CHARACTERISTICS OF RECYCLED FIBRES FROM DIGITAL PRINTS USING SOLID AND LIQUID TONER

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Abstract: Flotation deinking process depends on a large number of physical and chemical parameters, such as type and amount of chemicals used, pH, pulp concentration, water hardness, presence of dissolved and colloidal substances, size of ink particles, degree of ink particles hydrophobicity, flotation cell flow hydrodynamics and shape of air bubbles. These variables affect secondary processes, e.g. air bubble-ink particle attachment mechanism and flotation froth stability. Printing technique and ink type also significantly determine the effectiveness of deinking operation. Removal of dispersed ink particles is governed by ink surface chemistry, particle size distribution and geometry.

In our work, digital prints produced on art paper substrate by two different printing techniques – liquid toner-based digital offset and solid toner-based electrophotography – were used to study impact of various process variables on recycled fibres characteristics and subsequently on flotation deinking efficiency. Effects of eight process variables were evaluated by measuring number and size of the residual ink particles (dirt count) in paper sheets using image analysis. Experimental design and multifactorial ANOVA were applied to setup the tests and to interpret the obtained results.

Keywords: flotation deinking, digital prints, recycled fibers, image analysis, ANOVA

1. INTRODUCTION

Conventional and the most widely used process in printed paper recycling is flotation deinking. Printing ink is detached from the cellulose fibers in deinking process and removed by flotation. Hydrophobic particles of ink adhere to air bubbles and are transported due to buoyancy to the surface, while the hydrophilic cellulose fibers remain in the water phase. Froth is formed on the liquid/air boundary containing ink particles, fillers, coating pigments, stickies and binders.

Parameters of the surface chemistry that affect deinking are: chemical composition of fillers (calcium carbonate, kaolin, etc.), pH, temperature, water hardness, surfactant chemicals, gas type and gas flow rate, hydrodynamics in flotation cells, bubble shape and bubble size, size of ink particles and the degree of hydrophobicity of ink particles [1-5]. The efficiency of the deinking operation also depends on pulp ageing [6]. Other considerations include factors such as ink characteristics and type of the printing process [7], [8]. Letterpress printing inks can be detached from prints without major problems. To process these prints effectively into bright pulps a combination of different methods is necessary, e.g. flotation after ink particle fragmentation and detachment by dispersing or kneading [9]. Rotogravure prints using toluene-based inks can be deinked more easily than offset printed papers. Under conventional alkaline deinking conditions, the water-based inks are less deinkable compared to the toluene-based rotogravure prints. Similar considerations apply to the water-based rotogravure inks, which are characterized by small particles and hydrophilic character [10]. Deinking of coated papers is more successful compared to the uncoated substrates.

Toners from some digital prints – prints produced by laser printers and copiers – detach in flat plate-like structures and are too large to be removed by flotation [11], [12]. Removal of plastics, coating binders, contact adhesives and hot melts is important, since these materials can cause problems in the paper production and later during the printing process.

Results presented in this paper are part of a broader study dealing with flotation deinking and investigating different printing techniques. Discussion will be focused on flotation deinking of digital prints obtained with liquid and solid toner where printing conditions were varied. Recycling process efficiency was monitored by
means of image analysis and by measuring several optical properties of laboratory paper sheets. Analysis of variance (ANOVA) was implemented to aid in the interpretation of results.

2. EXPERIMENTAL

Before being recycled, one series of samples was subject to artificial accelerated procedure (temperature: 80°C, relative humidity: 65%, ageing time: 30 days). Prints for recycling were obtained by digital offset printing machine based on electrophotography using ElectroInk liquid toner (Indigo E-Print 1000+) and by digital printing machine with indirect transfer of the dry toner (Xerox DocuColor 2045). Drum voltages were for Indigo printer 300 and 600 V and for Xerox printer 136 and 212 V. Print test chart was designed in Adobe Photoshop using standard ISO and ECI elements. Prints were made on an art paper with grammages 200 and 280 g/m².

Printed samples were recycled using alkaline chemical deinking process. After the stage of sample soaking, deinking chemicals (1% hydrogen peroxide, 0,4% surfactant, 0,2% DTPA, 1% sodium hydroxide, 1% sodium silicate) were added. The consistency of suspension was 10%. After disintegration (45 minutes) the suspension was diluted to 0,6% pulp consistency. An optimal level of hardness was maintained in the flotation cell at 200 ppm CaCO₃. The flotation time was eight minutes. Laboratory handsheets were made using laboratory sheet former according to the standard TAPPI test method T 205.

Optical measurements were performed with X-Rite spectrophotometer with the support of ColorShop program. Residual ink spot size, ink number and ink area were assessed by image analysis software Spec*Scan (Apogee System Inc., Powder Springs, GA). Scanner optical resolution was set to 600 dpi. Threshold value 100, white level 75 and black level 65 were chosen after comparing computer images to the handsheets.

Effects of several variables on efficiency of flotation deinking was assessed by performing experiments according to a standard 2⁵ factorial design scheme with randomised runs varying each of the factors at two levels. Factors – process variables – studied were as follows:

1. Artificial ageing (AGE): no (0) / yes (1)
2. Printing drum voltage (VOL): low (0) / high (1)
3. Grammage (GRAM): 200 g/m² (0) / 280 g/m² (1)
4. Flotation deinking process (FLOT): no (0) / yes (1)
5. Handsheet side (PAPS): bottom (0) / top (1)

Data on the following three parameters related to the number and size of ink particles as obtained by image analysis software were recorded:

a) Total number of specks (NOS_T)
b) Average specks area (ASA_T)
c) Greyscale brightness (GSB)

3. RESULTS AND DISCUSSION

Figures 1 and 2 show paper sheet ISO brightness before and after deinking of prints made with Indigo and Xerox printer, respectively. Effects of paper grammage, printing drum voltage and artificial ageing are also considered. As can be seen, deinking process has a beneficial impact on paper brightness regardless of the other experimental conditions. Similar observations can be made when investigating sheet brightness for the recycled Xerox prints. Here, however, brightness is lower compared to the corresponding Indigo prints. This is true for non-deinked as well as for deinked samples.

Obtained results can be explained from the viewpoint of mechanism of the respective printing technique and of the toner-paper attachment process and by understanding toner chemistry. Both printing methods are based on electrophotography, Indigo also belongs to offset printing. On the other hand, there are differences between the two methods in toner consistency (liquid vs. solid) and in the amount of toner transferred to the paper surface; dry, i.e. powder toner yields higher color density values. Prints also dry by different mechanisms. With Indigo prints, toner dries when being in contact with a cold printing substrate, whereas in case of Xerox printer, prints are produced by depositing toner onto the paper surface by means of a hot roll. As a result, ink particles are of irregular shapes and have bigger surface area.
Ink particle size and area distribution on paper sheets before flotation assessed on non-aged Indigo and Xerox prints is displayed in Figures 3 and 4. Data were recorded at higher printer voltages and lower paper grammage (200 g/m²). It is evident that in case of paper sheets obtained from Indigo prints much bigger particles can be found when compared to the paper from disintegrated (pulped) Xerox prints where maximum particle size is limited to 0,10-0,15 mm².

Figure 1: Paper brightness as a function of grammage, printing drum voltage, artificial ageing and deinking process for Indigo prints

Figure 2: Paper brightness as a function of grammage, printing drum voltage, artificial ageing and deinking process for Xerox prints

Figure 3: Size- and area distribution of particles in paper sheets before flotation for Indigo prints.
Figure 4: Size- and area distribution of particles in paper sheets before flotation for Xerox prints.

Effects of process variables on size and number of particles found in the paper sheet – and therefore on deinking flotation efficiency – can be studied by analyzing ANOVA results. Only findings for recycled Indigo prints will be presented. In Figure 5 individual factors and their two-way interactions in a decreasing order of influence on number of specks (NOS_T) are listed. Printing drum voltage has by far the biggest – negative – impact on NOS_T: higher voltage produces lower residual number of ink particles in paper sheet (and vice versa) corresponding to a more efficient deinking process. Other statistically significant (95% confidence limits) effects include grammage, artificial ageing, deinking and three two-way interactions. As can be seen from Figure 6, the most desirable combination of the factors – leading to the lowest NOS_T – is the following one: higher voltage (600 V), higher grammage (280 g/m²), absence of ageing. Flotation deinking process (factor FLOT) reduces NOS_T, but effect is not statistically significant.

Figure 5: Influence of process variables and their two-way interactions on the number of specks for paper from Indigo prints

Figure 6: Effect of process variables on the number of specks for paper from Indigo prints
Pareto charts for average particles area (ASA_T) and greyscale brightness (GSB) are given in Figure 7 and 8, respectively. ASA_T is almost exclusively influenced by drum voltage and, to much smaller extent, by paper side: smaller particles are produced using lower printing voltage and inspecting paper bottom side. On the other hand, the only important effect on GSB is that of paper grammage: higher grammage leads to higher GSB values.

![Figure 7: Influence of process variables and their two-way interactions on the average specks area for paper from Indigo prints](image)

![Figure 8: Influence of process variables and their two-way interactions on the greyscale brightness for paper from Indigo prints](image)

4. CONCLUSIONS

Results of the study show that the monitored process conditions, such as printer’s drum voltage or paper sheet grammage affect printed paper recycling process in a complex way and to various degrees. Significant differences in behaviour between the prints produced with liquid toner and those made with solid toner were identified in terms of the greyscale brightness, size and number of residual ink specks found in lab paper sheet. In our further work we will try to examine and explain these differences more closely, using modern analytical equipment (FTIR, NIR) and statistical tools (ANOVA).

5. REFERENCES


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