transparency of high bright CaCO3, both the brightness and the particle size distribution of the CaCO3 should be modified to ensure that optical coverage of fibres is maximised.

Introduction :

Many years ago clay used to be the dominant mineral used in paper. However, the ability to produce under neutral pH conditions, an ever more demanding market requirement for high paper whiteness, and an increasing focus on operating cost has meant that calcium carbonate has now overtaken clay as the mineral of choice in the production of paper and board.

Since 2007 the global consumption of Ground Calcium Carbonate (GCC) in the paper and board industry has grown by over 10% whereas kaolin consumption has decreased by nearly 30%. This trend seems likely to continue since there are strong cost drivers to utilise still higher amounts of GCC.see Fig.1a,b.



Pigment	Change from 2007 to 2015
WGCC	14%
PCC	-3%
Kaolin	-27%
Talc	-247%
TiO2	-5%
Other	-75%

Fig 1a. Global mineral consumption 2015 **Fig 1b.** Changes in consumption 2007 - 2015

However, depending on local availability of minerals, and local "evolution" of coating equipment and practice significant differences can still occur within different regions. See Fig 2.

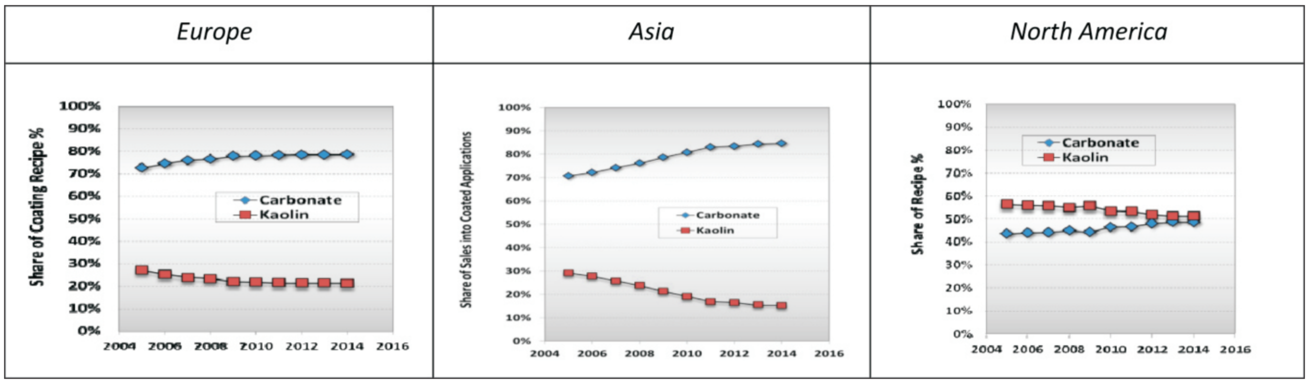


Fig2. Mineral consumption trends in coating by global region

These regional differences in mineral consumption are obviously translated in to differences in generic coating formulations. But, in addition, even within the same geographical region, paper with the same finished technical specification are often produced with formulations containing different types and very different ratios of calcium carbonate and clay.

Formulations for coated board also show wide variation. Certain producers use 100% calcium carbonate in both precoat and topcoat (GCC/engineered GCC/PCC), however it is still common to use some clay in to improve optical and physical coverageand laser marking.

In this paper we outline the main differences in properties afforded by the different pigment types and also show some of the main levers which can be used to optimise formulation for good runnability and final properties. This is a review of a significant body of practical work carried out for research purposes and for customers within Imerys Minerals.

Strengths and weaknesses of minerals

In moderns coating formulations, within the constraints of mineral availability and cost, minerals should be used for "what they are good at" as described by Nutbeem*et al*.

It is well known that calcium carbonates particles are blocky particles (low aspect ratio) with the potential (depending on the source raw material) for high whiteness (blue shade). Some typical values for different pigment brightness areshown in Fig.3a. It is also well known that clay particles generally have significantly higher aspect ratio, and lower brightness.

Therefore in simple terms, clays should be used to maximise good physical coverage of a surface and to reduce surface porosity, , whereas calcium carbonates should be used to achieve maximum whiteness and increase surface porosity.A summary table of strengths and weaknesses is shown in Fig3b. In many cases a blend of different minerals is desirable to obtain the optimum balance of properties.

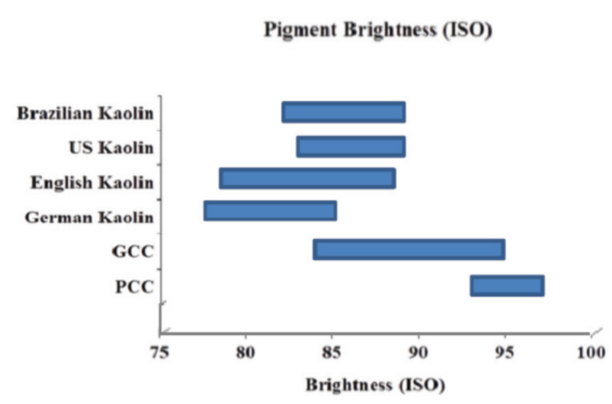


Fig 3a. Range brightness for various minerals

	Color Solids	Paper Brightness	Paper Opacity	Fiber coverage	Paper Gloss	Print Gloss
Coarse WGCC	++	+	–	+	– –	– –
Fine WGCC	+ +	+	–	– – –	–	– –
Fine Ground Chalk	+ +	–	+ +	– – –	–	– –
Fine PCC	+	+	+	–	+/-	– –
Fine Kaolin	–	–	+	+	+ +	+ +

Fig 3b. Strengths and weaknesses of various minerals

This approach is especially interesting in multilayer coatings where each layer can provide specific functionality. This will be discussed further in the second half of this paper.

The key benefits of maximising the use of calcium carbonate are:

- Lower mineral cost
- Improved whiteness and blue shade (leading to lower OBA requirement),
- Faster ink setting rate (reduced problems of water interference mottle issues or set off),
- Higher surface strength for a given amount of binder (this can translate in to a lower binder demand thus further reducing costs)
- Higher solids applications (reduced energy of drying).

Provided that a base paper is of high brightness, the simple replacement of clay by fine carbonate in the topcoat will significantly increase brightness and whiteness. However, because GCC particles show intrinsically poorer physical coverage and poorer dynamic water retention, properties such as paper and print gloss will be lower at equivalent coating solids.Therefore operating a 100% carbonate topcoat requires the optimisation of the total system.

Optimisation of coating solids

After the particle size, the most important factor to optimise is that of coating colour solids.Fortunately "blocky" GCC particles have good rheology and therefore can be coated at much higher solids than formulations containing clay.In Europe, papermakers routinely coat topcoats in double and triple coated CWFand board and packaging grades at >70% solids without issues of dilatency.

Higher coating solids have a positive effect on paper and print gloss. For example an increase in topcoating solids from 65% solids to 69% can increase gloss by around 5 units, when coated on a precoated smooth base (Fig 4.)

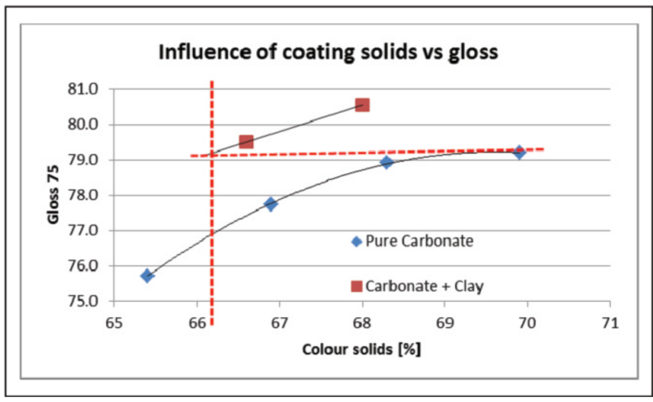


Fig 4. Effect of particle size on gloss of 100% GCC coatings

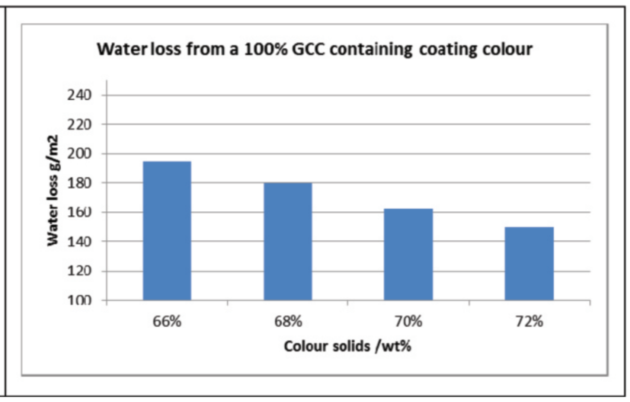


Fig 5. Effect of colour solids on water retention

Higher solids will also help to improve the coating colour dewatering behaviour. The following example compares the AA GWR static dewatering of fine broad GCC at 4 different solids levels to give an indication of the impact of varying solids content on dewatering. The method is described bySandas*et al*. As the initial coating colour solids content increases, the dewatering decreases. See Fig.5.

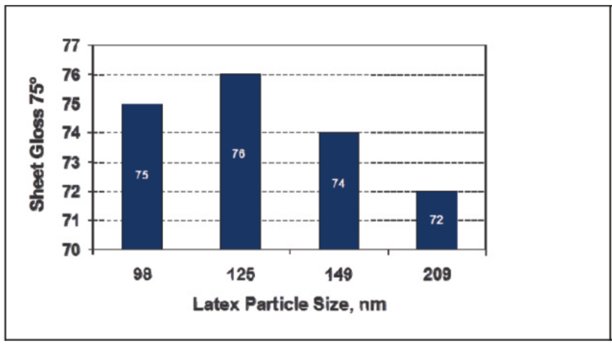
The lower amount of water present in a coating colour at high solids obviously also has the additional benefit of requiring less drying energy –for example an increase of 4% in coating colour solids (66 to 70%) will reduce the energy needed to dry the coating colour by around 20-30kWhr/T.There have been several publications concerning the migration of binder during coating colour application, the consolidation and drying process,,and the dewatering process and interactions between coating colours and basepaper,,. An excellent review of the subject is given by Engstrom and additional data is given in a second paper in this conference .

Optimisation of binder, cobinder and other additives

Another benefit of high solids coating associated with 100% calcium carbonate formulations is the possibility to make considerable reductions in binder concentrations. These reductions both reduce cost, and provide an additional route to increasing the gloss of the unprinted surface since binder level has a significant impact on gloss.

The nature of the binder itself can also be varied in order to influence both paper and print gloss. Paper gloss is influenced by the particle size of the latex. See Fig. 6a.

Print gloss is impacted by the roughness of the paper substrate , the pore structure of the coating layer and finally by the polar nature of the polymer chains and networks.Incorporating polar monomers such as acrylonitrile or butyl acrylate into the latex reduces the interaction with ink vehicle. The interaction between the ink oils and the binder chemistry will impact the rate that the ink will immobilise and set, and this will impact the final print gloss ,, . See Fig. 6b.



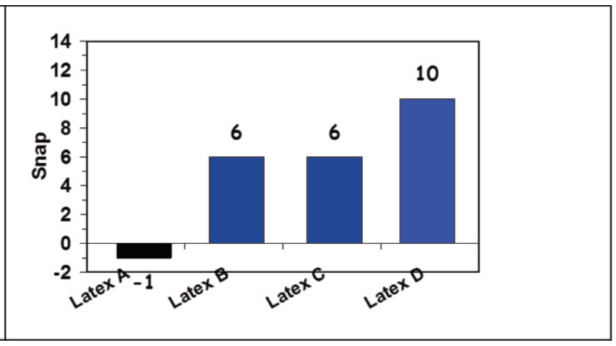


Fig 6a. The influence of latex particle size on sheet gloss. **Fig 6b.** The influence of latex on "snap" or Delta Ink gloss

As pigment particle size becomes finer, the optimum binder particle size also needs to be finer. The finer latex is better accommodated within the coating pore structure, and ink tack development is slowed down leading to higher print gloss. Maximum gloss is often obtained with synthetic thickeners that allow the highest solids operating window. The example in Fig.7 shows that changing cobinder from 0.5pph CMC to 0.2pph synthetic thickener improves the dewatering characteristics of a 100% ultrafine carbonate coating colour and therefore allows it to be run at 1 unit higher solids. The measurements were made using a PaarPhysica immobilisation cell and precoated base paper with a shear rate of $2000s^{-1}$.

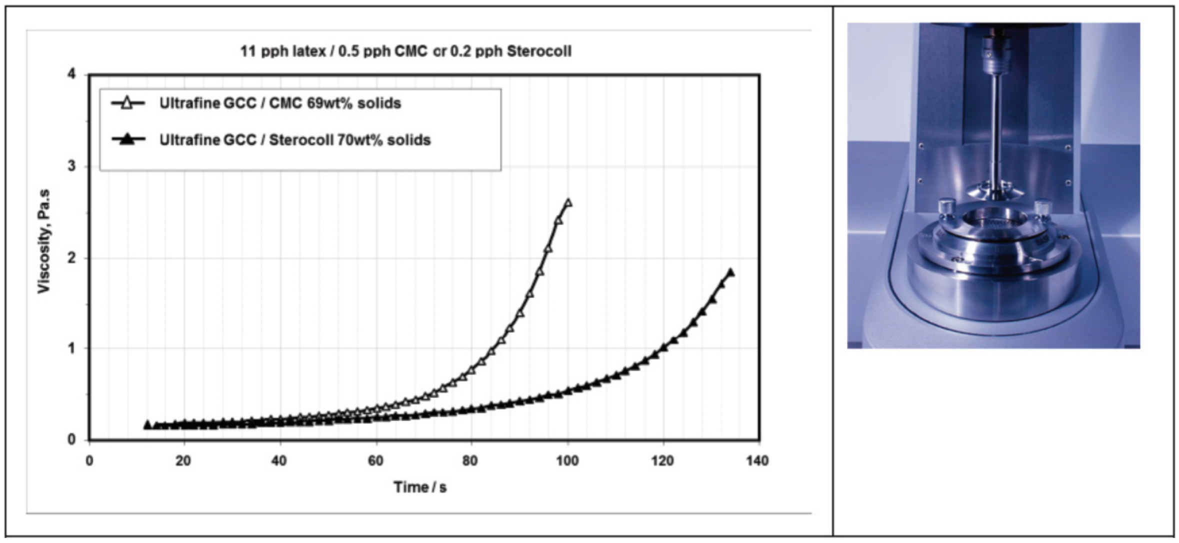


Fig. 7 Influence of thickener on coating colour solids and dewatering (Par Physica immobilisation cell).

Other optimisations that should be considered when using high levels of GCC in topcoats include the reformulation of additives such as OBA and OBA activators (eg. PVOH).

In particular, if the full whiteness gains that are obtained when replacing clay by ultrafine GCC in a topcoat are not required, then the concentrations of both OBA and OBA activators can be reduced, often by over 50% or repositioned to the precoat, since the increased transparency of a 100% ultrafine GCC coating will allow the fluorescence from the precoatto dominate sheet brightness. For example, in the graph in Fig.8below, the final sheet brightness +UV could be maintained with a reduction of OBA addition in the precoat from 0.7pph to 0.4pph.

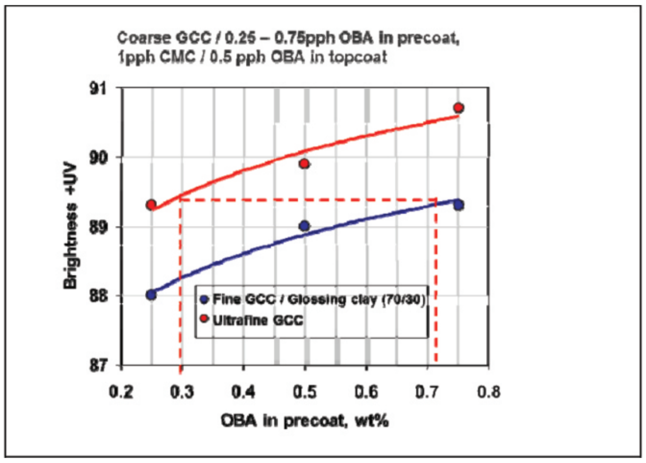


Fig 8. Potential for OBA reduction with high white 100% GCC formulations.

Total system optimisation

So far we have seen that optimisation of a single coating layer can allow increased use of calcium carbonate in topcoats, however, in multilayer systems often the best strategy is to optimise both precoat and topcoat together.

In Europe the traditional way of making board was to use a strategy of low cost carbonates in precoat and clay/calcium carbonate blends in topcoat for coverage and gloss. However, over recent years, the European board industry has taken a total system approach and has moved to clay / carbonate precoats for combined optical and physical coverage of the basepaper, together with maximum high solids carbonate for topcoating.

In this approach each pigment is used for its key strengths.(Fig. 9.)

In papers or boards containing multilayer coatings, the role of the precoat is to provide cost effective basepaper coverage. The topcoat must then provide a micro-smooth surface that is suitable for paper and print gloss development. It also controls the surface porosity to ensure fast ink setting and a homogeneous uptake of ink (low mottle).

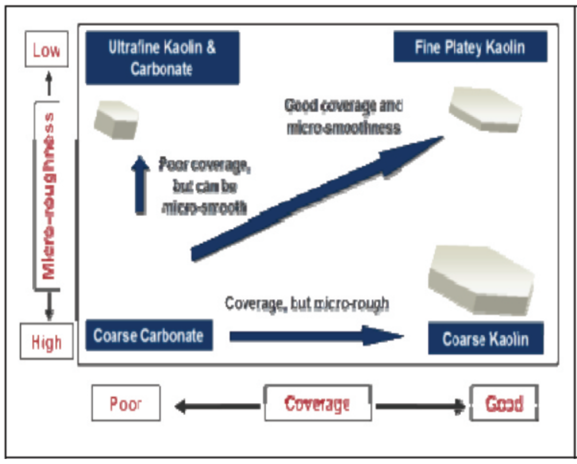


Fig. 9. Illustration of pigment influence on the relationship between coverage and micro-roughness

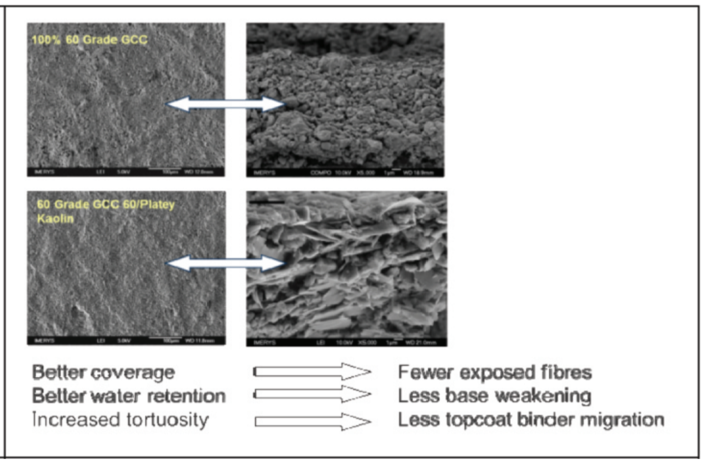


Fig. 10. The influence of kaolin in precoat.

In the optimised system approach, inclusion of plateykaolins together with GCC in the precoat improves both optical and physical coverage of the fibres. Fig. 10.

Summary

Calcium carbonate is dominant mineral used in paper and board production. This paper has reviewed various approaches to maximising its use in coating formulations. Topcoats containing 100% Calcium carbonate can match the performance of traditional coatings provided that all aspects of the coating formulation are optimised, including mineral particle size, coating colour solids, and coating formulation. In particular, when producing double coated paper and board, the key strengths of both Calcium Carbonate and kaolins should be synergistically combined within the different coating layers in order to provide maximum optical and physical coverage of the base as well as high whiteness and lowest chemical demand.

RISI market data combined with Imerys internal information.

Hiorns A.G, Preston J.S., Morgan J., Metters L., "Laser marking of double coated board" Proc 2012 Tappi Advanced Coating Fundamentals Symposium, Atlanta, GA, Sept 10-12 12

Nutbeem C., Hiorns A.G, Hallam B., "Optimised Precoats for Multilayer Coating" Proc 2011 TappiPaperCon. May 1-4 2011, Northern Kentucky Convention Centre, tappi press, Atlanta GA

Hiorns&Eade, "Effect Of Kaolin Addition To Calcium Carbonate Precoats", 2003 TAPPI Spring Technical Conference

Hiorns& Winter. Effect Of Kaolin Addition To Calcium Carbonate Precoats: Part 2: MSP Coating", 2004 TAPPI Coating Conference

Strom G., Preston J. "Impact of local variation in coating structure on uniformity in print gloss" MAY 2013 | VOL. 12 NO. 5 | TAPPI JOURNAL pp 43-51

Stefan E. Sandas, Pekka J. Salminen, and Dan E. Eklund "Measuring the water retention of coating colors," Tappi Journal, Vol. 72, No. 12, December 1989 issue.

Bushhouse, S.G., "The effect of coating viscosity on surface latex concentration", TAPPI J., 231-237, (1992),

Backfolk, K., Grankvist, T., Ghosh, T., Astola, J., Sinervo, L., and Luttikhedde, T., "The effect of water retention and rheology modifiers on the formation of coating structure and migration of particles", TAPPI Advanced Coating Fundamentals Symposium, 2006, p.311-321,

Young, T.S., Pivonka, D.E., Weyer, L.G., and Ching, B., "A study of coating water loss and immobilization under dynamic conditions", TAPPI J., 76, 10, 71-82 (1993),

Eklund, D.E. and Salminen, P.J., "Water transport in the blade coating process", TAPPI J., 116 – 119 (1986),

Salminen, P., Roper, J., Pollock, M., and Chonde, Y., "Determining the dynamic water retention contribution of various cobinders and thickeners", TAPPI Coating Conf. Proc., 1995, p. 277-286.,

Eriksson, U. and Rigdahl, M., "Dewatering of coating colours containing CMC or starch", JPPS, 20, 11, J333-337 (1994),

Engstrom G., "Interactions between coating colour and base sheet in pigment coating", FRC Review Article Cambridge, in Advances in Paper Science and Technology, Vol 2 pp 1011-1073, 2005

Preston J.S., Findlay A., Husband J., Dev K., "Pigment impacts on strength in a paper coating and movement of binder during coating colour consolidation" Submitted for PaperEx 2015

Preston J.S., Nutbeem C., Parsons D.J., Jones A., "The printability of papers with controlled microstructures", Paper Technol., Vol. 42, No. 2, March 2001

Preston J.S., Elton N.J., Legrix A., Nutbeem C., Husband J.C., "The role of pore density in the setting of offset printing ink on coated paper", Tappi Journal Vol 1., No. 3, May 2002, pp3-5

Gane, P.A.C. and Seyler, E.N., "Tack development : an analysis of ink paper interaction in offset printing", Proc. TAPPI Coating Conf. (1994), pp.243-260, TAPPI Press, Atlanta,

Gane, P.A.C., Schoelkopf, J., and Matthews, G.P., "Coating imbibition rate studies of offset inks : a novel determination of ink-on-paper viscosity and solids concentration using the ink force-time integral", Proc. TAPPI International Printing and Graphic Arts Conf. (2000), pp. 71-88, TAPPI Press, Atlanta,

Preston J.S. PhD Thesis, "Factors impacting the print gloss of coated paper", Bristol University, UK, 2001