Unapređenje utroška papira u području heatset tiskarske tehnologije metodom mjerenja gustoće zacrnjenja sustavom zatvorene petlje

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CLOSE LOOP DENSITY CONTROL AS AN IMPROVEMENT REGARDING PAPER WASTE IN HEATSET PRINTING TECHNOLOGY

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Original scientific paper
The strategy of close loop density control installation systems in heatset printing technology is proposed as a method for automatization and decreasing paper waste during the printing process. Parameters are proposed by which an improved structure and manner of control as well as more efficient printing monitoring are introduced. Two new definitions are introduced into the system and it is suggested that they be adopted as an advanced control method in heatset printing technology. The experimental plan has been carried out for large facilities whereby printing practice is highly improved in general, the goal being to optimize paper waste control. Variables are respected defining colour reproduction density, limitations of machine technique and investments into new automatization. A process set in this manner improves control mechanisms in the area of making choices and designing machine facility configuration on an advanced level of computer controlled production.

Keywords: *close loop density control, heatset printing technology, process paper waste, startup paper waste*

Unapređenje utroška papira u području heatset tiskarske tehnologije metodom mjerenja gustoće zacrnjenja sustavom zatvorene petlje

Izvorni znanstveni članak
Predložena je strategija sustava strojne instalacije reprodukcije gustoće obojenja u tehnologiji "heatset" otiskivanja kao metoda automatizacije i smanjenja utroška papira tijekom tiskanja. Predloženi su parametri kojima se uvodi unaprijeđena struktura i način praćenja te efikasniji monitoring otiskivanja od uobičajenih u praksi. Uvode se dvije nove definicije u sustav te se predlaže njihovo usvajanje kao napredna metoda upravljanja unutar "heatset" tehnologije tiskanja. Eksperimentalni plan proveden je za velika postrojenja čime se znatno unapređuje tiskarska praksa općenito a s ciljem optimaliziranja upravljanja potrošnje papira. Respektiraju se varijable koje definiraju reprodukciju gustoće obojenja, ograničenja strojne tehnike te ulaganje u novu automatizaciju. Ovako postavljen proces unapređuje upravljačke mehanizme u području odabira i dizajniranja konfiguracije strojnog postrojenja na naprednoj razini računarskog vođenja novinske proizvodnje.

Ključne riječi: *"heatset" tiskarska tehnologija, mjerenja gustoće zacrnjenja zatvorenom petljom, početna makulatura tiska, procesna makulatura tiska*

1 Introduction

According to Bergman [1], offset printing technology is the most widely spread technological solution for printing publications and printed matter in the area of mass marketing. Heatset printing production with big machines is a must in the development of variables in the graphic printing industry. Although it is possible to print marketing and publications products with the help of numerous printing techniques [2], Heatset Printing Technology (HSPT) is the only existing offset technology that enables producing publications of the highest quality in high volume requirements. These are printing runs amounting to several hundred thousand copies and increasing all the way up to several million copies. Deficiencies that need to be eliminated are determined with the SWOT analysis [3] of the HSPT environment as seen in the analysis of industrial solutions in the rotation printing of publication and marketing products. Also, the technological processes should be improved significantly because there is a strong motive for the progress of publication business activities and the use of HSPT as the optimal technological environment for high volume printing of publications.

The area of overall paper consumption is determined as the technology's key deficiency area, and solutions are proposed by which this process could be improved and made more rational. The key points determining paper consumption are therefore detected as paper manipulation in the warehouse, categorizing wrapping material waste from the roll as well as startup waste, start-up waste copies with first sheet production, waste copies in intermediate movement, i.e. the movement of the other sheets, process waste of copies during the overall printing run printout and copies that are a technological overplus for graphic processing and the final phase of graphic processing. Close Loop Density Control is defined as a closed system for automatic measuring of printing values and parameters, and automatic correction during printing. From the technical point of view it is carried out through a system of cameras and measuring instruments mounted on a moving console. With the help of a servo motor, movements are made in a direction vertical to the paper roll movement.

Statistical analysis points towards the fact that there is still a very small number of printing rotations in the HSPT area in Europe that are equipped with the necessary automatization elements and advancing towards a more rational printing and paper consumption monitoring, also pointed out by GAIN [4]. The task of the test is to create optimal print quality based on the set standards and in the shortest time period. The high speed of printing rotations in the HSPT technology in respect to the tested samples has been considered, bearing in mind the fact that all the corrections and adjustment parameters for quality printing are necessary during rotation operation. Printing parameters are measured while detecting the state of the highest paper consumption level, paper consumption before and following the phase of process printing. The proposal for paper consumption monitoring is determined based on the newly proposed structure, firstly through the Startup Paper Waste parameters: SPW (waste copies during rotation movement and intermediate movement) and through the Process Paper Waste (PPW).

Two new definitions are introduced and their adoption is proposed as a method of clear and transparent monitoring of paper consumption while printing inside HSPT:

- SPW is defined as the overall quantity of all waste copies from the first copy to the n^{th} copy necessary to obtain the optimal print beginning from rotation startup, with the correct and prescribed density values and with the optimal water-dye ratio, controlled raster increase, and with the optimal gray balance parameters;
- PPW is defined as the overall quantity of waste copies during printing created by the very process of printing the overall printing run when washing the rubber covers, roll exchange and elimination of various process errors during printing.

The defined parameters and measurement areas note down and structure down printing results on the printing press that rely on the operation of the printer himself and manual adjustment of all printing parameters (machine R1 – Polyman) and these results are opposed to those obtained when printing on the machine where parameters are measured automatically and mechanically (R2 – Rotoman). Results are shown interpreted through all parameters defined for the SPW and PPW areas.

2 The theoretical basis and research plan

Successful printing within the HSPT is the realization of the required printing quality within the minimal consummed printing reproduction material, primarily roto paper. A good-quality print is such where the printing values remain within the standards set for the printing process execution during the overall process of printing the complete printing run. The manner of carrying out quality control is by measuring control strips that are placed at the paper edge and on that part of the paper sheet that will be cut off and eliminated after the test has been made. In the area of printing quality focus is aimed at reaching standard values. Details of measuring the printing itself are not considered because the measurement areas would then be more complex, as in numerous printing quality tests, and as detected by Donderi and associates [5]. This activity points to the necessity of introducing a significantly more rational printing process, especially due to the fact that further slowing down of investments into HSPT technology are predicted due to the crisis in the global printing economic segment, and due to the influence of other media, as warned by Primir [6].

Density values of all process dyes are measured and this is carried out in real time machine operation during printing and that sustains the optimum colouring levels as a target. The printing quality of each of the colors is determined with the colour strip. Elements are measured with the help of two methods: manually - measured by the operator carrying out the printing (the machine not equipped with Close Loop Density Control system - CLDC – machine R1) and mechanically (with built-in CLDC system – machine R2). Density values are measured on both machines. The colour strip (Fig. 1, Fig. 2) is placed so as to measure the following:

- density values for full tones k, c, m and y – basic process dyes are measured in full intensity;
- density values for areas of raster tone values of 25 %, 50 % and 75 % - printing values are measured for light, middle and dark shades;
- density values of combined three color process dyes: cmy 25 %, cmy 50 %, cmy 75 % – the interrelationship of three multi-coloured dyes is controlled with the visual method as well as their combinations in mixing two colours my 100 %, cm 100 %, cy 100 %.

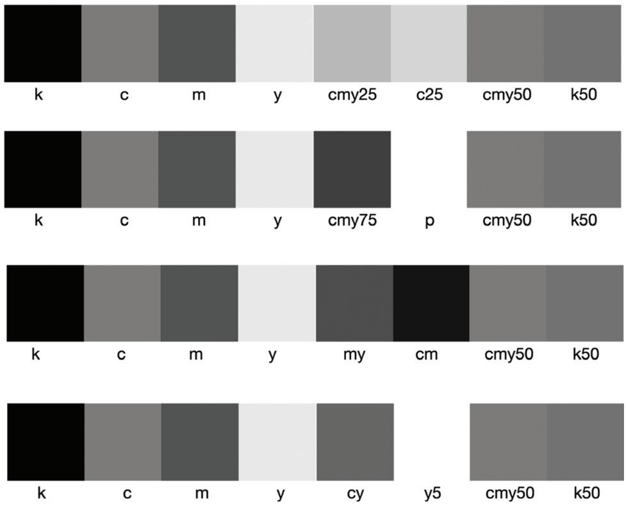

Figure 1 Control strip for density value control for testing printing results on the R1 machine

Figure 2 Control strip for density value control for testing printing results on the R2 machine

The appearance and architecture of the control strip for machine R1 (manual measuring) and the manner of measuring printed fields are set for experiment needs. For machine R2 it is taken from the installed CLDC system (QuadTech – Instrument Flight) that is found on the machine itself.

Strip R2 is more complex and more informative than the manually created R1 strip but the focus is on identical fields and measurement area, whereas the other elements are for visual print control. Testing and measuring is done according to the Colorsource [7] classification basis for four product groups, classified according to complexity and the required output quality. Classification has been finalized and modified as additional adjustment to the tested samples (Tab. 1).

Table 1 Classification of tested product samples according to quality parameters

Product Quality Class A:	*Product Quality Class B:*
• Products of high and very high quality requirements • Printing paper: very high quality value - LWC,WFC • Paper grammage (mass in grams for 1m^2 of paper): 70 grams or more • Control parameters: continuous monitoring and control by the operator in charge • Raster tone values: 70 ÷ 150 lpc for amplitude modulated raster and 25 μm for frequency mod. raster • Print register tolerance: 0,06 • Total color deviation tolerance (ΔE): 3 • Reference standard: Fogra 46	• Products of high quality requirements • Printing paper: high quality - LWC • Paper grammage (mass in grams for 1 m^2 paper): 50 ÷ 70 g • Control parameters: continuous control by the operator in charge of the shift • Raster values: 60 ÷ 150 lpc for amplitude modulated raster and 25 μm for frequency modulated raster • Register tolerance: 0,08 • Total colour deviation tolerance (ΔE): 5 • Reference standard: Fogra 46
Product Quality Class C:	*Product Quality Class D:*
• Average product quality requirements • Printing paper: average quality value - SC, LWC, MFC • Paper grammage (mass in grams for 1m^2 of paper): up to a maximum of 60 grams • Control parameters: the usual regulated control by the printer • Raster tone values: 60 ÷ 150 lpc for amplitude modulated screen and 35 μm for frequency modulated screen • Register tolerance: 0,10 • Total allowed colour deviation (ΔE): 5 • Reference standard: Fogra 41	• Low quality requirements • Printing paper: low quality paper - newspaper paper and improved newspaper paper • Paper grammage (mass in grams for 1m^2 of paper): up to a maximum of 60 grams • Control parameters: the usual regulated control by the machine operator in charge and printer • Raster tone values: 40 ÷ 133 lpc for amplitude mod. raster and 35 μm for frequency mod. raster • Register tolerance: 0,15 • Total allowed colour deviation (ΔE): 7 • Reference standard: Fogra 42

Table 2 Characteristics of R1 and R2 machines on which the experiment had been carried out

R1 Machine	R2 Machine
• Manroland Polyman 40, • Capacity: 16 pages (format A4, printed on both sides, folded and formed into sheets) • Printing speed: 35 000 p/h • Equipped with CLDMC system - NO	• Manroland Rotoman 65 • Capacity: 16 pages (format A4, printed on both sides, • folded into sheets) • Printing speed: 35 000 p/h • Equipped with CLDMC system - YES • Type of installed CLDMC system: Quad Tec

Technical characteristics of the R1 and R2 machine are given on which the experimenting is carried out (Tab. 2.) The number of waste copies (STPW and PPW) is measured for classified products A, B, C, and D according to the herewith enclosed procedure. They are proposed for measuring areas where the analysis of the number of waste copies is made defined for the very process of testing the printed samples in real-life production (Tab. 3).

Table 3 Newly proposed structure according to which waste copies are measured and analysed

Startup paper waste - SPW	*Waste copies in printing - PPW*	*Paper roll waste*
• Printing machine acceleration • Colour register • Cut-off register • Transportation strip adjustment • Plug adjustment • Gluing adjustment • Adjustment	• Washing of rubber covers (R1 - manually, R2 - mechanically) • Paper roll exchange • Controlled samples • Additional difficulties (if any)	• Hilze • Natron • White paper

Values are given for standard density parameters for HSPT ISO 12647-2:2004 (offset lithographic print, heatset rotation print and printing from sheet) and testing is carried out with the presence of the following colour profiles in application [8]:

- ISOcoated.icc (in accordance with FOGRA27 specification) – for printing from sheets with the use of AM and FM screen (depending on the paper);
- ISOwebcoated.icc (in accordance with the FOGRA28 specification) - for printing magazines (except for newspaper papers) with the use of AM and FM screens (depending on the paper);
- PSO_SNP_paper_eci.icc (in accordance with FOGRA42 specification) – for newspaper paper in magazine rotation using a 35 μm FM screen.

World trends within the HSPT are aimed at installing machines of higher capacity than the machines on which testing is carried out – according to Aumiller [9]. The set goal for paper consumption improvement comprises targeted density as obligatory for each copy of the printing run that will be sold. All the copies that do not comply with the required goal are considered as waste copies.

The experiment carried out is part of the complex printing process inside of which processes are detected according to the experimental plan groups:

- **Mechanical processes**: friction, static and dynamic loads; pressure between the cylinders inside the printing phases; bearing and support ring quality; corrosion; different tribological processes; number, type, layout and cylinder quality for dyeing and water application.
- **Physical and chemical processes**: chemistry and structure of the moistening solution; dye composition and structure; dye pigmentation.
- **Subjective characteristics**: training and quality of printing operators, auxiliary operator quality in manipulating paper printing rolls.

In order to achieve precise measuring of the obtained density measurement results, the listed parameters are additionally isolated, and measuring of the dependability and influence of all variables and their interdependency is not fully realistic in practice. The listed parameters are therefore controlled in an optimal manner with the goal to have their minimal influence on the printing results. The following constant values are defined on both the systems (Tab. 4).

Table 4 R1 and R2 characteristics - additional

• **Crews on machines (two printers and two auxiliary operators)** On the basis of agreement with the printing works where the experiment was taking place, - (printing on both sheet sides), similarly trained and educated operators worked in the shifts where measuring was done. On the basis of measuring, monitoring and comparing their achieved results through a period of several years (and this is done regularly in the printing works), conclusions are made that different printing results are not to be expected on both of the machines (human factor) in a degree that would influence the overall results.
• **Process dye** Identical dye is used on R1 and R2.
• **Printing paper** Due to the printed matter being identical and spread on two machines (different sheets) - the paper is also identical.
• **Dampening solution** Puffer, the industrial water composition, parameters and the dampening solution components are identical on both of the machines.
• **Printing plates as carriers of the printed form** Identical plates are used on R1 and R2.
• **Machine operation speed** Although the machines are in comparison different as to their generation and they achieve different maximum speeds, the same speed is maintained on R1 and R2 - the basic speed is on the level of 30 000 sheets per hour. There may be minimal deviations as to speed because of the technological process and printing parameters, but not to such extent that could influence the overall results.

Increase of raster tone values has been measured on both machines in order to eliminate the possibility of the printing results to depend on unforeseen parameters within the printing system, as also mentioned by Bolanca [10]. The very increase of raster tone values is one of the key parameters that make influence on the printing quality and testing has been carried out on the machine itself. The state of the machine (record) is shown and the desirable increase value according to rates, for R1 (Fig. 3) and R2 (Fig. 4).

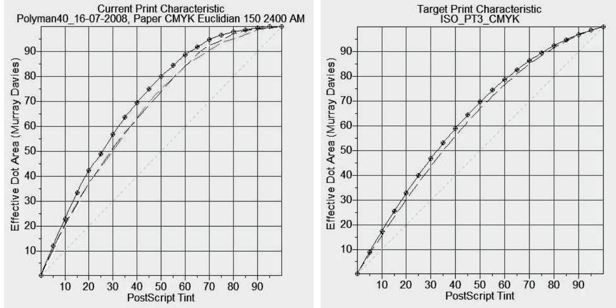

Figure 3 Measured state for R1 in comparison to the standard

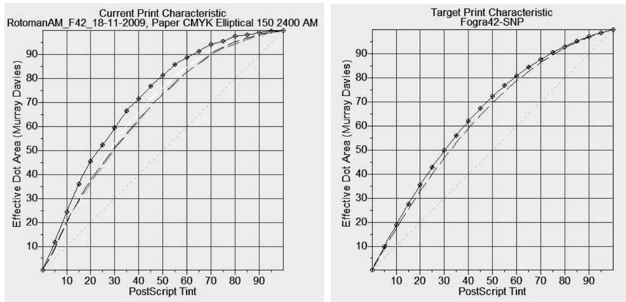

Figure 4 Measured state for R2 in comparison to the standard

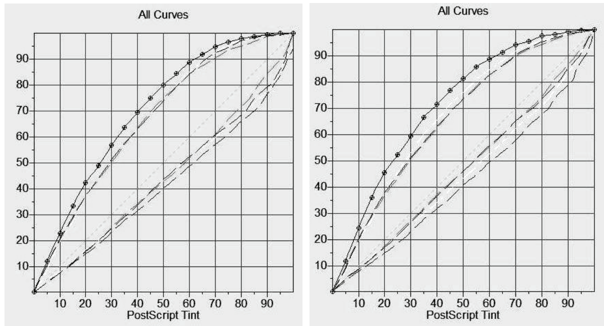

Figure 5 The corrected curve for R1 (left) and R2 (right)

The measured results turn into the base for carrying out the compensation curve that corrects the measured raster tone value increase for R1 and R2 (Fig. 5) and we thus achieve the desired standardization of printing plants. Controlled and standardized results in printing are obtained with the help of the compensation (calibration) curve that annuls unexpected deviations as to standards. Three levels of the curve given in the graphs show the following measurement levels:

- *Current curve* - shows the initially measured values on the machine, for each machine separately. The result depends on the characteristics that are given in Table 2 and Table 4, on the machine condition, on the quality level and type of reproduction material used during printing, on the rubber cover state (number of prints present in the machine), on the paper quality and the conditions in the plant itself;
- *Target curve* - the expected RTV increase, according to standardized values for products A, B, C and D, i.e. the desired result of raster tone values and increase during printing;
- *Calibration curve* - calibration adapting of rastertone value increase carried out for the testing needs according to the following formula principles:

Calibration value = current / target

It is evident that in the area of raster tone value as 50 % the value of 81 % was measured on black, whereas the expected standardized value amounted to 72 %. Therefore, while testing the 50 % raster is decreased by 9 % on the raster image processor. Each colour is thus corrected (c, m, j, k), on both of the tested printing machines in all raster value areas.

Such uniform conditions on R1 and R2 are a sufficient guarantee to conclude how CLDC is the key parameter in measuring and creating the differences in paper consumption. The subject of measuring was defined (printed sheets of the same printed matter on machines R1 and R2), quality parameters (A, B, C, and D product groups), the structure of measuring waste copies (SPW and PPW), the additional parameters were then isolated and the measuring was begun.

3 Measuring of printed samples and result interpretation

Measuring parameters start from *L*a*b** value standards and paper tolerance, the full shade of each primary (CMYK) and secondary (RGB) colour, CMY combination, and dot gain; separately for black and separately for the three multi-colours.

Differences are determined in the quality parameters, reproduction possibilities, and the demanding side of the reproduction, tolerance and also the possibilities of the reproduction paper. After being set in this manner, the following targeted density achievements are given for each production group (Tab. 5).

Table 5 Targeted density values

Class A i B – Fogra 46	Class C – Fogra 41	Class D – Fogra 42
C: 1,30 ÷ 1,40	C: 1,30 – 1,40	C: 1,05 ÷ 1,20
M: 1,30 ÷ 1,50	M: 1,30 ÷ 1,50	M: 1,05 ÷ 1,20
Y: 1,30 ÷ 1,40	Y: 1,30 ÷ 1,40	Y: 1,05 ÷ 1,15
K: 1,55 ÷ 1,75	K: 1,50 ÷ 1,70	K: 1,20 ÷ 1,40

Ten samples (sheets) were printed for each product group, forty samples on both R1 and R2 - a total of 80 samples. None of the printed samples were specially prepared testing material, but part of the daily printing works production where the testing was taking place - journal and magazine sheets and various marketing material. Except for adaptation of the machines to standardized values through compensation caliber curves, there had been no additional testing adaptations made during the testing, and only the results of the actual production process were measured. Average achieved results for the printed samples are given graphically for each product group.

It is evident that there is significantly higher paper consumption on the R1 machine that does not have the CLDC measuring system. The reaction of the operator is slower than the machine adaptation and the time spent on detecting production mismatch generates large waste paper quantities. It is necessary to accept the situation where results are based on the assumption that the printer is wakeful and present at all times, and they exclude the human factor as the possible additional error factor in excessive paper consumption. It has been noted that due to only several minutes of the operator not paying attention to his work, paper consumption increased a great deal. The results were not included in the measurements in order to isolate the subject of measuring - comparison in respect to the necessity of the CLDC installation - but such results are expected in practice.

The following graphs (Fig. 6 – Fig. 9) show the achieved mean results and they are shown graphically based on the arithmetical mean values resulting from: $(x_1 + x_2 + ... + x_n)/n$, where $n = 10$, for each product group (A, B, C, D), on both of the tested printing machines (R1, R2).

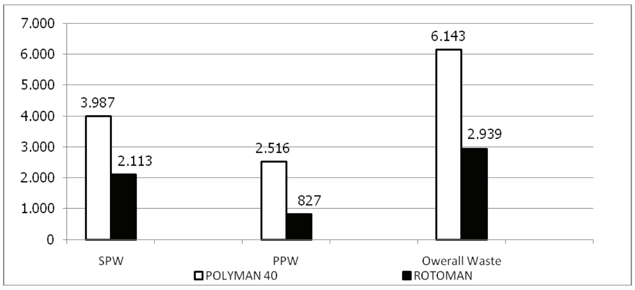

Figure 6 SPW, PPW and the overall consumption on machines R1 and R2 for the tested class A products

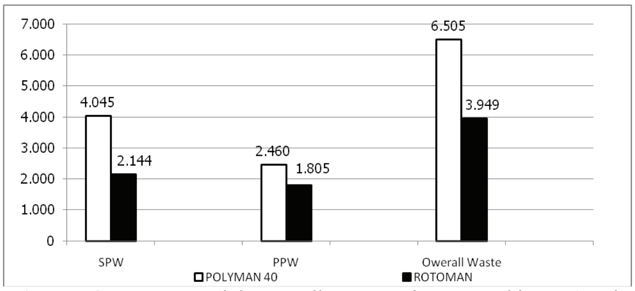

Figure 7 SPW, PPW and the overall consumption on machines R1 and R2 for the tested class B products

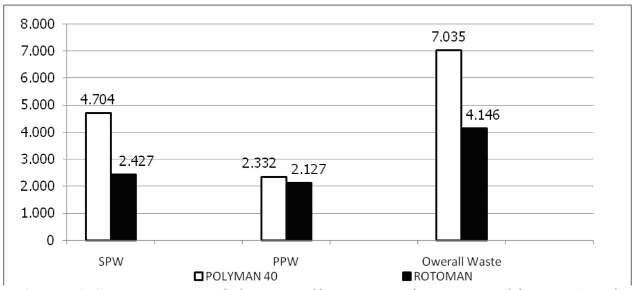

Figure 8 SPW, PPW and the overall consumption on machines R1 and R2 for the tested class C products

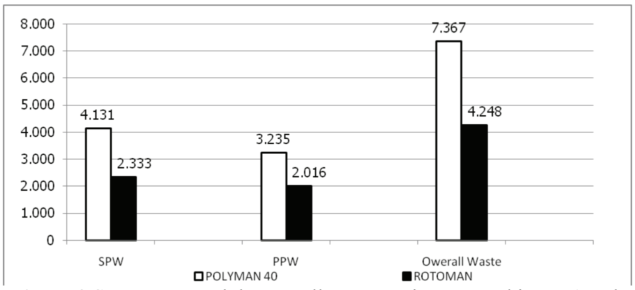

Figure 9 SPW, PPW and the overall consumption on machines R1 and R2 for the tested class D products

Axis *y* has data on the consumed number of copies necessary in order to obtain the first print in accordance with the targeted and standardized density values. Axis *x* has product groups - A, B, C, D.

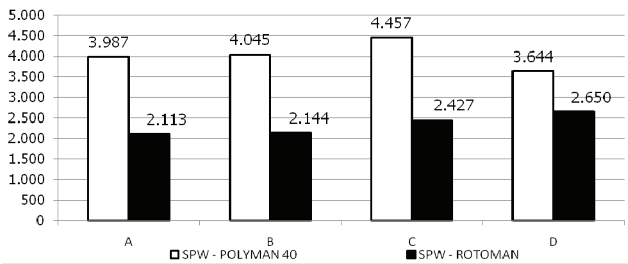

Figure 10 Overall SPW for R1 and R2

The obtained results for all four product groups in both of the processes with newly defined monitoring SPW and PPW are much more agreeable in the R2 system. In the R1 system it is necessary to have over a thousand sheets more than with R2 for the standardized print only in the area of startup waste samples. Those values are characteristic for all four product groups. During the printing process PPW a great difference is obvious in the consumption of printed sheets. Fig. 10 and Fig. 11 show the overall average results for SPW and PPW.

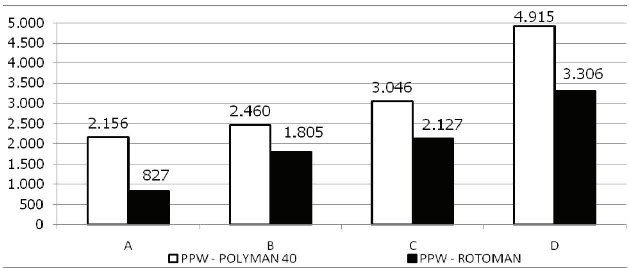

Figure 11 Overall PPW for R1 and R2

The summing up of SPW and PPW shows significantly better results on R2. The mentioned human factor is especially evident in the PPW process. During the SPW process printers note full concentration and process errors are not noted down. After print stabilization, it was shown at the tested speed rate that one minute of human negligence produced from 500 ÷ 700 wasted sheets on R1. There is no such scenario on R2 due to mechanical control. The machine reacts itself and carries out corrections in real time (Fig. 13).

Fig. 12 shows the overall achieved results. In accordance with the already stressed fact that much more agreeable results had been obtained with R2, the difference between the product groups themselves can also be noticed – the worse the printing paper quality is and the more demanding in respect to quality, – the total number of waste copies also increases.

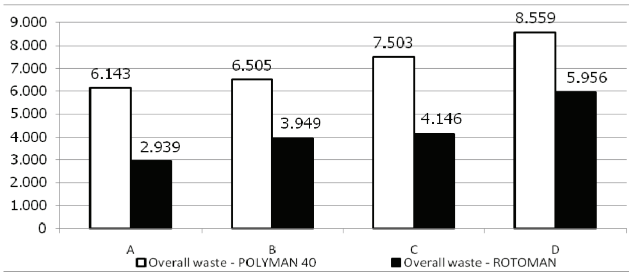

Figure 12 Overall achieved results in respect to paper consumption during the printing of 80 samples — SPW + PPW on R1 and R2

On the basis of the obtained results we can observe the abundance of information that can be used within the CLDC system. The printing machine R2 is equipped with a Quadtech CLDC system and evidences all the printing parameters throughout the overall printing process and experiment duration:

- machine operating speed throughout the overall printing run;
- ink density for all four process dyes throughout the overall printing run - with a stable printing process and stable colours and density system;
- ink density for all four process dyes throughout the overall printing run - with an unstable printing process and stable colours and density system;
- raster dot gain in stable printing conditions during the experiment;
- raster dot gain in unstable printing conditions during the experiment;
- measurements for initial waste samples (Fig. 14).

The report shows the monitoring of the overall print-protocol, in all printing segments, in all time periods and for each sample of the printing run (Fig. 15).

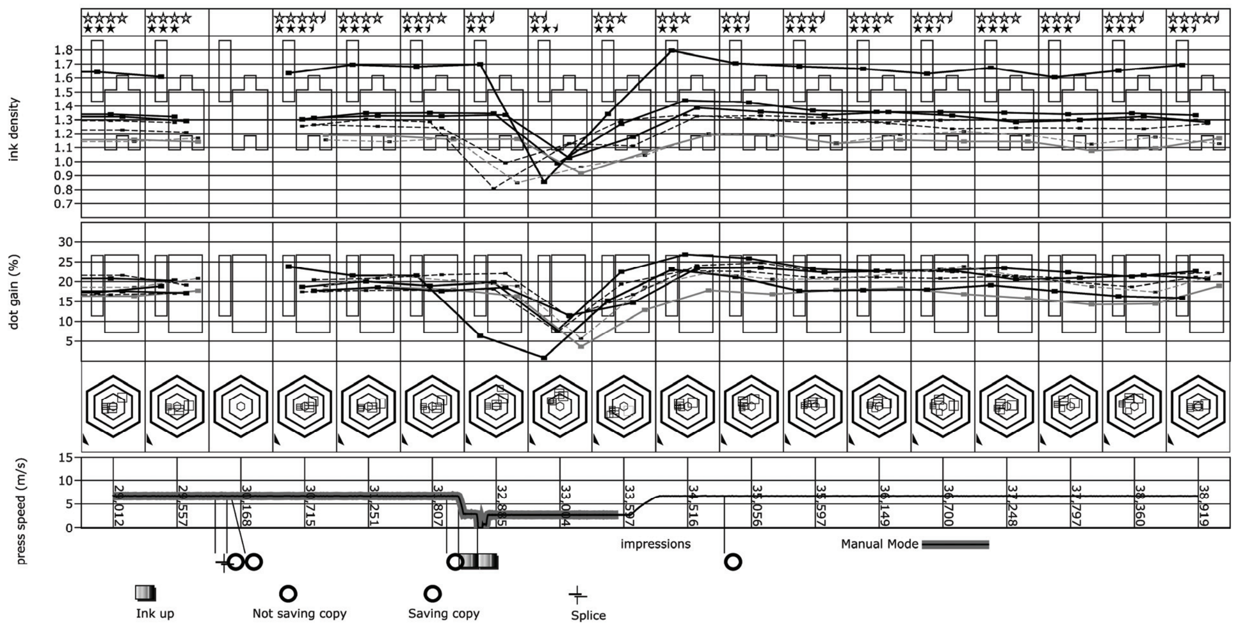

Figure 13 Mechanical correction on R2 during the observed instabilities

	target	actual	difference	percent
Color Register	1,025			
Ribbon Control	1,005			
Color Control	2,000	2,420	420	21%
First saved impression	2,000	2,420	420	21%

	target	actual	difference	percent
Color Register	1,025			
Ribbon Control	1,005			
Color Control	2,000	1,217	-783	-39%
First saved impression	2,000	1,217	-783	-39%

Figure 14 Measuring of initial waste samples on machine R2

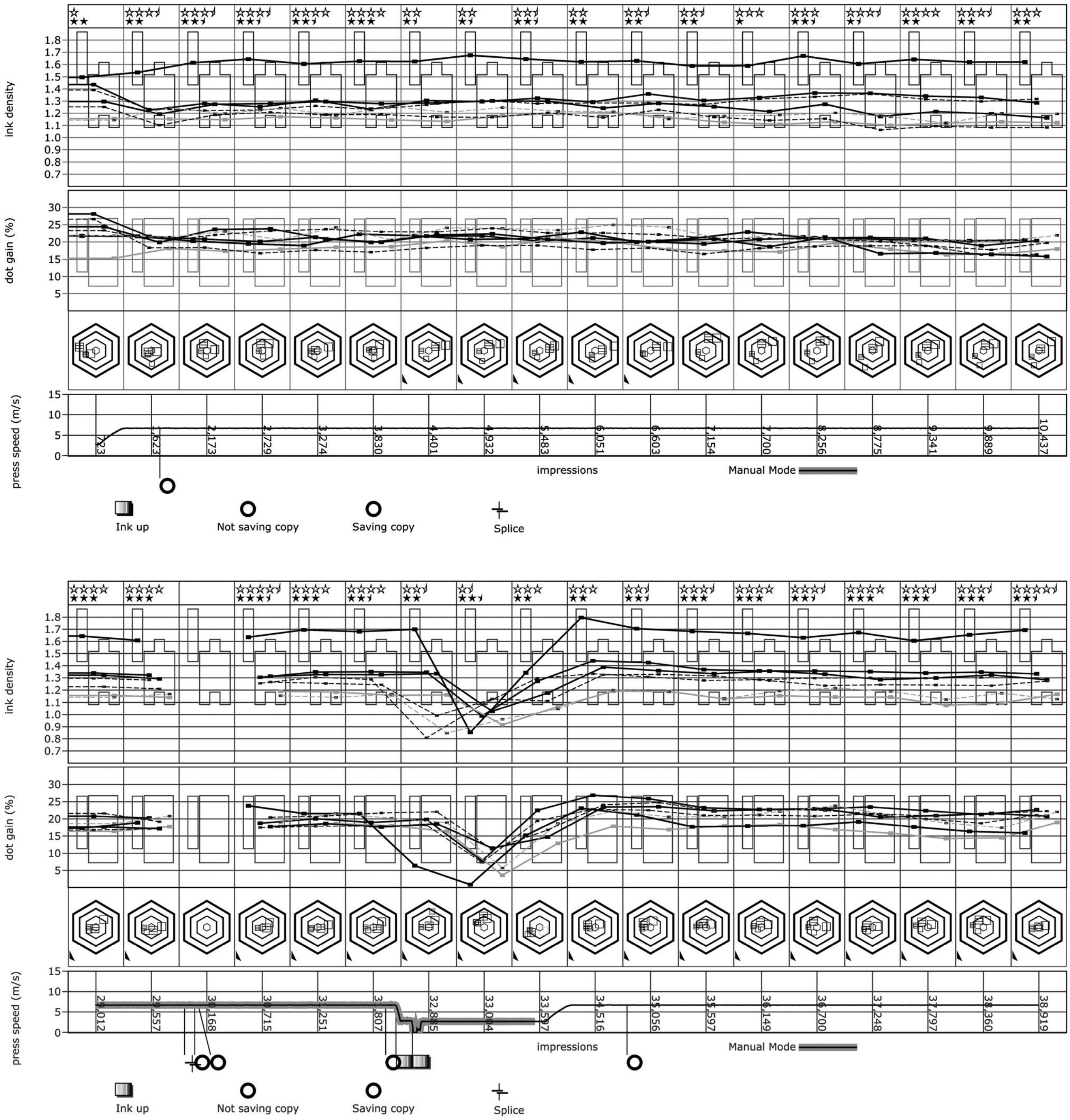

Figure 15 Print-protocol with the tested printing run on the R2 machine

4 Conclusion

On the basis of the measurements made and the obtained results, there is proof in connection with the assertions on more advanced and better quality values in printing with an installed Close Loop Density Control measuring system. The results are more acceptable on all levels of product quality, in all printing runs and in all printing conditions.

During the overall printing process and monitoring of process waste samples, the advantages of the automatic system have been proven. Any misbalance during printing, any washing of the rubber covers and any additional adjustments in accordance with the parameters of standard printing are carried out significantly faster on automatic CLDC system setting.

There are numerous other factors besides installing of the CLDC system that make an influence on the results - dye covering capacity, printing paper quality, the print contrast factor, the overall printing run, but also some additional parameters. These are areas for generating starting points for experimental plans. A new structure and manner of monitoring waste samples through printing has been proposed as well as new definitions for Startup Paper Waste and Process.

In comparison to the usual monitoring up till now, it is different in respect to clarity, transparency and immediate deviation obviousness during the printing process. The achieved results exclude the human factor.

Investing in the CLDC system amounts to approximately five to six percent of the overall rotation cost - this applies to not so very big rotations with a capacity of 16 pages. When there are rotations with greater capacity in the range of 64 ÷ 96 pages, the percentage amounts to three and a half to four percent. Those are improvements that mean technological processes with rotation printing machines allowing the processing of some ten tons of paper on a yearly basis. Rotations with bigger capacities can print up to some 30 tons. In accordance with printing results, it is evident that an investment into the CLDC system can be covered in two years at the most, and this applies only to savings in respect to paper. Additional advantages of such an installation are detected:

- Prompt and continuous print control,
- Dynamic communication with the machine and dynamic corrections during the machine's operation at full speed
- Security
- Monitoring of gray-balance parameters as the key stability in printing
- Report of the overall printing protocol.

The results are especially important nowadays, when there are great challenges and rationalization in the graphic industry, especially inside HSPT. The experiment was carried out only on the basic Close Loop system segment - measurement of density values. Bearing in mind other possibilities - gray balance, dot increase control, paper roll tension control, register correction - the practical overall results are much more concrete. The results of this research point towards the possibility of significant savings in paper consumption during printing.

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6 Abbreviations

SPW - Startup Paper Waste - number of initial waste copies
PPW - Process Paper Waste - number of waste copies during the process of stable printing, following startup standardization all through to the end of printing
HSPT - Heatset Printing Technology - fast-drying offset magazine printing procedure
CLDC - Close Loop Density Control - automatic closed online density value measuring system, as a segment of the overall Close Loop installation
CMYK - abbreviation for cyan, magenta, yellow and black - basic colours of supractive synthesis
RGB - abbreviation for red, green, blue - basic additive synthesis colours
Lab - mark for Lab colour system, based on CIE Lab standard dating from 1976 where L stands for lightness and a and b for opposite dimensions and coordinates of this system for colour display

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