

Print-Paper Interactions are Beneficial for Digital Print Quality

John Anderson and Libby Pearson
Eka Chemicals, Akzo Nobel, Worle, UK

Abstract

Experiences and conclusions are presented from two major studies which investigated the effect of internal and surface composition of uncoated paper on non-impact printing behaviour. The key substrate properties affecting print quality, and the chemical treatments which can be used to modify them are identified. A model is proposed for the parameters with the greatest influence on print behaviour.

Using the know-how and market awareness gained from these earlier projects, the recent rapid and extensive developments in non-impact printing technology, the changes in its areas of application, and the implications for paper media are examined. The transition of office ink-jet printing from a growing market to a mature technology, and the redirection of effort towards wide format, photorealistic and digital production printing is tracked. The print-paper interaction model is reassessed in the light of current and predicted non-impact printing trends, and used to provide a strategy for the design of paper media in the new decade.

The conclusion is reached that, rather than striving for substrate independence, print-paper interactions are beneficial and desirable for digital print quality, and these interactions should be recognised in non-impact printing technology developments.

Introduction

In the 90's, the expansion of ink-jet printing and its rapid and widespread acceptance in the SOHO market caught some papermakers by surprise. The physical and chemical treatments traditionally applied to paper, and the measurements made to assess paper quality were not adequate to predict or control ink-jet print quality. This led to the perception that paper media has a negative influence on ink-jet print quality. The reaction from the printing industry was to search for 'substrate independence' and to forecast the onset of the paperless office. As suppliers of chemical solutions to the paper industry we seek to promote the positive contribution of print-paper interactions on print quality. Our response was to embark on a programme to investigate the interactions that occur when ink-jet ink is printed on paper, and to find better ways to measure and predict the parameters that influence these interactions. Our final goal was to design chemical systems to work with the inks and printers to improve final print quality.

In addition to our internal development work, we participated in two major, three-year projects with other European partners from the paper, printer, ink industries and graphic arts technologies (see refs. [1] & [2]). Collectively more than 40 man-years of activity was invested in activities which included production of paper on a pilot machine, method development and testing, and developing new print-paper systems. The vast amount of data collected helped us to understand better the critical substrate parameters involved in SOHO ink-jet printing, and to build a 'best-fit' model of the print-paper interactions.

As we enter the twenty-first century the paperless office remains elusive. We are still using consuming in excess of 100 million tonnes of printing and writing papers worldwide, and the prediction is for paper consumption to continue to increase up to 2010, despite the expansion of digital media. However, the way we print, the media we use, and the methods of distribution and type of printed product are certain to change as confirmed by the wide array of new technology demonstrated at the recent DRUPA exhibition in Düsseldorf. For non-impact printing, the focus for innovation has shifted from the SOHO market to digital production printing. The task now for the paper industry is to respond to the vast changes occurring in the printing industry by using knowledge gained in the SOHO environment to adapt to the digital production printing.

Print-Paper Interaction Studies

Paper Industry Perspective and Performance Targets

Reference was made at NIP15 to the gap that exists between the paper and printing industries, even though they are closely linked as suppliers and customers (see ref. [3]). We approached our investigations from the perspective of the paper industry, but kept aware that chemical treatment and chemical influences exist at all stages of the workflow from pulping through papermaking to printing and final end-use of the printed product, and so treatments must be compatible (see figure 1). Print performance targets were based on image quality, durability of the printed sheet, and operability and runnability of the printer. Runnability is affected by strength and friction properties but these properties are not the subject of this paper. It was also important that improvements made in ink-jet printing should not adversely affect electrophotographic properties since much emphasis at the time was placed on multipurpose paper grades.

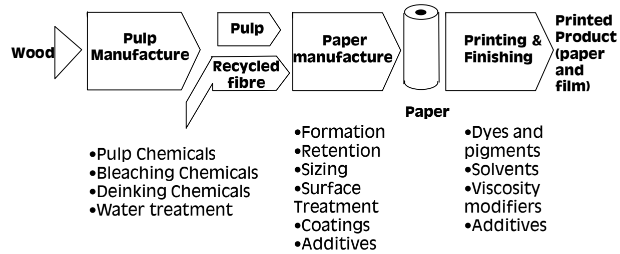

Figure 1: Chemical treatment involved in the pulp/paper/printing workflow

At the start of the projects our main focus was on image quality and, in particular, improving colour-to-colour bleed for mainly office graphics. However, increasingly image durability, print drying time and print mottle took priority as technology developments such as smaller drop size, higher speed printing, better compatibility of inks, introduction of pigment colorants, and photo-quality printers were introduced. Towards the completion of the projects the most important combination of properties for ink-jet printing media was judged to be:

- ❑ High print density
- ❑ Good edge definition
- ❑ Low mottle
- ❑ No print through
- ❑ Fast drying
- ❑ Good light-fastness and wet-fastness.

Benchmarking of Commercial Papers

Attempts to relate image quality parameters of commercial papers to conventional paper industry specifications were largely unsuccessful as hown in figure 2.

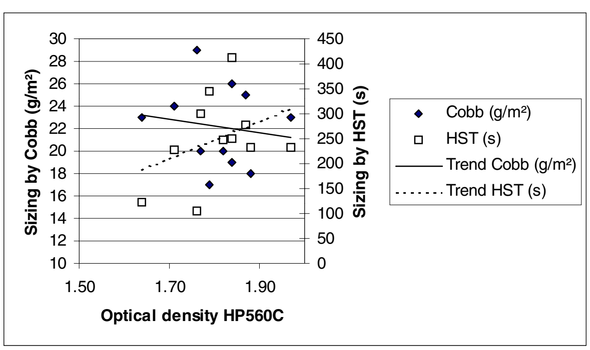

Figure 2: Measurements of sizing related to ink-jet optical print density

As expected, there was a basic relationship between sizing of the paper and print density of the water-based inks - as the degree of sizing was raised by increase in HST or decrease in Cobb value the print density increased - but there was also an associated tendency for greater colour-to-colour bleed and print mottle. Similarly there was no simple relationship between air permeability or smoothness of the paper and the image quality. It became clear that traditional paper industry specifications are not sensitive enough to account for subtle aspects of image quality, and may not be measuring the paper properties critical to print-paper interactions. So, the paper industry was faced with the dilemma of trying to adapt to the production of paper grades for non-impact printing without satisfactory parameters to measure and control the image quality.

Sizing tests are based on average values of relatively long-term absorption and penetration properties of the sheet on a macro scale, whereas ink-paper interactions occur over a short time scale, and depend on the micro structure of the sheet. Variations in the formation and composition of the sheet can interfere with the paper-image quality relationship. Measurement of short term wetting and absorption properties such as contact angle were found to give more meaningful information and related better to observed printing performance, but still there were inconsistencies when comparing a range of commercial papers.

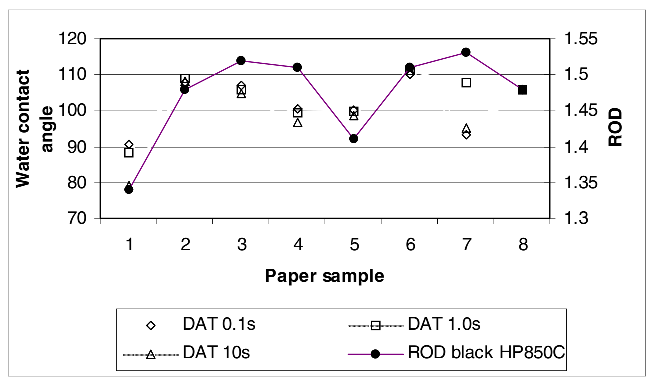

Figure 3: The relationship between short-term contact angle and optical density

Pilot Paper-Machine Trials

More systematic information was gained from pilot paper machine trials made at the University of Manchester Institute of Science and Technology in the UK. Because these papers were made using a higher concentration of fresh water and at slower speed than a full-scale machine, their characteristics were not fully representative of the printing properties of commercial grades. However, the main advantage was that controlled and incremental changes could be made to the paper composition and chemical treatment.

Many chemical and physical variables were investigated including:

- ❑ Type and amount of fibre and filler
- ❑ Sheet smoothness and porosity
- ❑ Optical brighteners
- ❑ Type and amount of internal sizing agents

- Surface treatment with synthetic polymeric surface sizes, starches, hydrophilic polymers (anionic and cationic), colloidal silica, and pigments

Of the variables tested, the internal sizing and surface treatment chemicals were found to have the greatest influence on ink-jet print quality, and usually a balanced combination of internal and surface treatment was the most effective. The improvements were strongest when applied to short term ink absorption, print density and image durability, which influence ink drying time, the tendency to give print mottle, and the wet-fastness and light-fastness of the print. Some examples are given below.

Measurements made with the Bristow Wheel sorption tester showed how the choice of combined sizing treatment could be used to influence the ink-jet ink absorption rate even though the overall sizing level was unchanged. This was achieved without reduction in print density or increase in print-through (see figure 4).

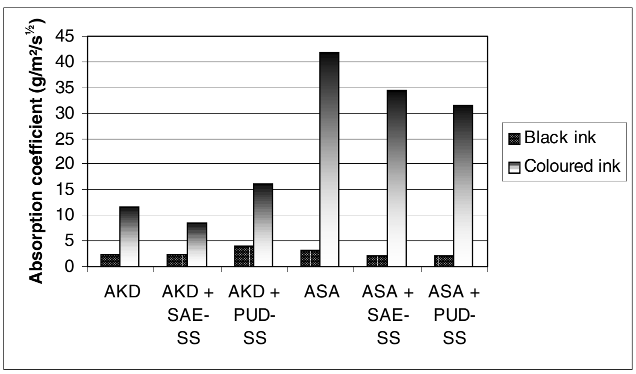

Figure 4: Combined sizing influences short-term ink absorption

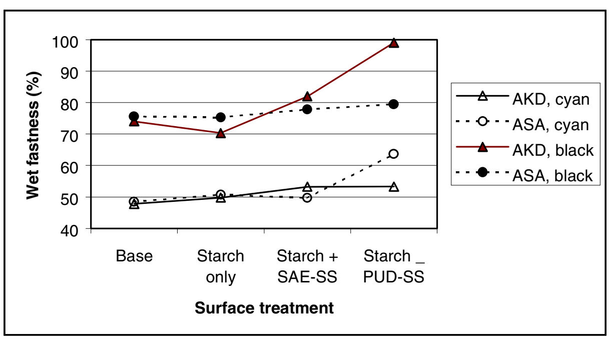

Figure 5: The effect of surface treatment on wet-fastness

The durability of ink-jet inks was shown to be improved by surface treatment The wet-fastness of both coloured and black ink-jet inks was increased, and the light-fastness of magenta ink in particular (see figs. 5 and 6).

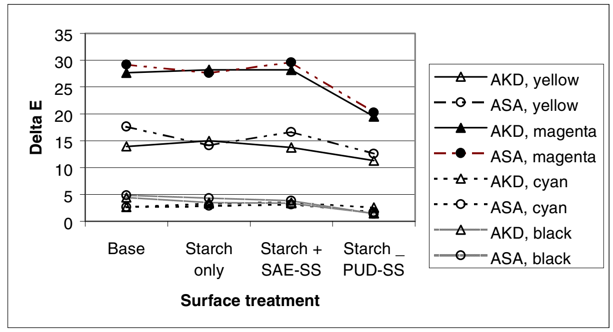

Figure 6: The effect of surface treatment on light-fastness

Colloidal silica applied at the surface had the interesting effect of increasing short-term contact angle even though the sizing effect was reduced. This resulted in an improvement in print density and edge definition, probably because of the increase in surface receptive sites for the colourant. The surface could also be made cationic or anionic depending on the demands of the ink.

Ink jet mottle was also affected by chemical treatment. The causes of mottle are complex but are believed to relate to the wetting of the ink, and the rate and uniformity of penetration in the x,y and z directions of the sheet. Evidence was found that mottle was reduced by the correct choice and balance of surface treatment and internal sizing. This was shown especially in binary colours such as green colour-fill areas (see figure 7).

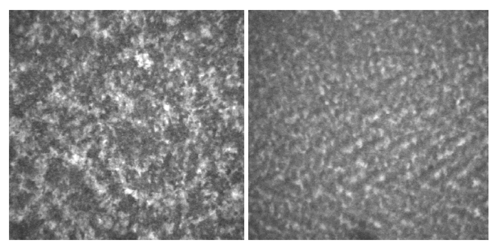

Figure 7: The effect of surface polymer type on ink-jet mottle of a green colour-fill area.

Model for Print-Paper Interaction in SOHO Ink-Jet

From the results of the investigations made with SOHO ink-jet printer systems, a model was constructed to best explain the print - paper interactions observed and their effect on print quality and behaviour (see figure 8).

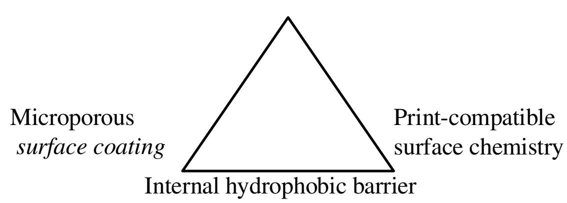

Figure 8: Print-paper interactions triangle

This model assumes a minimum amount of internal size is needed to create a barrier to print-through to the reverse of the sheet. The correct chemistry at the surface is important to give good fixation and durability of the colorant in the ink. In addition a microporous surface is needed to allow rapid penetration of the ink vehicle and fast drying.

Latest Developments in Digital Printing

Differences between SOHO and DPP

The recent DRUPA exhibition confirmed the rapid development of digital printing processes. Digital workflow and automation of pre-press are now accepted technology within the industry, and direct digital printing is becoming established. SOHO non-impact printing can be considered a mature technology with OEM's concentrating new development effort towards lower cost or faster printers. Printing of photo-quality images is also expanding but usually on special coated media.

An area of high growth and innovation is digital production printing using ink-jet or electrophotographic processes, and this has been recognised by IS&T who launch the first DPP conference in Antwerp in 2001. So the challenge now for the paper industry is to use the knowledge and experience built-up from SOHO systems and apply it to the digital production environment.

Many of the differences between SOHO and digital production printing were well summarised at NIP 15 (see ref. [4]). Performance requirements in the industrial, large format and packaging environments include high speed printing, good press reliability, fast drying and good durability including satisfactory wet-fastness, light-fastness and scuff resistance. The inks may be monochrome or wide colour gamut, solvent-based, oil-based or UV-curing inks.

Design of Digital Paper

Because of the different priorities for digital printing in industrial applications it follows there may be differences in the critical design parameters for digital production paper. It is particularly important that the paper has properties that are uniform throughout the sheet and consistent from batch to batch in respect of wetting, absorption and spreading for a range of solvents, moisture content, surface energy, and thermal and electrical properties for electrophotography. Higher production speeds and the need for good reliability and fast turn-around time between jobs means a clean printing process with low contamination from the paper media is essential. Hence more emphasis must be placed on low dusting and linting properties.

Improvements in printing paper have to be achieved at a time when the paper industry is driving towards higher efficiency, and the trend towards cheaper raw materials and using higher filler content. This means in addition to optimizing the internal sizing and surface treatment, attention must be given to retention, formation and strength properties of the sheet, and these parameters should be included in a revised print-paper interactions model.

Conclusions

The use of paper for printing and writing has not declined despite the expansion of digital media. The preference for printing on paper continues and consumption of printing and writing papers is expected to grow in the foreseeable future. However, the way we print and the use of the printed product will change.

The chemical design of paper has been shown to have a significant influence on image quality and durability. We need to appreciate this positive influence of paper media and incorporate the beneficial print-paper interactions into future digital printing developments.

Acknowledgments

We acknowledge the contributions from participants in the Project CEDRIC, and to Ebbe Lyrmalm who acted as project leader for Eka Chemicals. We also acknowledge the assistance from the team at University of Manchester Institute of Science and Technology who worked with Libby Pearson on her PhD project

References

1. Synthesis report from project CEDRIC-BE95-2003, High Performance Products for Ink Jet Printing'
2. Elizabeth Pearson, 'The Study of Ink / Paper Interactions during Non-Impact Printing, PhD thesis to the University of Manchester Institute of Science and Technology, September 1999.
3. Paul Kallmes, Bridging the Gap between Paper and Printing: A Perspective from the Paper Industry, Proc. IS&Ts NIP 15, p.181 (1999).
4. Carol K. Keller, The Evolution of Jet Inks to Meet New Application Needs, Proc. IS&Ts NIP15, p.95 (1999).

Biography

John Anderson has a BSc in Chemistry and PhD in Minerals Engineering. Over a career of 20 years he has worked in various industries in product and application development, but for the past 15 years has worked with Eka Chemicals and its predecessors in pulp and paper chemistry, surface treatment and now set up a new Printability Group concerned with printing issues in various paper grades. Libby Pearson first studied for a BSc in Printing and Photographic Technology, and has recently been awarded a PhD in Paper Science from UMIST in Manchester, UK for research work partly sponsored by Eka Chemicals and Zeneca Specialities. She is now employed by Eka Chemicals in the Printability Group.