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Prints Recycling in Function of the Press Conditions and Substrate Characteristics

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Abstract

The directions of the ecological sustainability in printing reproduction are in the area of the application of the renewable and recycled raw materials, in the decrease of the energy consumption, the usage of the energy from the renewable sources and in the production without waste. This article presents the research results of voltage changes of the intermediate cylinder in indirect electrophotography with liquid toner on dirt count and area on handsheet made from fibers after prints pulping and flotation, brightness and effective residual ink concentration. Since on the indirect transfer of ElectroInk except the voltage of the intermediate cylinder also impacts temperature, its influence on the dirt count and area is showed. Uncoated and both side coated substrates were used for printing. The results show that changes in voltage of the intermediate cylinder in the printing affects the characteristics of pulped and floated fibers and dirt count and area on handsheets. Dominant factor of studied process is surface treatment of the printing substrate. Maximum efficiency of deinking flotation (87.7%) was observed on non coated paper print, at the voltage of the intermediate cylinder of 700V. The efficiency of deinking flotation on both sides coated paper prints in dependence on the voltage of the intermediate cylinder in most cases is below 10%. The results show that an increase in temperature of the intermediate cylinder increases dirt count and area on handsheetst after pulping prints under experimental conditions. Increased efficiency of flotation was found for print obtained at a lower temperature of the intermediate cylinder.

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Keywords: Indirect electrofotography; ElectroInk transfer; Voltage; Temperature; Recycling; Image analysis; Brightness; ERIC

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1. Introduction

The digital printing contributes to sustainable development [1, 2]. The poor deinking ability of ink jet and liquid toner electrophotography especially from earlier formulations is the biggest environmental challenge of digital printing [3, 4]. Liquid toner in electrophotography used to be difficult to eliminate in a flotation deinking plant, but the new generation of ElectroInk appears to produce smaller dirt after pulping [5, 6]. This dirt is floatable in second flotation loop [7].

The process of paper recycling is studied a lot [8, 9]. The domain of influential process factors is being researched: the kind and the amount of chemicals used in various process stages, pH values and fiber suspension consistency, temperature of suspension, the time of disintegration and hydrodynamic flotation factors [10-13]. Machildon and co-authors and Magda have researched the efficiency of the flotation in relation to size, shape and surface characteristics of dispersed particles of printing dye, the volume of the air and the size of the air bubbles [14, 15]. In the described issues the most of the studies were dedicated to hydrodynamic factors of recycling process, the influence of chemical and physical system conditions to the process efficiency and influence of graphic materials [14]. The influence of printing process conditions to the deinking flotation efficiency was less studied [17, 18].

This article presents the results of research on the impact on changes in voltage and temperature of intermediate cylinder in indirect electrophotography printing on recycling efficiency and characteristics of recycled fibres. The gained results are explained with the principle of the printing process and are discussed in relation to these terms in the printing and the characteristics of the printing substrate. Results are significant in the field of new material formulations.

2. Experimental

The prints on the basis of indirect electrophotography made on machine Turbo Stream HP Indigo were used for recycling. The printing form contained different printing elements: standard CMYK step wedge in the range from 10-100 % tone value, standard ISO illustration for the visual control, textual positive and negative microelements, wedges for determination the grayness and the standard wedge with 378 patches for production of ICC profiles and 3D gamut.

Prints for recycling were obtained by varying the voltage of the intermediate cylinder in indirect electrophotography printing with liquid toner (intermediate cylinder voltage: 500V, 550V, 600V, 650V and 700V). Parameters of other phases of indirect electrophotography are defined with calibration of the printing machine. Given that except voltage during the indirect transfer of liquid ElectroInk also temperature of the intermediate cylinder is essential, for comparison prints obtained at temperatures 125^0C and 145^0C were also covered with recycling.

The third generation ElectroInk was used. Two types of substrates were used for printing: Symbol FreeLife gloss and Arcoprint E.W. Symbol FreeLife gloss is environmentally-friendly ECF (Elemental Chlorine Free) paper, double side coated. It contains a high content of selected recycled material. Other features of this paper are shown in Table 1.

Table 1. Characteristics of Symbol FreeLife gloss paper.

Parameter	Method	Value (*t*)
Basis weigh	ISO 536	115(*g/m*^{2})
Caliper	ISO 534	0.099 (*mm*)
Brightness	ISO 2470	95(*%*)
Roughness (Bendtsen)	ISO 8791/2-90	34.43 (*ml/min*)
Water absorption (Cobb)	ISO 535	30.5 (*g/m*^{2})

Arcoprint E.W. is woodfree uncoated paper. Concentration of chlorine in the paper is less than 0.6 kg/T.

This paper is certified with CE 94/62 which guarantees a low concentration of heavy metals. Other characteristics are shown in Table 2.

Table 2. Characteristics of Acoprint E.W. paper.

Parameter	Method	Value (*t*)
Basis weigh	ISO 536	120(*g/m*^{2})
Caliper	ISO 534	0.151 (*mm*)
Brightness	ISO 2470	94(*%*)
Roughness (Bendtsen)	ISO 8791/2-90	31.74 (*ml/min*)
Water absorption (Cobb)	ISO 535	265.8 (*g/m*^{2})

Alkaline chemical deinking flotation is used for the prints recycling [19]. After the pulping and flotation laboratory handsheets are made according to TAPPI standard 205 [20]. On handsheets made from fibres after pulping and recycling using spectrophotometer Technidyne Color Touch 2 model ISO, brightness and Effective Residual Ink Concentration (ERIC) are measured [21,22]. According to the recycling process phases image analysis is made with the use of Spec*Scan Apogee System software [23].

3. Results and discussion

The effectiveness of the paper recycling can be estimated by image analysis. In Fig.1a count of the dirt on handshsheets made from fibers after pulping of prints gained by varying the voltage of the intermediate cylinder in indirect electrophotorgaphy is shown. Prints were made on uncoated substrate.

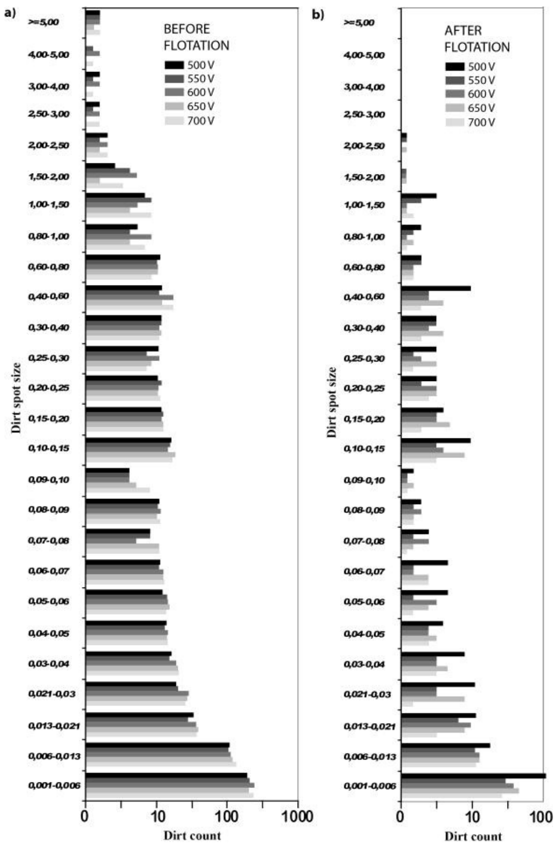

Fig. 1. Dirt count on handsheet versus voltage of the intermediate cylinder- uncoated substrate (a) handsheets made from fibers after prints Pulping; (b) handsheets made from floated fibers.

The highest total dirt count is on handsheet made from fibers after pulping prints on uncoated substrate obtained on intermediate cylinder at voltage of 700 V (Fig 1a). Class 0,001-0,006 mm^2 contains the largest dirt count, regardless of the voltage of the intermediate cylinder in the printing. Dirt count decreases in classes that follow, than increases in the class from 0,10-0,15 mm^2 and after that again decreases. Such trend of dirt distribution is observed regardless of the voltage of the intermediate cylinder in the printing in the experimental context. In this series there are 1-2 dirt <= 5 mm^2.

Flotation reduces the total dirt count on handsheet for 73.9%, 84.7%, 83.0%, 79.7% and 87.7% in the series by increasing voltages of the intermediate cylinder in the printing (Fig.1b). A similar trend of decreasing dirt count by flotation is present in the class of smallest dirts (0,001-0,006 mm^2) while for larger dirts (class higher from 2.00-2.50 mm^2) higher efficiency can be expected.

Figure 2a shows the count of the dirt on handshsheet made from fibers after pulping and Figure 2b after flotation prints on both side coated substrates gained by varying voltage of the intermediate cylinder. A significant change in total dirt count on handsheets made from the fibers after pulping in relation to intermediate cylinder voltage in printing of samples for recycling is not noticed (Fig.2.a). However, the total dirt count in most cases is higher compared with the same size for each respective voltage when uncoated paper is used for printing (Fig. 1a).

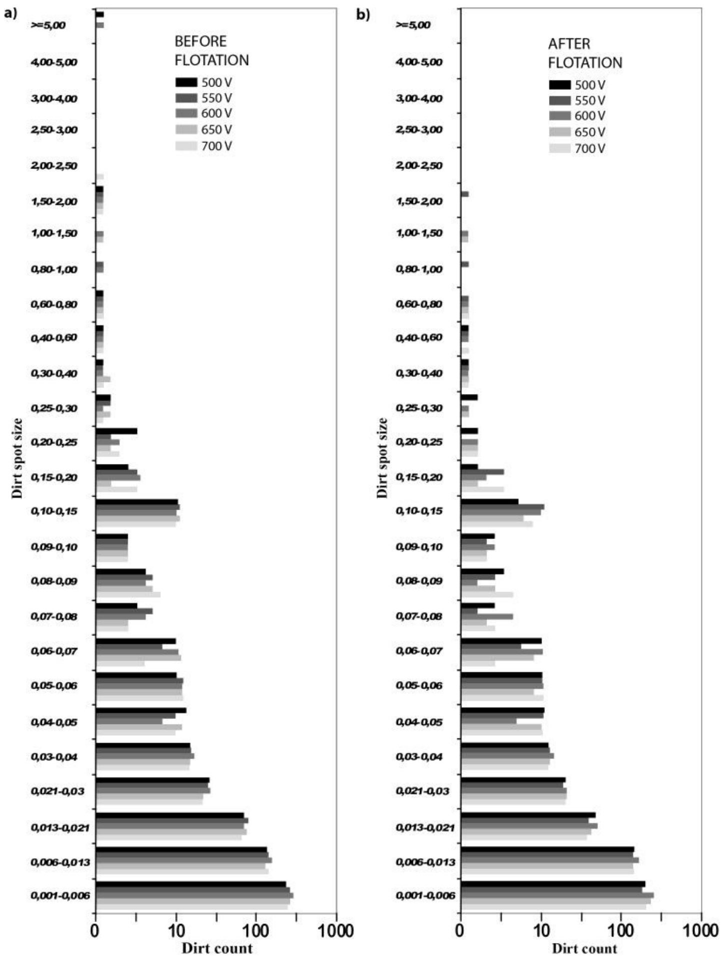

Fig. 2. Dirt count on handsheet versus voltage of the intermediate cylinder - both side coated substrate (a) handsheets made from fibers after prints pulping; (b) handsheets made from floated fibers.

Total dirt count is increased for 72, 114, 88, and 54 dirts according to the increasing voltage of the intermediate cylinder, while the print made at voltage of 700V is lower for 13 dirts. Characteristic is, that after pulping prints on coated paper in the class > = 5.00 only one dirt is present on handsheet made from fibers of pulped prints made at voltage of 500V and 600V, while the other voltages in this class have no dirts.

Given that the big dirts flotate poorly the dirt count in the range from >=5.00mm^2 up to 1.50-2.00 mm^2, depending on the voltage of the intermediate cylinder and the type of the substrate is shown in Table 3.

Table 3. Total dirt count >=5.00mm^2/1.50-2.00 mm^2 in relation with substrate and voltage of the intermediate cylinder in printing.

Printing substrate	Dirt count/500(*V*)	Dirt count/ 550(*V*)	Dirt count/ 600(*V*)	Dirt count/650 (*V*)	Dirt count/700(*V*)
Uncoated paper	13	13	18	5	14
Coated paper	2	1	2	1	2

The results indicate that for the same voltage of the intermediate cylinder in the printing a far greater number of particles with larger surface area in the range from > = 5.00mm^2 up to 1.50-2.00 mm^2 can be expected if coated paper is used in printing.

Table 4 shows the efficiency of the deinking flotation in relation to the change in voltage of the intermediate cylinder and type of printing substrate.

Table 4. Recycling efficiency in relation of substrate and varying voltage of the intermediate cylinder in the printing.

Printing substrate	500 (*V*)	550 (*V*)	600 (*V*)	650 (*V*)	700 (*V*)
Recycling efficiency (*%*) - uncoated paper	73,9	84,7	83,0	79.7	87,7
Recycling efficiency (*%*) – coated paper	5.2	13.7	5.4	9.5	7.4

The results in Table 4 show that the type of the printing substrate is the dominant factor of recycling efficiency even when the prints are made by varying the voltage of the intermediate cylinder in the press. Maximum efficiency of deinking flotation (87.7%) is observed in print on uncoated paper, when the voltage of the intermediate cylinder was 700V. The efficiency of flotation deinking of prints on both sides coated paper depending on the voltage of the intermediate cylinder in most cases is less than 10%.

The coating of paper is a significant factor of the recycling process effectiveness. The coating process assists in dispersing the fillers in the coating. Coated papers have smoother surface and lower air permeability compared to uncoated ones. Micro capillary structures also remarkably differ each other. All these effect the behaviors and the interaction between printing substrate and liquid ink. Generally, pigments over the coated substrate accumulate mostly in the coating layers, between fillers.

During pulping the fillers in substrates get separated from fibers. The amount of filler was bigger in the pulping of coated papers. In recycling process dispersants are at time surface active and together with alkali can lead to acceptable ink detachment from the coated paper. These species can hydrophilise ink containing agglomerates and hinder flotation efficiency. It can also contribute to unwanted foam generation and stability.

Fillers in uncoated papers are distributed in the inner structure of substrate matrix. On uncoated paper the adhesion of printing ink to paper depends on paper properties such as: surface structure, fiber type, ash content and drying mechanism of the chosen printing process. Generally, ink penetration can be deeper in the uncoated paper compared to coated printing substrate.

To determine the relation of small dirts that by its size can cause grayness of handsheet compared to larger, visible ones that impact on optical inhomogenity of handsheet on figures 3a, 4a, 3b and 4b the dirt count and dirt area for classes of dirts <0.04 mm^2 and >=0.04 mm^2 in relation to the voltage of the intermediate cylinder and type of printing substrate is shown.

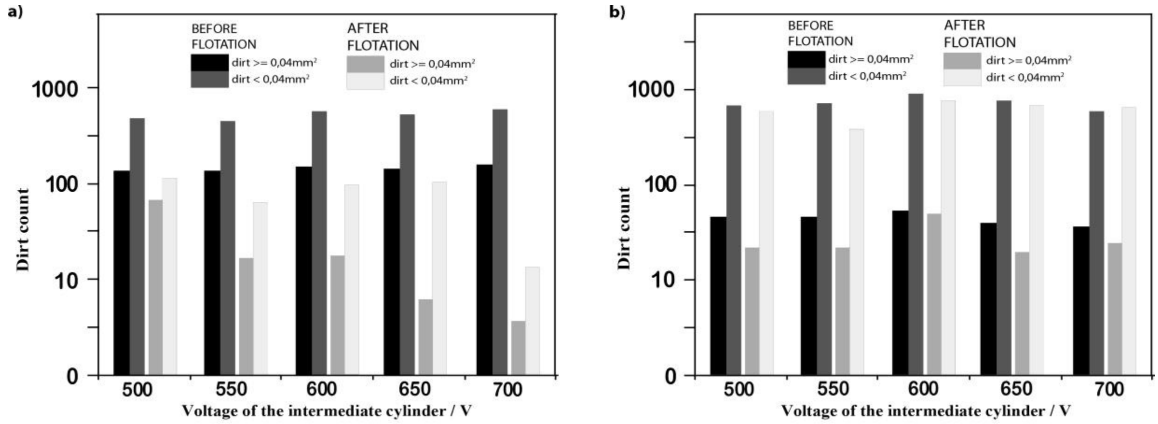

Fig. 3. Dirts <0.04 mm^2 and >=0.04 mm^2 count on handsheet versus voltage of the intermediate cylinder (a) uncoated substrate, (b) both side coated substrate.

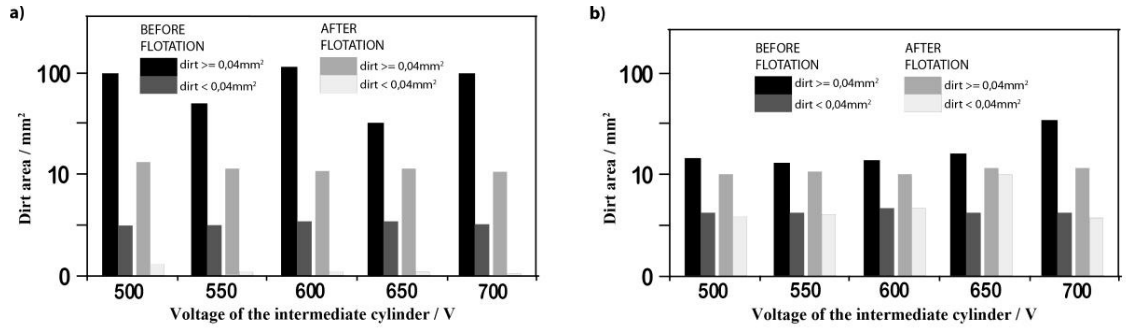

Fig. 4. Dirts area on handsheet versus voltage of the intermediate cylinder (a) uncoated substrate (b) both side coated substrate.

On handsheet made from fibres after pulping prints on uncoated paper dirt count > =0.04mm^2 increases with increasing of voltage in the printing, and reduces dirt count <0.04mm^2 in relation to mutual coated paper at the same voltage of the intermediate cylinder as seen in Figure 3a and 3b and detailed difference of dirt count >=0.04mm^2 and <0.04mm^2 from uncoated and coated paper is shown in Table 5.

Table 5. Difference of dirt count >= 0.04mm^2 and <0.04mm^2 from uncoated and coated paper.

	500 (*V*)	550 (*V*)	600(*V*)	650(*V*)	700(*V*)
Dirts count >= 0.04mm^2 Difference uncoated paper – coated paper	136	135	145	148	162
Dirts count < 0.04mm^2 Difference coated paper – uncoated paper	208	250	234	202	105

Maximum recycling efficiency is determined at uncoated prints for dirt <0.04mm^2 and ranges in dependence on the voltage of the intermediate cylinder in the area of 70.1% to 89.2%. Minimum recycling efficiency is established for prints on both side coated paper for dirt <0.04mm^2 and ranges depending on the voltage of the intermediate cylinder in the range of 2.5% to 12.5%. Recycling efficiency for dirt count depending on the voltage of the intermediate cylinder for dirt > = 0.04 mm^2 obtained by print recycling on the coated substrate moving from 6.8% to 27.0%, while on uncoated substrate this amount is far greater and amounts 61.9% to 78.9 %.

The final definitions of the findings are significant brightness and Effective Residual Ink Concentration ERIC of the handsheet, which are shown in Figure 5. The Figure 5 shows the differences between brightness and ERIC handsheet after pulping and after flotation to voltage of the intermediate cylinder and the type of substrate.

Table 6. Difference in brightness and ERIC (%) for handshets after pulping and flotation in dependence of the type of substrate and voltage of the intermediate cylinder in printing.

	500 (*V*)	550 (*V*)	600(*V*)	650(*V*)	700(*V*)
Brightness gain, uncoated paper	9.6	10.4	12.3	10.4	11.4
Brightness gain, coated paper	1.3	0.9	0.1	2.0	0.3
Δ ERIC, uncoated paper	43.1	41.4	49.4	48.5	54.6
Δ ERIC, coated paper	5.2	0.5	12.3	0.9	2.1

Results presented in Table 6 have good matching and confirm the results presented before, distribution of dirt count and area, depending on the voltage of the intermediate cylinder and the type of printing substrate.

Flotation of prints on uncoated paper in relation to the voltage of the intermediate cylinder increases handsheet brightness gain from 9.6 to 12.3, while on the print on both sides coated paper maximum values are 2.0. Effective residual ink concentration decreases far more on handsheets obtained from flotated fibers on uncoated paper prints in relation to both sides coated paper prints.

Given that the indirect transfer of liquid ElectroInk using intermediate cylinder is dependent not only on the voltage, but also on the temperature of the heated rubber blanket, and this factor should also be taken into account.

At high temperature the Isopar evaporates which results in the change of the physical state of ElectroInk. From the liquid state the Electroink change into the paste state. The part of Isopar can be regulated in the paste ElectroInk by adjusting the temperature of the intermediate cylinder. The second transfer follows. Isopar forms a thin layer among the pigment particles and the rubber blanket. The toner particles are pressed into the cold paper and the rest of Isopar evaporates completely.

Table 7 shows the dirt count and area on handsheets obtained from fibers after pulping and flotation of prints made at intermediate cylinder temperature of 125^0C and 145^0C.

Table 7. Dirt count and area in relation of the temperature of the intermediate cylinder in printing.

Sample: Prints on uncoated paper	total dirt count after pulping	total dirt count after flotation	total dirt area after pulping (mm^2)	total dirt area after flotation (mm^2)
T 125^0C	646	192	59.751	17.065
T 145^0C	641	390	139.982	52.600

The described principle and the change of the temperature are loads to the increased count and area of dirts in the recycling as it is presented in Table 7.

Results show that an increase in temperature of the intermediate cylinder, increases dirt count and area on handsheet after pulping prints under experimental conditions. Flotation efficiency is higher for prints made at lower temperatures of the intermediate cylinder (T125^0C - flotation efficiency of 70.3%, T145^0C - flotation efficiency of 39.2%).

4. Conclusion

Based on the results it can be concluded that the change in voltage of the intermediate cylinder in indirect electrophotographic printing with liquid toner in the range of 500 V-700 V less effects on the recycling efficiency of prints compared to surface treatment of printing substrate. Results of image analysis of the handsheet made of fibers after pulping and after flotation, match very good with the results of brightness and effective residual ink concentration.

In addition to this it was found that increasing the temperature of the intermediate cylinder increases dirt count, which then in turn affects the efficiency of the recycling process and the characteristics of recycled fibers.

Knowing that the indirect electrophotography printing is a complex process, with six separate, synchronous phases, the needs and characteristics of the graphic material, along with a number of factors in the field of chemical deinking flotation should be considered. In the further research the experimental design will be used and statistical models will be created to obtain information about optimising processes in the direction of environmental sustainability in this area.

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