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RECYCLING OF THE OFFICE PAPERS BY CHEMICAL DEINKING WITH DOUBLE STAGE FLOTATION

RECIKLACIJA UREDSKIH PAPIRA KEMIJSKIM DEINKINGOM S DVOSTUPANJSKOM FLOTACIJOM

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Prethodno priopćenje / Preliminary note

Abstract: Recycling of paper printed with colour laser printer XEROX PHASER 7700 has been investigated in this work. The recycling was performed by chemical deinking with double stage flotation with the usage of non ionic surfactant. Froths collected by flotation were re-floated in which the increased usage of fibers was achieved.
The effective removal of magenta particles (98,3%), cyan (96,9%) and carbon ones (91.49%) was proved by the image analysis. The same method was not effective for the identification of the yellow toner particles. During the second flotation the part of the particles which was left after the first flotation was removed. The removal of the coloured toner particles from the suspension by flotation, improves the lightness and the brightness of the recycled sheets. Colorimetric values "a" and "b" of all the recycled sheets are extremely low and have approximate values regardless the colours of the recycled output.
Key words: Office papers, recycling, chemical deinking, double stage flotation

Sažetak: U ovom radu ispitana je reciklacija papira ispisanih laserskim pisačem u boji, XEROX PHASER 7700. Reciklacija je načinjena kemijskim deinkingom s dvostupanjskom flotacijom uz uporabu neionske površinsko aktivne tvari. Flotacijama sakupljene pjene ponovo su flotirane pri čemu se postiglo povećanje iskorištenja vlakanaca.
Slikovnom analizom je dokazano učinkovito uklanjanje magenta čestica (98,3%), cijan (96,9%) te karbon (91,49%).Ista metoda nije učinkovita za identifikaciju čestica žutog tonera. Tijekom druge flotacije uklonjen je dio čestica zaostalih poslije prve flotacije. Uklanjanjem čestica obojenih tonera iz suspenzije flotacijom poboljšava se bjelina i svjetlina recikliranih listova. Kolorimetrijske vrijednosti a i b svih recikliranih listova izuzetno su niske i približno jednakih vrijednosti bez obzira na obojenje recikliranog ispisa
Ključne riječi: uredski papiri, reciklacija, kemijski deinking, dvostupanjska flotacija

INTRODUCTION

The life without the paper would be almost impossible today. Huge quantities of paper and paper products have been used in the whole world today, in households as well as on the working places, in industry, schools and in all the domains of the public life. Paper is the product which is made from fibers of vegetable origin, mostly of wood. In order to decrease the cutting of trees, which are used as the raw materials for paper production, the recycling of the used papers for obtaining the fibers for the production of the recycled papers is necessary.

Recycling of the used papers is a complicated technological process composed of four basic process units: a) disintegration or defibering – which comprises the preparation of used paper suspension, b) removal of impurities from the suspension, mostly by washing or flotation, c) whitening of fibers and d) treatment of the process water [1].

It is difficult to define the recycling rules which would be equally valid for all the used papers. Chemical composition of paper and of the printing ink has an important influence on the recycling efficiency. The printing technique and the working principle of the printing machine or of the printer must not be forgotten. Many printer producers are known today: Xerox, Canon, HP, Lexmark.

Nonimpact printed white office papers that include xerographic and laser printed papers are dificult to deink with conventional deinking methods [2]. Because offices use more laser printers and copy machines every year, the amount of nonimpact printed papers entering the recycled paper stream is increasing. Ink removal from these papers remains a major challenge. Deinking processes are also substantial sources of solid and liquid waste.

Conventional chemical deinking is not an effective mean for deinking nonimpact printed papers. The efficiency is due primarily to the strong adherence of the toner particles to the paper surfaces [3,4].

Enzymatic deinking methods represent a new approach to convert these recycled papers into quality products [5,6].

An attractive alternative is the possibillity of recycling office paper within the office, without destroying the mechanical sructure of the paper [7].

The possibility of paper recycling printed with cyan, magenta, yellow and black toner with laser colour printer has been investigated in this work.

The aim of this investigation is: a) to determine the efficiency of colour toner removal by double stage flotation after paper disintegration printed by different colour toners and b) to achieve the maximal usage of fibers by froth flotation collected during the first and the second flotation.

EXPERIMENTAL PART

In the recycling investigations by means of deinking flotation the Navigator paper with the grammage of 80 gm^{-2} was used, printed separately with cyan, magenta, yellow and black toner on the laser colour printer XEROX PHASER 7700. Each differently coloured output contained 848 words arranged in 56 lines. The schematic presentation of deinking flotation process flow is presented in figure 1. In the same way but separately, the cyan, magenta yellow and black prints on Navigator paper were recycled. The sample of print with the mass of 100 g was disintegrated for 10 minutes in 2 liter water from the water supply system at the temperature of 50^{o}C, pH value of 11 (adjusted with soda alkali) and the consistency of the suspension of 5%. As the nonionic surfactant the sodium laurylethersulphate was used. The suspension obtained by the disintegration was homogenized with 10 liter of cold water from the water supply system, and the temperature was decreased at 30^{o}C, with the pH value of 7,5 and the consistency of 0,83%. The suspension obtained by homogenization was divided into two suspensions A and B, of equal volume, which were separately floated after the addition of 6 liter of tap water during the time of 8 minutes (the first flotation). During the flotation the froth was manually collected. The handsheet was made for each suspension before flotation (Ad, Bd) and after flotation (Af, Bf). After the production of the laboratory sheets after the first flotation, the rests of A and B suspensions were mixed into the suspension AB which was floated (the second flotation) under the same conditions as A and B suspension during the first flotation. After the second flotation the laboratory sheet ABf was made. The froth collected in the second flotation was mixed with the froths A and B collected in the first flotation. The collected froth was homogenized with the addition of 10 liters tap water and after that floated for 8 minutes.

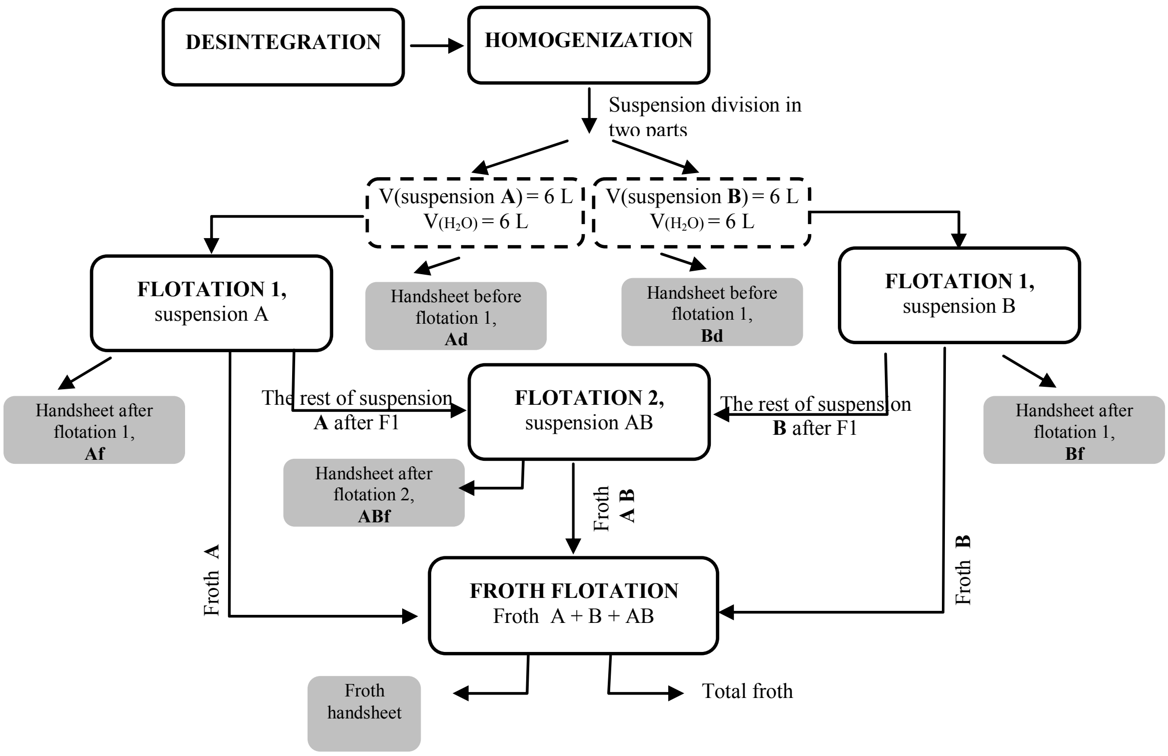

Figure 1. Schematic presentation of the recycling process flow

Laboratory sheet before flotation (Ad, Bd) and after flotation (Af and Bf) was made from each suspension. After the laboratory sheets were made after the first flotation the rests of the suspensions A and B were mixed into the suspension AB which was floated (the second flotation) under the same conditions as A and B suspension during the first flotation. After the second flotation the laboratory sheet ABf was made. The froth AB collected in the second flotation was mixed with the froths A and B collected in the first flotation. The collected froth was homogenized with the addition of 10 liter of tap water and after that floated for 8 minutes.

By froth flotation the impurities were manually collected separated on the suspension surface. After the flotation time the whole suspension from the flotation chamber was used for making the laboratory sheet from froth.

On all the laboratory sheets obtained by the recycling of all four samples the image analysis was made and the optical characteristics were determined. The optical characteristics were determined by the spectrophotometric measurements in the visible part of the spectrum of electromagnetic emission at the wave length of 410- to 700 nm in reflection, according to the TAPPI 519 standard 96. The measuring results of reflections were mathematically processes by the program Data Analysis and technical Graphic Origin 6.0 Professional.

RESULTS AND DISCUSSION

The results of the image analysis are presented in figure 2. The total number and the total particle surface on laboratory handsheets made during the recycling of cyan, magenta, yellow and black prints of Navigator paper were identified. Black and cyan laboratory sheets after the first flotation - Ad and Bd – contain considerably greater number of particles in comparison with the magenta and yellow sheets. The total surface points that the carbon particles are greater than the cyan ones. Smaller number of particles in magenta Ad and Bd sheets points at the supposition that the disintegrated particles of magenta toner are fragmented up to the size which are either better removed by flotation or which are so small that they pass through the openings on the screen used for laboratory sheet formation. The efficiency of black particles removal from the suspension A during the flotation is 91,49%, of cyan particles removal it is 96,9% and magenta particles removal it is 98,3%. After making the sheets Af and Bf, the rests of A and B suspensions are mixed in order to make the flotation of the AB suspension. By the image analysis of cyan, magenta and black AB laboratory sheets the decrease of particle number in relation to Af and Bf sheets was shown. The efficiency of black particles removal from the suspension AB by the second flotation is 80,7%, for cyan it is 89,05 and for magenta it is 79,31%.

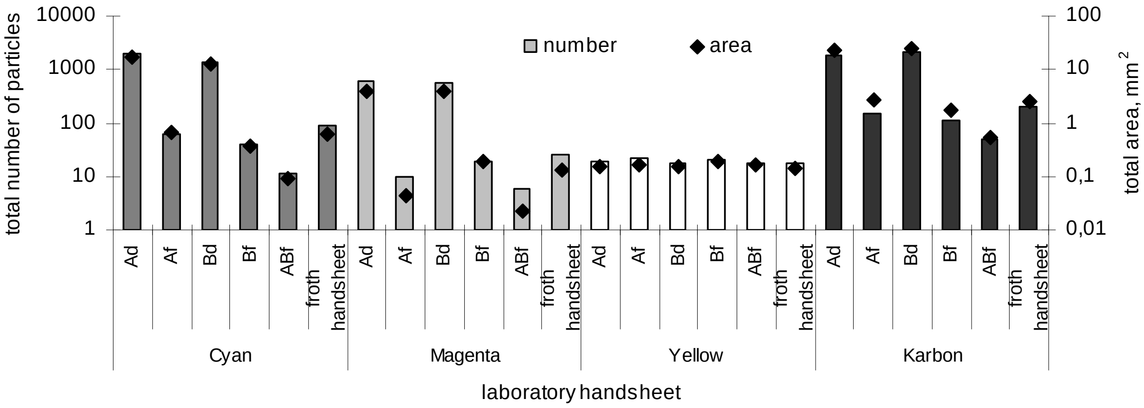

Figure 2. Image analysis results of the handsheets

During the flotation of the suspension A, suspension B and the suspension AB the froths were obtained with the separated particles of toner and fibers. With the increase of fiber share in the froth their loss increases as well. In order to decrease the fiber loss the flotation of the total froth collected during the first and the second flotation was made in this investigation. The image analysis results of the froth handsheet (fh) of each sample presented in figure 2 show somewhat greater total particle number in relation to the sheet of the same sample after the first and the second flotation (except with the yellow sample).

This investigation points at the problem of yellow print recycling. Laboratory sheets before and after the flotations contain approximately the same number of the yellow toner. In the sheets Af and Bf, made after the first flotation more particles were analyzed in relation to the sheets before the flotation Ad and Bd. In the sheet after the second flotation, ABf, as well as in the sheet of froth, the equal number of particles was analyzed. The results point at the more difficult identification of yellow toner particles in the recycled paper by means of the image analysis method.

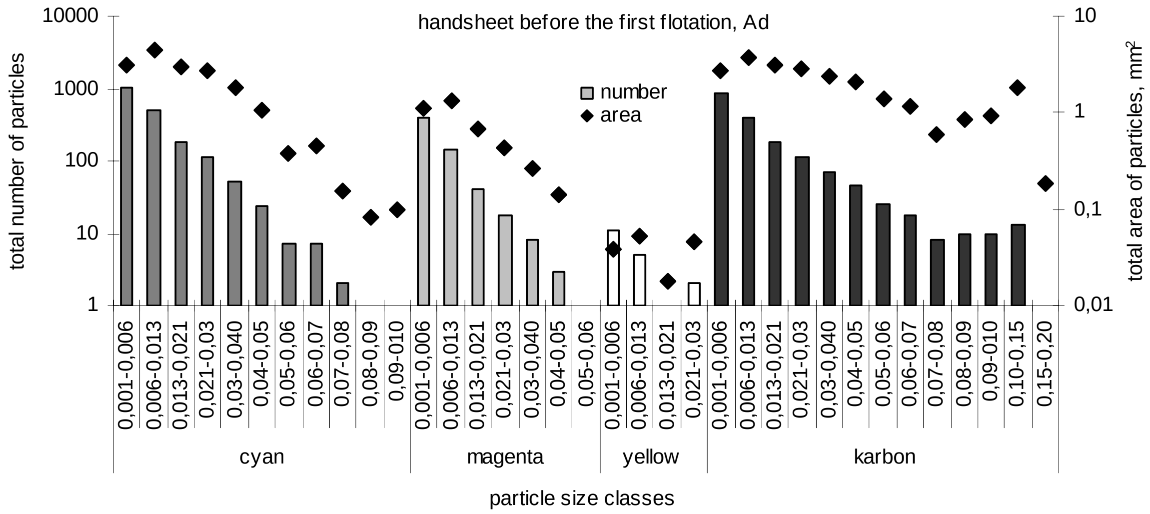

Figure 3. Classes of the particle sizes identified on handsheets before the first flotation (Ad) and after the first flotation (Af).

By image analysis, the particle with the size range from 0,001 mm^2 up to greater than 5 mm^2 divided into 25 size classes are identified. In figure 3 the classes of the particle sizes identified on laboratory sheets before (the sheet Ad) and after (the sheet Af) the first flotation are presented. Black particles are fragmented by disintegration into the size ranging from 0,001 to 0,002 mm^2, cyan up to 0,100 mm^2 and magenta up to 0,06 mm^2. Magenta and cyan toners are fragmented into the particles of smaller sizes in comparison with the particles of the black toner. Although the samples of different colours are printed with the same number of signs, the equal number and size of toner particles of laboratory sheets before flotation was not identified. The identification of the particles smaller than 0,001 mm^2 was not possible by image analysis. The number of the identified magenta particles is considerably smaller in comparison with cyan and black particles. It is supposed that magenta particles are better fragmented by disintegration than the carbon and cyan particles, and consequently they are better removed by flotation (figure 2).

The optical characteristics [8] of the handsheets which confirm the results of the image analysis have been obtained by spectrophotometric measurements. According to the standard TAPPI T 452, brightness is the optical characteristic of paper which is connected with the experience of whiteness caused by the short wave lengths. It is defined by reflection value of the observed sample on the wave length of 457 nm, at which the reflected light, which passes through the blue filter, is measured. The results presented in figure 4 show the brightness increase of the laboratory sheets after the first flotation, Af and Bf, in relation to the sheets before the flotation, Ad and Bd. As the particles of the coloured toner are separated from the suspension during the flotation, so the brightness increases. The brightness of sheets made after the second flotation, ABf is somewhat greater than the brightness of the sheets made before the first flotation, Af and Bf. The results of the image analysis of the laboratory sheet of the froth of all the samples which showed the possibility of fiber usage from the froth collected by double flotation have been confirmed by measuring the optical characteristics. In comparison with the sheets after the first and the second flotation the brightness of the froth sheet of the same sample is smaller. It is supposed that the brightness is influenced by the inorganic components primarily by calcium carbonate (filler) and titanium(II) oxide (optical whiteness) except for the toner particles.

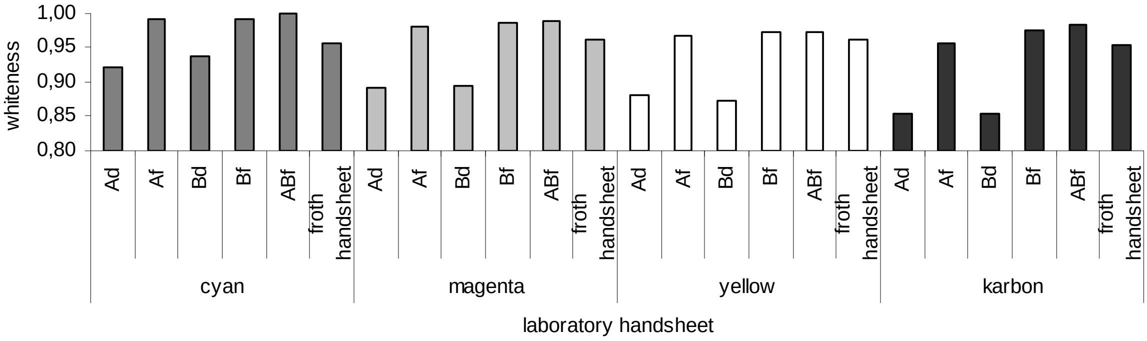

Figure 4. Brightness of the handsheets, λ = 460 nm.

The difference of brightness of the yellow sample before and after the first flotation shows the removal of the yellow toner by flotation. This result confirms the supposition connected with the not efficiency of the image analysis for the identification of the number and surface of the yellow toner particles in the recycled sheets.

The colorimetric CIE Lab values of handsheets for the presentation of the change of colour experience are presented in figure 5. According to the standard TAPPI T 524 the colorimetric value:

- ***L*** presents the lightness which is 100% for ideal white, i.e. 0% for ideal black;
- ***a*** presents the redness when the sign is positive, greenness when it is negative, i.e. grey when it equals zero;
- ***b*** presents the yelowness when the sign is positive, blueness when the sign is negative and grey when it equals zero.

The lightness increase (figure 5) after the first flotation in regard to the sheet lightness before the first flotation shows the efficiency of toner particle removal by flotation. Greater lightness difference is noticeable for cyan, carbon and magenta opposite to the yellow sheets which is in harmony with the image analysis results. After the second flotation the lightness is insignificantly increased because of the repeated particle removal. The lightness of froth sheets is less than the lightness of sheets after the first and the second flotation because of greater number of the left particles. It can be supposed that in the froth sheet, there is the greater share of the inorganic components which were not removed by flotation, which influenced the decrease of lightness.

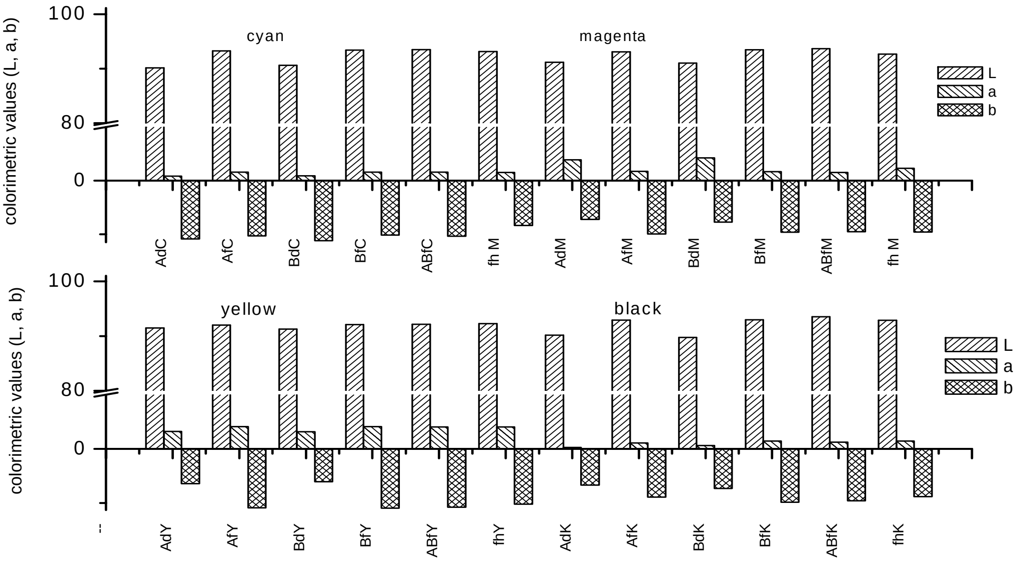

Figure 5. Colorimetric values (L, a, b) of laboratory sheets of the colour samples.

CONCLUSION

The recycling efficiency of the Navigator paper printed with the colour laser printer XEROX PHASER 7700 has been shown by this investigation. The efficiency of the process has been increased by double stage flotation. The particles of cyan, magenta and carbon toner have been better removed in regard to the particles of the yellow toner which have been hard for identification with the image analysis method.

With the increase of flotation efficiency, the optical characteristics of the recycled papers, primarily the lighteness and brightness have been increased. Colorimetric values "a" and "b" are decreased, coming near the value of zero which results that the recycled papers made from cyan, magenta, yellow and black prints are in the area of grey regardless the toner colour.

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