The Effects of the Process Parameter Adjustments on Print Quality in a Web Fed Electrophotographic Color Printing Process

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Abstract

The aim of this study was to relate the adjustments of the main process parameters of an electrophotographic color printing process to the numerical print quality, measured as variation of the CIELAB color coordinates.

Samples printed with different process parameter combinations were measured with a spectrophotometer. The variation of the CIELAB color coordinates was analyzed from the parallel measurements.

The effects of the main process parameter adjustments on the amount of variation were in line with the visual print quality optimization and paper testing method. The CIELAB value variation could be used to numerically estimate the effects of process parameter adjustments on print quality. The testing environment built can be utilized to collect data for the analysis of the paper property requirements in electrophotography.

Introduction

A testing installation for studying paper requirements in electrophotography had been built. The installation included a Xeikon based Agfa Chromapress 32i (machine type DCP/32D) digital printing machine installed in a controlled environment. The printing machine was equipped with a datalogging system to collect information from the process and paper during printing. In this printing process, the process parameters can be widely adjusted by the operator of the press. Because of this possibility of being able to adjust the transfer parameters and the moisture level of paper from the user interface, different process parameter combinations can be easily created for research purposes.

When the process has been optimized for some specific paper grade, the settings can be saved into a script file, to be used when printing on that paper grade with a similar press. When optimizing the process parameters for a certain paper grade the process parameters requiring most optimization are U2 voltage, transfer currents and duplex currents[1]. The correct level of these process parameters is connected to the electrical properties of paper. The U2 voltage measures the resistivity characteristics of the paper by measuring how much of the initially applied voltage (U1) is left at the following U2 measurement, and this value is used to control the drying of paper. The transfer current is used to create the field to transfer the toner from the photoconductor to the paper, and the duplex corona treatment reverses the surface charges on paper to prevent the already transferred toner from moving to the following color units.

To have numerical information of the print quality, samples produced using different main process parameter combinations were measured with a spectrophotometer. The CIELAB color coordinate variation within the parallel measurements was used as a numerical print quality estimate. The data collection system, recording 52 different paper and printing process parameters, was tested to see if it can be utilized in further trial series.

Methods

During the process of determining the optimal setpoints for the process parameters for a certain paper grade, or making a script file, the print quality is observed visually. Based on a testing procedure that has been used to make hundreds of script files, the optional main process parameter adjustments to optimize the print quality are listed in table 1[1]. Examples of the most common defect types related to unsuitable process settings or unsuitable paper type, named here as high frequency cloudiness (HFC)[1] and low frequency cloudiness (LFC)[1], are shown in figures 1 and 2.

Table 1. The optional process parameter adjustments to optimize the print quality

	U2 voltage	Transfer currents	Duplex currents
HFC	⇑	⇓	⇑
LFC	⇓	⇑	⇓
Duplex lines	⇑	⇓	⇑
Banding	⇓	⇑	⇓
⇑ = increase needed, ⇓ = decrease needed			

Graininess (~3…5 mm)

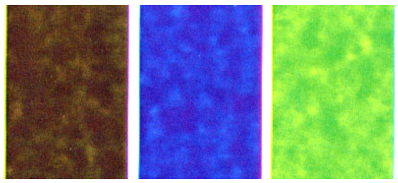

Figure 1. High Frequency Cloudiness (HFC)

Low density areas (~5…10 mm)

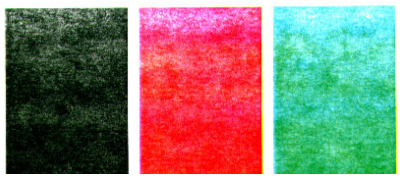

Figure 2. Low Frequency Cloudiness (LFC)

To study if the effects of engine parameter changes on numerical print quality follow the visual print quality optimization process of table 1, a trial point matrix of the three main engine parameters was printed. The range where the process parameter values were changed covered the range of the values that are reasonable to use with the type of paper used in testing. The range of the process parameter values used in the trial point matrix is shown in table 2.

Table 2. The trial points printed

	U2 voltage [V] (T4.N2~25°C)	Trf current [µA]	Dplx current neg/pos [µA]
Low	330	55	40 / 80
High	390	195	100 / 140
Step	20	20	20 / 20

The both side printed test sheet contained full tone areas of C, M, Y, K, C+M, C+Y, M+Y and C+M+Y positioned across the web. To get numerical estimates of the print quality, all test prints were measured with a spectrophotometer equipped with x/y-table. The spectrophotometer aperture size was 4 mm, backing was black, illuminant D50 and observer angle 2°. From a color strip 90 parallel measurements were taken. This data was tagged and stored in a database for later analysis needs so, that 30 parallel measurements were taken from both web edge areas of the printed sample, and 30 parallel measurements from the area in the middle of the web. The CIELAB color coordinate variation was calculated from these parallel measurements using equation 1. For the purposes of this study, a value based on all 90 parallel measurements taken from a sample was used, calculated using equation 2.

The topside green color evenness is an important evaluation criteria in the print quality optimization process[1]. The average of the rms_E values within the data of all the printed samples was higher with the green color compared to the other colors. Therefore the rms_E value of the topside green color area (100%Y+100%C) was used as the numerical print quality estimate.

$$rms_{Eareas} = \left\{ \frac{1}{n} \sum_i \left[\left(L_i^* - \overline{L^*}\right)^2 + \left(a^*_i - \overline{a^*}\right)^2 + \left(b^*_i - \overline{b^*}\right)^2 \right] \right\}^{1/2} \quad (1)$$

$$rms_E = (rms^2_{edge1} + rms^2_{middle} + rms^2_{edge2})^{1/2} \quad (2)$$

Results

The optimum setting combination of the 130 gsm uncoated paper used in testing, determined based on the visual print quality (table1), was U2 = 370 V (IPS/T4.N2 ~ 25 °C), transfer currents CMY = 75 µA, and duplex currents = 60/100 µA (negative/positive).

The effect of changing the transfer and duplex currents with fixed U2 voltage

The effect of the transfer and duplex current adjustment on the rms_E when the U2 voltage was fixed to its optimal level of 370V is shown in figure 3.

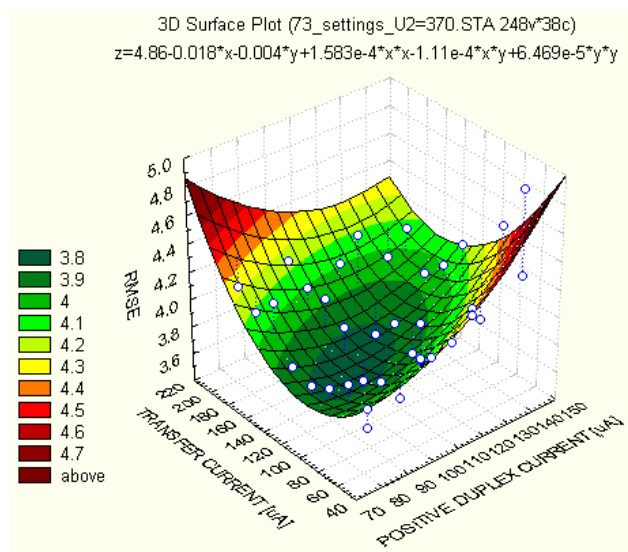

Figure 3. The effect of changing the transfer and duplex currents with fixed U2 voltage

When the transfer currents were clearly raised from the visually selected optimum level of 75 µA, the rms_E value of green color increased. The rms_E value increased also when the duplex currents were raised from the optimum level of 60/100 µA (negative/positive). With the optimum setting combination, giving the optimal visual print quality, also the rms_E value was on a low level.

The effect of changing the transfer currents and U2 voltage with fixed duplex currents

The effect of the U2 voltage and transfer current adjustments on the rms_E value of the topside green area is shown in figure 4. The duplex currents have been fixed to the optimum of 60/100 µA. When the U2 was on a low level, meaning paper being moist, also the transfer currents had to be low to have a low rms_E value. The combination of moist paper and high transfer currents increased the rms_E value. At the optimum level selected visually, requiring a high U2 value in this case, the rms_E was on a low level.

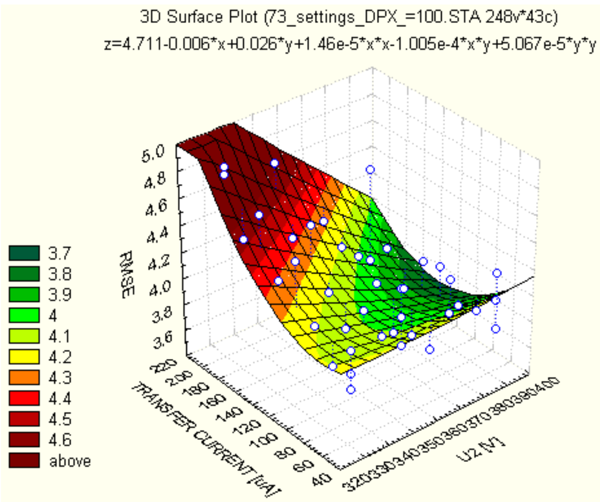

Figure 4. The effect of changing transfer currents and U2 voltage with fixed duplex currents

The effect of changing the U2 voltage and duplex currents with fixed transfer currents

Because of the lower amount of possible parameter combinations, the development of the rms_E could not be plotted as well as when the transfer current was a variable. The relation of the U2 voltage and duplex currents to the rms_E when the transfer current was 95 µA is shown in figure 5. The rms_E was on a slightly higher level when both the U2 and duplex currents were high.

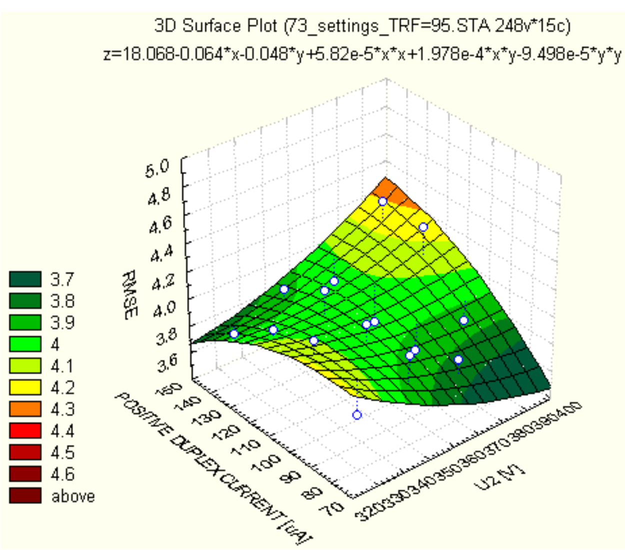

Figure 5. The effect of changing U2 voltage and duplex currents with fixed transfer currents

Discussion

As paper moisture level decreases, the volume resistivity of paper increases exponentially[2]. The moisture level has a similar type of effect also on the surface resistivity[3], because these two resistivity measurements correlate strongly[4]. The effect of this on the resistivity adjustment of this printing process can be seen in figure 6, showing experimental data of the remaining voltage U2 value and the corresponding heating roll temperature. The data was collected with the data collection system using frequency of 1/s during a 53-minute test trial with an uncoated paper. In this case the dependency of the U2 voltage on drying intensity was nearly linear.

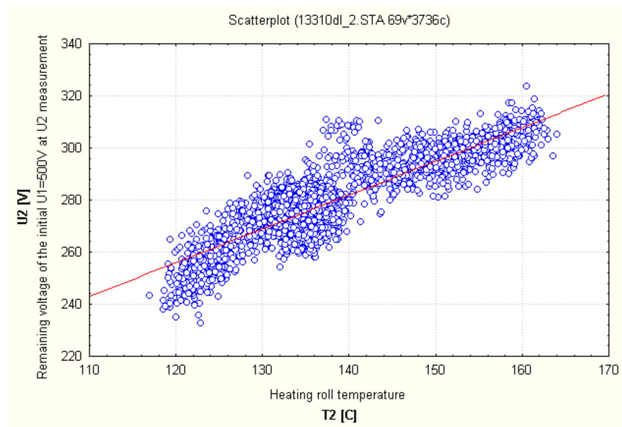

Figure 6. The relation of the voltage relaxation and the intensity of paper drying

A separate trial was made where the LFC and HFC print quality defects were caused deliberately (table 1). When the defect could be seen on the print quality the printing process was halted, to see where the toner missing from the paper was located.

When paper was heavily dried, meaning the U2 voltage set point was high (figure 6), the toner had not been transferred properly from the photoconductor to the paper. This can be due to the charges applied on the paper at the negative duplex precharge corona and the polarization of paper not having relaxed sufficiently before the transfer area, preventing the negatively charged toner to transfer properly. In this case of dry paper with an LFC type of defect, the duplex precharge should be lower, or the transfer current higher to allow higher transfer efficiency (table 1). The effects of these transfer and duplex current adjustments on rms_E when paper is dry are shown in figure 7.

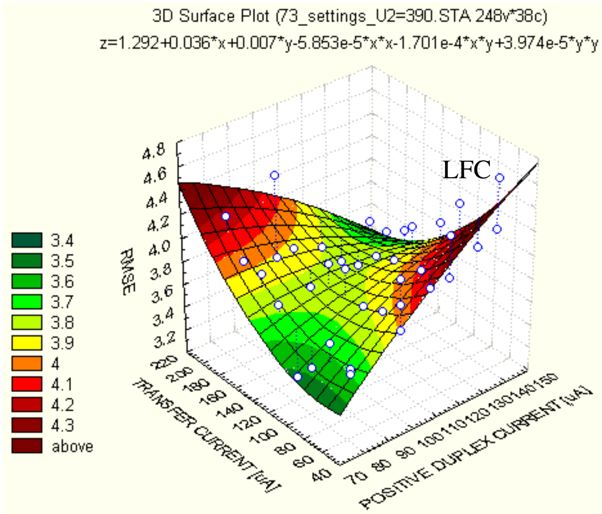

Figure 7. The effect of changing the transfer and duplex currents, dry paper (U2=390 V)

In case of HFC type of defect some toner of a certain color missing from paper could be seen on the photoconductors of the following color units. In this case the paper contained a higher amount of moisture, and was more conductive. The effects of the parameter adjustments on rmsE with moist paper can be seen from figure 8. If paper is printed moist, the negative and positive duplex precharges can be increased to prevent the toner on paper from moving to the negatively charged photoconductor of the next color unit, or to the positive transfer current wire. Based on the effect on the rms_E, the transfer current adjustment is more significant in the case of a HFC type defect.

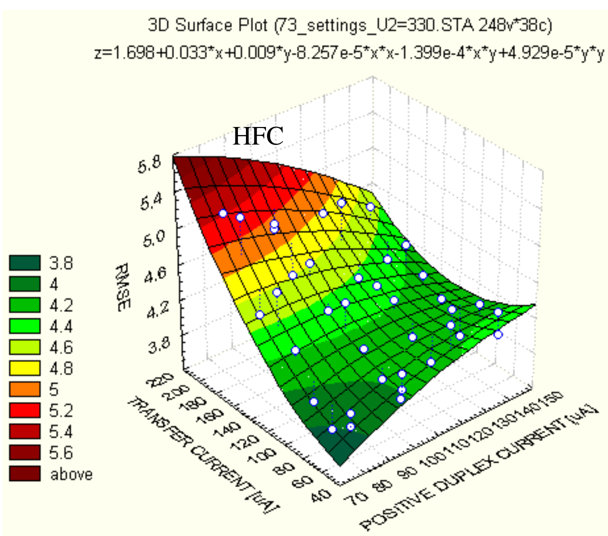

Figure 8. The effect of changing the transfer and duplex currents, moist paper (U2=330 V)

The optimum settings selected using the print quality optimization procedure had low rms_E values. The effects of the main process parameter adjustment on the rms_E values were in line with the print quality optimization procedure (table 1). When the paper properties and the process parameters affecting the electrophotographic toner transfer phase do not match each other, the print quality can be significantly deteriorated from the optimal print quality. The rmsE reacted to these differences when there was enough trial points to compare.

The developed testing environment including the printing machine, data collection system and numerical print quality measurement can be used in further work of studying paper needs in electrophotography. Further trial series of pilot papers with controllably changed properties have been tested with this installation, to collect data for the analysis of the paper property requirements.

Conclusions

The variation of the green color CIELAB coordinates could be used to numerically estimate the effects of the process parameter adjustments on print quality. If the process parameters affecting the electrophotographic toner transfer phase are on a clearly unsuitable level, both numerical and visual print quality deteriorates significantly. The testing environment built is a useful tool and can be utilized in further research projects.

Acknowledgements

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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 a research scientist of digital printing in Stora Enso Research involves paper testing 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.