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R·I·T Printing Industry Center

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Papers for Digital Printing, Part I

Over the past ten years, the market for digitally printed documents has soared. The best runnability and image quality for digital printing is obtained from papers designed specifically for electrophotographic operations. This month's eReview will cover the first portion of a recent Printing Industry Center research monograph entitled *An Investigation into Papers for Digital Printing*, by Mary Anne Evans, Ph.D., and Bernice A. LeMaire (PICRM-2005-06).

With new technological developments in electrophotographic printing, more stringent demands are being placed on paper performance. Expectations of higher run speeds and higher image quality are challenging paper manufacturers to produce papers with the appropriate characteristics at acceptable price points. The trend is toward graphic-intense documents, with near photo-quality color, and therefore digital substrates must be able to handle higher levels of toner from four component colors while maintaining sharp line edge acuity and accurate dot placement.

Intermediate decision makers in the value chain may not have an understanding of paper attributes that differentiate digital papers from those grades designed for traditional technologies. A technical understanding of these issues is essential if print buyers are to appreciate the value offered by digital papers.

Paper Performance Characteristics Required for Printing

In general, printing papers must perform adequately in three functional areas:

- **runnability** – sheets or webs of paper running smoothly through the print engine without jamming,
- **printability** – image quality and overall appearance of the printed sheet, and
- **fitness for use** – usability, meeting permanence requirements, and the ability to be finished and distributed in the required manner.

Acceptable levels of performance in these areas are required for all types of printing processes.

Additional Paper Requirements for Digital Printing

Digital printing makes greater demands on paper than offset printing. Two steps in the electrophotographic imaging process are critically related to paper properties: toner transfer and fusing.

Inside an electrophotographic printer, the image is written using a laser or other light-based system to a photosensitive drum or belt known as the photoreceptor. Charged toner is attracted to the image areas of the photoreceptor, which are charged differently than the background areas. The dielectric force that drives the toner transfer arises from a charge placed on the paper before it reaches the transfer gap. The strength and uniformity of this force determines the efficiency of toner transfer.

Toner transfer efficiency is related to the distribution and density of fillers within the paper structure, and variations in the thickness of the paper. Moisture variations can also affect the dielectric force strength sufficiently to produce visible optical density variation. Where toner transfer is inefficient, residual toner remains on the photoreceptor and may be transferred to the next image, increasing background speckle or producing "ghosting."

Once on the paper, the toned image must be fused to become permanent, usually by heat and pressure, cold pressure, radiation, or vapor methods. Generally, fusing quality decreases as the surface roughness of the paper increases.

Liquid "inks," consisting of toner particles dispersed in a vehicle, are used in HP Indigo digital printing systems. Vehicle penetration into the paper pores and evaporation leave the toner particles on the substrate surface. The fusing step in this process tends to require lower temperatures and pressures compared with powder toner technologies.

Characteristics of Efficient Digital Papers

In order to produce high quality images and good on-press runnability, electrophotographic papers are required to have certain characteristics that offset papers do not necessarily share. These are briefly outlined below.

- **Moisture levels.** Of all digital paper properties, the moisture level and moisture history are arguably the most critical, and are often the only rigid paper specifications provided by a press manufacturer. The moisture level of most digital papers generally varies from 4 to just below 5 percent of the paper's overall weight. Paper that is too dry may result in static discharge within the print engine, resulting in paper jams. Too much moisture causes print defects, curl, and again, jamming. Moisture history is also a factor: paper "remembers" moisture and temperature exposures, and may not fully recover from an inappropriate environmental exposure.

- **Runnability.** Out-of-plane deformation (such as curl or cockle) is a problem that is exacerbated at the higher toner levels and fuser temperatures used in full-color digital printing. Like incorrect moisture levels, out-of-plane deformation will also reduce a paper's runnability. Compared with many offset press requirements, sheet properties for digital printing must be more stringently controlled in terms of stiffness, moisture level, edge quality, and dimensional integrity in order to meet the jam-free requirements of complex high-speed paper paths.

- **Capiler (Thickness).** Managing caliper in digital printing is critical because the magnitude of the electrostatic force

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About the Center

Dedicated to the study of major business environment influences in the printing industry precipitated by new technologies and societal changes, the Printing Industry Center at RIT addresses the concerns of the printing industry through educational outreach and research initiatives.

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which pulls toner towards the sheet surface in the toner transfer step depends on how much material is beneath the surface. Sheet thickness variation, or z-direction non-uniformity, has been shown to be a significant factor in the variation of surface charge density.

- **Grain direction.** In digital presses, feeding sheets with the grain in the wrong direction can cause paper jams if the stiffness in not in the functional range.

- **Formation.** The performance of paper in digital printing has been shown to be very closely related to formation, or the distribution of mass density. Ink penetration depends on the right size, depth, shape and distribution of voids and pores in the surface.

- **Surface properties.** Fluctuations in paper surface composition can result in variations in surface resistivity, and hence toner density, degrading the print quality of graphic images. The distribution of fillers within the body of the paper both laterally and perpendicularly to the surface will affect the charge density at the surface, influencing toner transfer.

- **Toner adhesion.** Dry toners used in digital printing generally penetrate much less into the surface than offset inks, even though there is a molten phase in which some liquid polymer or resin is able to penetrate pores and voids. Thus there is a higher concentration of colorant on the surface than with similar offset inking levels. Coated papers retain more toner on the surfaces, but do still rely on some pore penetration for effective adhesion.

- **Surface strength.** In the toner fusing stage, paper surface strength must be adequate to prevent delamination of coatings, or fiber-picking with uncoated papers. Either fuser oil or surface control agents on the toner particles themselves may be used to enable release from fuser rolls.

- **Smoothness.** Very smooth surfaces cause high levels of light reflection from the paper surface, or gloss. In areas with differential toner coverage, or if fusing is non-uniform, differential gloss across solid tones can be distracting. Also, gloss stock can blister if the underlying moisture is heated in the fusing step and the steam has nowhere to go. Therefore environmental conditioning and low, uniform moisture levels are particularly important with high-gloss digital papers.

- **Dimensional stability.** In a digital press, papers are subjected to heat, pressure and a variety of other forces, most of which are imposed in the fusing cycle. High temperatures can cause expansion, contraction, curl, cockle, and in some cases accelerated creep. Digital papers must be able to maintain adequate dimensional stability in toner fusing cycles up to 400 degrees F to enable the accurate registration of images on both sides of the paper.

- **Charging characteristics.** Digital papers must be able to

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IBM Printing Systems
MeadWestvaco
NPES
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Standard Register
U.S. Government Printing Office
Vertis
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Weyerhaeuser
Xerox Corporation

take and hold a charge in order to effect a clean and efficient image transfer. The characteristics that relate to efficient toner transfer include the paper's intrinsic conductivity (the product of the charge density and mobility) and also the charge injection and charge lifetimes. The paper must be able to allow charge transfer to exactly the right extent, followed by a limited decay, all the while holding the charge for long enough for the transfer step to take place.

- **Appearance properties.** Early digital printers suffered from significant inconsistency of color and image density during print runs, and a common practice was to operate in several shorter runs to allow "recovery" to a normalized state. The stability requirements of papers for color rendering ability and brightness are tighter with the newer digital technologies. Opacity is another important consideration. Although toners do not penetrate as deeply as offset and inkjet inks into the structure of the paper, highly toned areas can lead to show-through in two-sided printing. This is more of a challenge to color printing in which toner levels in some systems may approach 400%.

Pricing Trends and Paper Availability

The cost of digital papers remains high compared to offset papers, and this is a challenge for sales personnel selling both categories to a print provider. The range of digital papers is already wide – currently one paper manufacturer offers more than 1,000 offerings (different sizes, basis weights, finishes, etc.) in its digital lineup. Printing complex jobs using multiple stocks in one pass through a digital production press is a key advantage of digital printing. With one-pass document printing and finishing, the concept of "productivity" extends beyond press run speeds to the idea of finished pieces per unit time. This integrated capability is driving the need for wider and matched substrate ranges which can run concurrently in a print job.

Conclusion

The chemical composition, spatial distribution of components, and thickness uniformity of papers used in digital printing are more critical than those of papers for other printing processes. Thus the design and production of high quality digital papers requires more thought than just, for example, turning up the dryer on an offset formulation to reduce moisture levels, or tightening specification latitudes. In many cases the economic viability of a print job depends on the quality of the substrate; poor runnability and low image quality can differentiate between profit and loss in an industry with tight profit margins. The demands on paper manufacturers and the need for open research into digital papers have never been greater.

Next

Next month we will look at research that was designed to gain an overall impression of how and why different papers are selected for digital printing jobs.

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