Offset Quality "Short Run Colour Printing" Using a Dry 4-Colour Bi-Component Electrophotographic Process

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Introduction

In order to design 'quality consumables' a definition of 'quality' has to be given. In global terms, the consumables should interact with the process and the system to yield the required 'quality image', but also other 'qualifiers' should be fulfilled:

offset-like 'image quality':

* resolution	edge profile
* full density quality	full density/grey rendition/ noise/background
* colour rendition	gamut, ...
* 'look and feel'	gloss, ...

'qualifiers' such as:

* economics	* the targetted work-flow (e.g. heavy duty)
* environmental issues	* reproducibility of the quality
* image stability for light, mechanics,...	

When 'image quality' is high, no compromise on the other 'qualifiers' is allowed in order to achieve said high 'image quality'. In the case of 'Short Run Colour Printing' (SRCP), complementing 'classical' Offset Printing at lower run lengths, the user should have a similar general 'quality' feeling as he experiences with his classical technology. Therefore, design of quality consumables is more than optimizing classical materials. New design concepts and principles have to be implemented. The development of the Chromapress® consumables will be given as an illustration of the principles used in the design of 'quality consumables'.

General Analysis of the System

The consumables have been designed for use in the SRCP-devices Chromapress® and DCP-1®. Close cooperation took place with expert teams of Xeikon N.V., responsible for the innovative hardware and process of the print module. The system can schematically be given as a combination of following subparts. A detailed description of the system is given by L. De Schamphelaere et al.[1]:

* illumination latent image	resolution:	600 dpi
	mode:	multi level
	photoconductor:	OPC (negative charge)
* development	magnetic brush:	2-component
	development:	reversal
* transfer	type:	electrical (corona)
	mode:	collect on paper back-front alternating duplex
* fusing	type:	radiative/convective
	mode:	simultaneous duplex
* general process:	speed:	12.5 cm/sec
	type:	2*4 colour stations

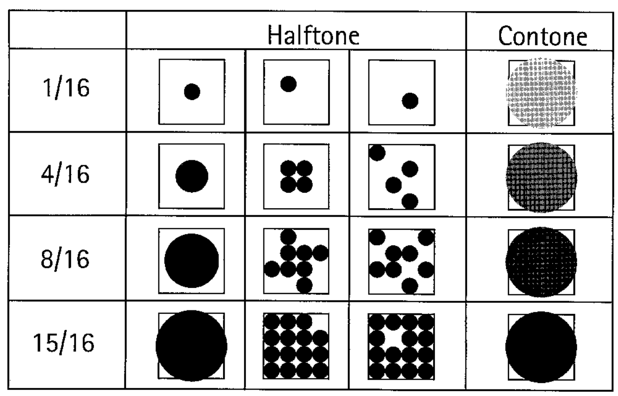

Figure 1. Intrinsic possibilities to create grey levels.

The output is 2000 duplex A4 colour pages pro hour at nominal 'Offset Quality' level. Images are created combining excellent line art quality and grey rendition. Figure 1 shows intrinsic possibilities to create grey levels. Full contone technologies (e.g. AgX-photography) can use the right scheme. Purely binary technologies like offset printing or B&W laser printers rely on pure halftoning, where a 'spatially integrated' density value is observed. One can use one pixel per dot or subpixels.

There is an equivalence in grey level rendition as shown schematically in Figure 2. Adding the criterium for good line-art work (>600 dpi), an operation system window is found.

At 600 dpi a good spatial response as well as a good density response at microscopic level is requested from the toner/developer system. A two component concept was chosen in order to fill in this expectation.

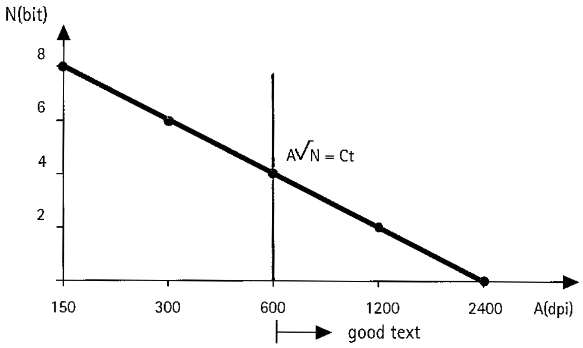

Figure 2. Equivalence plot for grey levels.

Consumables Design

General Principles

A set was designed, being composed of four colour subsets (YMCK) each comprising a toner (dv50=8µm) and a corresponding fine carrier (dv50=55µm). Different unique technologies were used whereby the following scheme of principles was applied:

action item	importance
*definition of the physical properties to be incorporated	+++
*definition of the concept to incorporate these properties	+++
*definition of the interrelation between these properties	+++
*setting the mean value of the properties	+++
*designing narrow distributions for each property	++++
*optimizing for cost and manufacturability	++++

Further on distributions will be discussed. The relative width of a distribution will be defined as:

$$p = \frac{\text{Width at Half Maximum}}{2 \;\; * \;\; \text{Average Value}} \qquad (1)$$

Particle Size Distribution

Reduction of the toner size and narrowing of its distribution is an important key to improve print quality. A good representation can be achieved with toning particles if their size is at least 5 times smaller than the smallest line width, (in case they are ideally deposited and fused). This means that for a 600 dpi illumination a 8.4 µm toner size would be ideal. When behavior is less ideal, further size reduction and narrowing of the distribution will be necessary to compensate for said deviation, implying however a higher production cost etc. ... for the toner.

In the Chromapress® case it was decided to go for 'ideal' toner behavior and to take the size around the theoretical limit. The amount of particles not participating in a normal way to the process was reduced. No particles larger than two times the nominal size were allowed. To the lower size, two actions were undertaken. The developability was optimized by a reduction of cohesive/adhesive interactions, giving as a result a lower smallest size showing restricted developability. This improvement can be seen in Figure 3 as a shift in the particle enrichment process to lower sizes. Then a clear size cut was made removing undersizes from the distribution.

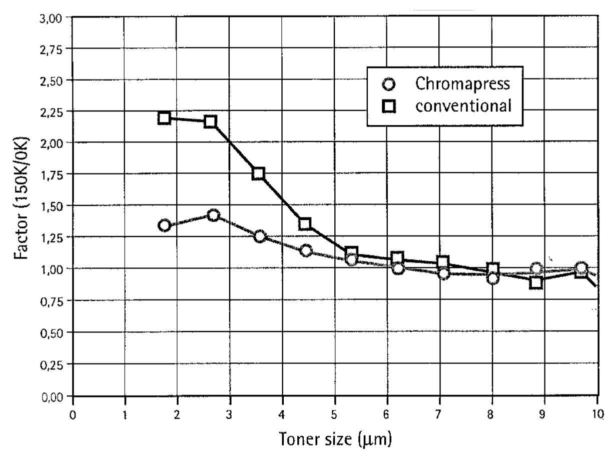

Figure 3. Particle enrichment in 150K-old developer mix.

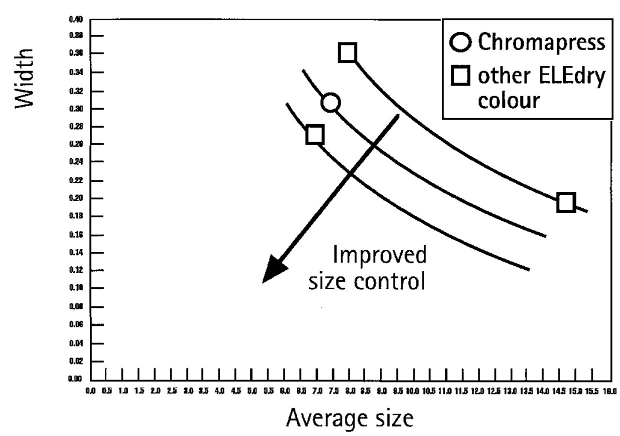

Figure 4. Particle size quality of colour toner.

Figure 4 shows the relative width and mean value of the resulting distribution in comparison with other ele-dry systems. It shows fair particle size control without going for extremes, thus allowing for moderate cost and complexity during manufacturing. This is an indirect consequence of the option to design for ideal behavior with respect to charge, flow and fusing behavior.

Toner Charge Distribution

In order to induce outstanding particle behavior, the toner charge should be controlled accurately. Development theories, such as proposed by Schein[2], Scharfe[3], etc. ... allow to set an optimum mean value for the toner charge as a function of process speed, development potential, ... Apart from this average value it is essential to consider also the charge distribution, e.g. in terms of a q/d-ratio as can be measured by different techniques.[4]

The charge distribution is the result of a complex combination of factors:

*toner particle size distribution
*surface composition distribution of toner and carrier
*surface state distribution of toner and carrier
*activation/deactivation statistics

The resulting width of the charge distribution reflects the degree of (non)-ideality of each composing factor. Taking all factors ideal, the charge distribution will in the limit only depend on the size distribution. A general expression relating the 'q/d'-ratio to the toner size 'd' is given by:

$$q/d = cte * d^{b} \quad \text{with} \quad 0<b<1 \qquad (2)$$

where (b=0) reflects toner charging being limited by surface potential and where (b=1) reflects toner charging limited by electrical field. Experimentally[5] b-values between 0.5 up to 1 are found. Relation [2] then implies a q/d distribution with a relative width somewhat lower than to almost proportional to the relative width of the particle size distribution.

The consumables were designed such as to reduce the width of the q/d distribution. This effort was further complemented by innovative design of the developing unit with respect to charging and admixing capabilities.

A dedicated toner polyestermatrix was elaborated together with a special charge control technology. Colouring substances were shielded by induction of a specific affinity towards the polymer matrix.

Also the carrier was especially designed. Dedicated coating was elaborated and emphasis was put on the quality of the coating in order to minimize the spread in charging properties.

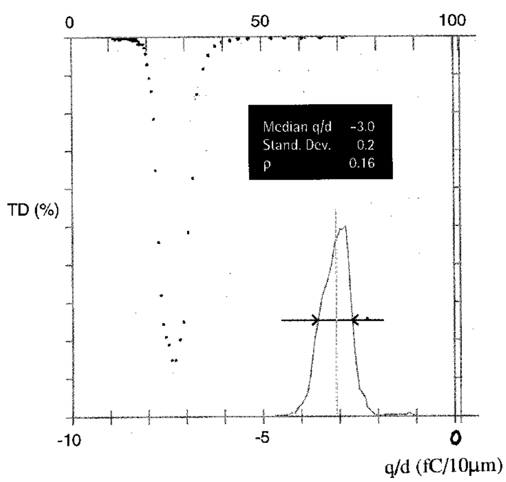

Figure 5. Charge distribution of Chromapress® colour.

The resulting charging properties are shown in Figure 5. The absence of uncharged, or wrongly charged species is apparent as well as the narrow distribution. Comparison with other ele-dry systems is made in Figure 6. Qualitative curves indicate the increasing difficulty to get narrow distribution while designing for lower charge. Different Chromapress® designs reflect the possibility to achieve a low charge with a sharp distribution. This gives the developer unique developing capabilities even with less stringent particle size. Figure 7 relates the relative width of q/d with that of the particle size. Two conclusions can be made: a b-value smaller than 1 is found and the actual toner/carrier design does not increase the width of the q/d distribution, and this in spite of the small size of both constituents.

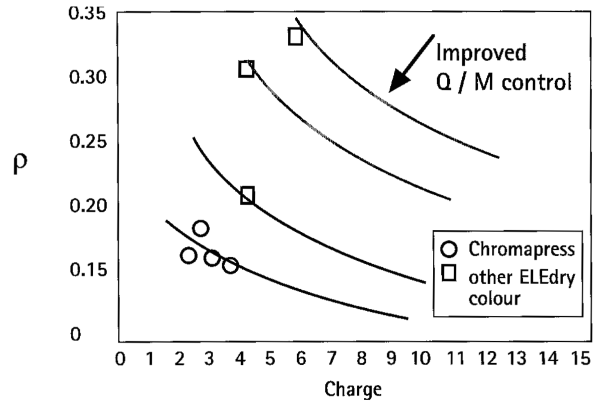

Figure 6. Charge quality of colour toners.

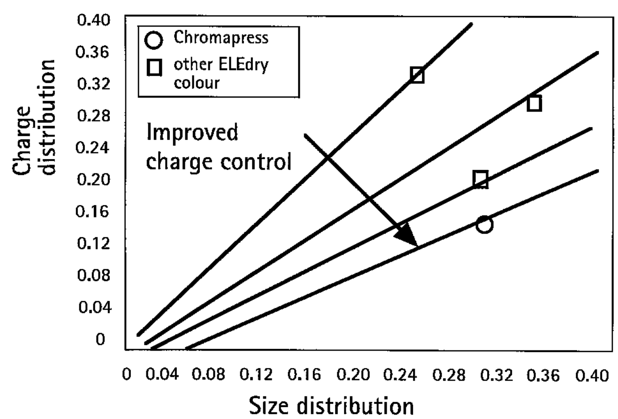

Figure 7. Interrelation between charge and size quality of colour toners.

Flow Control within Toner/Developer

Apart from ideal size and charge also rheological issues are important during all imaging subprocesses:

* individual toner particle control during development
* soft developer rheology during development
* superior transfer behaviour towards the final receptor
* absence of cohesive/adhesive artifacts

In the Chromapress® system the toning system should respond accurately to low development potentials at microscopic level (grey rendition). Low adhesion to the carrier coating and low intercohesion of the toner is necessary, i.e. a high free flow behavior in general.

The unique transfer system of the Chromapress® asks for adhesive properties of the toner. An alternating back-front simultaneous duplex transfer is used[1], asking both high transfer efficiency and low toner retro pick-up in subsequent stations. Also degradation due to artefacts caused e.g. by cohesive agglom-aretes should be avoided.

The carrier was optimized in its size to reduce image deterioration due to the footprint of the magnetic brush, however optimizing also for minimal carrier bead loss. The average particle size is set at 50-60 μm, and optimal rheological behavior was achieved by dedicated coating technology, and complementary toner design.

Taking into account the small size of the toner, an adapted technology was needed to design for low adhesion, cohesion and high free flow (Figure 8).

The difficulties to achieve a high flow number with decreasing particle size is shown qualitatively by the sloping lines. Careful control of the surface state and composition as well as optimized additive technology enables to reach high flowability even for small sized toner systems. This leads to a unique situation whereby the latent image can be developed in optimal conditions and can be transferred to the final substrate with minimum quality perturbance.

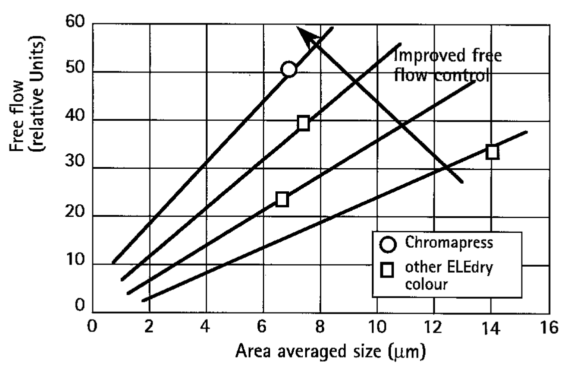

Figure 8. Free flow of quality colour toners.

Fusing Behavior

Quality extends also to the step of fusing of the image, so apart from classical aspects of fusing, other parameters are important:

* colour rendition
* optical efficiency or covering power
* gloss characteristics

In order to comply with the typical Chromapress® fusing system a special melt behavior was designed enabling good mechanical adhesion and fair spreading towards the receptor, without reducing sharpness of the images. At the same time a good melt fluidity is necessary in order to close the toner layer so that 'white holes' disappear which reduce the optical reflection density.

This also results in adequate colour mixing, necessary to obtain full extended colour gamut. Most intriguing issue is the 'gloss characteristic', whereby offset-feel, and gloss independence from image content are requested. An adapted toner technology was developed. Figure 9 shows the gloss behavior of the toner and other ele-dry systems. Whereas for Chromapress® the gloss is largely flattened out, other technologies are more influenced by the different layer thicknesses typical for a dry toner based multi-colour image.

Quality Performance of the Chromapress® Consumables

By optimizing the physical properties, not only in their mean value, but especially in their distribution and interrelations, and by associating appropriate weighting factors to each parameter, a high performance was achieved without impeding economics or manufacturability. Some examples of the reached performance are given. Figure 10 illustrates the high degree of observable sharpness that can be reached with the system. It shows the real physical image of a point 6 character 's' (1mm high) printed using different technologies and the corresponding images perceived by a human observer at 25 cm viewing distance. The metrics used to obtain said perceived image have been explained elsewhere[6].

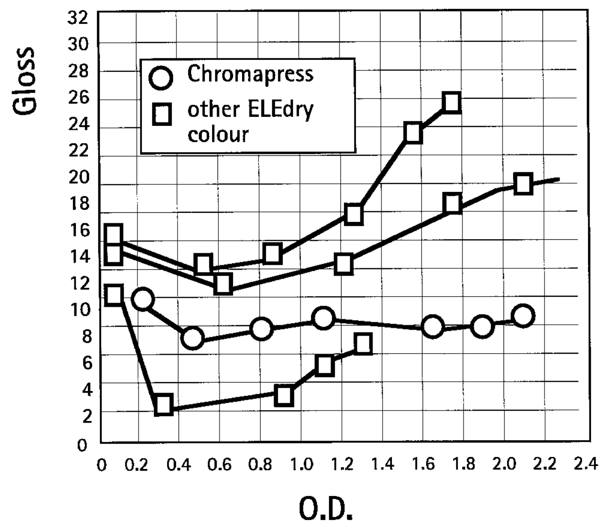

Figure 9. Gloss behavior versus image density for colour toner based systems.

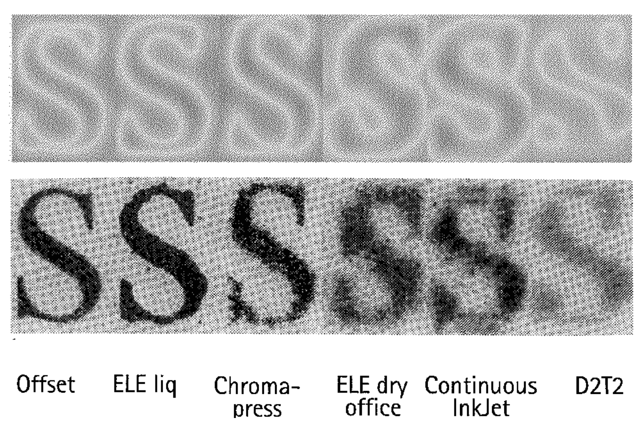

Figure 10. Perceived image quality (25 cm) (a) versus physical images (b) created using different technologies.

The figure shows the capability of Chromapress® to give 'offset-like' images with respect to sharpness. With respect to grey rendition, Figure 11 shows noise as a function of visual reflection density. Optimization of ele-dry technology as is done for the discussed consumables gives a noise level similar to offset quality.

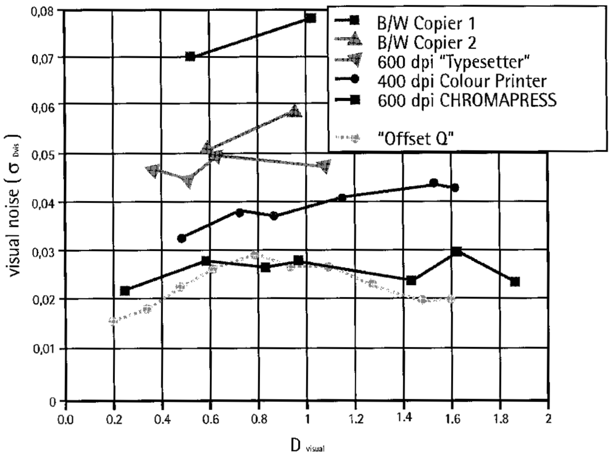

Figure 11. Comparison in noise quality of ele-dry technology versus offset.

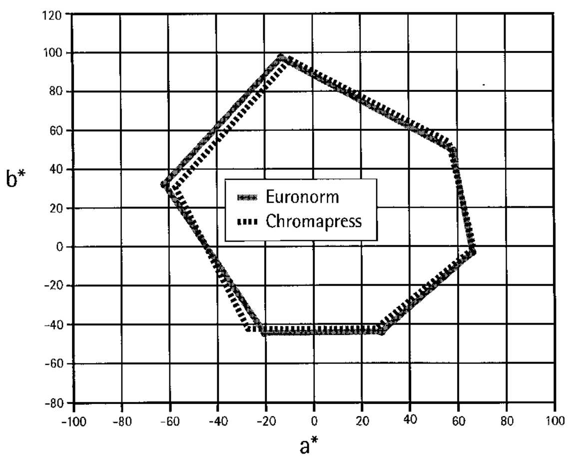

Figure 12. Chromapress® colour gamut related to EURO offset specification.

Apart from sharpness, grey rendition and gloss characteristics, another quality parameter of the system is shown in Figure 12. Comparison is made between the offset colour gamut (EURO) and the gamut of the Chromapress® system. The tuned fusing behavior gives good colour intermixing yielding extended colour gamut.

A last but not unimportant issue is the fact that the Chromapress consumables enable to reach full density at 0.65 mg/cm**2, corresponding almost to a monolayer deposition of the toner, reflecting the control over deposition, transfer and fusing of the small particles.

This fact is important as it gives good covering power, interesting economics for the user, and thinner layers on the image.

Conclusions

The principles followed during the design of high quality dry electrophotographic consumables were discussed using Chromapress® consumables as an example. It was shown that not only mean values but also the distribution of said properties and their interrelations are important. It is also important to associate appropriate weighting factors to each item, allowing optimization of other important parameters such as manufacturability, costs, etc.

It was shown that applying these principles it is possible to design a high quality set of consumables that in combination with innovative hardware design and innovative process concepts, reach the target of offset quality, by combining in a unique way resolution and grey rendition.

The stability of the system and subsystems put forward, enabled to achieve offset quality at appreciable process speed, giving the opportunity to exploit said technology in the area of short run colour printing.

References

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