High Speed Ink Absorption using microporous RC Based Photomedia. Fundamentals, Status and Challenges

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Abstract

In the last couple of years printing images using Inkjet technologies got faster and faster whereas the total volume of ink jetted to the media seems to stay stable. The absorption capacity of actual microporous Inkjet media can cope with these volumes but what about the kinetics? Low absorption speed manifests itself in problems like bronzing and bleeding. If the ink laydown per time and area is still increasing we may face a situation where media can be the bottleneck of higher printing speeds.

In this article an investigation with focus on aqueous dye based inks regarding the development of next generation Inkjet media is presented. Key factors like total pore volume and average pore size distribution is studied using Mercury porosimetry. Measuring absorption speeds with respect to "real life demands" is quite challenging. High speed camera systems are widely used to investigate ink absorption kinetics, a technique mainly focused on single drop analysis. Looking for a more practical way of evaluating and differentiating absorption speeds of a variety of inkjet media using a modified Bristow Wheel technology is presented.

Introduction & Fundamentals

Today's Inkjet Photo Media generally use RC coated substrates combined with microporous, absorptive layers of Silica or Alumina on the front side. Typical values for the front side coatings are 25-35g/sqm coat weight and calipers of 35-40 µm. The absorption capacity of these layers ranges from approx. 15-25 ml/sqm, sufficient to cope with most actual printing systems.

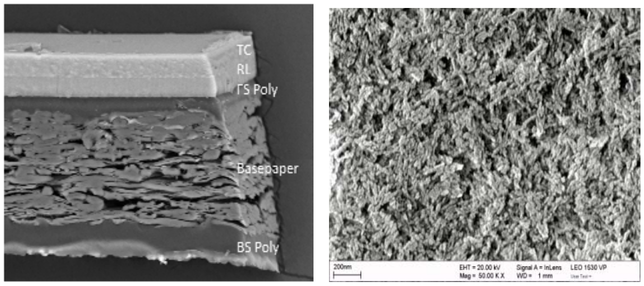


Figure 1: Media Cross-section and Surface appearance (Mag. 50K)

The absorption speed of a given Ink is mainly influenced by the geometry of the capillary sponge (dimension/radius of capillaries, network, length) and in multilayer systems through the adjustments between the capillaries in each layer. Typical values for pore diameters in microporous systems are 10-25 nm. The driving force for effectivity is the pore diameter. Large pores support fast transport, smaller pores increase capillarity. The smaller the pore, the deeper the liquid can penetrate into the media. The corresponding mathematical law is the Washburne equation showing that the height a liquid can reach in a capillary system is dependent on surface tension, contact angle, density and radius of a capillary.

$$h = \frac{2\sigma \cdot \cos\theta}{\rho g R} \tag{1}$$

Example for a theoretical ink (28 dyn/20°)

Radius R	Example	Height *h*
10 nm	Pigment A	540 m
17 nm	Pigment B	330 m
500 nm	Paper Fiber	10 m

Figure 2: Capillary forces with respect to capillary radius

High capillary pressure and corresponding capillary forces are realized in microporous coatings.

Speed of Flow is described by Hagen-Poiseuilles Law

$$\frac{\mathrm{d}V}{\mathrm{d}t} = \frac{\pi R^4}{8\eta}\frac{\Delta p}{l} \tag{2}$$

Combination of both equations leads to the Lucas-Washburne Equation [1,2.]

$$x(t) = \sqrt{\frac{R \cdot \sigma \cdot t \cdot \cos\theta}{2\eta}} \tag{3}$$

It describes the temporary progress of a liquid in a cylinder shaped capillary.

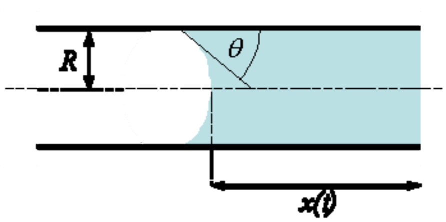


Figure 3: Cylindrical Capillary

Idealized microporous media consist of numerous amounts of (cylindrical) capillaries N per area A. N/A is linked to the mass specific Volume of a coating.

$$V(t) = \frac{\widetilde{V}m_A}{l} \sqrt{\frac{\sigma \cdot \cos\theta}{2\eta} R} \cdot \sqrt{t} \qquad (4)$$

The total absorbable volume is proportional to $t^{1/2}$. The proportionality constant is of huge importance to penetration measurements using the Bristow method and is therefore called *Bristow Coefficient* C_B.

$$C_B = \frac{\widetilde{V}m_A}{l} \sqrt{\frac{\sigma \cdot \cos\theta}{2\eta} R} \qquad (5)$$

It is clearly a scale for penetration speed and available as the slope in a V to $t^{1/2}$ plot

Experimental

Measuring absorption speed on microporous media is quite challenging due to the high absorption speeds. Classical instruments like the F*ibro tester*[3] are too slow. Highly sophisticated scientific approaches using high speed CCD camera systems in combination with microscopes are described but are restricted to analysis of only single drops [4,5].

A new, practical test method to determine absorption speed of microporous media with respect to dye based inks using an adjusted *BRISTOW WHEEL* has been developed. The use of the Bristow wheel is well known in the paper industry[6] but the application to microporous media has been challenging.

A test media is attached to the Bristow wheel and brought into contact with a dispenser containing a defined Volume of a Test liquid (artificial ink). Absorption occurs while moving the media at a known speed along the dispenser. After the liquid is absorbed totally by the media the area necessary is measured using a scanner device.

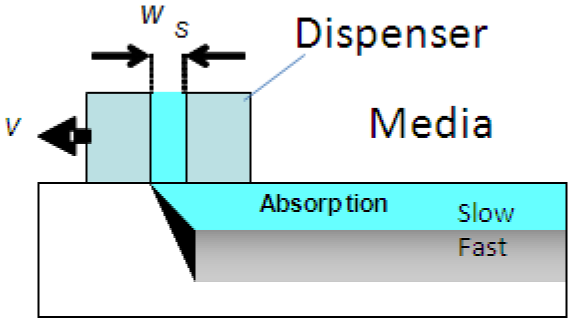


Figure 4: Principle of the Bristow Wheel

Total contact time: $t_C = w\, s/v$
Specific Volume: $V(t) = C_B\, t_c$

A huge range of different media was measured and typical examples are shown below in a CB vs. $t^{1/2}$ plot.

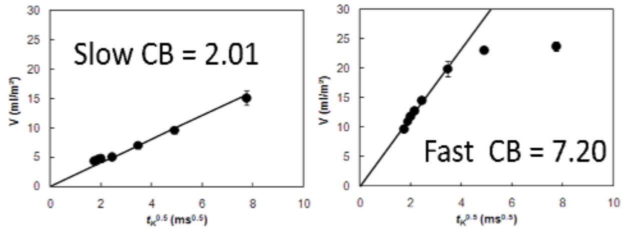
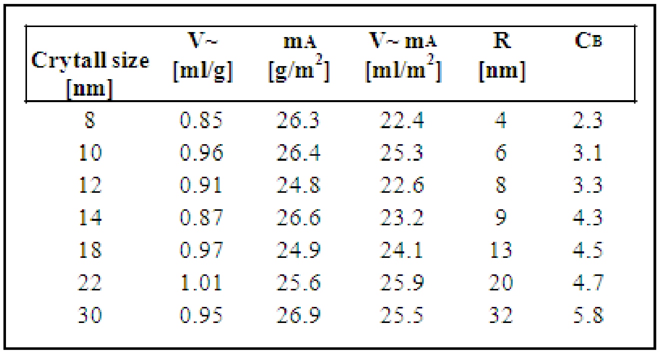


Figure 5: Absorption Speeds of two different microporous media

A clear differentiation in absorption speed of microporous media was found. C_B values vary from 2.0 (slow) to 7, 2 (fast).. Flattening of the curve at high volumes is related to total absorption volume (saturation effects). Although a lot of experimental effort is necessary, we feel that it's worth in doing so to quantify absorption kinetics.

Going back to the Lucas Washburne equation most of the parameters can't be influenced by the media. The most important one controlled by the design of the absorption layer is porosity. The corresponding parameter is the radius of the capillary controlled by particle size and shape of the pigments.

A lab study was done by preparing a range of microporous layers, all of the same recipe, pigment type and coat weight but varying the pigment primary crystal sizes. We chose crystallites between 8 and 30 nm and a coat weight around 25g/sqm. The samples were characterized with respect to their real coat weights, total volumes, Bristow coefficients and capillary pore radii using the Bristow wheel and Mercury Porosimetry.(*PASCAl*/Porotec & *POREMASTER*/Quantachrome) Dispersion makeup and process were all kept the same.



Crytall size [nm]	V~ [ml/g]	mA [g/m^2]	V~ mA [ml/m^2]	R [nm]	CB
8	0.85	26.3	22.4	4	2.3
10	0.96	26.4	25.3	6	3.1
12	0.91	24.8	22.6	8	3.3
14	0.87	26.6	23.2	9	4.3
18	0.97	24.9	24.1	13	4.5
22	1.01	25.6	25.9	20	4.7
30	0.95	26.9	25.5	32	5.8

Figure 6: Test results of Lab Study

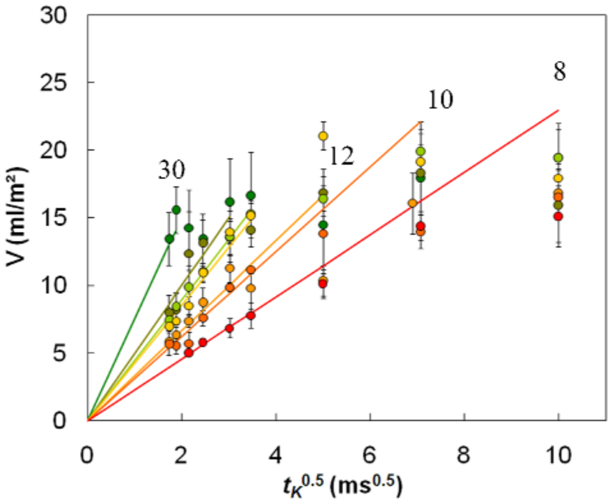


Figure 7: Bristow Coefficients for varying Crystal sizes

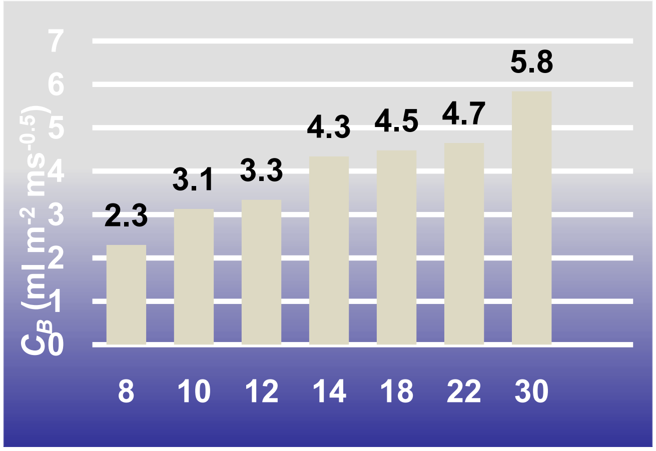


Figure 8: Crystal sizes & corresponding CB

As expected, a correlation between pore size and absorption speed was found. Assuming, that a typical capillary is not longer than 40µm the capillary pressure as shown in Figure 2 has no significant pressure drop and capillary forces are assumed to be constant. The driving force for absorption speed in this model is the pore radius itself. The larger the pores, the faster the absorption rates are.

Higher absorption speeds can be realized by opening the pores right at the surface of the coated layers. Unfortunately most of the media in the market are of a high glossy type. Gloss itself is impacted by the particle size of the pigment causing some limitations for media developers. On the other hand transparency as a key factor for high optical densities which is also reduced by using larger particles. A compromise between OD, gloss and absorption speed describes the status of actual media development.

A comparison between the experimental data and calculated results using equation (5) was done . The prediction of the model shows an acceptable correlation to real measurements using a least square fit.

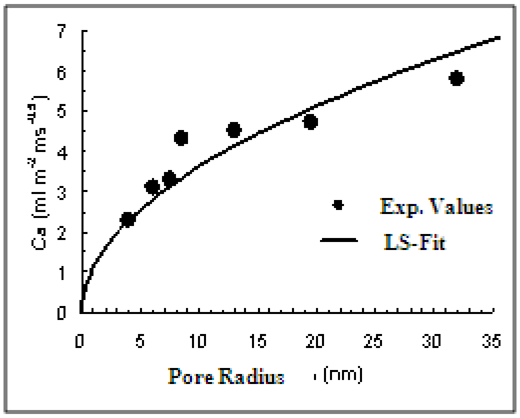


Figure 9: Prediction vs. experimental data

Conclusion

A combination of Mercury porosimetry and the newly developed Bristow Wheel method is capable to describe structure and porosity of microporous layers. A direct link to absorption speed is found. Compared to microscopic evaluations, were the initial wetting process plays an important role, a more macroscopic test to describe behavior of media in real life is described.

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Author Biography

Knut Hornig received his BS and PhD in Chemistry from the University of Muenster/Germany (1992) working in the field of Metal organic and computational Chemistry. He started working for Felix Schoeller Company in 1992 in the R&D Department. In 1993 he took over responsibility for the Analytical Department. Paper testing and a newly founded Application Center for Inkjet media were combined to an integrated service Department. Since end of the 90th he was focused to Inkjet media development, first taking care of basic research, later to media development. Today he is responsible as a group leader for coating and digital media.

Carsten Schönfeld received his Diploma and PhD in chemistry (1992) from RWTH Aachen, Germany. He has been working in solid state and polymer physics at Forschungszentrum Jülich and had several industrial appointments in the fields of digital printing and paper technology including Heidelberger Druckmaschinen, NexPress, and Felix Schoeller jr. Today he focuses on paper coating as a senior research project manager at Papiertechnische Stiftung in Heidenau, Germany

Rainer Klein received his Dipl.-Eng. in process engineering (paper technology) from the Technical University of Dresden in 1978. He acquired his Dr.-Eng. (PhD) in 1985. From 1978 to 1989 he worked at TU Dresden in R&D (waste paper treatment) and education of students. Since 1990 he has worked at Papiertechnische Stiftung (PTS) in Munich (until 2000) and now in Heidenau. His work has focused on image analysis, topography, printing and measurement techniques for paper testing.