About Paper Properties for Modern Dry Toner Presses

Petri Sirviö
Stora Enso Research
Imatra, Finland

Abstract

Modern dry toner production colour presses can produce good print quality on a much wider substrate selection than what has been possible earlier. Because of the use of indirect or single pass toner transfer processes, which enables imaging on a known intermediate substrate with optimized electrical properties and/or only one transfer to paper, these systems are clearly more robust against the macro electrical properties of paper than the machines transferring directly from the photoconductor to the paper. This is a clear development from the copy shop machines utilizing four consecutive toner transfers directly onto the paper sheet. So, with the modern dry toner colour presses the emphasis, what comes to print quality, is more on surface evenness and good uniformity, than on the macro-scale electrical properties. This brings out also the print quality and related business advantages that can be attained with coated papers, like in offset printing.

Introduction

Graphical end uses require reliable printing of both sides of the sheet in significantly longer runs than in an office environment. Runnability and reliability are key issues when small batches are manufactured with demanding timetables. For example, low stiffness, curl, waviness, insufficient dimensional stability and bad cutting quality of paper sheets bring runnability problems on dry toner based colour production presses. Especially the coated lowest grammage papers place requirements for both paper and machine design.

The latest generation dry toner machines, with indirect, or single pass toner transfer from photoconductor to paper via an intermediate belt or drum, enable production printing on substrates not earlier possible, like papers with moisture content as in offset-papers, board substrates and coated papers. The printers also use larger sheet sizes than in office environment. The print quality has been significantly enhanced, in many end uses approaching the quality achievable with offset CMYK process.

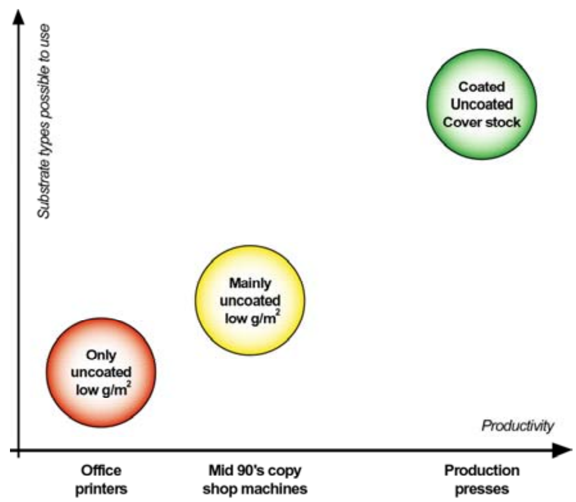

Figure 1. Expansion of substrate possibilities in digital printing.

On Paper Requirements for Good Print Quality

As paper moisture level decreases, the resistivity of paper increases exponentially.[1,2] This makes the resistivity of paper very important for a successful toner transfer in direct toner transfer systems,[3] since resistivity influences heavily the dissipation of free charges placed on paper in the toner transfer phase. When discussing the reduced significance of electrical properties or moisture of paper with modern dry toner presses, the basic reason for this development is the use of indirect or single pass transfer processes enabling imaging on a known substrate and/or only one optimized transfer to paper, and the use of materials in the transfer nip that have suitable electrical resistivity and dielectric properties. The volume resistivity of some of the machine materials present in the transfer nip together with paper, exceed clearly the resistivity characteristics of paper in normal conditions. For example, the volume resistivity properties of materials present in the transfer phase can be 10^{14} Ω·cm or even 10^{17} Ω·cm depending on the machine. Paper volume resistivity is normally in the area of $10^{9}\ldots10^{12}$ Ω·cm, depending mainly on the ion- and moisture content of paper. Therefore, the apparent volume resistivity over the series of layer thicknesses (toner, air, paper, transfer members), and the charge transportation and the time constant of free charge dissipation is governed by the resistivity of the conveyor or other polymer materials present in the nip. This resistivity is significantly greater than that of the paper, unless the paper is excessively dry or other vise abnormally resistive. In such a case paper resistivity related imaging problems could start to arise due to insufficient transfer efficiency, especially during the second pass after paper has dried further, and related to this also due to the increased significance of local electrical property variations of the paper sheet. Also the dielectric constants of the materials, or the ability of polarization of non-free charges, are on levels indicating the transfer member influencing much the electric field formation in the nip. The requirements for electrical properties for sufficient print quality fit most offset-moisture fine papers. Here is a clear development from the previous generation copy shop machines, which transfer toner from the photoconductor drum directly to the paper.

Smooth paper surface enhances the print quality with the modern dry toner machines on the markets today, in some cases even more than before. Figure 2 shows data from a pilot paper test series printed on a dry toner press utilizing indirect transfer. This effect of smoothness is influenced by the toner layer thickness having been clearly reduced, Figure 3, making the topography of paper increasingly important for good toner-paper contact. In older machines toner layers are much thicker, so the toner masks much more the roughness cavities. Roughness can influence the print quality also via fusing-related defects.[4] For example, poor contact and the resulting lowered heat transfer between paper and fuser roll[5] or belt can cause gloss mottle.

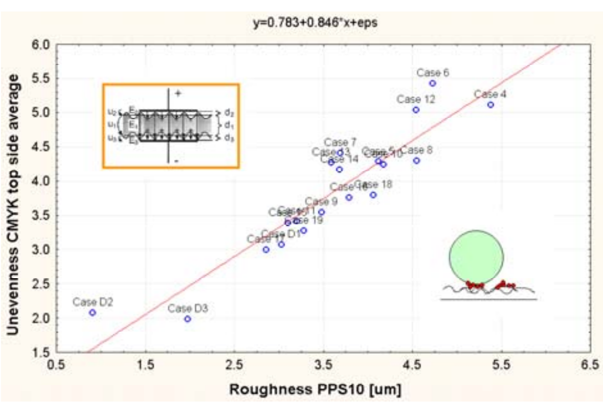

Figure 2. PPS roughness and print quality with an indirect dry toner press. When roughness increases, the unevenness of especially single toner layer areas increase.

New methods of producing toners chemically by polymerization instead of traditional grinding gives increased control over size and shape distribution of toner particles. It can be expected that the toner layer thickness may still decrease by this manufacturing technology, to realize advantages in costs per page, print quality and in post processing operations. Thinner layers would in principle mean also increased requirements on paper surface.

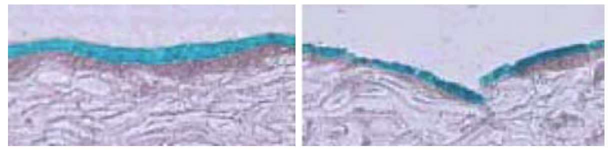

Figure 3. Single colour toner layers (100%) of a mid 90's direct transfer machine (left) and a modern dry toner press having significantly lower toner layer thickness[6]

Smoothness, and also other non-uniformity of different scales, like for example insufficient formation, can affect to some extent also through the variations of local electrical conditions in the transfer nip, Figure 4. The significance of these effects depends also on the machine construction. In case of a relatively high paper roughness, the transfer field can locally relax if the voltage exceeds the ionization limit and Paschen air-breakdown discharge occurs. The toner will not transfer properly onto the paper sheet at such locations.

So with the modern dry toner colour presses the emphasis – what comes to print quality – is more on surface evenness and good uniformity, than on the macro-scale electrical properties, which is a change compared to the copy-shop generation machines. Paper should conduct electricity enough and have a relatively smooth surface. This brings out also the print quality and related business advantages that can be attained with coated papers. Figure 5 shows data of trial series on a modern dry toner press with a set of papers having different resistivities and smoothness levels.

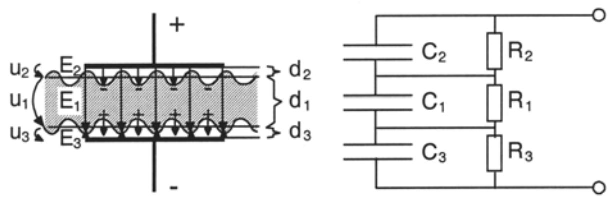

Figure 4. Non-uniform material in a transfer nip.

Although the mechanisms of effect differ, the paper property requirements for good print quality have clearly approached those important also in traditional offset printing, when toner based colour printing has developed from office and mid 90's copy-shop environment machines to production presses. The production printing applications are facilitated by the clearly enhanced print quality over the few recent years, and the widening selection of substrates possible to use. If having the printed gloss, print evenness and detail reproduction on a level good enough for comparison with offset, there are actually benefits like the slightly larger CMYK colour gamut possible with dry toner printing, Figure 6.

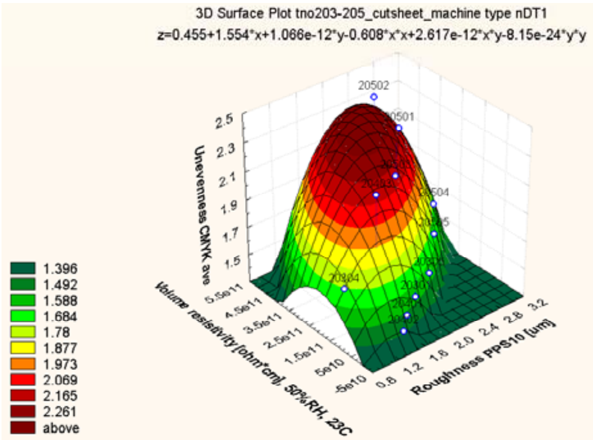

Figure 5. The print quality on modern colour presses is enhanced by sufficient conductivity and smoothness of paper.

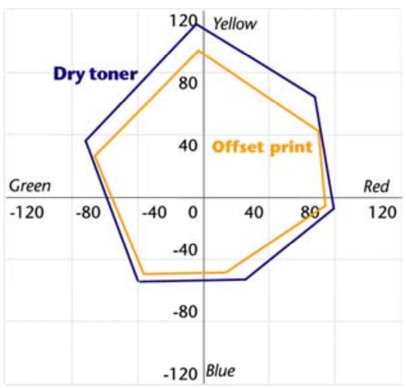

Figure 6. Gamuts with CMYK offset and a modern dry toner press

With modern machines, it is possible to use uncoated, coated and cover stocks. This creates needs to have a wider selection of papers and also mill-cut sheet sizes available for digital printers than a few years ago. Guillotine cutting creates easily runnability problems especially with low grammages, and also dusting-related print quality problems.

On Paper Requirements for Good Runnability

The modern toner-based production colour machines can print on coated papers and heavy grammages, when with the earlier machines only uncoated about 100 g/m^2 paper could be run reliably from the high capacity trays. The improvements allowing the wider substrate range are related to the use of indirect toner transfer, more straight paper paths, and also to the developments in the fusing processes, allowing longer dwell times and less dramatic material moisture change with coated and high-grammage materials.

Reliable printing and low downtime are key issues in efficient production printing. Paper must run though the press with very high reliability, regardless of are the sheets being simplex- or duplex-printed. This leads to high runnability and quality consistency requirements of the paper. Runnability trials on high-speed colour machines have for example demonstrated an increasing importance of controlling the curl and waviness tendency of the sheet. Coated papers with low grammage and low stiffness have been problematic from the runnability aspect also on modern machines.

Low stiffness, high curl and waviness, insufficient dimensional stability and bad cutting quality bring runnability problems on toner-based colour production presses. Stiffness is naturally not the only variable having effect on low grammage coated paper runnability, since many other parameters like waviness, cockling, drying and heating (density) are related to the grammage and stiffness. Temperatures in area of about 160-180°C are applied on paper when fusing the image, drying the sheet heavily, and causing these deformation problems. Also friction and static electricity can create problems as speeds increase, like with high speed B&W cut sheet presses. Paper temperature elevation in fuser may cause coatings to loose some of their stiffness or increase friction, which can influence runnability.

The normal trade-off for enhanced stiffness properties tends to be reduced smoothness, which influences negatively on print quality in colour electrophotography. This situation can be aided by paper sheet design. By using suitable materials and functional structures the runnability of low substance coated paper can be enhanced significantly without losing the benefits that coated surface offers for good print quality. Optimizing the coating colours and base paper recipes, coated paper can be designed for good surface smoothness and thermal properties for high print quality, while the base paper needs to give bulk, stiffness, flatness and other properties needed for good runnability, Figure 7. Also machine manufacturers are naturally engineering to make solutions that would make the presses more robust against runnability issues originating from the properties of low grammage papers, especially from the coated ones. At the moment these issues remain problematic with the lowest grammages.

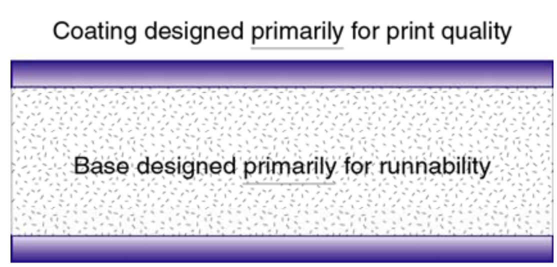

Figure 7. Coated low gsm paper with a functional layer structure

The reliability and efficiency of the post processing operations are in general a problematic area for dry toner production, mainly because paper dries heavily in the printing process, resulting in waviness and other dimensional stability problems, static electricity and cracking when folded. Adding to this, there is normally no time in print-on-demand production to let the paper piles acclimatize. With web fed applications, the use of remoisturizing equipment can help the situation, but on cut sheet area, these issues are more pronounced. Paper manufacturers can help this to some extent by designing papers that have enhanced or optimized thermal properties for fusing and fiber structure minimizing dimensional distortion problems caused by the drying of paper in dry toner fusing.

Conclusion

As the result of development of toner transfer, the print quality attainable with the modern dry toner production colour presses is much less influenced by moisture content or macro scale electrical properties of paper compared to earlier direct transfer machines. Fuser systems and paper paths allow reliable printing on coated papers and heavy substances. The print quality requirements are placed on surface properties, for example on smoothness of paper, bringing out the benefits possible to gain with coated substrates.

Trouble-free runnability of untraditionally long runs is a necessity in production digital printing. Runnability issues can occur especially on lowest grammage coated papers. These problems can be approached by paper sheet design, moving the surface, mechanical, and thermal properties of the sheet towards the direction optimal in dry toner colour printing. In future as the speeds of colour printing increase, the thermal properties of papers become increasingly important for being able to run and fuse prints at maximum speed independent of the surface type or material substance.

References

1. S. Simula and K. Niskanen, Nordic Pulp and Paper Research Journal, 14, 3:243-246 (1999).
2. E.M. Williams, The Physics and Technology of Xerographic Processes, Krieger Publishing Company, Malabar FL, 1993, pg. 214.
3. A.C. Chen, Borch J., Garcia C.E., Linn B., J. Imaging. Sci., 29 (1), (1985).
4. Apel R., Knott J., Schleusener M, Benno P., The Influence of Paper Roughness and Toner Properties on Fusing Quality, Proc. IS&T NIP11, (1995).
5. S. Simula and K. Niskanen, Nordic Pulp and Paper Research Journal, 14, 3:236-242 (1999).
6. Ilmonen A., Experiments on Print Unevenness in Electrophotography, KCL Reports 2657. (2003).

Biography

Petri Sirviö received his M.Sc. degree in Graphic Arts Technology from the Helsinki University of Technology, Finland, in 1996 and joined Stora Enso Oyj. His work as research specialist of digital printing in Stora Enso Research involves R&D activities and method development in the Digital Printing Laboratory, established in 1996. His work has primarily focused on paper development for the electrophotographic printing processes.